37th Anomalous Absorption Conference

Sheraton Maui Resort
Ka'anapali Beach, Maui
August 27-31, 2007

Organization Committee

- W. B. Mori , Chairman
- F. S. Tsung
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- M. Guerrero, Conference Secretary
- M. J. Robertson, Designer

Technical Program & Book of Abstracts

	Monday	**August 27th**	**8:30-11:00PM**	
Po-1	**Meyer-ter-Vehn**	Juergen	MPI/ Quantum Optics	Ignition of precompressed fusion targets by fast electrons
Po-2	**Bradley**	David	LLNL	NIF-ablator Characterization Experiments on the OMEGA laser system
Po-3	**Rosen**	Mordecai	LLNL	Analytic model of double shell performance
Po-4	**Stevenson**	R. M.	AWE	Understanding the Plasma Evolution in Scaled Halfraum Targets at 2w
Po-5	**Afeyan**	Bedros	Polymath Research	Quantitative Radiation Symmetry Characterization of thin Shells in Hohlraums via X ray Backlighting Images Denoised Using Annulets
Po-6	**Cohen**	Bruce	LLNL	Kinetic-Ion Simulations Addressing Whether Ion Trapping Inflates Stimulated Brillouin Backscattering Reflectivities
Po-7	**Loiseau**	Pascal	CEA	An ion Fokker-Planck code for LPI physics
Po-8	**Schroeder**	Carl	LBNL	Free -Electron Lasers driven by Laser -Plasma Accelerators
Po-9	**D'Humieres**	Emmanual	U.Reno	Analytic Model of Hot Plasma Expansion And Application to IsoChoric Heating
Po-10	**Johnston**	Tudor	INRS	Extremely Nonsinusoidal Emissions and Related Phenomena from Strong Laser Pulses Obliquely P-Incident on Sharp-Edged Plasmas
Po-11	**Pak**	Art	UCLA	Spectral Modulation of Self-Guided Laser Pulses
Po-12	**Tsung****	Frank	UCLA	Particle-in-Cell simulations of the 2wp instability in a density gradient
Po-13	**Schmitt**	Mark	LANL	Simulation of Energy Deposition Options fo ons for Warm Dense Matter Creation and Radiation-Hydrodynamic Perturbations
Po-14	**Tzoufras**	Michail	UCLA	Design and simulation of a single 100GeV-stage Laser Wakefield Accelerator
Po-15	**Charbonneau-Lefort**	Mathieu	Polymath Research	Optical Parametric Amplifiers Using Chirped QPM Gratings in PPLN Images Denoised Using Annulets

Tuesday August 28th 8:30-11:00PM

Wednesday August 29th 8:30-11:00PM

Friday **August 31st**

7:00-8:30		**Breakfast**	Keka'a Terrace
Oral Session			**Session Chairman: David Strozzi**
8:30-8:50	**J. Fernandez**	LANL	The Enhanced Trident Laser Facility at Los Alamos National Laboratory: A new tool for High Energy Density Physics
8:50-9:10	**M. Roth**	TU-Darmstadt	Intense Laser and Ion Beams Next years plasma physics experiments at GSI
9:10-9:30	**R. P. Drake**	U. Michigan	Structure in Radiative Shocks
9:30-9:50	**R. Petrasso**	MIT	Monoenergetic Particle backlighter for radiography and measuring E and B fields and Plasma areal density
9:50-10:10	**C. K. Li**	MIT	Observation of the Decay Dynamics and Instabilities of Megagauss Field Structures in Laser-Produced Plasmas
10:10-10:30		**Coffee Break**	
Oral Session			**Session Chairman: Carl Schroeder**
10:30-10:50	**H. Ruhl**	Univ. of Bochum	Anharmonic Resonance Absorption of High Power Laser Beams
10:50-11:10	**A. Kemp**	LLNL	Laser heating of solid matter by light pressure driven shocks at ultra-relativistic intensities
11:10-11:30	**M. S. Wei**	UCSD	Integrated Lsp modeling of relativistic electron beam transport in a wire target
11:30-11:50	**E. Esarey**	LBNL	High Quality GeV Electron Beams from Laser Plasma Accelerators
11:50-12:10	**J. Ralph**	UCLA	Experiments on Self-Guiding Mechanisms of High Power Laser Pulses in a Plasma
12:10-12:30	**T. Matsuoka**	U.Michigan	Electron Acceleration in Laser-Ablated Plasmas Using 30 TW 30 fs Laser Pulses

See you in 2008!

Monday, August 27th, 2007

Morning Session

8:30AM - 10:10AM Chairman: Chris Niemann, UCLA

10:10AM - 10:30AM Coffee Break

10:30AM - 12:30PM Chairman: Bedros Afeyan, Polymath Research Inc.

Evening Session

7:30PM - 8:30PM Invited Talk, Chairman: Tudor Johnston, INRS

8:30PM - 11:00PM Poster Session

Controlling Stimulated Brillouin backscatter with beam smoothing in weakly damped systems

L. Divol and R. L. Berger

Lawrence Livermore National Laboratory,

University of California P.~O.~Box 808, CA 94551, U.S.A.

We derive an analytical estimate of the effect of temporal smoothing of laser beams on Stimulated Brillouin Scattering (SBS) in a regime relevant to forthcoming attempts at indirect drive ignition. We predict a strong reduction of SBS in the gold plasma expanding from the hohlraum wall with as little as 60 GHz of bandwidth at 1 micron laser wavelength. This is a new regime far above threshold for SBS where, even if the laser bandwidth is smaller than the linear growth rate of SBS, the time to reach convective saturation is long enough to allow for an effective contrast reduction of the beam intensity pattern driving the instability. This result is confirmed by three dimensional simulations. We show that using polarization smoothing (PS) doubles the effective bandwidth in this regime.

Modeling of Two-Plasmon-Decay Instability Under Incoherent Laser Irradiation

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In direct-drive inertial confinement fusion plasmas, the two-plasmon-decay (TPD) instability is responsible for the generation of hot electrons, observed in experiments on the OMEGA Laser System.[1] In OMEGA plasmas, the laser–plasma interaction is driven by multiple crossing laser beams, randomized in space with distributed phase plates and randomized in time with smoothing by spectral dispersion.

A model for the TPD instability driven by incoherent laser light in inhomogeneous plasmas is developed. It modifies the results of the three-wave TPD model[2] for the instability thresholds.

Our model includes low-frequency plasma perturbations that are driven directly by the laser beams, as well as by the beating of plasma waves. The influence of these perturbations back on the TPD through the modification of the density profile is considered.

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.

1. C. Stoeckl, R. E. Bahr, B. Yaakobi, W. Seka, S. P. Regan, R. S. Craxton, J. A. Delettrez, R. W. Short, J. Myatt, A. V. Maximov, and H. Baldis, Phys. Rev. Lett. **90**, 235002 (2003).
2. A. Simon, R. W. Short, E. A. Williams, and T. Dewandre, Phys. Fluids **26,** 3107 (1983).

Prefer oral presentation.

Towards a nonlinear kinetic modeling of SRS

Didier Bénisti[1], David J. Strozzi[2], and Laurent Gremillet[1]
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[2]*Laurence Livermore National Laboratory, University of California, CA 94550, USA.*

This work presents results from the nonlinear kinetic modeling of stimulated Raman scattering (SRS) in a 3-D geometry, and comparisons between the theoretical predictions and 1-D kinetic simulations of SRS.

Theoretically, SRS is investigated within the three-wave model, where the plasma and scattered waves are assumed to be nearly monochromatic. Our main theoretical result is the derivation, from first principles, of the electronic susceptibility, χ. From Re(χ), calculated by making use of the adiabatic approximation, is derived the dispersion relation of the SRS-driven electron plasma wave (EPW). As for Im(χ), calculated by mixing perturbative and non-perturbative techniques, it yields the envelope equation of the plasma wave (including the nonlinear Landau damping rate). Im(χ), and therefore the envelope equation of the EPW, are shown to be non-local due to the symmetric detrapping of electrons experiencing a decreasing wave amplitude.

The theoretically derived dispersion relation of the EPW is compared to that deduced from 1-D numerical simulations of SRS using the Vlasov-Maxwell code ELVIS and the PIC code CALDER. Excellent agreement between the numerical and theoretical results is found over a wide range of $k\lambda_D$ (k being the plasma wave number and λ_D the Debye length). A particular emphasis will be laid on the limits of purely electrostatic predictions regarding the nonlinear frequency shift of the EPW.

We numerically demonstrate that, due to the frequency downshift of the EPW, the scattered wave is always driven slightly off-resonance. This entails a phase shift between the EPW and the laser drive, which limits the growth of SRS. We however numerically observe the ability of SRS to adapt to the frequency shift of the EPW. Indeed, the wave numbers are shown to vary so as to reduce the off-resonance drive of the scattered wave, and therefore the impact of the frequency shift of the EPW on SRS saturation.

Calculating the wave number shifts remains the main point to elucidate to get to a nonlinear kinetic description of SRS within the three-wave model, whose limits will also be addressed.

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

DEPLETE - a code for rapid assessment of backscatter activity

D. J. Strozzi, E. A. Williams, and D. E. Hinkel
Lawrence Livermore National Laboratory (LLNL), Livermore, CA 94550

We are developing the code DEPLETE, an extension to the linear gain calculation code NEWLIP, to provide a rapid assessment of backscatter risk for ICF targets. DEPLETE solves the steady-state coupled-mode equations for the pump laser and scattered light wave intensities (for a set of Raman and Brillouin scattered frequencies), along inhomogeneous profiles taken from a ray path. The daughter electrostatic waves (electron-plasma and ion-acoustic for Raman and Brillouin, respectively) are calculated in the strongly-damped limit. Bremsstrahlung noise and Thomson scattering sources are included. Depletion of the pump laser due to stimulated scattering is included, as well as inverse-bremsstrahlung damping of both the pump and scattered light waves. To accurately integrate through narrow resonances in the coupling coefficient, we use a rational-function integration method first developed for NEWLIP by E. A. Williams.

DEPLETE provides several enhanced capabilities for rapid laser-plasma interaction assessment. The inclusion of physical noise sources allows absolute reflectivities, rather than just gain coefficients, to be obtained, which facilitates experimental comparisons. The energy deposition profile or local heating rate, including both pump and scattered lights waves, can be found. Besides reflectivities, the amplitude of the electrostatic waves generated by the beating of the pump and scattered light waves is also available. This allows for comparison with thresholds for nonlinearities, such as the Langmuir decay instability and kinetic inflation due to electron trapping. In addition, one can estimate the resulting hot electron spectrum and level.

We will present the DEPLETE analysis of some NIF ignition designs, and compare with NEWLIP results.

*This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL under Contract W-7405-Eng-48.

SLIP: a new tool for laser-plasma interaction study on NIF

Pierre Michel, Laurent Divol, and Ed Williams
LLNL

We have developed a new code ("SLIP") that models the 3D, steady-state paraxial propagation of a whole 3D NIF laser beam in a realistic ignition hohlraum. The backscattered waves are also paraxial, and are coupled to the laser wave via a linear kinetic model. The simulation domain in SLIP is split into blocks, with the propagation algorithm sweeping back and forth within each block for the forward and backward propagation of the waves; this allows us to achieve full 3D simulations with relatively inexpensive computer time and memory, and positions SLIP between ray tracing code with 1D gain calculation (such as the code "LIP") and full time-resolved propagation codes (such as pF3d), both in terms of physical description and computing requirements.
SLIP has been successfully benchmarked against experimental data from the Omega laser facility at LLE. It has also provided a detailed analysis of the origins of parametric instabilities in NIF targets, and is currently being used to validate risk mitigation strategies for various targets designs.
We will first present the physics model used in the code. Then, we will show different methods that could help reduce parametric instabilities (such as adding low-Z material in order to enhance Landau damping or modifying the polarization smoothing setup). Finally, a study of the energy transfer between different beams crossing at the entrance of the hohlraum will be presented.
This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

Abstract for Anomalous Absorption Conference – 2007:

The Role of Pump Depletion in Stimulated Raman Scattering for NIF Parameters

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

Using the full-PIC code OSIRIS in 1D, we have studied stimulated Raman scattering (SRS) in a range of parameters relevant to NIF. In recent years, a wide range of trapped particle effects have been implicated in the behavior of SRS in this regime: detuning due to a kinetic frequency shift, beam modes, electron-acoustic Thompson scattering from these beam modes, and sidebands (the trapped-particle instability). Relatively little mention has been made of pump depletion. We will present results demonstrating that for some parameter ranges, pump depletion due to a convecting scattered packet is the primary mechanism for wave saturation. Furthermore, once pump depletion saturates the instability, the laser can still Raman scatter off the nonlinear, convective plasma wave groups. Once a localized pulse of plasma waves has convected out of the system, or traveled a distance sufficient for convective growth to recur, the instability may restart again. We also show that the behavior changes dramatically when the plasma length becomes much longer than the convective gain length.

Work supported by DOE under DE-FG52-06NA26195 and NSF under NSF-Phy-0321345. Simulations performed on the DAWSON Cluster.

Driven Plasma Waves Relevant to Stimulated Raman Scattering

J. Fahlen, B. Winjum, J. Tonge, F.S. Tsung, V. Decyk, W.B. Mori UCLA

In fully self-consistent particle-in-cell (PIC) simulations the saturation of Stimulated Raman Scattering (SRS) is quite complicated. To better understand possible saturation mechanisms of SRS, we study the excitation of plasma waves by imposing an external ponderomotive force in 1D electrostatic PIC simulations. By varying the phase velocity, the drive frequency (detuning) with respect to the linear frequency, and the strength of the driving force, several saturation mechanisms are explored, including fluid and kinetic nonlinear frequency shifts, sideband generation, and particle trapping. The simulations indicate that simple frequency shift models are inadequate in describing the wave saturation. Wave harmonics are also observed and these can contribute to the non-linear frequency shift. A theory for harmonic-generated frequency shifts in the absence of particle trapping is presented along with simulations corroborating both the predicted shift and the harmonic amplitudes. Further, the simulations are used to understand the effects necessary, including the distribution function's spatial dependence, for developing a consistent frequency shift calculation for driven waves that includes both harmonics and particle trapping.

Work supported by DOE under DE-FG52-06NA26195 and NSF under NSF-Phy-0321345. Simulations were carried out on the DAWSON Cluster.

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Approximating kinetic Langmuir waves by enveloped fluid equations.

E. A. Williams, L. Divol, P. Michel and C. H. Still

Lawrence Livermore National Laboratory, Box 808, Livermore CA 94550

The laser plasma interaction code pF3d is used to model the propagation of high intensity laser beams through plasma, including filamentation and stimulated Raman and Brillouin scattering. Making these calculations feasible (even on massively parallel computers), for ignition-related applications with simulation volumes of several cubic millimeters and simulation times of tens or even hundreds of picoseconds require that the equations for the light and Langmuir waves be enveloped in both space and time in a “paraxial” approximation. For the Raman back-scattered light, typically the time dependence is enveloped around the peak of the (anticipated) spectrum. The Langmuir wave is enveloped around the corresponding parametric matching frequency and wave-number.

For homogeneous plasmas, it is straightforward to arrange for the properties (frequency, damping rate, group velocity, ponderomotive response) of the Langmuir wave, modeled by an enveloped fluid equation, to match those of a kinetic model arising from the Landau dispersion relation.

As our computer resources have increased, we have been able to model larger and larger plasma volumes with the background plasma encompassing a larger range of electron density and temperatures. This stresses the Langmuir wave model. For instance, SRS backscatter can originate in a region where the plasma waves are weakly damped, but undergo final amplification in lower density, higher temperature plasma where the plasma wave resonance is broader but not on the peak of the growth curve. No single choice of plasma wave parameterization as a function of local plasma conditions can match kinetic theory both on and off the nominal matching frequency. Some compromise is required.

In this paper we describe current and proposed modifications to the pF3d Langmuir wave (enveloped fluid) model and compare them to the kinetic benchmark in a theoretical context and also, using the SLIP code, in the context of NIF ignition design calculations.

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.

UCRL-ABS-232295

For oral presentation at the 37th Anomalous Absorption Conference, Aug.27-31, 2007

Further Implications of the Trapping-Inflation Scenario for the Nonlinear behavior of SRS

Don DuBois*, Hoanh Vu**, Bandel Bezzerides* and Evan Dodd*
*** Los Alamos National Laboratory, ** University. of California at San Diego**

Inflation of backward stimulated Raman scattering (BSRS) (and stimulated Brillouin scattering (BSBS)[1]), by trapping, to levels above linear convective predictions is predicted by 1D and 2D PIC simulations of single laser hot spots (intense speckles)[2]. A comparable sudden onset of BSRS with increasing laser intensity in single hot spot experiments has been observed [3]. A theory for the inflation intensity threshold was developed for 1D PIC simulations [4]. A nonlinear three coupled envelope model in which the trapping induced damping reduction and frequency shift for the SRS Langmuir wave are turned on at this threshold reproduces the essential features observed in 1D PIC simulations for *single hot spots*. It is necessary to generalize this approach to a 3D, many speckle, system. Here we use the 3D linear theory of the convective amplification of BSRS in the strong damping limit, based on solutions given by Divol and Mounaix [5] for a Gaussian hot spot, to estimate the inflation intensity thresholds for a 3D hot spot at which the amplified Langmuir wave can trap electrons in competition with electron-electron collisions. Side loss of trapped electrons in Gaussian, gain narrowed, hot spots is compared to the loss by collisions. The goal is to use these results to put SRS inflation physics into macroscopic propagation codes. Interaction of hot spots by seeding from the scattered light from hot spots further from the laser entrance lowers the inflation threshold of the seeded hot spots. The Langmuir waves from a shallow hot spot can affect the dynamics of a deeper hot spot. We compare RPIC simulations with the three-envelope-model to see if such reduced models can adequately model speckle-speckle interactions.

[1] B. Cohen, E.A. Williams,and H.X. Vu, "Kinetic ion simulations addressing whether ion trapping inflates stimulated Brillouin backscatter reflectivity", (submitted manuscript June 2007)
[2] H.X. Vu, D.F. DuBois and B. Bezzerides, Phys.Rev. Lett. **86,** 4306, (2001), Phys. Plasmas **9**, 1745 ((2002)., L.Yin, W. Daughton, B.J. Albright, B. Bezzerides, D.F. DuBois, J.M. Kindel, ,H.X. Vu, Phys. Rev. E, **73**, 025401 (2006)
[3] D. Montgomery *et al,* Phys. Plasmas **9**, 2311 (2002)
[4] H.X Vu, D.F. DuBois, and B. Bezzerides, Phys. Plasmas**14**, 012702 (2007)
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** Research supported by DOE Research Grant No.DE-FG52-04NA00141/A000

37th Anomalous Absorption Conference, Maui, Hawaii, August 27-31, 2007

Saturation of backward stimulated scattering of laser in kinetic regime: Wavefront bowing, trapped particle modulational instability and trapped particle self-focusing of plasma waves*

L. Yin, B. J. Albright, K. J. Bowers♦, W. Daughton, and H. A. Rose

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Backward stimulated Raman and Brillouin scattering (SRS and SBS) of laser are examined in the kinetic regime using particle-in-cell simulations. The SRS reflectivity measured as a function of the laser intensity in a single hot spot from two-dimensional (2D) simulations shows a sharp onset at a threshold laser intensity and a saturated level at higher intensities, as obtained previously in Trident experiments [1]. In these simulations, wavefront bowing of electron plasma waves (ion acoustic waves) due to the trapped particle nonlinear frequency shift is observed in the SRS (SBS) regime for the first time, which increases with laser intensity. Self-focusing from trapped particle modulational instability (TPMI) [2] is shown to occur in both 2D and 3D SRS simulations. The key physics underlying nonlinear saturation of SRS is identified as a combination of wavefront bowing, TPMI and self-focusing: The wavefront bowing marks the beginning of SRS saturation and self-focusing terminates the SRS reflectivity, both effects resulting from cancellation of the source term for SRS. Ion acoustic wave bowing also contributes to the SBS saturation. Velocity diffusion by transverse modes and rapid loss of hot electrons in regions of small transverse extent formed from self-focusing lead to dissipation of the wave energy and an increase in the Landau damping rate in spite of strong electron trapping that reduces Landau damping initially. The ranges of wavelength and growth rate associated with transverse break-up of the electron plasma waves are also examined in 2D speckle simulations as well as in 2D periodic systems from BGK equilibrium and are compared with theory predictions.

[1] D. S. Montgomery, et al., Phys. Plasmas, 9, 2311 (2002).
[2] H. A. Rose, Phys. Plasmas, 12, 12318 (2005).

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Simulation of stimulated Raman scattering in 2D

P-E Masson-Laborde[1], W. Rozmus[1], Zongling Peng[1], V. Yu. Bychenkov[1,2], and C. E. Capjack[1]
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[2)] P. N. Lebedev Physics Institute, Russian Academy of Sciences, Moscow, Russia

Results of particle-in-cell (PIC) simulations of the stimulated Raman scattering (SRS) in one and two spatial dimensions are discussed. With the focus on plasma conditions corresponding to large $k\lambda_D$ values of SRS driven Langmuir waves ($k\lambda_D > 0.2$) we examine secondary instabilities of plasma waves in the presence of trapped particles. For $k\lambda_D > 0.3$ transverse trapped particle modulational instability (Rose, Phys. Plasmas **12**, 2005) dominates nonlinear evolution of SRS. We have studied interplay between Langmuir decay and modulation instability in the intermediate regime of $k\lambda_D \sim 0.2$. New effects are examined in two spatial dimensions where large fraction of trapped particles gives rise to electric current of fast electrons and the generation of magnetic field. Magnetic field and the transverse ponderomotive force of localized Langmuir waves modify trapped particle dynamics and alter frequency shift and side loss damping of Langmuir waves. Experimental signatures of the 2D effects such as angular broadening of the backscattered light are discussed.

Recent Progress in Laser- and Beam-Driven Plasma Accelerators

Chan Joshi, University of California Los Angeles, Los Angeles, CA 90095 U.S.A.

Abstract

In the past year plasma accelerators have set new records: The first laser wakefield accelerator (LWFA) to demonstrate a GeV electron beam with a significant charge and good beam quality in a "table-top" device at Lawrence Berkeley National laboratory (LBNL) [1], and the energy doubling of 42 GeV electrons from the SLAC linac in a meter-scale plasma wakefield accelerator (PWFA) by the UCLA, USC, SLAC collaboration known as E167 [2]. These two events happening at two different laboratories represent a very significant advance of the field to be sure, but there have been many other extremely important advances for the field of plasma-accelerators that deserve special recognition [3-6]. In this paper after reviewing these two major acceleration results, I focus on these latter advances and speculate how the field is likely to develop in the next few years.

1) W.P.Leemans Nature Physics 2,696,2006
2) I.Blumenfeld et.al. Nature 445,741,2007
3) N.H.Matlis et.al. Nature Physics 2,749,2006
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5) D.Johnson et.al. Phys.Rev.Lett. 97,175003,2006
6) E.Oz et.al. Phys.Rev. Lett.98, 084801,2007

Monday **August 27th** **8:30-11:00PM**

Po-1	**Meyer-ter-Vehn**	Juergen	MPI/ Quantum Optics	Ignition of precompressed fusion targets by fast electrons
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Po-14	**Tzoufras**	Michail	UCLA	Design and simulation of a single 100GeV-stage Laser Wakefield Accelerator
Po-15	**Charbonneau-Lefort**	Mathieu	Polymath Research	Optical Parametric Amplifiers Using Chirped QPM Gratings in PPLN Images Denoised Using Annulets

Abstract for AA2007, Maui, August 27-31, 2007

Ignition of precompressed fusion targets by fast electrons

HONRUBIA, J. Javier[1] and J. MEYER-TER-VEHN, Juergen[2]
[1] *ETSII, Universidad Politécnica, Madrid, Spain*
[2] *Max-Planck-Institut für Quantenoptik, Garching, Germany*

Fast ignition [1, 2] involves transport of GA currents of laser-driven electrons through dense coronal plasma of imploded fusion targets. Here we present hybrid PIC simulations, taking full account of collective magnetic effects. The relativistic electron beam is treated by 2D/3D PIC including collisional energy loss, while the high-density background plasma is modelled by resistive MHD equations to describe magnetic field suppression by plasma return currents [3]. Full-scale kinetic simulation may become possible in the future [3], but presently the hybrid approach pursued here offers a unique option to investigate important transport features such as current filamentation and magnetic beam collimation *simultaneously* with ignition physics (fusion reactions, alpha-particle transport and deposition, hydrodynamics, heat conduction). One may recall that, so far, most fast ignition simulations (see e.g. [4]) assumed ballistic straight-line beam transport, neglecting all the intricacies of high-current (GA) transport in plasma.

In this talk, we present first results on actual ignition of an imploded fast ignition configuration, including the high-current effects. To be explicit, a cone-guided configuration is considered, and target ignition is studied as a function of injected electron energy, distance of cone-tip to dense core, and initial divergence of the relativistic electron beam. Laser interaction and electron beam generation inside the cone are not treated explicitly; rather the electron beam is injected at the boundary with transverse, angular, and energy distribution controlled by a few parameters [5]; they are chosen close to experimental values [6, 7]. The present hybrid-PIC approach reproduces cone-target experiments [6], similar to previous simulations of same kind [8].

Ignition of DT fuel (super-Gaussian profile with central density of 400 g/cm^3 and radius of 41 μm) is obtained for electron pulses of 22 - 35 kJ injected under an half-angle of 22° at a distance of $d = 75$ - 150 μm from peak density, respectively. Beam collimation supports ignition significantly. Beam filamentation shows up for $d > 125$ μm and leads to fragmented energy deposition [4]. Beam deposition in the high-density core is due to classical Coulomb stopping. - These results have been used to design cone targets igniting with short-pulse laser energies on the level of 70 kJ, as it is envisioned for the HiPER project [10].

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NIF-ablator characterization experiments on the Omega laser system

D. K Bradley, D. G. Braun, G. W. Collins, S. W. Haan, S. G. Glendinning, R. H. Page, J L. Milovich, O. Landen
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The accurate characterization of ablator materials is crucial for successful ignition of indirect-drive ICF capsules. This includes, but is not limited to measurements of preheat and instability growth. The ablator material for the point design NIF ignition capsule is Cu-doped Be, which is a polycrystalline material in the solid phase and melts at high temperature and pressure. It has the potential to seed unstable growth as a result of microstructure, material strength or surface non-uniformities. The alternate ablator candidate, high density carbon, is expected to exhibit similar properties. The number of Rayleigh Taylor growth factors experienced by an imploding NIF ignition capsule is predicted to be very large (hundreds), so small seeds are important.

We have previously reported on the development of a high-growth planar Rayleigh Taylor platform[1] in which we have demonstrated growth factors of 200x for sinusoidal 2-D modulations in CH foils. The technique has now been adapted to study 3D surface perturbations in actual NIF ablator materials. In this presentation we show the results of experiments carried out on sputtered Cu-doped Be with random surface perturbations at levels close to those expected on the NIF ignition capsule

1. D. K. Bradley et al, Phys. Plasmas **14**, 056313 (2007)

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UCRL-ABS-232051

Abstract:

Analytic model of double shell performance*

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Hohlraum-driven double-shell capsules are being considered as ignition / moderate gain systems for the National Ignition Facility. They are currently being tested on the Omega Laser Facility. We present a simple model for the performance of these double shell capsules by focusing on the dynamics of the inner Au shell and the DT gas within. We calculate the DT preheat (if any), its post shock conditions, and follow that with a calculation of its adiabatic compression. At stagnation time, the ultra-high density Au shell is treated simply as a Fermi-degenerate system. We equate the peak kinetic energy of that shell to the internal energies of the DT and the Au upon stagnation. We close the system of equations via a pressure balance between the Au and the DT. This "hydro phase" of the analytic calculation results in predictions for peak DT density and temperature. We then analytically calculate ignition criteria for this system followed by a simple model for fusion burn-up and gain. Results from all of this are compared with published results of the simulations of Amendt et. al. (PoP 14, 056312 [2007]). In hopes of finding optimal operating regimes, we use our analytic formulae to study parameter variations such as DT initial density and radius as they vary with driver scale.

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Understanding the Plasma Evolution in Scaled Halfraum Targets at 2ω

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37th Anomalous Absorption Conference
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Abstract

Several years ago we presented the data for a series of experiments [1] investigating the performance of scaled halfraum targets illuminated with 2ω light at the HELEN laser facility at AWE. At that time we were unable to fully explain the anomalous behaviour in the radiation temperature for the smallest targets (NOVA scale 0.1) which did not exhibit the expected fall in temperature due to high levels of plasma filling, hot electron production and backscatter. Hydrocode modelling of the targets at the time could not be completed as the then currently available code was Lagrangian mesh based. Due to mesh tangling, the code could only investigate the very early temperature profile. Since then, a new code has become available which utilises ALE techniques enabling us to return to the questions posed in the earlier work. We present a more detailed analysis of the evolution of the plasma within the scale 0.1 targets.

[1] Temperature and Stimulated Scattering Evolution on Scaled Halfraum Targets using 2ω Light. R.M. Stevenson, *et al*
32nd Anomalous Absorption Conference, Oahu, Hawaii, July 21-26, 2002

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Quantitative Radiation Symmetry Characterization of thin Shells in Hohlraums via X ray Backlighting Images Denoised Using Annulets

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We will show results from synthetic (numerically simulated) and real images of radiation drive on a thin shell. Both areal and point projection backlighting are allowed. using (1+1)D wavelet or annulet denoising, we will reconstruct the Legendre Polynmial coefficients of the denoised images and compare to other methods.

The regularization of the problem using wavelets and the avoidance of catastrophic failure modes in previous techniques will be pointed out.

A systematic study of noise level (usually very large), low order mode amplitudes, and recovery with fidelity performance of standard deviations and means will be presented. Both single and multiple modes will be considered and their potential detectability interference examined.

**This work was funded by LLNL.

Prefer poster Session

37th Annual Anomalous Absorption Conference
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Kinetic-Ion Simulations Addressing Whether Ion Trapping Inflates Stimulated Brillouin Backscattering Reflectivities*

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An investigation of the possible inflation[1] of stimulated Brillouin backscattering (SBS) due to ion kinetic effects is presented using electromagnetic particle simulations[2,3] and integrations of three-wave coupled-mode equations with linear and nonlinear models of the ion physics. Electrostatic simulations of linear ion Landau damping in an ion acoustic wave, nonlinear reduction of damping due to ion trapping, and nonlinear frequency shifts due to ion trapping establish a baseline for modeling the electromagnetic SBS simulations. Systematic scans of the laser intensity have been undertaken with both one-dimensional particle simulations and coupled-mode-equations integrations, and two values of the electron-to-ion temperature ratio (to vary the linear ion Landau damping) are considered. Three of the four intensity scans have evidence of SBS inflation as determined by observing more reflectivity in the particle simulations than in the corresponding three-wave mode-coupling integrations with a linear ion-wave model, and the particle simulations show evidence of ion trapping. There is some success in capturing the nonlinear saturation of SBS observed in the particle simulations with the coupled-mode equations using a simple reduced model for the effects of trapping on the SBS ion acoustic waves.[4]

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37th Anomalous Absorption Conference, Hawaii, Aug. 27-31, 2007

Prefer **poster** session

An ion Fokker-Planck code for laser-plasma interaction physics

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In the framework of the laser megajoule (LMJ) and National Ignition Facility (NIF) projects, parametric instabilities still remain a major risk of ignition failure. We are concerned with backward stimulated Brillouin scattering (BSBS). BSBS is the process by which the incident laser wave couples to an ion acoustic wave to give rise to a scattered transverse wave. Ion acoustic waves related to BSBS are a rich topic. First, it is well known that the BSBS reflectivity is modified in multi-species plasmas. Then numerous studies demonstrated that BSBS reflectivity was limited due to non linear development of the acoutic waves or due to plasma inhomogeneity. Finally, recent studies emphasized that ion-ion collisions in a weakly collisional plasma play a non negligible role in maintaining Landau damping on a time longer than expected in the collisionless limit [1]. Thus, modeling the whole range of phenomena requires an ion kinetic approach.

Most of the previous works used hybrid PIC codes, that are well suited in describing collisionless plasmas where electrons are treated as a fluid. For weakly collisional plasmas, PIC codes may be extended by the use of some *ad hoc* modeling of collisions [2]. Another approach is to directly solve the Vlasov-Fokker-planck (VFP) equations describing the evolution of the ions distributions functions. In this case, numerical noise is limited and ion-ion collisions are properly taken into account. We use the VFP code **FPion** initially developed for ion transport studies [3]. The FPion code is a multi-species ion kinetic code with fluid electrons. We present simulations dedicated to ion-wave studies using the FPion code. On the one hand, we show that FPion simulations of the collapse of a large amplitude wave are in agreement with the theory developed by Forslund [4]. On the other hand, we compare simulations of the evolution of ion wave including ion-ion collisions or not.

The FPion code is a good tool for evaluating ion damping in multi-species plasma [5]. Also it should give insights when mitigating laser-plasma instabilities by changing the gas composition inside the hohlraum.

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Abstract for Poster Presentation:
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Free-Electron Lasers driven by Laser-Plasma Accelerators

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Electron plasma waves, ponderomotively excited by ultra-short, relativistically-intense, laser pulses, can sustain gradients on the order of 100 GV/m. These plasma waves have relativistic phase velocities and can be used to accelerate charged particles. Recent experiments at LBNL have demonstrated the stable production of high-quality electron beams with GeV energies. These experiments generated GeV electron beams over centimeter-scale plasmas using 40 TW laser pulses. The laser-plasma-accelerated electron beams are ultra-short (tens of fs) and quasi-monoenergtic (percent-level energy spread), with mrad divergences. We consider driving a free-electron laser (FEL) with the laser-plasma-accelerated electron beams, producing a source of ultra-fast, high-peak flux, VUV pulses. This proposed ultra-fast light source would be intrinsically temporally synchronized to the drive laser pulse, enabling pump-probe studies in ultra-fast science with fs pulse durations. Owing both to the high current (>10 kA) and reasonable charge/pulse (0.1-0.5 nC) of the laser-plasma-accelerated electron beams, saturated output fluxes are potentially 10^{13}-10^{14} photons/pulse. We examine devices based both on self-amplified spontaneous emission and high-harmonic generated input seeds to give improved coherence and reduced undulator length. Numerical modeling of the expected FEL performance is presented. A successful source would result in a new class of compact laser-plasma-accelerator driven FELs in which a conventional radio-frequency accelerator is replaced by a GeV-class laser-plasma accelerator whose active acceleration region is only a few cm in length.

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ANALYTICAL MODEL OF HOT PLASMA EXPANSION AND APPLICATION TO ISOCHORIC HEATING

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Plasma expansion models are of great interest for several research domains. In particular, they have gotten a lot of attention in the laser-plasma interaction community to model ion acceleration from solid targets irradiated with high intensity lasers. Another application of these models is the optimization of the isochoric heating of a dense target by a high intensity laser because the target expansion is an important source of energy loss.

We have developed a 1D analytical model of the adiabatic expansion of a hot plasma based on the results obtained by P. Mora [*]. This model includes the treatment of energy transfers between hot electrons and cold electrons through collisions. It is therefore also able to describe the evolution of the bulk temperature of the plasma.

We have compared the results of this model to 1D PIC simulation results of both the expansion of an initially hot plasma and of the expansion of a laser-heated plasma. Our model is able to accurately reproduce the hot electron temperature evolution and the evolution of the position of the ion front. The number of degrees of freedom for energy transfers that we have to use in the adiabatic expansion part of the model depends on the initial simulation setup.

We also show that for our model to accurately describe the heating of the target, we need to implement other energy transfer mechanism to the bulk electrons such as transfers due to kinetic effects. This part of the model is more complex, but even without it, our model is a good tool to evaluate the energy loss due to plasma expansion to optimize isochoric heating of a laser irradiated target.

[*] P. Mora, Phys. Rev. Lett. **90**, 185002 (2003).

Extremely Nonsinusoidal Emissions and Related Phenomena from Strong Laser Pulses Obliquely P-Incident on Sharp-Edged Plasmas

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Extremely high laser harmonics emissions [1] emerge from the Vulcan petawatt laser's sub-picosecond laser pulses obliquely incident on slab targets with extremely low pre-pulse energy. Similar studies are to be made using the ALLS 200 TW Ti-Saph laser (24 fs at 10 Hz with 10^{-10} contrast even without plasma mirrors).

We discuss our 2-D PIC simulations using the OSIRIS code with a view to (a) understanding the basic mechanism(s) for the production of the harmonics and (b) establishing the effect of density gradients. Typical results resemble those of Naumova et al. [2] and of Thaury et al. [3], including the presence of a very large and asymmetric electromagnetic "spikes" which account for the high harmonic content. These are produced by extremely concentrated very nonlinear current structures on the plasma surface.

While the understanding of the formation of these structures is the principal objective of this work, the effects of the fast electrons are also discussed, including some interesting ~ steady magnetic fields they produce.

Some oddities in harmonic emissions result when two strong beams are used from opposite sides of the target normal, and these can be understood as the result of the interaction of each beam's moving current system with the other beam.

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Spectral Modulation of Self-Guided Laser Pulses

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In this paper the experimental results of spectral modulation of a self-guided laser pulse in an underdense plasma will be presented. Experiments were conducted using an ultrashort laser pulse (~50 fs) generated from the UCLA Ti:Sapphire laser system capable of delivering up to 10 TW of power. A gas jet was used to create a dense column of helium gas which the laser pulse ionized and self-guided through. By varying the laser pulse width, laser energy, gas jet density and gas jet length, different physical mechanisms of self-guiding were explored [1]. In these experiments the guided laser pulse was spectrally and spatially resolved using a .25 m imaging spectrograph with 1.2 nm spectral resolution and 13 μm spatial resolution. Evidence of photon acceleration / deceleration due to the laser pulse interacting with density oscillations of a plasma wakefield will be presented and compared to simulation results. Additionally using the imaging spectrograph the percentage of the laser energy that was self-guided was determined.

[1] J.E. Ralph, A.E. Pak, K.A. Marsh, C.E. Clayton, F. Fang, C. Joshi., *These Proceedings*

Particle-in-Cell Simulations of the $2\omega_p$ Instability

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Abstract

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 (PPMP) point is at the parabolic peak density. We will also test the theorys 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. 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. Building on these experiences, we have now begun to investigate nonlinear effects on a longer time-scale, such as the saturation mechanism, the spectrum of the fast electrons at saturation, the relaxation and recurrence of the instability, and ion effects.

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Simulation of Energy Deposition Options for Warm Dense Matter Creation and Radiation-Hydrodynamic Perturbations

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Future experiments examining the properties of warm dense matter (WDM) hinge on the ability to prepare a material sample with uniform temperature and density. We report here on the evaluation of WDM generation using protons from the LANSCE accelerator and electrons from the DAHRT-1 accelerator. The effectiveness of these methods will then be compared to laser heated foils (~10 micron thick) employing high-contrast picosecond-regime temporal pulses.

Ion beams generated by high-intensity ultra-short-pulse lasers can be used to create temporally and spatially precise perturbations during the implosion of ICF capsules. Such perturbations are useful for the validation of radiation-hydrodynamic models. We will define the ion beam parameters needed to produce significant capsule perturbations and the laser power required to produce these ion beams. Simulation examples will be shown.
*This work is sponsored by the US DOE and the LANL LDRD program.

Poster preferred

Design and simulation of a single 100GeV-stage Laser Wakefield Accelerator*

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[2]Department of Physics and Astronomy, University of California, Los Angeles, CA 90095

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The design of a Laser WakeField Accelerator (LWFA) involves understanding and control of various plasma physics phenomena related to the laser evolution, the response of the plasma medium and its effect on the accelerating particles. Within the framework developed by W. Lu et al. [1] we study these phenomena in the weakly nonlinear blowout regime, where the laser power is similar to the critical power for self-focusing. High quality electron beams can be efficiently accelerated in this regime in a single stage with average gradient 3.6GeV/m to reach 100 GeV. Full and reduced particle-in-cell simulations are presented to illuminate the physics and verify the applicability of the design.

[1] W. Lu et al, "Generating multi-GeV electron bunches using single stage laser wakefield acceleration in a 3D nonlinear regime", Phys. Rev. ST Accel. Beams 10, 061301 (2007)

*Work supported by: DE-FG03-92ER40727, DE-FG52-06NA26195, DE-FC02-01ER41179, DE-FG02-03ER54721, NSF-Phy-0321345.

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Sheraton Maui Resort, Kaanapali Beach, Maui, Hawaii
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Optical Parametric Amplifiers Using Chirped QPM Gratings in PPLN Images Denoised Using Annulets

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Experimental investigations of Optical Parametric Amplifiers (OPA) using Chirped Quasi-Phase-Matched (QPM) gratings in periodically poled Lithium Niobate (PPLN) crystals revealed that one dimensional models of these parametric instabilities are inadequate [1]. In fact, near forward direction modes were found which grow over lengths much longer than the Rosenbluth gain model [2] would indicate. These gain guided modes have a discrete spectrum in a transversely localized laser profile.

We will show numerical and theoretical results [1,3] which elucidate the physics behind these surprising modes which grew out of noise and flooded our experimental signal of seeded [4], signal driven modes that would otherwise obey the Rosenbluth convective amplification model.

Implications of this work in ferroelectric gain media to laser plasma instabilities will be indicated. The connection is immediate from a modeling point of view except for features such as Landau damping and DPP beams which are less common in nonlinear optics of crystals.

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[3] B. Afeyan, M. Charbonneau-Lefort, and M. M. Fejer, "Variational and WKB Descriptions of Laterally Localized Eigenmodes in Non-Collinear Optical Parametric Amplifiers", Conference for Lasers and Electro-Optics 2007, (CWB1).
[4] M. Charbonneau-Lefort, B. Afeyan, and M. M. Fejer, "Gain Enhancement Due to Transverse Effects in Chirped Quasi-Phase-Matched Optical Parametric Amplifiers", Conference for Lasers and Electro-Optics 2007, (CThC2).

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Prefer poster Session

Tuesday, August 28th, 2007

Morning Session

8:30AM - 10:10AM Chairman: Chuang Ren, LLE/Rochester

10:10AM - 10:30AM Coffee Break

10:30AM - 12:30PM Chairman: Andrey Solodev, LLE/Rochester

Evening Session

7:30PM - 8:30PM Invited Talk, Chairman: Juergen Meyer-ter-Vehn, MPI

8:30PM - 11:00PM Poster Session

Fast Ignition with Ultra-High Intensity Lasers

J. Tonge[1], M. Tzoufras[1], F. S. Tsung[1], W. B. Mori[1], C. Ren[2], M. Marti[3], L. Silva[3]

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Energy transport within overdense plasma with a fast ignition target is explored by examining the interaction of different intensity ignition lasers with a 50 μ radius target using two-dimensional Particle-In-Cell simulation. In fast ignition schemes the ignition energy must be delivered to a small region (~ 20 μ in radius) of dense plasma within the target in order to create a localized region where fusion occurs. The electron stopping length in the core and the energy spectrum of the ignition electrons determines the depth of this region. This depth is sensitive to the spectrum of the energy flux of fast electrons generated as a function of laser intensity at the critical surface. Coupled with current assumptions of the spectrum of electrons generated by high intensity lasers this limits ignition laser intensity to 5×10^{19} W/cm^2. Our simulations show that the peak energy flux of the ignition electrons is significantly lowered as the electrons traverse the collisionless plasma from the critical density surface of the plasma to the high density target core where ignition occurs. This allows higher intensity lasers to be used thus delivering power to a narrower region. In addition we find that a higher percentage of the ignition lasers energy is delivered to the core with the higher intensity laser.

Work Supported by Fusion Science Center for Extreme States of Matter

Modeling the Filamentation Instability of Relativistic Electron Beams for Fast Ignition

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Filamentation of relativistic electron beams is a problem of much current interest due to its relevance to the fast-ignition approach to laser-driven fusion, in which such beams must propagate through several hundred microns of dense plasma. Several recent papers have given calculations of temporal growth rates for filamentation based on various fluid and kinetic models.[1–3] However, in the fast-ignition scenario it is expected that the instability will be instigated by irregularities in the region where the beam is produced, and that the resulting filamentation will amplify as the beam propagates into the plasma, which is observed in simulations. Thus, it is of interest to analyze the spatial-growth properties of filamentation, both to model the initial phase of instability growth and to benchmark simulation codes.

This talk will present results for spatial growth and the related phenomenon of absolute instability of filamentation. Dispersion relations valid for arbitrary complex wave vectors have been derived for both fluid and kinetic models. Fluid models effectively approximate the transcendental plasma dispersion function (the *Z*-function for a Maxwellian) by an asymptotic algebraic approximation. The argument of this function is essentially the instability phase velocity (the complex frequency over the wave number) divided by the thermal velocity. It is found that fluid models are unreliable near the threshold for spatial growth or when the beam thermal velocity is a significant fraction of its directed velocity, since then the argument of the dispersion function is small and the asymptotic approximation fails.

Spatially growing modes must be distinguished from evanescent modes by analyzing the behavior of the complex wave number roots of the dispersion relation as the imaginary part of the frequency is varied. In addition, this analysis reveals the occurrence of absolute instability, in which two such roots merge across the real axis. Examples of this phenomenon will also be presented.

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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Competition between the resistive Weibel instability and the electrothermal instability in fast ignition

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A dispersion relationship for a local hybrid model in which a current of relativistic fast electrons of finite temperature are spatially superposed on an equal and opposite current of resistively driven cold electrons in a denser plasma has been derived. The model is similar to an earlier model of instabilities in nonlinear heat flow [M.G.Haines, Phys. Rev. Lett. **47**, 917 (1981)] except that the hot electrons are relativistic, and their inertia is included. The latter ensures zero growth rate as the wave number tends to zero. It is shown that the resistive Weibel mode can be adequately modeled by a hot electron fluid model. The combined physics includes resistivity perturbations due to changing cold electron temperature associated with Ohmic heating, and ion motion due to pressure perturbations. A comparison will be made between these competing modes[1].

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.

Integrated Simulation of Fast Ignition ICF

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and S. Skupsky

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To develop a thorough understanding of the complex physics of fast ignition, numerical modeling of the integrated fast-ignition experiments using different types of codes is required. Implosions of the cryogenic shells of DT fuel with a gold cone inserted to provide a plasma-free pass for an igniting pettawatt pulse need to be simulated using hydrodynamic codes. The transport of relativistic electrons from the inner cone surface to the dense fuel core needs to be simulated using particle and/or hybrid-PIC codes. To perform an integrated fast-ignition simulation, we have coupled the 2-D cylindrically symmetric hydrocode *DRACO*[1] and the hybrid-PIC code *LSP*.[2] *LSP* is used to simulate the heating of the dense fuel by hot electrons and generate additional source terms in the temperature equation used in *DRACO*. *DRACO* is a 2-D hydrocode that includes all the necessary physics required to simulate the ignition and burn of an imploded capsule. The plasma profiles in *LSP* are periodically updated according to *DRACO* results. The results of an integrated fast-ignition simulation will be presented in this talk using high-density and high-ρR fuel assembly recently suggested for fast ignition.[3]

This work was supported by the U.S. Department of Energy under Cooperative Agreement Nos. DE-FC02-04ER54789 (Office of Fusion Energy Sciences) and DE-FC52-92SF19460 (Office of Inertial Confinement Fusion), 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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Ion-driven fast ignition (IFI) *

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Research at Los Alamos on fusion fast ignition (FI) [1] initiated by laser-driven ion beams heavier than protons has produced encouraging results so far. Compared to protons or electrons, FI based on a beam of heavier ions has the potential advantage of a more localized energy deposition, which could minimize the required total beam energy, bringing it close to the theoretical minimum of ≈ 10 kJ [2]. High-current, laser-driven ion beams [3,4] are excellent for this purpose. Because of their ultra-low transverse emittance, these beams can be focused to the required dimension, ~ 10s of _m. Because they are created in ps timescales, these beams can deliver the power required to ignite the compressed D-T fuel, ~ 10 kJ / 50 ps. When using a technologically convenient light-ion species such as Carbon for the ignitor beam, this FI scheme requires about 100-fold fewer ions to deliver the necessary energy to ignite, a significant benefit in target fabrication. Three key requirements for the success of this scheme include the generation of a sufficiently monoenergetic beam (energy spread not exceeding ~ 10%), with a sufficiently high ion kinetic energy (≈ 400 MeV for C), along with a sufficiently high conversion efficiency of laser to beam energy. Our research program is concentrated on fulfilling these three requirements. Better understanding of the ion-acceleration mechanism and requisite target preparation has culminated in the successful demonstration of a laser-driven C ion beam with the required low energy spread [4]. An important benefit of this scheme is that such a high-energy, quasi-monoenergetic ignitor beam could be generated far from the capsule (≥ 1 cm away), so that the laser-target providing the beam may be protected from the implosion. This would eliminate the need for a reentrant cone in the capsule, a tremendous practical benefit. A new scheme for laser-driven ion acceleration under investigation at Los Alamos, the laser-breakout afterburner [5], promises to deliver the necessary ion kinetic energy, at high efficiency, while preserving the required monoenergetic character. Preliminary capsule designs for C-based FI have been developed, and are being refined and assessed. This presentation summarizes the ion-based FI concept; the progress in developing a suitable ignitor ion beam and an optimized implosion capsule design; and the ignition calculation, demonstrating the feasibility of the concept.

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The Role of Fast-Electron Preheating in Low-Adiabat Cryogenic and Plastic (CH) Shell Implosions on OMEGA

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In direct-drive ICF implosions, fast electrons generated by the two-plasmon-decay instability can degrade target performance by preheating the low-adiabat cold shell. The levels of fast-electron preheating the areal densities at peak burn have been measured and studied numerically in low-adiabat cryogenic and plastic (CH) shell implosions on OMEGA. Preheating energy levels on the order of 10 to 100 J were inferred from the hard-x-ray (>50-KeV) measurements and found to be correlated to the degradation, up to a factor of 2.5 in cryogenic implosions at high laser intensities, in inferred areal density from that predicted by 1-D hydrodynamic simulations. Numerical simulations and an analytical model show that the areal-density degradation are consistent with the measured preheating levels.

To reduce the preheating levels, low-adiabat (<2.5) cryogenic target implosions were driven by laser pulses with a relatively low value of the peak laser intensities ($<3 \times 10^{14}$ W/cm^2). Results show that the areal densities were significantly closer to 1-D predictions under these conditions and higher than those measured in higher-intensity implosions. The significance of such results to future low-adiabat implosion experiments required for ignition and high-gain ICF will be discussed.

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Determination of Hot-Electron Conversion Efficiency and Isochoric Heating of Low-Mass Targets Irradiated by the MTW Laser

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The absorption of laser light at relativistic intensities ($I > 10^{18}$ W/cm^2) by near-solid density plasma is observed to be mainly into hot ~MeV electrons. The efficiency of hot-electron generation, while poorly understood, is of central importance for several applications, including fast-ignition ICF, ion-beam generation, and backlighting.

Conversion efficiency and isochoric heating of low-mass, mid-*Z* targets have been determined at the RAL and NOVA petawatt facilities using a variety of techniques, including K_α imaging,[1] but such measurements are limited by significant uncertainties in the interaction conditions.

Surprisingly, it is shown that the multiterawatt (MTW) laser at LLE with ~4 J is able to access the same physics by using extremely low-mass, mid-*Z* targets, $M \sim 10^{-9}$ g, but with more precisely defined interaction conditions. In this talk, the modeling strategy for these "precision" experiments is outlined. Using a combination of hydro/PIC and atomic model codes, absolute and relative K-shell fluoresce lines are used to quantify both the isochoric heating and the hot electron conversion efficiency to high accuracy. The connection with previous work on the RAL petawatt laser is discussed.[2]

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Prefer oral presentation.

Effects of Hot-Electron Preheat in Direct-Drive Experiments on OMEGA

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Direct-drive, inertial confinement fusion ignition target performance is sensitive to the details of thermal coupling, transport, and preheat that directly affect the fuel adiabat. The results of plastic, planar thin-foil acceleration and thick-foil compression experiments on OMEGA at laser intensities from ~2×10^{14} W/cm^2 agree well with 2D simulations using a constant flux limiter (0.06). However, at intensities of ~1×10^{15} W/cm^2, a nonlocal thermal-transport model or time-dependent flux limiter is necessary to explain the experimental results. In addition, a deposited preheating of ~30 J is required to be included into simulations at high drive intensities to match the experimental results. This is in agreement with experimentally measured hot-electron preheat. In cryogenic implosions, the areal densities at peak burn were correlated with measured target preheat levels caused by hot electrons. An areal-density reduction of up to ~2.5 at the highest drive intensities is consistent with a preheat energy of ~150 J (~0.5% of total laser energy)—in agreement with 1-D simulations of the preheated targets. The preheat appears to be due to the two-plasmon-decay instability that is more virulent in cryogenic D_2. An areal density of >200 mg/cm^2 was measured during 10-μm-thick CD, 100-μm D_2 ice implosions at laser intensities of ~5×10^{14} W/cm^2. In this case, the CD is ablated throughout the laser pulse, reducing the preheat levels. This talk will summarize the effects of preheating on direct-drive target physics.

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Prefer oral session.

Simulations of the Effect of Energetic Electrons Produced from Two-Plasmon Decay in the 1-D Hydrodynamic Code *LILAC*

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The generation of electrons from two-plasmon decay and the subsequent preheat of the imploding shell has been previously described.[1,2] The effect of two-plasmon-decay electrons on the implosion of cryogenic targets[3] has been the subject of intense scrutiny at the Laboratory for Laser Energetics. In particular, preheat of the fuel caused by these electrons can reduce the maximum areal density attainable at stagnation and can potentially result in a failure to ignite. The fast-electron transport package in *LILAC*, which was originally used to model exploding pushers, has been modified to model the production and transport of the two-plasmon-decay electrons. These electrons are created at the quarter-critical surface when a threshold depending on laser intensity and local thermal-electron scale-length is attained.[4] The fraction of the laser energy absorbed is a parameter that depends exponentially on the threshold condition and saturates at laser intensities of 10^{15} W/cm^2. The source distribution is Maxwellian with a temperature scaling inferred from the measurement of hard x rays. The electrons are transported with a multi-group diffusion model in which the free-streaming electrons are treated by a modified P_2 model. The energy loss to fast ions is included and the x-ray radiation spectrum is computed to compare with measurements. Simulation results from warm plastic and cryogenic implosions are compared with the following experimental diagnostics: the hard-x-ray temporal and time-integrated emission, the fast-ion spectrum,[5] and the neutron-averaged areal density at stagnation.

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Prefer oral session.

Time-Dependent Spectral Shifts of Scattered Laser Light in Direct-Drive Inertial Confinement Fusion Implosion Experiments

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Time-resolved scattered light spectroscopy near $\lambda = 351$ nm from spherical target implosions on OMEGA provides information on the time-dependent laser absorption. The time-dependent absorbed fraction during spherical room-temperature and cryogenic direct-drive implosions is inferred from these measurements. For complex pulse shapes the measured time-dependent absorption often differs from that predicted by hydrodynamic simulations while the time-integrated absorption fraction tends to be in good agreement. The sources of the discrepancies are being studied by examining the temporally dependent spectral shift of the scattered light. The spectral shift results from a combination of a Doppler shift due to the evolving coronal plasma and nonlinear processes that can shift energy between crossed beams. Measured spectral shifts for different pulse shapes are compared with the shifts predicted using a ray-trace code and the plasma profiles from a hydrodynamic code with a variety of electron-heat transport models (i.e., fixed flux-limited, variable flux-limited, and nonlocal electron-heat transport). The predicted spectral shifts vary dramatically with the assumed electron-heat conduction model. The nonlocal electron-heat transport model provides the best match to the measured spectral shifts. The remaining discrepancies between predictions and measured data suggest nonlinear energy exchange occurs between crossed beams due to stimulated Brillouin scattering.

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.

Prefer oral presentation.

Calculations for Omega symmetry capsule implosion experiments in ~0.2 NIF scale high temperature hohlraums

N.D. Delamater, D.C. Wilson, G.A. Kyrala, A. Seifter, N.M. Hoffman, E. Dodd, D. Schmidt, *Los Alamos National Laboratory*, V. Glebov, C. Stoeckl, *L.L.E., University of Rochester*, and C.K. Li, *M.I.T.*

Symmetry capsules are planned to be used as a diagnostic of implosion symmetry at varying times during the NIF drive. A suitably designed symmetry capsule samples the drive symmetry up to the implosion "commit" time of the capsule, which varies for symmetry capsules of different shell thickness. Our capsules use Ge-doped plastic shells with shell thickness varying from 25 μm to 55 μm. We present calculations for Omega experiments using symmetry capsule implosions in gold hohlraums 1900 μm x 1200 μm, and 70 % laser entrance hole, which is approximately a 0.2 NIF scale ignition hohlraum and reaches temperatures of 265-275 eV similar to those during the NIF drive. We show simulations using 40 Omega beams driving the hohlraum with 3 cones from each side (cone angles of 21, 42 and 59 degrees) and 19.5 kJ of laser energy. Beam phasing may achieved by decreasing the energy separately, in each of the three cones, by 3 kJ for a total drive energy of 16.5 kJ. This results in a more asymmetric drive, which will vary the shape of the imploded symmetry capsule core from round to oblate or prolate in a systematic and controlled manner. Implosion core time dependent simulated x-ray images show the expected change in symmetry due to beam phasing. Limb brightened images were seen in the simulations for some of the capsules, due to the presence of Ge doping in the plastic shell. These capsules also may be used as a diagnostic of shell ρr, since the gas fill is d-He3 at 36 atm. The protons produced in the implosion escape through the shell and produce a proton spectrum, which is measured using wedge range filters. The neutron, proton yield and spectra change with capsule shell thickness as the un-ablated mass or remaining capsule ρr changes. The neutron yield increases with increasing shell thickness since the shell converges more, but the proton yield is expected to decrease with increasing shell thickness since fewer protons can escape through a thicker shell. This technique to measure capsule un-ablated mass will be applied to future NIF experiments with ignition scale capsules. Experiments were recently performed at the Omega laser facility to test these concepts, and some preliminary results will be presented.

Progress in Fast Ignition Research

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Fusion Science Center, University of Rochester

This talk will review the present status of fast ignition research within the Fusion Science Center for Extreme States of Matter and Fast Ignition Physics. It will review the progress in the theory and experiments on fast ignition fuel assembly, hydrodynamics and hybrid simulations of ignition and burn, integrated simulations of hot electron generation and transport for both 'hole-boring' and coned-target scenarios, benchmark experiments of hot electron transport in nail and wire targets, and conversion efficiency experiments in planar targets.

Tuesday August 28th 8:30-11:00PM

Po-1	**Rozmus**	Wojciech	U. Alberta	Nonstationary Nonlocal Transport Theory of Fully Ionized Two Component Plasma
Po-2	**MacFarlane**	Joseph	Prism Comp.Sci.	VISRAD – A 3-D Design Tool and View Factor Code for High Energy Density Physics Experiments
Po-3	**Ross**	James Steve	LLNL	Simultaneous Measurement of the Electron Temperature and Density in a High Temperature Hohlraum
Po-4	**Cooley**	J. H.	LANL	Development of a more physical basis for a fall-line mix model for inertial confinement fusion targets
Po-5	**Afeyan**	Bedros	Polymath Research	Separating Morphologically Diverse Features Causing Target Surface Nonuniformity: From Global Structures To Artifacts to Local Bumps and Tests of Multifractality
Po-6	**Constantin**	Carmen	UCLA	Laser-plasma coupling to Alfvén waves in a large magnetized plasma
Po-7	**Meyer-ter-Vehn**	Juergen	MPI/Quantum Optics	Physical Collision Frequency neff (T, w) for Metals and Warm Dense Matter
Po-8	**Neumayer**	Paul	LLNL	Suppression of Stimulated Brillouin Scattering in multiple-ion species inertial confinement fusion Hohlraum Plasmas
Po-9	**Esarey**	Eric	LBNL	Unphysical Kinetic Effects in Laser Wakefield Accelerators Modeled with PIC Codes
Po-10	**Matsuoka**	Takeshi	U.Michigan	Proton Generation from Ultrathin Foils via High Contrast 10^(20) W/cm^(2) 30 fs Laser Pulses
Po-11	**Fang**	Fang	UCLA	Evolution of Relativistic Plasma-Wave front in LWFA
Po-12	**Schroeder**	Carl	LBNL	Warm Wavebreaking of Nonlinear Laser-Driven Electron Plasma Waves
Po-13	**Ren**	Chuang	U. Rochester	Laser channeling in mm-scale underdense plasmas of fast ignition
Po-14	**D'Humieres**	Emmanuel	UNR	Investigation of Proton Acceleration with High Intensity Lasers in a Density Gradient
Po-15	**Prisbrey**	Shon	LLNL	High Energy Laser Platform for Isentropic Compression Utilizing Indirect-Drive on the National Ignition Facility

Nonstationary Nonlocal Transport Theory of Fully Ionized Two Component Plasma

Zhen Zheng[1], W. Rozmus[1], A. Brantov[2] and V. Yu. Bychenkov[1,2]
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Linearized electron transport theory that is fully equivalent to the solution of a Fokker-Planck equation [1,2] has been generalized to include ion transport. Starting from the complete Lanadu collision operators expressed in terms of Rosenbluth potentials, electron and ion velocity distribution functions are expressed in terms of infinite series of angular harmonics. Hydrodynamical equations and transport closure relations are derived in response to initial perturbations. They involve re-summation of large number of harmonics ensuring transition to the collisionless regime.

The complete set of frequency and k-number dependent transport coefficients has been discussed. Our results show reduction in ion thermal conductivity and ion viscosity for $k\lambda_{ii}>10^{-2}$ (λ_{ii} - ion-ion collision mean free path, k – wave number related to the inhomogeneity scale length) as compared to standard Chapman-Enskog theory results. The role of ion-electron collisions has been examined. Applications of this theory to the calculations of the dynamical form factor, ion-acoustic and entropy modes dispersion relations have been presented. Our results provide an exact limit for the nonlinear transport calculations.

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VISRAD – A 3-D Design Tool and View Factor Code for High Energy Density Physics Experiments

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The 3-D view factor code VISRAD is used to both design high energy density physics (HEDP) experiments at OMEGA, NIF, and other laser facilities, and to simulate the multi-dimensional radiation environment within target systems; i.e., hohlraums and associated components such as diagnostic holes, capsules, and backlighters. VISRAD target systems are built using a variety of geometric primitives, and surface removal algorithms (e.g., drilling holes in cylinders) can be employed to build complex targets. Laser beam parameters – power profiles, pointing, and focusing – can be specified for either individual beams or groups of beams. The use of multiple coordinate systems is supported so that target components can be positioned and oriented, and laser beams can be pointed, in the target chamber coordinate system or in the coordinate system of any target component. Radiation flux distributions about the target system are computed by solving a coupled set of power balance equations in which the emission from a given surface element in the target grid is coupled to all other surface elements. At any point in the grid, the time- and frequency-dependent flux incident onto that point can be viewed and/or written to a file to be used as input to radiation-hydrodynamics simulations. Energy source models include laser energy deposition – computed using 3-D ray-trace algorithms – and self-radiating target components. To aid designers in setting up targets, pointing beams, and viewing results, VISRAD has an easy-to-use graphical user interface and interactive 3-D graphics. The code has been designed for cross-platform use on Windows, Unix, and Mac OS X platforms. We will describe new capabilities recently added to VISRAD, such as interfacing with the OMEGA SRF database and the ability in import STEP CAD files.

Simultaneous Measurement of the Electron Temperature and Density in a High Temperature Hohlraum

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Abstract

Plasma parameters near the laser entrance hole of high-temperature hohlraums (T_{rad}>300eV) are critical to understand coupling of the laser beams to the hohlraum. We report measured electron temperatures up to 12 keV, with density ranging from $5x10^{20}$ to 10^{21} cm^{-3}, 200 μm outside the laser entrance hole. These measurements were made in the collective ion-acoustic regime where multiple-wavelength Thomson scattering is required ($\alpha \sim 1$) to make an accurate measurement of the electron temperature or density. We will discuss the accuracy of our multiple-wavelength Thomson-scattering technique for high energy density parameters.

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 and grant number DE-FG52-2005NA26017 (NLUF).

Development of a more physical basis for a fall-line mix model for inertial confinement fusion targets

James H. Cooley, Leslie Welser-Sherrill, Douglas C. Wilson, and Hans Herrmann

Los Alamos National Laboratory

Abstract:

Imploding capsules are used for a wide range of science experiments in Inertial Confinement Fusion (ICF) to better understand the thermonuclear and atomic processes present in a burning plasma. There are a large number of diagnostics which can be used to elucidate many different areas of physics simultaneously e.g., various thermonuclear yields and yield rates, x-ray emission, and ion temperature. Unfortunately, for directly driven targets we have difficulty consistently simply predicting the expected yield for these implosions. One obvious weakness in our modeling ability is the potential effects of the shell mixing into the fuel and thus reducing the yield. Attempts have been made at modeling this process both dynamically with the model by Scanepiaco and Cheng and with post-processing techniques like Hann's and Youngs' models. Although the dynamic models have had some success in matching expected yields they often have difficulty matching other diagnostics such as reaction history or ion temperature. The Haan and Youngs models usually produce predicted yields similar to the clean calculation as the expected mix width in these models is small and does not necessarily incorperate all of the mixing processes seen in the experimental data.

Gabett and Amendt have both discussed a fall-line model as another technique to address this problem and Garbet has developed a model which allows him to be quantitative about the expected effect on yield; however, this model still misses much of the other diagnostic data such as ion temperature. In this paper we will present a model based on a fall-line but which attempts to use additional physical considerations to better agree with the wealth of available experimental data. In this model we assume that some fraction of the inner shell is ejected into the fuel as the shock passes and proceeds with the fall line. This material effectively cools the fuel and thus reduces both the yield and ion temperature. We will compare the results of this model to implosion experiments performed on Omega.

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Separating Morphologically Diverse Features Causing Target Surface Nonuniformity: From Global Structures To Artifacts to Local Bumps and Tests of Multifractality

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J. L. Starck[2], E. Mapoles, S. Haan[3]
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We have studied a series of images generated by Atomic Force Microscopy (AFM), phase shifting spherical diffraction interferometry (PSSDI), X ray precision radiography (PR) and X ray phase contrast imaging (X-PCI). These images are made up of fine scale bumps and scratches, measurement artifacts, global features and very fine scale multi-fractality. Using modern advances in harmonic analysis, we have successfully separated these features using a technique we call Morphological Diversity Extraction. It consists of an iterative variational minimization where overcomplete libraries of functions are used, each adept at achieving maximally sparse representations of one type of feature of the image. This could also be called sparsity pursuit.

We will show spherical data from the AFM technique, 16 medallions making up a belt around the target in some equatorial plane in PSSDI, 16 channels of X ray absorption vs angle in PR and very thin, possibly distorted, ICE layers in X-PCI. We denoise and feature separate all these images using a variety of known and newly developed techniques and comment on how these can be automated to be part of GA's target fabrication quality control.

Moreover, we also apply Haan hydrodynamic instability integrated growth factors to these separated features' mode decomposition amplitudes and compare his criteria (so called Haan specs for the NIF) for implodability. We try to understand how individual features or their aggregates may cause shell breakup at peak implosion velocity or at stagnation.

**This work was funded by LLNL and GA.

Prefer poster Session

Laser-plasma coupling to Alfvén waves in a large magnetized plasma

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Large amplitude shear Alfvén waves have been observed in recent experiments coupling a laser pulse of 20 J, 5 ns, at 1064 nm wavelength to a large (18 m), magnetized plasma of uniform density ($4x10^{12}$ cm^{-3}) at $T_e \sim 5$ eV. The expansion velocity of the laser blowoff plasma responsible for electromagnetic waves propagating along the magnetic field in the ambient plasma has been inferred from a fast-shutter imaging diagnostic. Simultaneously, the magnetohydrodynamic turbulence caused by the fast particles passage has been recorded by ten magnetic probes aligned along the Large Plasma Device (LAPD), in three directions.

The laser (PHOENIX) has been employed in a previous campaign at lower energy (3 J at 532 nm wavelength). It is the first run at 20 J and the highest energy that has been used for irradiating low-Z targets (100 mm thick plastic foils and graphite rods) in the LAPD. The results show an increase of the magnetic turbulence an order of magnitude above the previous results.

Formation of shocks with M_A and b above unity, at a sufficiently small density to approach collisionless regimes is the principal goal in these series of experiments.

This work is supported by the DOE and the Basic Plasma Science Facility.

Abstract for AA2007, Maui, August 27-31, 2007

Physical Collision Frequency $\nu_{eff}(T, \omega)$ for Metals and Warm Dense Matter

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The collision frequency between electrons and ions is a central quantity for laser absorption and transport processes in dense plasma. Here we study the collision frequency in metal-like, partially degenerate, warm dense matter, where free electrons play the major role. In particular, the transition from cold metallic to hot plasma states through states near the Fermi temperature is of considerable practical interest. This regime at temperatures between T = 0 – 100 eV is poorly understood, so far. The Spitzer formula applying to high temperature plasma breaks down in this regime, and typically ad hoc fit formulas are used [1, 2]. In addition to T, the frequency dependence of $\nu_{eff}(T, \omega)$ has to be taken into account for absorption of VUV light at frequencies ω larger than the plasma frequency ω_p. VUV absorption has been the primary motivation for this work [3, 4].

Here we derive $\nu_{eff}(T, \omega)$ from the bremsstrahlung cross section, using Sommerfeld's exact expression [6]. The essential new observation [5, 7] then is that the collision rate depends on electron velocity u like $1/u$ for "slow electrons" ($u < Z\alpha c$, Z ion charge, $\alpha = 1/137$), which applies to the low temperature regime considered here. This is different from the usual $1/u^3$ scaling for fast electrons which, after thermal averaging, leads to the Coulomb logarithm with appropriate cut-offs. For slow electrons, however, averaging $< 1/u >$ over a Fermi distribution leads to a finite analytical expression which represents the central result of this work. The new formula, containing no free parameters, covers the whole temperature regime of warm dense matter down to metals at room temperature and frequencies from $\omega = 0$ (DC) to optical and VUV photon energies. For $\omega < \omega_p$, $\nu_{eff}(T, \omega)$ is replaced by $\nu_{eff}(T, \omega_p)$ to account for Debye screening. The formula applies surprisingly well with existing data. This will be shown in the talk.

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Suppression of Stimulated Brillouin Scattering in multiple-ion species inertial confinement fusion Hohlraum Plasmas

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The optimization of laser coupling into a low-Z gas-filled hohlraum is of importance to the success of the indirect-drive approach to inertial confinement fusion (ICF). Parametric instabilities such as stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) can backscatter the incident laser light reducing the total drive energy and affecting radiation symmetry. Increasing the Landau damping of acoustic waves by employing multiple-ion species plasmas offers the perspective of controlling SBS. In this contribution we report on recent experiments at the Omega laser facility demonstrating the potential of multiple-ion species plasmas to control stimulated Brillouin scattering (SBS). By adding a low-mass ion species (Hydrogen) to a CO_2 hohlraum gas fill, the SBS reflectivity was reduced by 3 orders of magnitude. The reduction in the total backscattered energy resulted in an increase of the hohlraum radiation temperature indicating improved coupling of the heater beams. These observations may be scaled to the plasma conditions within ignition scale hohlraums and support employing multiple-ion species plasmas in target designs for the first attempt at ignition on the National Ignition Facility.

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Abstract for Poster Presentation:
37th Anomalous Absorption Conference
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Unphysical Kinetic Effects in Laser Wakefield Accelerators Modeled with Particle-in-Cell Codes

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Unphysical heating and particle trapping in the numerical modeling of laser wakefield accelerators using particle-in-cell codes are investigated. A dark current free laser wakefield accelerator stage, in which no physical trapping should occur, as well as a highly nonlinear blowout wake, in which a physical trapped bunch should be present, are modeled. Numerical errors can lead to displacements in the macro-particle orbits in both phase and momentum. These displacements grow as a function of distance behind the drive laser and can be sufficiently large as to result in unphysical trapping in the wake. The resulting numerical heating grows much faster and to a higher level then the numerical heating of a warm plasma in an undriven system. In general, the amount of heating in the region immediately behind the laser pulse can be decreased by decreasing the grid size, increasing the number of particles per cell, or using higher-order particle shapes. Eventually, numerical heating will be sufficiently high to cause unphysical trapping in a region sufficiently far behind the laser pulse. The effects of numerical heating are less severe in a highly nonlinear blowout wake, since trapping occurs in the first plasma wave period immediately behind the laser pulse. Modeling of ongoing laser-plasma experiments will also be presented.

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

ABSTRACT
Proton Generation from Ultrathin Foils via High Contrast 10^{20} W/cm^2 30 fs Laser Pulses

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High intensity laser plasma interactions have the ability to generate quasi-monoenergetic, collimated proton beams, which can be used in applications such as cancer therapy, or inertial fusion energy. Simulations show that for sufficiently high laser intensities, ultra-bright proton beams having 100's of MeV energy can be produced by irradiating thin targets with the thickness that approaching the foil transparency[1]. We report a detailed study of proton production by irradiating submicron foils (50 nm – 1000 nm) with a short (30 fs), high intensity (4×10^{20} W/cm^2), high contrast (10^{-11}) [2] laser pulse with in an effort to achieve the Directed Coulomb Explosion regime of proton acceleration[1]. Proton and hot electron energies were measured as a function of target thickness for Mylar and silicon nitride foils. Protons observed from the Mylar foils were at least two times higher in energies than protons from the non-hydrogen containing material (Si_3N_4). For laser-matter interaction with a sufficient ASE contrast the laser's ponderomotive potential imposed at the target front creates a longitudinal electrostatic field where protons can be accelerated to several MeV energies. 2D PIC simulations show that the front surface accelerated protons propagate through the target and experience an additional field (Target Normal Sheath Acceleration) at the rear surface which accelerates them to higher energies compared to protons accelerated just from the rear surface. Therefore, experiments and simulations suggest that in high-intensity laser interaction with ultra-thin foils protons that the maximum energy is produced through the front side ponderomotive acceleration and post-acceleration at the rear of the foil. This effect is more pronounced for the hydrogen containing materials which generate highest proton energies.

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This study was supported by the National Science Foundation through the Frontiers in Optical and Coherent Ultrafast Science Center at the University of Michigan and the National Institute of Health.

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Evolution of Relativistic Plasma-Wave front in LWFA*

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Abstract

In a laser wake field accelerator experiment where the length of the pump laser pulse is several plasma period long, the leading edge of the laser pulse undergoes frequency downshifting as the laser energy is transferred to the wake. Therefore, after some propagation distance, the group velocity of the leading edge of of the pump pulse, and therefore of the driven electron plasma wave, will slow down. This can have implications for the dephasing length of the accelerated electrons and therefore needs to be understood experimentally. We have carried out an experimental investigation where we have measured the velocity v_f of the 'wave-front' of the plasma wave driven by a nominally 50fs (FWHM), intense (a0 ~ 1), 0.8μm laser pulse. To determine the speed of the wave front, time- and space-resolved reflectometry, interferometry, and Thomson scattering were used. Although low density data ($n_e \sim 1.3 * 10^{19} cm^{-3}$) showed no significant changes in v_f over 1.5mm (and no accelerated electrons), high-density data ($n_e \sim 5*10^{19} cm^{-3}$) shows accelerated electrons and an approximately 5% drop in v_f after a propagation distance of about 800μm.

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Warm Wavebreaking of Nonlinear Laser-Driven Electron Plasma Waves

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We present a calculation of the maximum amplitude of a nonlinear electron plasma wave, valid for nonrelativistic plasma temperatures, that can be applied to Langmuir waves driven by short-pulse laser-plasma interactions. Short-pulse (sub-ps) intense laser-plasma interactions access a physical regime where the plasma electrons experience relativistic motion while the plasma temperature (electron momentum spread) remains small. The nonequilibrium plasma is typically created by the laser through photoionization and the laser-plasma interaction occurs on a timescale short compared to the ion motion and the collision frequency. We analyze the nonlinear electron plasma waves excited by intense short-pulse lasers propagating in underdense plasma using a warm, relativistic fluid model of a nonequilibrium, collisionless plasma. Properties of the nonlinear plasma wave, such as the plasma temperature evolution and nonlinear wavelength, are examined, and the maximum amplitude of the oscillation is derived, including the presence of an intense laser field. Nonlinear electron plasma waves with relativistic phase velocities driven by intense short-pulse laser-plasma interactions have applications to charged particle acceleration, and the maximum plasma wave amplitude sets a limit on the achievable accelerating gradient. The presence of an intense laser field is shown to increase the maximum plasma wave amplitude for relativistic phase velocities. In the regime of non-relativistic phase velocities, the presence of an intense laser field is shown to decrease the maximum plasma wave amplitude owing to the coupling between transverse and longitudinal plasma momentum. Implications for stimulated Raman scattering are discussed.

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Laser channeling in mm-scale underdense plasmas of fast ignition

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In the fast ignition approach to laser fusion, non-linear laser-plasma interactions could cause significant energy loss for an ignition laser in an underdense plasma. One way to avoid this is to use a channeling pulse to create a low-density channel for the ignition pulse. Two dimensional particle-in-cell simulations show that laser channeling in mm-scale underdense plasmas is a highly nonlinear and dynamic process involving laser self-focusing and filamentation, channel expansion through ponderomotive blowout and high mach number shock waves, plasma density snowplowing, laser hosing, and channel bifurcation and merging. The channeling speed is much less than the laser linear group velocity. The simulations find that the channeling time T_c and the total required energy E_c to reach the critical surface scale with the laser intensity I as $T_c \sim I^{-0.64}$ and $E_c \sim I^{0.36}$. The scaling shows that low-intensity channeling pulses are preferred to minimize the required pulse energy but with an estimated lower bound on the intensity of $I \approx 4\times 10^{18}$ W/cm^2 if the channel is to be established within 100ps. These results will also be compared with those from smaller scale 3D simulations. This work was supported by the U.S. Department of Energy under Cooperative Agreement and Grant Nos. DE-FC52-92SF19460, DE-FC02-04ER54789, and DE-FG02-06ER54879.

INVESTIGATION OF PROTON ACCELERATION WITH HIGH INTENSITY LASERS IN A DENSITY GRADIENT

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In the last few years, intense research has been conducted on laser-accelerated ion sources and their applications [*,**]. Proton beams accelerated from solid planar targets have exceptional properties, i.e. high brightness and high spectral cut-off, high directionality and laminarity, and short burst duration (~ps at the source). These proton sources open new opportunities for ion beam generation and control, and could stimulate development of compact ion accelerators for many applications.

Recently, experiments have shown that a gaseous target can produce proton beams with characteristics comparable to those obtained with solid targets [***]. These gaseous targets typically have long density gradients at the front and at the back of the gas jet. Other experiments showed that a small density gradient at the back of a solid target does not strongly hamper the production of energetic protons when this target is irradiated by a high intensity lasers [****].

Using 1D and 2D PIC simulations, we have studied in detail the effect of a density gradient on proton acceleration with high intensity lasers both for underdense and overdense targets. This effect strongly depends on the length, the shape and the amplitude of the density gradient. It also depends on the maximum density of the target. These results were used to prepare new experiments of laser proton acceleration with gaseous targets.

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***High Energy Laser Platform for Isentropic Compression Utilizing Indirect-Drive on the National Ignition Facility**

Shon Prisbrey, Dave Braun, Bruce Remington, Hye-Sook Park, Raymond Smith

To be presented at 37th Anomalous Absorption Conference
Aug. 27-31, 2007

Abstract:

The desire to more fully understand the behavior of materials under high pressure and density – such as iron in planetary cores or theoretical phase transitions of molybdenum (Remington et al, Rev. of Modern Physics, vol. 78, p 755, 2006) – has driven interest in isentropic compression experiments (ICE). The traditional method of determining the high pressure equation-of-state relies on the use of shocks, which drastically raise the entropy of the material, makes high pressure, high density measurements unrealizable with present resources. We present an indirect-drive platform for the National Ignition Facility for near isentropic ramp compression experiments that can achieve pressures greater than 10^6 bar in molybdenum. The platform that we propose for the National Ignition Facility utilizes a hohlraum to generate a strong shock which pressurizes a reservoir of material. The reservoir then unloads from its rear surface across a vacuum gap before piling up against a planar sample. The ram pressure of the unloading reservoir produces an increasing pressure history as it collides with the sample. The temporal stretching of the compression wave helps to avoid inducing a large shock in the material and can be controlled by the gap size and the materials chosen for the reservoir. The materials in the ablating reservoir can be chosen to be optically thick to X-rays produced during deposition of the laser energy so as to avoid any possibility of preheating, and therefore, thermal variation in the sample. The continuous measurement of the samples back surface velocity via velocity interferometry (VISAR) is adequate to determine the material response during compression.

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Wednesday, August 29th, 2007

Morning Session

8:30AM - 10:10AM Chairman: Mark Schmitt, LANL

10:10AM - 10:30AM Coffee Break

10:30AM - 12:30PM Chairman: Steve Haan, LLNL

Evening Session

7:30PM - 8:30PM Invited Talk, Chairperson: Denise Hinkel, LLNL

8:30PM - 11:00PM Poster Session

NIF ignition target design, requirements, margins, and uncertainties

Steven W. Haan, J.D. Salmonson, D.S. Clark, D.A. Callahan, B.A. Hammel, L. J. Suter, M.J. Edwards, and J.D. Lindl
Lawrence Livermore National Laboratory

We describe simulation effort for NIF ignition, focused on a point design target that uses 1.3 MJ of light to drive a hohlraum to 285eV. The point design capsule has 5 layers of varying Cu dopant to minimize RT instability growth. We describe the optimization of this target, using 1D and 2D simulations.

A set of requirements has been developed that describes all aspects of the target, its fabrication and fielding, the laser pulse delivered to it, and the features of the pre-ignition experiments that are needed to finalize the design. We describe a model that characterizes the margin of the target as a function of the input parameters and uncertainties. The model has been defined by 1D, 2D, and 3D simulations. Using the margin model, statistical ensembles of input parameters are considered to describe shot-to-shot variations, and the impact of residual systematic errors. This model has been used to define and update the point design, to quantify the impact of each requirement, and to ensure that the requirements are optimally defined. The model can be used to project the probability of ignition, as shot-to-shot variations and more globally given systematic errors.

There are several backup targets that are being kept active, including other drive temperatures from 270 to 300eV, CH ablators, and high density C ablators. The relative performance, and specific pertinent issues, regarding these targets are described.

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ROBUSTNESS STUDIES OF NIF IGNITION TARGETS IN TWO DIMENSIONS *

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Inertial confinement fusion (ICF) capsules are critically dependent on the integrity of their hot spots to ignite. At the time of ignition, only a certain fractional perturbation of the nominally spherical hot spot boundary can be tolerated and the capsule still achieve ignition. The degree to which the expected hot spot perturbation in any given capsule design is less than this maximum tolerable perturbation is a measure of the ignition margin or robustness of that design. Moreover, since there will inevitably be uncertainties in the initial character and implosion dynamics for any given capsule, all of which can contribute to the eventual hot spot perturbation, quantifying the robustness of that capsule against a range of parameter variations is an important consideration in the design. Here, the robustness of the 300 eV indirect drive target design for the National Ignition Facility (NIF) [J. D. Lindl, *et. al*., Phys. Plasmas **11**, 339 (2004)] is studied in the parameter space of inner ice roughness, implosion velocity, and capsule scale. A suite of two thousand two-dimensional simulations, run with the radiation hydrodynamics code Lasnex, is used as the data base for the study. For each scale, an ignition region in the two remaining variables is identified and the "ignition cliff" is mapped. In accordance with the theoretical arguments of [W. K. Levedahl and J. D. Lindl, Nucl. Fusion **37**, 165 (1997); R. Kishony and D. Shvarts, Phys. Plasmas **8**, 4925 (2001)], the location of this cliff is fitted to a power law of the capsule implosion velocity and scale. It is found that the cliff can be quite well represented in this power law form, and, using this scaling law, an assessment of the overall (one- and two-dimensional) ignition margin of the design can be made. The effect on the ignition margin of an increase or decrease in the density of the target fill gas is also assessed.

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

Multi-Variable Sensitivity Studies of Ignition Targets for NIF

J. D. Salmonson, S. W. Haan, D.S. Clark, and D.A. Callahan
Lawrence Livermore National Laboratory

Performance of indirect drive ignition targets being designed for the National Ignition Facility has been studied with multi-variable sensitivity studies. Large numbers of simulations are run, in each of which a number of parameters are set from statistical ensembles intended to represent expected variations in the variables characterizing the target. Parameters varied include target dimensions, compositions, densities, laser pulse variations, variations in the hohlraum parameters as they determine pulse shaping and symmetry variations, surface roughness, intrinsic hohlraum asymmetry, beam-to-beam power imbalance, and pointing errors. Statistical samples are very large (10,000) for variations of the 1D spherical implosion, and large enough for meaningful statistics (a few hundred runs) for the 2D variations. The overall performance trends can be predicted from a model that uses second order Taylor series to calculate the implosion velocity and DT fuel entropy, as functions of the target variables. The statistical variations allow us to address quantitatively questions such as "What is the distribution function describing the expectation of yield, given expected shot-to-shot variations in the parameters describing the experiment?"

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

Ignition Target Design with a High-Density Carbon (HDC) Ablator for the National Ignition Facility (NIF)

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Abstract: An ignition capsule with a nano-crystalline, high density, carbon ablator is emerging as a promising alternative target for NIF. There are four advantages in using the HDC ablator. First, for a given outer radius, the HDC ablator absorbs more hohlraum-driven x-ray energy than a beryllium ablator. Second, the HDC ablator will have smaller and more uniform crystalline grains than beryllium, enabling more isotropic shock propagation. Third, the higher density reduces the coupling between the DT ice surface and the unstable ablation front, thereby reducing the growth of the surface perturbations seeded by ice roughness. Fourth, material strength of the HDC can reduce instability growth at early times. Possible – though surmountable – challenges include: (1) The need for smoother outer ablator surfaces because of slightly lower ablation rates, and larger mass perturbations for a given surface roughness. (2) Ensuring that the HDC does not spend time in a partially melted state in which density or velocity variations could seed Rayleigh-Taylor instabilities. LASNEX design simulations show good 1-D performance and overall favorable 2-D stability behavior. In particular, the ablator is solid following the 1st shock, and completely melted upon passage of the 2nd shock. The capsule can tolerate about twice as rough a DT ice surface as with Beryllium, and instability growth is reduced by material-strength in the HDC ablator.

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Rugby-shaped Hohlraum Designs on Omega for Enhanced X-ray Drive*

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The energetics advantages for rugby-shaped hohlraums over standard cylindrical hohlraums have recently been predicted within the context of NIF double-shell ignition designs [1]. A recent study on using rugby-shaped hohlraums for achieving ignition with single-shell cryogenic capsules in early Laser MegaJoule experiments at reduced laser energy also shows promise [2]. For rugby hohlraums with 50% laser entrance holes, the high-Z hohlraum surface area is ~20% smaller, potentially leading to a ~10% energy savings from reduced wall losses. Other potential benefits include (1) the flexibility for fielding larger capsule targets to take advantage of greater clearance near the rugby hohlraum waist, (2) better laser-target coupling of the inner cone laser beams due to a higher incident angle, (3) reduced time-dependent flux asymmetry from outer-cone laser deposition closer to the hohlraum symmetry axis [2], and (4) less coupling of radiation asymmetry (Legendre) modes in a quasi-spherical geometry.

An experimental campaign on Omega to further test our notions of x-ray drive and symmetry in rugby-shaped hohlraums is proposed. Side-by-side comparisons with cylindrical hohlraums with identical waist radii are planned for demonstrating the energetics benefits of rugby hohlraums. Earlier x-ray implosion times by nearly 200 ps and increases in peak Dante temperatures >10 eV are predicted, based on 2D radiation-hydrodynamics simulations. Neutron yields well in excess of 10^{10} using pure deuterium fuel are expected according to 2D simulations, nearly 2x compared with cylindrical hohlraums. Such large neutron signatures avail the possibility for diagnosing burn histories in indirect drive with the neutron temporal diagnostic (NTD), potentially providing valuable time-dependent mix information. Capsules filled with D^3He at 50 atm will allow proton spectroscopy measurements with wedge range filters (WRFs) and burn histories with the proton temporal diagnostic (PTD). Calculations predict a decrease in spectral shift of ≈0.5-1 MeV of 14.7 MeV protons for the rugby-like hohlraums relative to cylinders, suggesting the "drive" equivalent of nearly 6 μm of extra ablated shell thickness with rugbies. With an accuracy of ≈100 keV for WRFs and an initial shell thickness of 45 μm, the inferred sensitivity in diagnosing mass ablation is 1-2% of the initial shell mass. An assessment of the backscatter conditions will also be undertaken, using the Laser Interaction with Plasma (LIP) postprocessor.

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37th Annual Anomalous Absorption Conference

3D calculations of NIF ignition core asymmetry due to random hohlraum and laser errors*

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In order to estimate the probability of a given ICF capsule reaching ignition on NIF, an error budget has been developed in which an allowable range of values for each important parameter is defined. The nominal value for each parameter is that which was used in detailed design calculations of a given point design. The deviations about those values are generally either due to the error in our ability to perfectly characterize the target prior to a shot (e.g. the uncertainty in measuring the ablator density), or due to an uncontrollable error at shot time (e.g. beam to beam differences in the laser power). We generally categorize the uncertainties as 1D (affecting the implosion velocity and fuel entropy) and 3D (affecting the amount of distortion of the imploded core at time of maximum compression).

In this work we focus on estimating the effect of various 3D errors. To do this we carried out numerous 3D calculations of ignition hohlraums and capsules with imposed errors in laser beam pointing, laser power, capsule centering, etc. The errors were taken from random Gaussian distributions and several realizations of each calculation were done in order to get sufficiently good statistics. The calculations were done using the Hydra radiation hydrodynamics code. Part of the challenge was simply getting these rather large calculations to run quickly enough to allow the study to be done in a reasonable amount of time. We will quantify the effect of each type of 3D random error and assess its impact on the overall error budget rollup.

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NLTE Opacities of Mid- and High-Z Cocktails

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Abstract:

With the expected increase in NIF hohlraum temperatures, a new class of high-Z hohlraum cocktail (U3Au) has been proposed to contain the radiation within the hohlraums. High-Z material at high temperatures in a plasma environment where the radiation field is not in equilibrium with the material temperature is an ideal condition to exhibit NLTE atomic kinetic behavior. This and other NLTE plasma applications have driven the development of a new capability to compute NLTE mid- to high- Z opacities at the level of detail only historically exhibited in LTE calculations. In this work we will discuss and contrast the impact of the radiation field's effects on the kinetics and resulting opacities for SnNb and U3Au cocktails.

LA-UR-07-4383

Equal-Channel-Angular-Extrusion Be-Cu as a NIF Ablator

J. A. Cobble, T. E. Tierney, B. G, DeVolder, I. L. Tregillis, N. M. Hoffman, R. D. Day, D. W. Schmidt, G. Rivera, A. Nobile, Jr., S. H. Batha, *Los Alamos National Laboratory*

Equal channel angular extrusion (ECAE) has been used at LANL to manufacture an exceptional, small-grained alloy of Be and Cu (0.9% by atom) for use as an ignition target ablator at the National Ignition Facility (NIF). Through expert machining capabilities, we have fabricated 40-μm thick planar ECAE Be-Cu samples 800 μm in diameter that are diamond turned to create a 0.25-μm amplitude sinusoid on one side. The sine wave period is 50 μm. The opposite side is lapped and polished to provide a very fine surface finish. These sinusoids have been mounted in hohlraum targets and driven by > 4 kJ of laser light at the OMEGA laser. The radiation drive has a foot pressure approaching 2 Mbar, and the radiation temperature peaks near 160 eV after ~6 ns. We have diagnosed the growth of the resulting Rayleigh-Taylor instability with x-ray backlighting. The R-T fluid instability is of course inhibited by material strength. With face-on imaging, we see no growth at all, indicating the strength of the ECAE sample compared to other materials. However, with side-on radiography, parallel the grooves of the sinusoid with twenty times the ρr, we see obvious modulation of the Be-Cu foil as it is launched out of the end of the hohlraum. After characterizing the sidelighter, we deduce the x-ray transmission. Hydrodynamic modeling matches the radiation temperature of the hohlraum, and calculations are compared to the velocity of ejection of the sample. The hydro code is used to calculate the sample mean x-ray mass absorption coefficient for the broadband backlighter energy. The time-dependent growth factor of the instability may be measured from data taken with a 16-frame gated x-ray imager.

LA-UR-07-4427

View factor analysis of drive symmetry in NIF ICF hohlraums

Cliff Thomas and John Edwards
Lawrence Livermore National Laboratory

To achieve ignition in a NIF capsule requires a high degree of drive symmetry. For indirect drive, the X-ray flux on the capsule must be uniform to ~ 1% , integrated in time, with limited swings in capsule flux. This is achieved in practice by a number of parameters such as the position of the laser spots on the hohlraum wall and the distribution of laser power between the laser cones. To optimize target designs and to better understand the effect of individual parameters rad-hydro codes such as HYDRA are commonly used. However it is often difficult to extract accurate time dependent radiation drive symmetry information from these integrated simulations, and the computational cost involved limits the parameter space that can be covered. This paper considers a view factor description of radiation transport, similar to previous studies, where the physics of rad transport are simplified, and which is computationally much cheaper than full rad-hydrocode simulation. It is then possible to consider symmetry as a function of a broad parameter space of laser pointing, laser spot size, cone balance, and hohlraum geometry (hohlraum length, capsule radius, LEH size). This facilitates understanding of symmetry trends, helps to determine which combinations are likely to provide adequate symmetry, and motivates much more expensive 2 and 3D rad-hydrocode simulations. A mode map (from the hohlraum to the capsule) technique has been developed that together with input from HYDRA, allows the drive symmetry to be fully described. This has been found to be a powerful tool to visualize and quantify symmetry trends, as well as to optimize parameter sets against any given requirement. The technique is described a number of results are presented. An example to minimize the the root-mean-square deviation in the capsule flux is shown, and extended to consider how to recover adequate symmetry after removing a small number of laser beams for backlighting purposes. In addition, it is shown that large spots can mitigate the risk of P6, P8, and P10+ flux moments compared to smaller spots. Lastly, it is found the separation of the 50' and 44' cones could allow time-dependent control of P4, especially for relatively small outer-cone phase plates. This could allow better control over the RMS capsule flux throughout compression. In total, the results suggest improvements can still be made in drive symmetry, consistent with energetics goals, compared to existing designs.

*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.

Fragmentation and Diagnostic Shielding Issues for Hohlraum Targets

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All targets on high-powered laser systems must be analyzed to determine whether or not fragmentation and debris issues will adversely impact the optics and diagnostics. Specific considerations for upcoming experiments include composition and fragmentation of cryogenic cooling ring structures. We discuss the analysis of current and past target configurations with an emphasis on how the target disintegrates and the effects on the surrounding chamber. For instance, in past LPI (Laser Plasma Interaction) experiments, concern was for flange material surrounding the laser entrance hole and whether or not this would necessitate the use of additional debris shields. More recently, cooper cooling ring structures on LPI experiments have rendered damage to debris shields mandating their replacement. We show simulations of these targets and ways to mitigate damage. For upcoming LPI experiments, we discuss predictions of cooling ring fragmentation for silicon and aluminum and discuss how these issues affect the experimental design. Novel fragmentation models are used for the simulations including brittle and ductile failure and advanced numerical techniques. We also discuss how to use cooling ring structures to provide shielding to radiation temperature diagnostics.

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.

Development of a fall-line mix model to predict degraded yield due to mix

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Abstract:

Mixing between fuel and shell material is an important topic in the inertial confinement fusion community, and is commonly accepted as the primary mechanism for neutron yield degradation. Typically, radiation hydrodynamic simulations that lack mixing (clean simulations) tend to considerably over-estimate the neutron yield. We present here a systematic technique for post-processing clean 1-D hydro simulations with a fall-line analysis in order to predict the degraded yield due to mix.

In the fall-line scenario, the converging shell is allowed to contaminate the fuel at a rate equal to the shell's peak velocity. Using clean 1-D hydro simulations as a basis, we implement full yield quenching as the free-falling shell material hits the fuel. We use these concepts to predict an upper bound for the amount of mix, which corresponds to a lower bound for the yield.

The degraded yields from the fall-line mix model are only slightly lower than the experimental yields from a series of direct drive OMEGA implosions. Matching the experimental data exactly with the fall-line model requires the implementation of partial rather than full yield quenching. We also compare to the yield-degrading effects of the mix regions calculated by Haan's and Youngs' mix models.

We will give an introduction to our implementation of the fall-line analysis, which is in the form of a graphical user interface designed in IDL. The tool is easy to use and works with any 1-D hydro simulation output. It provides an important step in understanding the mechanisms by which mix can degrade neutron yield.

LA-UR-07-4261

PATHS TOWARDS DEMONSTRATING IGNITION ON THE NIF USING NON-CRYOGENIC TARGETS

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The goal of demonstrating ignition on the National Ignition Facility (NIF) has motivated a revisit of double-shell targets[(1)] as a complementary path to the baseline cryogenic single-shell approach[(2)]. The benefits of double-shell targets extend well beyond room-temperature deuterium-tritium (DT) fuel preparation, including predicted minimal hohlraum-plasma-mediated laser backscatter, low threshold-ignition temperatures (≈4 keV) for relaxed hohlraum x-ray flux asymmetry tolerances,[(3)] and relatively loose shock-timing requirements. On the other hand, double-shell ignition presents several challenges, including room-temperature containment of high-pressure DT (790 atm) in the high-Z inner shell; strict concentricity requirements on the two shells; development of exotic, nano-porous, low-density, metallic foams for structural support of the inner shell and hydrodynamic instability mitigation; and effective control of perturbation growth on the high-Atwood number interface between the DT fuel and the pusher. Recent progress in double-shell ignition target designs using vacuum hohlraums is described, offering the potential for tolerably low levels of laser backscatter from stimulated Raman and Brillouin processes. In addition, vacuum hohlraums have the operational advantages of room temperature fielding and fabrication simplicity, as well as benefiting from extensive benchmarking on the Nova and Omega laser facilities. As an alternative to standard cylindrical hohlraums, a rugby-shaped geometry is also described that may provide energetics and symmetry tuning benefits for more robust double-shell designs with yields exceeding 10 MJ for 2 MJ of 3ω laser energy. The recent progress in hohlraum designs and required advanced materials development are scheduled to culminate in a NIF-scale ignition-ready double shell prototype in 2008. Analysis of a recent successful double-shell implosion campaign on the Omega laser facility at the University of Rochester will be described. Other room-temperature ignition designs such as dynamic-hohlraum-driven double shells and shock-ignition single shells will also be briefly described.

(1) P. Amendt *et al.*, PoP **9**, 2221 (2002); *ibid.* **14**, 056312 (2007).
(2) J.D. Lindl *et al.*, PoP **11**, 339 (2004).
(3) M.N. Chizhkov *et al.*, Laser Part. Beams **23**, 261 (2005).

In collaboration with Charlie Cerjan, Alex Hamza, Denise Hinkel, Jose Milovich, Hye-Sook Park, Harry Robey, Robert Tipton, Gail Glendinning and John Perkins

*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.

Wednesday August 29th 8:30-11:00PM

Po-1	**Afeyan**	Bedros	Polymath Research	Scale and Conformal Invariance and Phase Transitions in the Study of Coherent Structures and Turbulence in 2D Euler and the Vlasov-Poisson System
Po-2	**Niemann**	Christoph	UCLA	First results from the PHOENIX laser at UCLA
Po-3	**Weber**	Stephen	LLNL	Symmetry Capsules for NIF
Po-4	**Hughes**	S. J.	AWE	Continuing Development of Radiation-Hydrocode Modelling of Laser-Plasma Experiments at AWE
Po-5	**Benisti**	Didier	CEA	Nonlinear kinetic envelope equation for an SRS-driven plasma wave
Po-6	**Kruer**	William	UC Davis	Additional Considerations for Laser Plasma Instability Mitigation in Ignition-scale Hohlraums
Po-7	**Montgomery**	David	LANL	Mitigation on of Stimulated Raman an Scattering in Hohlraum Plasmas
Po-8	**Weaver**	J. L.	NRL	Status of LPI Experiments at the Nike Laser
Po-9	**Froula**	Dustin	LLNL	Creation of a multi-centimeter low density plasma channel using high magnetic fields
Po-10	**Messmer**	Peter	Tech-X Corp.	Neutron generation in Laser-ablated Material of Shaped Targets
Po-11	**Rozmus**	Wojciech	U. Alberta	Electron Acceleration by a Tightly Focused Laser Pulse
Po-12	**Kugland**	Nathan	UCLA	$K\alpha$ conversion efficiency in gas jet targets
Po-13	**Milovich**	Jose L.	LLNL	Short-wavelength perturbation growth studies of double-shell designs for the National Ignition Facility
Po-14	**Edgell**	Dana	LLE/ U.Rochester	Time-Resolved Scattered-Light Spectroscopy in Direct-Drive Implosion Experiments

37^{th} Annual Anomalous Absorption Conference
Sheraton Maui Resort, Kaanapali Beach, Maui, Hawaii
August 27-31, 2007

Scale and Conformal Invariance and Phase Transitions in the Study of Coherent Structures and Turbulence in 2D Euler and the Vlasov-Poisson System

B. Afeyan, M. Charbonneau Lefort, M. Mardirian

Polymath Research Inc., Pleasanton, CA

We will examine recent results on the connection between 2D Euler Turbulence, Conformal Field Theory, Scale and Conformal Invariances, Percolation Theory and Phase Transitions [1]. We will connect these findings to the Vlasov-Poisson system and the physics of KEEN waves and other traditional (stationary) coherent nonlinear structures such as BGK modes.

The question for laser-plasma instabilities is how the changes in the underlying phase space distributions of particles, as they adjust to coherent large amplitude waves, allow or disallow nonlinear structures to develop, to persist, to prepare the background for cascades or inverse cascades of energy in wave number or scale space, or else impede them.

Underlying these connections there are potential multifractal structures and stochastic processes which may not be captured by too coarse grained a simulation technique of the physics vs methods that are more fine scale resolving.

[1] Bernard, D., Boffetta, G., Celani, A. and Falkovich G. Nature Phys. 2, 124 (2006) and references therein.

**This work was supported by a grant from the DOE NNSA Program.

Prefer poster Session

First results from the PHOENIX laser at UCLA

C. Niemann [1,2], C. Constantin[1], A. Davidson[1], E. Everson[1], E. Dewald[2], N. Kugland[2], D. Schneider[2], S. Glenzer[2], M. Villagran Muniz[3], P. Pribyl[1]

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The PHOENIX glass-laser system was recently commissioned at UCLA as a student training and staging facility for high-energy density science experiments. The system currently delivers a maximum energy of 25 J in a 5 ns pulse in a near-diffraction limited beam with on-target intensities in excess of 10^{14} W/cm^2 at 1064 nm. First experiments performed so far include measurements of laser-produced hot-electrons from solid and gaseous targets using an electrostatic spectrometer and a time-resolved NIF-like filter-fluorescer detector. We will present a detailed description of the experimental capabilities, first experimental results, and plans for upgrades.

This work is supported by the DOE and the Basic Plasma Science Facility.

UCRL-ABS-231198

Symmetry Capsules for NIF*

Stephen V. Weber, Nobuhiko Izumi, and John Edwards
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Symmetry capsules (SymCaps) will be used to tune the symmetry of the 4th pulse of the laser drive for the ignition campaign of the National Ignition Facility (NIF). The NIF indirect drive ignition point design uses a four-step laser pulse to launch a series of shocks through the cryogenic DT fuel layer. Stringent symmetry requirements are specified for each component of the hohlraum x-ray drive. SymCaps are gas-filled surrogate capsules which will be used to tune the symmetry for the high-power 4th step of the pulse. Hohlraum x-ray irradiation symmetry is inferred from the shape of the x-ray emission from the gas in the stagnating core. Laser cone power ratio, beam pointing, and hohlraum length will be adjusted to achieve round SymCap images. Time-dependence of the drive symmetry may be inferred from SymCaps of different shell thicknesses. The first 3 steps of the pulse must be tuned by other diagnostics prior to SymCap experiments. A full-thickness SymCap replicates the shell $\rho\Delta R$ of the ignition capsule, by replacing the frozen DT layer with Be. This SymCap is predictive of the core shape at ignition of the cryogenic capsule. A thinner capsule will be used to tune the rise of the 4th pulse. Two temporal control points appear to be sufficient to achieve satisfactory time-dependent symmetry for the 4^{th} pulse. We will present a simulated tuning sequence and address the surrogacy of the SymCap and associated hohlraum with respect to the ignition design as well as the sensitivity of the technique to achieve ignition symmetry specifications. Tuning accuracy will be limited by 3-D asymmetries resulting from mix, pointing errors, and beam power imbalance. Simulations will be employed to quantify the error budget.

* 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.

Continuing Development of Radiation-Hydrocode Modelling of Laser-Plasma Experiments at AWE

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37th Anomalous Absorption Conference
Maui, Hawaii, August 27-31, 2007

Abstract

I present a summary of recent developments at AWE in our capability to model laser-plasma interactions at the higher intensities achievable in current and future facilities. The focus of current work is on developing a hybrid model for electron transport that combines a nonlocal model of conduction for the bulk population with a more detailed treatment of the fast electrons. An overview of the basic methodology is given and we show some results from continuing studies.

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Nonlinear kinetic envelope equation for an SRS-driven plasma wave

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We present the derivation, from first principles and in a 3D geometry, of the envelope equation of a plasma wave generated by stimulated Raman scattering (SRS), assuming that this wave is nearly monochromatic and that the ions are motionless.

Our results are compared to previously published ones, and we show in particular that the nonlinear plasma wave envelope equation cannot be derived by assuming that the electronic susceptibility is an analytic function of frequency. Such an assumption would indeed lead to a wrong estimate of the SRS growth rate. We moreover show that the plasma wave envelope equation is nonlocal : its coefficients do not only depend on the local value of the wave amplitude. This is the consequence of the symmetric detrapping of electrons experiencing a non-monotonic wave amplitude, which makes the electronic distribution function be nonlocal. This affects in particular the nonlinear Landau damping rate, for which we provide an explicit formula valid in 3D.

We also derive theoretically the nonlinear frequency downshift, $\delta\omega$, of the plasma wave. The theoretical values of $\delta\omega$ agree very well with those obtained from kinetic simulations of SRS, and may differ significantly from those given by purely electrostatic theories such as that due to Morales and O'Neil. The frequency shift entails a phase shift, $\delta\varphi$, between the plasma wave and the laser drive which reduces the efficiency of SRS. We however show that the value of $\delta\varphi$ is also affected by the plasma wave number upshift.

Finally, we discuss the limit of the hypothesis of a nearly monochromatic plasma wave. In particular, we show that symmetric detrapping induces electrostatic turbulence, which enriches the wave spectrum.

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

Additional Considerations for Laser Plasma Instability
Mitigation in Ignition-scale Hohlraums

William L. Kruer
University of California, Davis

Control of laser plasma instabilities in ignition-scale hohlraums is an important physics challenge, Current hohlraums[1] are designed to minimize the linear instability gains of stimulated Raman and Brillouin backscatter. To complement this work, attention is here given to other possibilities for the excitation of laser plasma instabilities in large hohlraums. Topics addressed include excitation of the two plasmon decay instability, especially by the inner beams in the ablator plasma, as well as cooperative excitation[2] of stimulated scattering by overlapped beams near the laser entrance holes. Particular attention is given to estimating gains and identifying signatures for the cooperative scattering. It is also found that diffraction of the Raman-scattered light wave can reduce the stimulated Raman gain in a speckle but can improve the communication between different ranks of speckles.

1. D. Callahan, N. Meezan, D. Hinkel, et. al., (private communication)
2. D. DuBois, B. Bezzerides, and H. Rose, Phys. FluidsB4, 241(1992)

This work was performed under the auspicies of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48 and Agreement B56595.

LA-UR-07-2630

Mitigation of Stimulated Raman Scattering in Hohlraum Plasmas

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One aspect of the research at Los Alamos National Laboratory to control Stimulated Raman Scattering (SRS) in hohlraum plasmas is the investigation of risk mitigation strategies for indirect drive inertial confinement fusion. Experimental tests of these strategies, based on prior theoretical and experimental knowledge of SRS, are performed in hohlraum experiments. In the last year, two strategies have been investigated. The first is the use of high Z dopants to reduce SRS backscatter. Gasbag experiments at the Helen laser showed that the addition of a small amount of high Z dopant could significantly reduce SRS. Efforts at Los Alamos National Laboratory have provided a theoretical basis for the reduction in SRS backscattered laser light due to high Z dopants. Beam spray of the laser, due to thermally-enhanced forward Brillouin scattering, results in a decrease in the longitudinal coherence lengths of the laser, which in turn reduces SRS. Since thermal effects depend strongly on Z^2, a small amount of a high Z dopant, 1-2%, can have a large effect. Experiments have been conducted at the Omega laser to test this theory by varying the amount of Xe dopant in neopentane gas-filled hohlraums. Using a Transmitted Beam Diagnostic, the beam spray of an interaction laser beam can be monitored along with the SRS backscattered light as a function of Xe dopant while monitoring for correlations between the two. The experimental measurements do show a decrease in SRS backscatter as Xe dopant is added. However, there are still uncertainties regarding the responsible mechanism. The second strategy investigated is using high $k\lambda_D$ plasmas to reduce SRS backscatter. Experiments conducted at the Omega laser facility in hohlraum plasmas determined the critical onset intensity for a range of $k\lambda_D$ by varying the plasma density and laser intensity. A scaling of the critical onset intensity as a function of $k\lambda_D$ has been determined. The scaling is compared with theoretical predictions. Results for both mitigation strategies will be presented, as well as suggested implementation strategies for ignition-relevant hohlraums.

This work was performed at Los Alamos National Laboratory under the auspices of Los Alamos National Security, LLC, for the Department of Energy under contract number DE-AC52-06NA25396.

Status of LPI Experiments at the Nike Laser*

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The target physics effort at the Nike laser is exploring laser plasma instabilities (LPI) driven by the short wavelength (248 nm), large bandwidth (~2-3 THz), and very uniform illumination available with krypton-fluoride (KrF) lasers.[1] The Nike laser can be used to create short pulses (T_{FWHM} < 0.5 ns) at intensities above those required for the implosions envisioned for the proposed Fusion Test Facility ($I_{<ave>} > 2\times10^{15}$ W/cm^2).[2] This poster will present the current status of LPI studies, including recent experimental observations. The results to date indicate that, for operation above the single beam intensity threshold for the two-plasmon decay instability, measurements of emissions at $3/2\ \omega_o$ and $1/2\ \omega_o$ harmonics of the incident laser wavelength show no evidence of this instability. An extensive suite of diagnostics has been deployed at the Nike target facility for experiments before the end of FY2007. These include time-resolved and time-integrated spectrometers for observation of stimulated Raman scattering, two-plasmon decay, stimulated Brillouin scattering, and the parametric decay instability. Hard x-ray spectrometers ($h\omega$> 2 keV) and a scintillator/photomultiplier array ($h\omega$> 10 keV) have been deployed to monitor emission associated with the hot electrons generated by LPI processes.

*Work supported by DoE/NNSA
Poster preferred

[1] J. Weaver, *et al.*, Phys. Plasmas **14**, 056316, 2007.
[2] S. Obenschain, *et al.*, Phys. Plasmas **13**, 056320, 2006.

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Creation of a multi-centimeter low density plasma channel using high magnetic fields

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We will present preliminary experimental results that show the control of a laser produced plasma channel using magnetic fields. This channel is suitable for guiding laser beams and is directly applicable to wakefield acceleration and short pulse laser amplification. This is accomplished by applying a technique that has been established at the Jupiter Laser Facility; an external magnetic field is used to prevent radial heat transport [D. H. Froula *et.al.*, Phys. Rev. Lett. 98, 135001 (2007)] resulting in an increased temperature gradient which produces a transverse density gradient. The density gradient is an optical plasma waveguide.

This work was partially supported by LDRD 06-ERD-056 and performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

Neutron generation in Laser-ablated Material of Shaped Targets

Peter Messmer, Peter Stoltz, Kevin Paul
Tech-X Corporation

Jean-Luc Cambier
AFRL, Edwards Air Force Base

Thermal neutrons are of considerable interest for a multitude of applications, including radiography. As they easily penetrate high-density targets but get effectively absorbed by low density materials like paraffin, nylon or explosives the effectively complement high-energy photons. One of the key challenges is to develop a generator for thermal neutrons with sufficient flux. The relatively short half-life, safety constraints and regulatory requirements make radio-isotopes unattractive for wide-spread use. Alternative designs therefore exploit the Deuterium-Tritium (D-T) fusion, which generates Alpha particles and fast neutrons. In these sources, Deuterium ions are accelerated in a diode configuration to about 130 keV and hit a Tritium target. The neutrons are then thermalized in an external moderator.

Recently, considerable success has been achieved in the acceleration of ions in the interaction of femto-second laser pulses with overdense targets. Here we investigate whether this interaction can be exploited to accelerate Deuterium and Tritium ions for the generation of neutrons. Using the plasma simulation framework VORPAL, we model the interaction of femto-second laser pulses with a variety of D-T targets and determine the neutron yield. In particular, we investigate a target design that utilizes the laser pulse to accelerate D in opposite direction to T, which helps to lower the required pulse energies. It turns out that the interaction of laser pulses at moderate intensity can be used to generate neutron fluxes sufficient for radiographic applications.

This work is supported by Air Force contract F04611-99-C-0025, ERC Incorporated and Tech-X Corporation.

Electron Acceleration by a Tightly Focused Laser Pulse

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Advances in laser technology have made possible compact multi-terawatt laser systems with high intensities up to 10^{22} W/cm^2, when a laser beam is focused to the focal spot on the order of one wavelength [1]. We use an exact solution to the Maxwell equations for electric and magnetic fields of the laser field in the focal region. Laser- electron interaction for tight focusing and small f-number of an optical system is very different from interaction in the fields corresponding to large f-number focusing optics. Such acceleration is dominated by the presence of high longitudinal fields at the laser focus and strong inhomogeneities across the laser propagation direction.

By using the test particle approach we have studied electron vacuum acceleration including nonadiabatic effects and synchronized trajectories which correspond to particles experiencing constant phase of electromagnetic fields and subluminous phase velocity [2]. After the averaging over the laser field phase, the energy and emission angle distributions versus the electron positions in the focal region have been obtained. The most effective acceleration was found for electrons placed at laser beam axes at the distance comparable to the Rayleigh length before the best focus position. The correlations between electron energies and the emission angles were studied. We also obtained the dependence of the maximum electron energy on the focal spot size. Results of test particle studies guided 3D particle-in-cell simulations with thin foil targets for the best conditions for electron acceleration in the Coulomb explosion regime.

[1] S.-W. Bahk, P. Rousseau, T. A. Planchoun, Opt. Lett. **29**, 2873 (2004).

[2] J. Pang et al, Phys. Rev. E **66**, 066501 (2002).

K_α conversion efficiency in gas jet targets

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We have measured the absolute conversion efficiency of K_α X-rays from short-pulse laser irradiation of chlorine and argon gas jet targets, and performed a direct comparison of Cl K_α yield from both gaseous and solid chlorine-containing targets. The K_α conversion efficiencies in a 3.5% Cl gas jet target and a 100% Ar target ($n_e \sim 10^{19}$ cm^{-3}) are comparable to the conversion efficiency obtained for 33% Cl solid saran targets ($n_e \sim 10^{23}$ cm^{-3}). Additionally, the broad-band conversion efficiency into X-ray line emission, integrated from K_α to K_β, is up to an order of magnitude higher in gas jet targets than in solid targets. This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory, through the Institute for Laser Science and Applications, under contract No. W-7405-Eng-48.

Short-wavelength perturbation growth studies of double-shell designs for the National Ignition Facility*

Jose L Milovich, Peter Amendt, Charlie Cerjan, Alex Hamza, Marty Marinak and Harry Robey
LLNL, Livermore CA, USA

To maximize the prospect for ignition on the National Ignition Facility, complementary targets to the baseline cryogenic signle-shell design are being pursued. Double-shell (DS) targets[1] offer several potential advantages, including fielding at room temperature and the use of a relatively simple laser pulse that minimizes the potential for laser backscatter losses from the hohlraum and avoids the need for careful shock timing. These benefits are offset, however, by the challenge of meeting tight fabrication tolerances, which are required to control the growth of short-wavelength perturbations resulting from both impulsive and time-dependent accelerations[2]. Left uncontrolled, the growth of these perturbations could result in a turbulent flow that could lead to shell disruption. To control these instabilities, new designs employing density-graded bi-metallic high-strength nano-crystalline inner shells and material-matching mid-Z nano-porous foams are being studied. These new designs predict a substantial reduction in the growth of short-wavelength perturbations and the suppression of turbulence. To guide these new designs, a host of highly-resolved 2D simulations are performed and used to address issues ranging from large-scale jet flows produced by the outer-shell joint to small-scale features resulting from the intrinsic porosity and interfacial roughness imposed by the low-density foam between the shells. These simulations are routinely used to identify sources of reduced performance as well as their possible remedies through improved fabrication processes. Current results indicate that foams with densities as large as 100 mg/cc are possible albeit with a modest reduction in robustness. Furthermore, pore sizes larger than 1 micron appear to be potentially problematic. High-resolution simulations have also been performed to assess the combined effect of low-order hohlraum radiation asymmetries and the growth of intrinsic surface perturbations. Preliminary results indicate that the transverse flows that are set up by these low-order mode features (which can excite Kelvin-Helmholtz instabilities) are not large enough to offset the overall robustness of our current ignition design. These results have motivated an intensive experimental campaign on the Omega laser facility to aid in code validation. The results of recent double-shell implosion experiments are being analyzed to identify areas of computational uncertainty and to motivate improved target fabrication methods for ensuring robust performance. The current thinking is that the hemispherical outer-shell joint and machined outer-surface foam roughness could play a major role in seeding instability to give reduced performance as experimentally observed.

[1]Amendt *et al.*, Physics of Plasmas **9**, 2221 (2002); *ibid.*, **14**, 056312 (2007).
[2]Milovich *et al.*, Physics of Plasmas **11**(4), 1552 (2004).

Work performed under the auspices of US DOE by the UC LLNL under Contract No. W-7405-Eng-48.

Time-Resolved Scattered-Light Spectroscopy in Direct-Drive Implosion Experiments

D. H. Edgell, W. Seka, V. N. Goncharov, I. V. Igumenshchev, R. S. Craxton, J. A. Delettrez, J. Myatt, A. V. Maximov, and R. W. Short

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We report on time-resolved scattered-light spectroscopy in OMEGA implosion experiments. These experiments have allowed us to quantitatively assess various absorption processes. Resonance absorption enhances absorption at early times. This has significant influence on picket-pulse shapes for adiabat shaping of the target implosions. The overall time-resolved scattered-light spectrum is very sensitive to the plasma evolution via the Dewandre effect. This spectrum is strongly influenced by the electron-heat transport near the critical density and allows for quantitative testing of various transport models. A nonlocal electron heat-transport model provides the best match to the measured spectral shifts. Enhanced scattering is observed after ~0.8 ns, when long scale lengths are established. We hypothesize that this enhanced scattering is due to SBS seeded by the ubiquitous scattered light present in spherical implosion experiments. Analogous experiments in planar geometry are used to test this hypothesis.

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.

Prefer poster presentation.

Wednesday, August 29th, 2007

Morning Session

8:30AM - 10:10AM Chairman: Mark Schmitt, LANL

10:10AM - 10:30AM Coffee Break

10:30AM - 12:30PM Chairman: Steve Haan, LLNL

Evening Session

7:30PM - 8:30PM Invited Talk, Chairperson: Denise Hinkel, LLNL

8:30PM - 11:00PM Poster Session

NIF ignition target design, requirements, margins, and uncertainties

Steven W. Haan, J.D. Salmonson, D.S. Clark, D.A. Callahan, B.A. Hammel, L. J. Suter, M.J. Edwards, and J.D. Lindl
Lawrence Livermore National Laboratory

We describe simulation effort for NIF ignition, focused on a point design target that uses 1.3 MJ of light to drive a hohlraum to 285eV. The point design capsule has 5 layers of varying Cu dopant to minimize RT instability growth. We describe the optimization of this target, using 1D and 2D simulations.

A set of requirements has been developed that describes all aspects of the target, its fabrication and fielding, the laser pulse delivered to it, and the features of the pre-ignition experiments that are needed to finalize the design. We describe a model that characterizes the margin of the target as a function of the input parameters and uncertainties. The model has been defined by 1D, 2D, and 3D simulations. Using the margin model, statistical ensembles of input parameters are considered to describe shot-to-shot variations, and the impact of residual systematic errors. This model has been used to define and update the point design, to quantify the impact of each requirement, and to ensure that the requirements are optimally defined. The model can be used to project the probability of ignition, as shot-to-shot variations and more globally given systematic errors.

There are several backup targets that are being kept active, including other drive temperatures from 270 to 300eV, CH ablators, and high density C ablators. The relative performance, and specific pertinent issues, regarding these targets are described.

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

ROBUSTNESS STUDIES OF NIF IGNITION TARGETS IN TWO DIMENSIONS *

D. S. Clark and S. W. Haan, Lawrence Livermore National Laboratory, 7000 East Ave., L-015, Livermore, CA, 94551

Inertial confinement fusion (ICF) capsules are critically dependent on the integrity of their hot spots to ignite. At the time of ignition, only a certain fractional perturbation of the nominally spherical hot spot boundary can be tolerated and the capsule still achieve ignition. The degree to which the expected hot spot perturbation in any given capsule design is less than this maximum tolerable perturbation is a measure of the ignition margin or robustness of that design. Moreover, since there will inevitably be uncertainties in the initial character and implosion dynamics for any given capsule, all of which can contribute to the eventual hot spot perturbation, quantifying the robustness of that capsule against a range of parameter variations is an important consideration in the design. Here, the robustness of the 300 eV indirect drive target design for the National Ignition Facility (NIF) [J. D. Lindl, *et. al*., Phys. Plasmas **11**, 339 (2004)] is studied in the parameter space of inner ice roughness, implosion velocity, and capsule scale. A suite of two thousand two-dimensional simulations, run with the radiation hydrodynamics code Lasnex, is used as the data base for the study. For each scale, an ignition region in the two remaining variables is identified and the "ignition cliff" is mapped. In accordance with the theoretical arguments of [W. K. Levedahl and J. D. Lindl, Nucl. Fusion **37**, 165 (1997); R. Kishony and D. Shvarts, Phys. Plasmas **8**, 4925 (2001)], the location of this cliff is fitted to a power law of the capsule implosion velocity and scale. It is found that the cliff can be quite well represented in this power law form, and, using this scaling law, an assessment of the overall (one- and two-dimensional) ignition margin of the design can be made. The effect on the ignition margin of an increase or decrease in the density of the target fill gas is also assessed.

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

Multi-Variable Sensitivity Studies of Ignition Targets for NIF

J. D. Salmonson, S. W. Haan, D.S. Clark, and D.A. Callahan
Lawrence Livermore National Laboratory

Performance of indirect drive ignition targets being designed for the National Ignition Facility has been studied with multi-variable sensitivity studies. Large numbers of simulations are run, in each of which a number of parameters are set from statistical ensembles intended to represent expected variations in the variables characterizing the target. Parameters varied include target dimensions, compositions, densities, laser pulse variations, variations in the hohlraum parameters as they determine pulse shaping and symmetry variations, surface roughness, intrinsic hohlraum asymmetry, beam-to-beam power imbalance, and pointing errors. Statistical samples are very large (10,000) for variations of the 1D spherical implosion, and large enough for meaningful statistics (a few hundred runs) for the 2D variations. The overall performance trends can be predicted from a model that uses second order Taylor series to calculate the implosion velocity and DT fuel entropy, as functions of the target variables. The statistical variations allow us to address quantitatively questions such as "What is the distribution function describing the expectation of yield, given expected shot-to-shot variations in the parameters describing the experiment?"

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

Ignition Target Design with a High-Density Carbon (HDC) Ablator for the National Ignition Facility (NIF)

Darwin D.-M. Ho[1], Richard P. Town[1], Steven W. Haan[1], Lorin Benedict[1],
Mark C. Herrmann[2*], Daniel A. Orlikowski[1], J. D. Salmonson[1], Eric R. Schwegler[1],
David A. Young[1]

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Abstract: An ignition capsule with a nano-crystalline, high density, carbon ablator is emerging as a promising alternative target for NIF. There are four advantages in using the HDC ablator. First, for a given outer radius, the HDC ablator absorbs more hohlraum-driven x-ray energy than a beryllium ablator. Second, the HDC ablator will have smaller and more uniform crystalline grains than beryllium, enabling more isotropic shock propagation. Third, the higher density reduces the coupling between the DT ice surface and the unstable ablation front, thereby reducing the growth of the surface perturbations seeded by ice roughness. Fourth, material strength of the HDC can reduce instability growth at early times. Possible – though surmountable – challenges include: (1) The need for smoother outer ablator surfaces because of slightly lower ablation rates, and larger mass perturbations for a given surface roughness. (2) Ensuring that the HDC does not spend time in a partially melted state in which density or velocity variations could seed Rayleigh-Taylor instabilities. LASNEX design simulations show good 1-D performance and overall favorable 2-D stability behavior. In particular, the ablator is solid following the 1st shock, and completely melted upon passage of the 2nd shock. The capsule can tolerate about twice as rough a DT ice surface as with Beryllium, and instability growth is reduced by material-strength in the HDC ablator.

* This work was performed under the auspices of the U.S. DOE by the University of California, LLNL under contract No. W-7405-Eng-48.

Rugby-shaped Hohlraum Designs on Omega for Enhanced X-ray Drive*

Peter Amendt, Charlie Cerjan, Denise Hinkel, Jose Milovich and Harry Robey

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The energetics advantages for rugby-shaped hohlraums over standard cylindrical hohlraums have recently been predicted within the context of NIF double-shell ignition designs [1]. A recent study on using rugby-shaped hohlraums for achieving ignition with single-shell cryogenic capsules in early Laser MegaJoule experiments at reduced laser energy also shows promise [2]. For rugby hohlraums with 50% laser entrance holes, the high-Z hohlraum surface area is ~20% smaller, potentially leading to a ~10% energy savings from reduced wall losses. Other potential benefits include (1) the flexibility for fielding larger capsule targets to take advantage of greater clearance near the rugby hohlraum waist, (2) better laser-target coupling of the inner cone laser beams due to a higher incident angle, (3) reduced time-dependent flux asymmetry from outer-cone laser deposition closer to the hohlraum symmetry axis [2], and (4) less coupling of radiation asymmetry (Legendre) modes in a quasi-spherical geometry.

An experimental campaign on Omega to further test our notions of x-ray drive and symmetry in rugby-shaped hohlraums is proposed. Side-by-side comparisons with cylindrical hohlraums with identical waist radii are planned for demonstrating the energetics benefits of rugby hohlraums. Earlier x-ray implosion times by nearly 200 ps and increases in peak Dante temperatures >10 eV are predicted, based on 2D radiation-hydrodynamics simulations. Neutron yields well in excess of 10^{10} using pure deuterium fuel are expected according to 2D simulations, nearly 2x compared with cylindrical hohlraums. Such large neutron signatures avail the possibility for diagnosing burn histories in indirect drive with the neutron temporal diagnostic (NTD), potentially providing valuable time-dependent mix information. Capsules filled with D^3He at 50 atm will allow proton spectroscopy measurements with wedge range filters (WRFs) and burn histories with the proton temporal diagnostic (PTD). Calculations predict a decrease in spectral shift of ≈0.5-1 MeV of 14.7 MeV protons for the rugby-like hohlraums relative to cylinders, suggesting the "drive" equivalent of nearly 6 μm of extra ablated shell thickness with rugbies. With an accuracy of ≈100 keV for WRFs and an initial shell thickness of 45 μm, the inferred sensitivity in diagnosing mass ablation is 1-2% of the initial shell mass. An assessment of the backscatter conditions will also be undertaken, using the Laser Interaction with Plasma (LIP) postprocessor.

(1) P. Amendt, C. Cerjan, A. Hamza, D. Hinkel, J. Milovich and H. Robey, PoP **14**, 056312 (2007).
(2) M. Vandenboomgaerde *et al*., Phys. Rev. Lett. (to appear).
(3) O.L. Landen, P. Amendt, L. Suter, *et al*., PoP **6**, 2137 (1999).

*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.

37th Annual Anomalous Absorption Conference

3D calculations of NIF ignition core asymmetry due to random hohlraum and laser errors*

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In order to estimate the probability of a given ICF capsule reaching ignition on NIF, an error budget has been developed in which an allowable range of values for each important parameter is defined. The nominal value for each parameter is that which was used in detailed design calculations of a given point design. The deviations about those values are generally either due to the error in our ability to perfectly characterize the target prior to a shot (e.g. the uncertainty in measuring the ablator density), or due to an uncontrollable error at shot time (e.g. beam to beam differences in the laser power). We generally categorize the uncertainties as 1D (affecting the implosion velocity and fuel entropy) and 3D (affecting the amount of distortion of the imploded core at time of maximum compression).

In this work we focus on estimating the effect of various 3D errors. To do this we carried out numerous 3D calculations of ignition hohlraums and capsules with imposed errors in laser beam pointing, laser power, capsule centering, etc. The errors were taken from random Gaussian distributions and several realizations of each calculation were done in order to get sufficiently good statistics. The calculations were done using the Hydra radiation hydrodynamics code. Part of the challenge was simply getting these rather large calculations to run quickly enough to allow the study to be done in a reasonable amount of time. We will quantify the effect of each type of 3D random error and assess its impact on the overall error budget rollup.

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

NLTE Opacities of Mid- and High-Z Cocktails

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J. Oelgoetz[2], H. Zhang[2] and R. Holmes[2]

[1] *Theoretical Division Los Alamos National Laboratory*
[2] *Applied Physics Division Los Alamos National Laboratory*

Abstract:

With the expected increase in NIF hohlraum temperatures, a new class of high-Z hohlraum cocktail (U3Au) has been proposed to contain the radiation within the hohlraums. High-Z material at high temperatures in a plasma environment where the radiation field is not in equilibrium with the material temperature is an ideal condition to exhibit NLTE atomic kinetic behavior. This and other NLTE plasma applications have driven the development of a new capability to compute NLTE mid- to high- Z opacities at the level of detail only historically exhibited in LTE calculations. In this work we will discuss and contrast the impact of the radiation field's effects on the kinetics and resulting opacities for SnNb and U3Au cocktails.

LA-UR-07-4383

Equal-Channel-Angular-Extrusion Be-Cu as a NIF Ablator

J. A. Cobble, T. E. Tierney, B. G, DeVolder, I. L. Tregillis, N. M. Hoffman, R. D. Day, D. W. Schmidt, G. Rivera, A. Nobile, Jr., S. H. Batha, *Los Alamos National Laboratory*

Equal channel angular extrusion (ECAE) has been used at LANL to manufacture an exceptional, small-grained alloy of Be and Cu (0.9% by atom) for use as an ignition target ablator at the National Ignition Facility (NIF). Through expert machining capabilities, we have fabricated 40-μm thick planar ECAE Be-Cu samples 800 μm in diameter that are diamond turned to create a 0.25-μm amplitude sinusoid on one side. The sine wave period is 50 μm. The opposite side is lapped and polished to provide a very fine surface finish. These sinusoids have been mounted in hohlraum targets and driven by > 4 kJ of laser light at the OMEGA laser. The radiation drive has a foot pressure approaching 2 Mbar, and the radiation temperature peaks near 160 eV after ~6 ns. We have diagnosed the growth of the resulting Rayleigh-Taylor instability with x-ray backlighting. The R-T fluid instability is of course inhibited by material strength. With face-on imaging, we see no growth at all, indicating the strength of the ECAE sample compared to other materials. However, with side-on radiography, parallel the grooves of the sinusoid with twenty times the ρr, we see obvious modulation of the Be-Cu foil as it is launched out of the end of the hohlraum. After characterizing the sidelighter, we deduce the x-ray transmission. Hydrodynamic modeling matches the radiation temperature of the hohlraum, and calculations are compared to the velocity of ejection of the sample. The hydro code is used to calculate the sample mean x-ray mass absorption coefficient for the broadband backlighter energy. The time-dependent growth factor of the instability may be measured from data taken with a 16-frame gated x-ray imager.

LA-UR-07-4427

View factor analysis of drive symmetry in NIF ICF hohlraums

Cliff Thomas and John Edwards
Lawrence Livermore National Laboratory

To achieve ignition in a NIF capsule requires a high degree of drive symmetry. For indirect drive, the X-ray flux on the capsule must be uniform to ~ 1% , integrated in time, with limited swings in capsule flux. This is achieved in practice by a number of parameters such as the position of the laser spots on the hohlraum wall and the distribution of laser power between the laser cones. To optimize target designs and to better understand the effect of individual parameters rad-hydro codes such as HYDRA are commonly used. However it is often difficult to extract accurate time dependent radiation drive symmetry information from these integrated simulations, and the computational cost involved limits the parameter space that can be covered. This paper considers a view factor description of radiation transport, similar to previous studies, where the physics of rad transport are simplified, and which is computationally much cheaper than full rad-hydrocode simulation. It is then possible to consider symmetry as a function of a broad parameter space of laser pointing, laser spot size, cone balance, and hohlraum geometry (hohlraum length, capsule radius, LEH size). This facilitates understanding of symmetry trends, helps to determine which combinations are likely to provide adequate symmetry, and motivates much more expensive 2 and 3D rad-hydrocode simulations. A mode map (from the hohlraum to the capsule) technique has been developed that together with input from HYDRA, allows the drive symmetry to be fully described. This has been found to be a powerful tool to visualize and quantify symmetry trends, as well as to optimize parameter sets against any given requirement. The technique is described a number of results are presented. An example to minimize the the root-mean-square deviation in the capsule flux is shown, and extended to consider how to recover adequate symmetry after removing a small number of laser beams for backlighting purposes. In addition, it is shown that large spots can mitigate the risk of P6, P8, and P10+ flux moments compared to smaller spots. Lastly, it is found the separation of the 50' and 44' cones could allow time-dependent control of P4, especially for relatively small outer-cone phase plates. This could allow better control over the RMS capsule flux throughout compression. In total, the results suggest improvements can still be made in drive symmetry, consistent with energetics goals, compared to existing designs.
*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.

Fragmentation and Diagnostic Shielding Issues for Hohlraum Targets

Alice Koniges[1], Robert Anderson[1], David Benson[2], David Eder[1], Parag Dixit[2], Aaron Fisher[1], Dustin Froula[1], Siegfried Glenzer[1], Brian Gunney[1], Nathan Masters[1], Nathan Meezan[1], Marilyn Schneider[1]

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All targets on high-powered laser systems must be analyzed to determine whether or not fragmentation and debris issues will adversely impact the optics and diagnostics. Specific considerations for upcoming experiments include composition and fragmentation of cryogenic cooling ring structures. We discuss the analysis of current and past target configurations with an emphasis on how the target disintegrates and the effects on the surrounding chamber. For instance, in past LPI (Laser Plasma Interaction) experiments, concern was for flange material surrounding the laser entrance hole and whether or not this would necessitate the use of additional debris shields. More recently, cooper cooling ring structures on LPI experiments have rendered damage to debris shields mandating their replacement. We show simulations of these targets and ways to mitigate damage. For upcoming LPI experiments, we discuss predictions of cooling ring fragmentation for silicon and aluminum and discuss how these issues affect the experimental design. Novel fragmentation models are used for the simulations including brittle and ductile failure and advanced numerical techniques. We also discuss how to use cooling ring structures to provide shielding to radiation temperature diagnostics.

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.

Development of a fall-line mix model to predict degraded yield due to mix

L. Welser-Sherrill[1], J. H. Cooley[1], D. C. Wilson[1], D.A. Haynes[1], H. Herrmann[1], M. E. Sherrill[1], R.C. Mancini[2]

[1] *Los Alamos National Laboratory*
[2] *University of Nevada, Reno*

Abstract:

Mixing between fuel and shell material is an important topic in the inertial confinement fusion community, and is commonly accepted as the primary mechanism for neutron yield degradation. Typically, radiation hydrodynamic simulations that lack mixing (clean simulations) tend to considerably over-estimate the neutron yield. We present here a systematic technique for post-processing clean 1-D hydro simulations with a fall-line analysis in order to predict the degraded yield due to mix.

In the fall-line scenario, the converging shell is allowed to contaminate the fuel at a rate equal to the shell's peak velocity. Using clean 1-D hydro simulations as a basis, we implement full yield quenching as the free-falling shell material hits the fuel. We use these concepts to predict an upper bound for the amount of mix, which corresponds to a lower bound for the yield.

The degraded yields from the fall-line mix model are only slightly lower than the experimental yields from a series of direct drive OMEGA implosions. Matching the experimental data exactly with the fall-line model requires the implementation of partial rather than full yield quenching. We also compare to the yield-degrading effects of the mix regions calculated by Haan's and Youngs' mix models.

We will give an introduction to our implementation of the fall-line analysis, which is in the form of a graphical user interface designed in IDL. The tool is easy to use and works with any 1-D hydro simulation output. It provides an important step in understanding the mechanisms by which mix can degrade neutron yield.

LA-UR-07-4261

	Wednesday	**August 29th**	**8:30-11:00PM**	
Po-1	**Afeyan**	Bedros	Polymath Research	Scale and Conformal Invariance and Phase Transitions in the Study of Coherent Structures and Turbulence in 2D Euler and the Vlasov-Poisson System
Po-2	**Niemann**	Christoph	UCLA	First results from the PHOENIX laser at UCLA
Po-3	**Weber**	Stephen	LLNL	Symmetry Capsules for NIF
Po-4	**Hughes**	S. J.	AWE	Continuing Development of Radiation-Hydrocode Modelling of Laser-Plasma Experiments at AWE
Po-5	**Benisti**	Didier	CEA	Nonlinear kinetic envelope equation for an SRS-driven plasma wave
Po-6	**Kruer**	William	UC Davis	Additional Considerations for Laser Plasma Instability Mitigation in Ignition-scale Hohlraums
Po-7	**Montgomery**	David	LANL	Mitigation on of Stimulated Raman an Scattering in Hohlraum Plasmas
Po-8	**Weaver**	J. L.	NRL	Status of LPI Experiments at the Nike Laser
Po-9	**Froula**	Dustin	LLNL	Creation of a multi-centimeter low density plasma channel using high magnetic fields
Po-10	**Messmer**	Peter	Tech-X Corp.	Neutron generation in Laser-ablated Material of Shaped Targets
Po-11	**Rozmus**	Wojciech	U. Alberta	Electron Acceleration by a Tightly Focused Laser Pulse
Po-12	**Kugland**	Nathan	UCLA	Kα conversion efficiency in gas jet targets
Po-13	**Milovich**	Jose L.	LLNL	Short-wavelength perturbation growth studies of double-shell designs for the National Ignition Facility
Po-14	**Edgell**	Dana	LLE/ U.Rochester	Time-Resolved Scattered-Light Spectroscopy in Direct-Drive Implosion Experiments

Thursday, August 30th, 2007

Morning Session

8:30AM - 9:30AM Invited Talk, Chairman: Bedros Afeyan, Polymath Research Inc.

9:30AM - 10:50AM Chairman: Dan Clark, LLNL

10:50AM - 11:10AM Coffee Break

11:10AM - 12:30PM Chairman: David Montgomery, LANL

12:30PM - 12:50PM Business Meeting

Evening Session

6:30PM Banquet

37th Annual Anomalous Absorption Meeting
Kaanapali Beach, Maui, Hawaii
August 27-,31, 2007

Modeling laser-plasma interactions in NIF ignition targets*

D. E. Hinkel, D. A. Callahan, A. B. Langdon, S. H. Langer, C. H. Still, E. A. Williams
University of California Lawrence Livermore National Laboratory

NIF ignition targets for the 2010 ignition campaign have been designed to provide good symmetry with reduced levels of stimulated scatter. These targets are high-Z cylinders that contain a DT capsule coated with a beryllium ablator, and are filled with a low-Z gas. The primary change in these targets over the past two years has been to increase the spot size of the incident laser beams while retaining symmetry.

As a first step in assessment of laser-plasma interactions (LPI) in these targets, the linear, kinetic, steady-state gain is calculated for stimulated Raman and Brillouin scatter, where the incident laser light scatters off electron plasma and ion acoustic waves, respectively. If, in this first "triage", the gain levels are acceptable, a "typical" ray along which the gain has been calculated is used to perform a beam propagation simulation, using pF3D.[1]

These "patch" pF3D simulations capture the effects of axial gradients on the reflectivity while retaining sufficient speckle statistics of the laser beam in the transverse direction. Such simulations will over-estimate the amount of SRS reflectivity, as the SRS light, which refracts differently than the incoming light, is constrained to re-trace the incident light path.

If the levels of reflectivity in the "patch" pF3D simulations are acceptable, then two-dimensional (2D) and "near-whole-beam" simulations are performed, which capture the full effects of transverse as well as axial gradients, refraction, and re-absorption of the scattered light. Reflectivity is over-estimated in 2D simulations, but they provide a path forward on how to best simulate near-whole-beam propagation.

To simulate a near-whole-beam, the entire radial extent of the beam is modeled from the laser entrance hole of the target to its wall. Enough of the beam in azimuthal extent is retained to provide good speckle statistics. These whole-beam simulations are unprecedented in the amount of physics they retain as well as in size. Results from gains to reflectivity in near-whole-beam simulations will be presented for NIF ignition designs.

1. R. L. Berger, C. H. Still, E. A. Williams, and A. B. Langdon, *Phys. Plasmas* **5**, 4337 (1998).

*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.

37th Anomalous Absorption Conference
Ka'anapali Beach, Maui, Hawaii
27-31 August 2007

Diagnosing Large Simulations of Laser-Plasma Interaction for NIF ignition targets.

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

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We have deployed a variety of diagnostics for the pF3d laser-plasma interaction (LPI) simulation code, which includes paraxial wave optics, multi-species hydrodynamics, and models for stimulated scattering. We present a survey of the diagnostics we use to process the data from the simulations and the directions of their development for very large massively-parallel simulations in support of upcoming 96 beam experiments at NIF next year and ignition. Two examples:

Now that we can simulate over the entire beam path in the complex interior of an indirect-drive ignition target, we need to be able to form the spatial distribution of the power absorption of the laser and backscattered light. Such post-processing is itself a parallel processing endeavor due to the large number of spatial cells involved.

To compare with experimental near-field streak spectra of backscattered and transmitted light, obtained at the "full aperture backscatter stations", we form synthetic near field streak spectra. For forensic purposes we can also calculate spectra inside the target, which are experimentally inaccessible.

As we move to more processors (>16k) we have had to defer most serially-coded diagnostics until they can be parallelized, for example the Fourier-based diagnostics. These are being re-implemented with redesigned I/O to handle the large volume of data.

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.

Multi-thousand Processor PF3D Simulations of Laser-Plasma Interaction in NIF Hohlraums *

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NIF inner cone laser beams cross up to 7 mm of plasma before they reach the hohlraum wall. This plasma is made up of plastic from the entrance hole liner, helium fill gas, beryllium from the capsule, and “gold cocktail” material from the hohlraum wall in recent NIF point designs. The incident laser beam is broken up into many speckles by the phase plates, but it has “elliptical symmetry” about the beam axis at scales larger than the speckles. Propagating through the complex plasma breaks the symmetry of the beam and leads to interesting 3D structure in the scattered light.

PF3D simulates LPI in NIF laser beams and it has recently been modified to import complex plasma profiles from Lasnex or HYDRA. Our goal is to run a PF3D simulation of a NIF beam crossing 4.5 mm of plasma, but that would require roughly 20 billion zones. Our largest runs so far had ~6 billion zones and modeled the full transverse extent of a NIF beam for about 1 mm (the 3D run) or a third of the transverse extent for 4.5 mm (the letterbox run). Simulations of this size require thousands of processors running for a week or more. A number of modifications were required to allow PF3D to run efficiently on this many processors.

The 3D run and the letterbox run were both carried out using 8192 processors. They were run in support of the NIF inner beam phase plate decision and show complex 3D structure in the scattered light. Visualizations of the scattered light show that SRS and SBS occur simultaneously, but with little spatial overlap. The effects of refraction on the SRS and the transmitted light are readily apparent. The SBS shows more time variability than the SRS in these simulations.

* 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

Simulations of Hohlraum Based Laser Plasma Interaction Experiments*

R. A. London, R. L. Berger, L. Divol, D. H. Froula, N. B. Meezan, P. A. Michel and P. B. Neumayer

The achievement of ignition in indirect drive inertial confinement fusion requires the minimization of backscatter of the laser beams that heat the hohlraum. Experiments are being been fielded at the Omega laser facility at LLE to study laser-plasma interaction in plasmas similar to those expected at the National Ignition Facility. This talk describes computational simulations of the radiation-hydrodynamics and laser-plasma interaction processes necessary to design and analyze such experiments. The focus of this study is on the use of gas-filled hohlraums to study the scaling of stimulated Brillouin scattering with laser path length and gas mixture. We describe the development of the plasma within laser-heated hohlraums and the resulting linear gains for stimulated backscatter. The results of coupled wave-propagation/linear hydro calculations of laser and backscatter propagation are presented. Simulated gains and beam backscatter are compared to experimental data.

*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.

37th Anomalous Absorption Conference, Hawaii, Aug. 27-31, 2007

Prefer **oral** session

Gas-filled hohlraums LPI experiments at the LIL facility

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The first LPI experiments at the LIL facility have been carried out in may and june 06. The LIL facility is a prototype of one quadruplet of the near coming french laser megajoule (LMJ). Two different gas-filled hohlraums have been designed in order to mimic plasma conditions that are expected along two particular beam paths in ignition hohlraums. The targets consist of 3- or 4-millimeters long, 1 atm neo-pentane gas-filled gold hohlraums. One target is closed at the opposite side of the laser entrance hole, allowing laser interaction with gold and gas plasmas. The LIL quadruplet is aligned with the hohlraum's axis and deliver a 6-ns long pulse with 15 kJ at 3ω. Optical smoothing is achieved by longitudinal dispersion and a phase plate giving a $2\,10^{15}$ W/cm^2 mean intensity on the focal spot at maximum power.

We will present and discuss hydrodynamic calculations together with preliminary results of the LPI campaign. Hydrodynamic calculations predict a 3 keV on-axis electron temperature and an electron density evolving on a wide range of densities during the pulse. Plasma conditions allow to calcule SBS and SRS linear gain with the PIRANAH code. The calculated spectra are compared to experimental results and confirm complex plasma evolution. Finally, We use the paraxial code HERA to investigate the propagation of the LIL quad.

Pushing the limits of plasma length in inertial fusion laser-plasma interaction experiments

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

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The next generation of lasers will produce long pulse lengths (>10ns) at high powers which will generate large blow-off plasmas. In order to deposit energy at regions of interest, laser beams will be required to propagate through long-dense plasmas. We present a plasma length scaling experiment where the backscatter increases, as predicted by linear theory, by four orders of magnitude when increasing the plasma length from 2 mm to 5 mm and varying the laser intensity. Adequate laser beam propagation and low backscatter in ignition size plasmas is demonstrated with a blue (3ω, 351 nm) laser beam at intensities $I<8 \times 10^{14}$ W-cm^{-2}. This laser beam propagates within the original beam cone through a L=5-mm long, high temperature (T_e=2.5 keV), high density (n_e=5x10^{20} cm^{-3}) plasma. A new steady state 3D laser-plasma interaction code developed for large ignition plasmas is used to calculate the laser beam propagation. These results bridge the gap from previous laser-plasma interaction studies to ignition scale plasmas building confidence in our ability to use the existing theoretical and experimental data base for assessing instabilities in long-scale ignition plasmas.

This work was partially supported by LDRD 06-ERD-056 and performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

37th Anomalous Absorption Conference, Hawaii, August 27-31, 2007.

First LPI experiments of the interaction of a 3ω, 15 kJ laser beam with gas-filled hohlraum targets at the LIL facility

C. Rousseaux, S. Depierreux, G. Huser, F. Philippe, M. Casanova, P. Loiseau, E. Alozy, S. Darbon, R. Wrobel, D. Raffestin*, O. Henry*, C. Meyer*, F. Jequier*, G. Thiell*

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

The targets consist of 1 atm, neo-pentane (C_5H_{12}) gas-filled, gold hohlraums. Hemi-spherical and 4 mm-long, opened hohlraums have been fired. At the maximum of the laser power, the mean electron density and electron temperature are calculated to be 8-10% n_c and 2.5 keV respectively.

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

Oral session preferred.

Laser-plasma interaction processes observed in direct-drive implosion experiments.

W. Seka, D. Edgell, C. Stoeckl, V. N. Goncharov, I. Igumenshchev, J. A. Delettrez, J. Myatt, A. Maximov, R. W. Short, C. Sangster.

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This talk summarizes the interaction processes observed in current direct-drive implosion experiments. These range from inverse bremsstrahlung (IB) absorption to resonance absorption, electromagnetic seed-enhanced stimulated Brillouin scattering (SBS) and the two-plasmon decay (TPD) instability. As usual for 351-nm irradiation, the bulk of absorption is IB absorption. However during the initial rise of the laser pulse the short density scale lengths cause significantly enhanced absorption due to resonance absorption. For pulse widths in excess of ~ 0.8 ns and particularly for complex shaped pulses one observes enhanced scattered light that appears to be associated with beam-to-beam energy transfer via EM-seeded SBS. SBS starting from thermal noise and stimulated Raman scattering have been never been observed in current implosion experiments. Finally, significant TPD activity is observed in room temperature targets at overlapped intensities of $> 5\text{x}10^{14}$ W/cm^2 as evidenced by $3\omega/2$ and hard x-ray emission. For thin-walled cryogenic target implosions significantly enhanced TPD activity is observed when the laser burns through the CH wall. Target design changes have been made to mitigate the consequences of these observations.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, 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.

Prefer oral presentation

Friday, August 31th, 2007

Morning Session

8:30AM - 10:10AM Chairman: David Strozzi, LLNL

10:10AM - 10:30AM Coffee Break

10:30AM - 12:30PM Chairman: Carl Schroeder, LBL

The Enhanced Trident Laser Facility at Los Alamos National Laboratory: A new tool for High Energy Density Physics*

Juan C. Fernández , B. Manuel Hegelich, Fred Archuleta, Ray Gonzalez, Randy Johnson, Justin Jorgenson, Frank Lopez, John Oertel, Danielle Pacheco, Tom Shimada, Sam Letzring , and Kirk A. Flippo

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The Trident laser-facility at Los Alamos has served for more than 20 years as an important tool in ICF and Material Dynamics research [1,2,3]. Trident is a three beam Nd:Glass laser, with A-, and B-beams delivering shaped pulses at a wavelength of 1054nm, the pulse duration ranging from 100ps up to 6μs. For ns-scale pulses, each beam can deliver 400J, while for μs pulses each can deliver in excess of a kJ. These pulses are often frequency doubled to provide 200 J ns-scale shaped pulses at 527nm. C-beam is capable of exceeding 100J IR and is typically used as a probe beam or for special applications like creating a single, diffraction limited hot spot. In 2002, a 30 TW level short pulse capability was added to C-beam, opening up a new field of research on Trident and producing extraordinary results, especially in the field of laser-ion acceleration [4,5]. Based on these successes the facility's capabilities are now further enhanced and physics based on short-pulse lasers has become one of its main thrust areas. In addition to an energy / power upgrade of the short pulse beam line to 150J / 250 TW, a new short pulse front end, allowing for extra short pulse probe beams, has been installed. Moreover, a third target area dedicated to combined short pulse / long pulse experiments is being built. The combination of this powerful new beam line with the two flexible long pulse beams and a total of three different target areas, makes Trident a highly flexible and versatile research tool. The new capabilities will enable novel experiments in key High Energy Density Physics topics, such as ICF, Fast Ignition, advanced accelerator development and dynamic material properties. Specifically, materials loaded with the long pulse beams will be probed in novel ways with the short-pulse one. These new capabilities will also allow LANL to stage efficiently and successfully to experiments at larger facilities, like Omega EP, NIF ARC and FIREX. It is also envisioned that Trident will become a user facility, where the worldwide HEDP research community can benefit from the unique capabilities and strong flexibility of Trident.

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

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2. D. S. Montgomery ert al., PRL V. 87, 155001 (2001)
3. Swift, Damian C., et al., Phys Rev E 69, 036406 (2004).
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5. B. M. Hegelich et al., Nature 439, 441 (2006).

Intense Laser and Ion Beams
Next years plasma physics experiments at GSI

Experiments using high energy / high power lasers are being pursued for almost a decade at GSI. In the new regime of ultra-intense lasers the PHELIX system has reached the 20 TW level and first successful experiments have been done. What is the program for the very next years?
In addition to the experiments on heavy ion energy loss in laser produced plasmas, the research on laser assisted particle acceleration and the use of high energy petawatt lasers (HEPW) for the diagnostics of dense plasmas has raised great interest in the international community. The plasma physics group at GSI, based on experiments in France, the UK and the US, has contributed significantly to this field of research in recent years. Now, with the upcoming commissioning of different power levels of the PHELIX laser those experiments can be performed and extended at GSI. Due to the funding of the virtual institute by the Helmholtz Gemeinschaft the opportunities for those experiments at GSI in the next years have grown significantly. The talk will give an overview of recent experimental results, show the link to the future GSI experimental program (including FAIR) and present new and exciting experiments that will be done at GSI within the next two years.

37th Anomalous Absorption Conference

Structure in Radiative Shocks

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Radiative shocks are shock waves fast enough that radiation from the shock-heated matter alters the structure of the shock. They are of fundamental interest to high-energy-density physics and also have applications throughout astrophysics. This talk will discuss the origins of structure in these shocks and recent experiments to measure it. The systems we produce have an optically thin upstream region, from which radiation escapes, and an optically thick downstream region, in which radiation is trapped. The shock transition itself heats mainly the ions. Immediately downstream of the shock, the ions heat the electrons and the electrons radiate, producing an optically thin cooling layer, followed by an optically thick layer of warm, shocked material. The axial structure of these systems is of interest, because the transition from precursor through the cooling layer to the final state is complex and difficult to calculate. Their lateral structure is also of interest, as they seem likely to be subject to some variation on the Vishniac instability of thin layers.

During the past few years we have developed an experimental system that produces quasi-planar radiative shocks suitable for detailed study of the shocked material. Laser ablation launches a Be plasma into a tube of Xe or Ar gas, at a velocity above 100 km/s. This plasma drives a shock down the tube. Radiography provides fundamental information about the structure and evolution of the shocked material in Xe. Thomson scattering has provided data from the cooling layer in Ar. We are working to obtain further data from these and other diagnostics. Data in hand provide some experimental evidence regarding both the axial and lateral structure, and it is hoped that further data will be obtained prior to the conference. The talk will review the physics that leads to both types of structure, will show and summarize the available evidence, and will show how we intend to obtain further evidence.

This research was sponsored by the National Nuclear Security Administration under the Stewardship Science Academic Alliances program through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA00064, and other grants and contracts.

37th Amnomalous AbsorptionConference

Monoenergetic Particle backlighter for radiography and measuring E and B fields and Plasma qreal density

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Abstract
To sensitively probe field distributions in laser-plasma interactions and implosions, as well as the areal density of HED experiments, a monoenergetic, isotropic proton backlighter [1] was utilized. It consists of an exploding pusher filled with D^3He that generates 14.7 and 3.0 MeV P's during a ~150 ps fusion burn (also generated are 3.6 MeV α and 1.0 MeV T). Accurate gating is achieved through the ~15 laser beams that drive the implosion. The remaining ~45 beams are used to either set up multiple laser-plasma experiments or to drive physics implosions. As the birth energy of the Ps (and α and T) are exactly known, the Lorentz force can be used to accurately map fields and/or to measure the energy loss. Using this technique, recent experiments have resolved, in space and time, the complete growth and decay dynamics of MG B fields of laser-plasma interactions [2,3]; the reconnection of MG magnetic "bubbles", the result of multiple laser-plasma interactions [4], in which the change in field topology is accurately mapped; and the radically evolving, extended, mottled field structures enveloping spherical and cone-in shell implosions. Current work involves the generation of areal density maps for these implosions. For single magnetic bubble experiments, 2D LASNEX gives, with the interaction laser on but not off, a reasonable match to the time resolved field maps. With the interaction laser off, 3D instabilities develop that break the 2D symmetry. 3D simulations that go beyond 2D LASNEX are clearly required. Future work will contrast these observations to 3D HYDRA after inclusion of a field generating capability in this code. Platforms are also being developed to exploit the class of monoenergetic particles to study the stopping power in Warm Dense Matter.

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).

[1] C. K. Li *et al.,* Rev. Sci. Instrum. **77**, 10E725 (2006).
[2] C. K. Li *et al.,* Phys. Rev. Lett. **97**, 135003 (2006).
[3] C. K. Li *et al.,* Phys. Rev. Lett. **99**, 015001 (2007).
[4] C. K. Li *et al.,* Phys. Rev. Lett. **99**, 055001 (2007).

* Oral presentation preferred

Observation of the Decay Dynamics and Instabilities of Megagauss Field Structures in Laser-Produced Plasmas

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Abstract
Monoenergetic proton radiography [1,2] was used to make the first measurements of the long-timescale dynamics and evolution of megagauss (MG) laser-plasma generated magnetic (B) field structures [3]. While a 1-ns 10^{14} W/cm^2 laser beam is on, the field structure expands in tandem with a hemispherical plasma bubble, maintaining a rigorous two-dimensional (2D) cylindrical symmetry. With the laser off, the bubble continues to expand as the field decays; however the outer field structure becomes distinctly asymmetric, indicating instability. Similarly, localized asymmetry growth in the bubble interior indicates another kind of instability. 2D LASNEX hydro simulations qualitatively match the *cylindrically-averaged* post-laser plasma evolution but even then it underpredicts the field dissipation rate and of course completely misses the 3D asymmetry growth.

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).

Reference:

[1] C. K. Li *et al.*, Rev. Sci. Instrum. **77**, 10E725 (2006).
[2] C. K. Li *et al.*, Phys. Rev. Lett. **97**, 135003 (2006).
[3] C. K. Li *et al.*, Phys. Rev. Lett. **99**, 015001 (2007).

* Oral presentation preferred

Anharmonic resonance absorption of high power laser beams

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Peter Mulser, Technical University Darmstadt, Germany
Dieter Bauer, Max-Planck-Institute for Nuclear Physics, Germany

Two decades after the invention of chirped pulse amplification the mechanism of collisionless absorption of ultrashort intense laser pulses in solid surfaces is still open to discussion. We show that anharmonic resonance of plasma layers in a self-generated semi-open plasma potential constitutes the physical mechanism of collisionless absorption in highly overdense plasma [1]. In a similar fashion as do collisions nonlinear resonance provides for the necessary phase shift between the driving laser field and the induced current density necessary for energy transfer from the laser into the medium.

For simplicity we analyze the resonance mechanism in one spatial dimension. The shape of the semi-open plasma potential is determined with the help of Particle-In-Cell simulations for fully ionized plasma with steep density gradient. The empirical numerical findings are incorporated into a test particle model that is capable of highlighting the resonance mechanism in the surface potential. The route of particles into resonance is discussed. The model predicts an intensity threshold for the mechanism to work as well as a limit for achievable peak electron energies. The finding may bear relevance for fast ignition.

[1] P. Mulser, D. Bauer, and H. Ruhl, Anharmonic resonance absorption of high power laser beams, submitted to PRL, June 2006.

Laser heating of solid matter by light pressure-driven shocks at ultra-relativistic intensities

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In recent RAL-Petawatt laser experiments where an ultra-intense short laser pulse at an intensity of I>4x10^{20}W/cm2 and pulse duration t<1ps interacts with 5um thin layered metal slab targets, a fully ionized solid density layer of Ni with a temperature >5keV and an extremely small temperature gradient scale length of <0.6um have been observed [Akli, submitted to PRL; Theobald PRE2006]. From previous experience one might expect that absorption of the intense short pulse is dominated by pre-plasma that has been generated by a pre-pulse, so that the thin hot layer has to be explained by ablation of the bulk material by the pre-pulse.
In the present work we interpret this experiment in terms of a light-pressure driven shock wave on the target surface. We study short pulse interaction with density profiles from hydro models using one- and two-dimensional collisional Particle-in-Cell codes. Our simulations predict that under certain conditions an intense short pulse can compress the pre-plasma and drive a shock wave into the solid. While a thin layer on the front is heated to extreme temperatures consistent with observations, our model also predicts resistive heating in the bulk target. We discuss alternative models that rely on resistive effects exclusively; and the transition between resistive- and shock heating in a broader context relevant for applications, like the fast ignition of inertial fusion targets.

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48

Integrated Lsp modeling of relativistic electron beam transport in a wire target *

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[3]Laboratory for Laser Energetics, University of Rochester
[4]Voss Scientific LLC, Albuquerque

Abstract

The production of a relativistic electron beam, by the interaction of a high intensity short pulse laser with a solid target, and the transport of this beam in a long, thin titanium wire, has been modeled using the 3D hybrid particle-in-cell code Lsp#. These simulations closely mimic the real target (50 μm diameter, 1 mm long Ti wire) and laser parameters ($I \sim 7.4\times10^{19}$ W/cm^2, pulse length ~ 0.5 ps, focal spot ~ 20 μm in diameter) used in a recent experiment [1] on the Titan laser at Lawrence Livermore National Laboratory.

Here we discuss the details of the nonlinear processes of high intensity laser plasma interaction and fast electron production exhibited in our simulation study. The implications and importance of these integrated simulations for fast electron propagation studies relevant to fast ignition are further demonstrated as regards the observed electron beam transport characteristics and resultant target heating. Localized energy deposition near the interaction region, fast electron propagation length of ~ 100 μm in the bulk, long range surface current and intense self-generated electric and magnetic fields are observed. Simulation results are in good agreement with the experiment.

* This work was performed under the auspices of the U.S. Department of Energy under contracts No. DE-FC02-04ER54789, DE-FG02-05ER54834, and DE-FG03-00ER54606. This work is also partially supported by the National Center for Supercomputing Applications under grant number TG-PHY050034T, TG-PHY060020T and TG-PHY070008T.

Lsp is a software product of ATK Mission Research.

Reference

[1] F. N. Beg, "Electron transport in wire targets", Invited talk for the 9th International Fast Ignition Workshop, Cambridge, MA, Nov. 3-5, 2006.

Abstract for Oral Presentation:
37th Anomalous Absorption Conference
August 27-31, 2007, Maui, HI

High Quality GeV Electron Beams from Laser Plasma Accelerators

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Laser wakefield accelerators can produce electric fields of order 10–100 GV/m, suitable for acceleration of electrons to relativistic energies. The wakefields are excited by a relativistically intense laser pulse propagating through an underdense plasma and have a phase velocity near the group velocity of the light pulse. Two important effects that can limit the acceleration distance and hence the electron energy gain are diffraction of the drive laser pulse and particle-wake dephasing. Diffraction of a focused ultrashort laser pulse can be overcome by using preformed plasma channels. The dephasing limit can be increased by operating at a lower plasma density, since this results in an increase in the laser group velocity. Recently, results were obtained on the generation of GeV-class electron beams using an intense femtosecond laser beam and a 3.3 cm long preformed discharge-based plasma channel [W. P. Leemans et al., Nature Physics 2, 696 (2006)]. The use of a discharge-based waveguide permitted operation at an order of magnitude lower density and 15 times longer distance than in previous experiments that relied on laser preformed plasma channels in gas jets. Laser pulses with peak power ranging from 10–40 TW were guided over more than 20 Rayleigh ranges and high quality electron beams with energy up to 1 GeV were produced. The dependence of the electron beam characteristics on capillary properties, plasma density, and laser parameters are discussed.

[\] Also at University of Tokyo, Japan

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

Experiments on Self-Guiding Mechanisms of High Power Laser Pulses in a Plasma

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Recent 3D theory and PIC simulations in the blowout regime, wherein the pondermotive force of laser with a pulse length on the order of a plasma wavelength expels all electrons, has predicted a range of parameter space where stable laser propagation can occur[1]. In this theory the density depression caused by electron blowout is the dominant mechism responsible for self-guiding. Prior self-guiding theory predicts self-guiding for long laser pulses [2]. In this paper we examine experimentally, self-focusing and self-guiding using a multiterawatt Ti:Saphire laser system focused into supersonic Helium gas jets with plasma densities ranging ranging from $2 * 10^{18}$ to $2 * 10^{19}$ cm^{-3}. Wake creation and amplitude were monitored using time resolved Thomson Scattering [3]. Conditions for long pulse guiding in which the laser pulse is several plasma wavelengths were achieved using up to a 400 fs pulse with energies up to 600 mJ. Short pulse guiding, wherein the laser pulse is on the order of a wavelength was explored using an approximately 50 fs pulse with energies up to 600 mJ. Images of the mode of the guided spot were made at the exit of the gas jets. Additionally, an imaging spectrometer was used to show photon acceleration and Raman Forward Scattering [4]. Preliminary results using 2 mm and 3 mm long gas jets will be presented.

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ABSTRACT
Electron Acceleration in Laser-Ablated Plasmas Using 30 TW 30 fs Laser Pulses

Takeshi Matsuoka[1], Chris McGuffey[1], Michael Levin[2], Stepan Bulanov[1], Vladimir Chvykov[1], Galina Kalintchenko[1], Stephen Reed[1], Pascal Rousseau[1], Victor Yanovsky[1], Arie Zigler[2], Karl Krushelnick[1] and Anatoly Maksimchuk[1]

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Electron wakefield acceleration in laser-ablated plasmas has been studied using the HERCULES Ti:Sapphire laser system at the University of Michigan, which delivers 30 TW pulses (1 J, 30 fs pulses at 800 nm) focused to intensity of 6.10^{18} W/cm^2 with an f/13 parabola. The laser-ablated plasma was produced by focusing a 10 ns pulse from a Nd:YAG laser (ablator) with energy up to 100 mJ onto the surface of a plastic target to peak intensity of $3x10^{10}$ W/cm^2. The interaction was comprehensively studied by electron beam imaging and spectroscopy as well as transmitted high-intensity laser mode imaging and spectroscopy. We found that electrons generated in the ablated plasma exhibit either a broad Maxwellian spectrum, or a quasi-monoenergetic spectrum depending on the plasma density where the interaction with the main beam takes place. We were able to control plasma density by changing the delay between the ablator and the interaction (Ti:Sa) pulse, the position of the interaction pulse relative to the target surface, and the energy of the ablator and demonstrated good reproducibility of the electron spectrum. We believe that this scheme has a potential advantage for high repetition rate operation compared with gas jet targets or a gas filled capillary since it does not require large pumping capacity of the vacuum system. Possible applications of the demonstrated wakefield accelerator will be discussed in the talk.

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