M.D. Rosen LLNL

32nd

Anomalous Absorption Conference

Turtle Bay Resort, Oahu, Hawaii

July 21-26, 2002

Hosted by UCLA

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Conference Organizer: Warren B. Mori

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PROGRAM **32nd Anomalous Absorption Conference**

Welcome **Monday, July 22, 2002** **8:50-9:00 AM**

Oral Session 1 **Monday, July 22, 2002** **9:00 - 12:20 AM**

Time	Paper No.	First Author	Presenter	Title
9:00 AM	01-1	Williams, E.	Williams, E.	Saturation of crossed beam and SBS interactions by trapping induced frequency shifts
9:20	01-2	Kirkwood, R.	Kirkwood, R.	Scaling of Energy Transfer Between Crossing Laser Beams with Beam Intensity and Plasma Size and Density
9:40	01-3	Bezzerides, B.	Bezzerides, B.	Spectral Properties of Backward StimulatedD Raman Scattering (BSRS) in the Trapping-Saturation Regime
10:00	01-4	Dubois, D.	Dubois, D.	Three-Wave Modeling of Backward StimulatedD Raman Scattering (BSRS) in the Trapping-Saturation Regime
10:20	01-5	Vu, H.	Vu, H.	Two-Dimensional RPIC Simulations of Laser-Induced Instabilities in Single Hot Spots
10:40	**Break**			**Kahuku Foyer**
11:00	01-6	Divol, L.	Divol, L.	Non-linear behavior of Stimulated Brillouin Scattering in 1D-PIC simulations of 500μm long Be plasma
11:20	01-7	Rose, H.	Rose, H.	Upper bounds on SRS in the large kID strong damping regime and failure of first order mode coupling model
11:40	01-8	Seka,W.	Seka,W.	Fast Electron Preheat of Direct-Drive Targets due to the Two-Plasmon-Decay Instability
12:00	01-9	Stevenson,R	Stevenson,R	Temperature and Stimulated Scattering Evolution on Scaled Halfraum Targets using 2w Light

12:20 PM **LUNCH** **at 21° North**

Review Session 1 **Monday, July 22, 2002** **7:30-8:30 PM**

7:30 PM	R1	JOSHI, C.	JOSHI, C.	Laser and Beam Driven Accelerators--Turning John Dawson's Vision into Reality

Poster Session 1 **Monday, July 22, 2002** **8:30-11:00 PM**

Time	Paper No.	First Author	Presenter	Title
8:30 PM	P1-1	Bates, J.	Bates, J.	on the evolution of perturbed shock waves in Materials with Non-Ideal Equations of state
8:30	P1-2	Stevenson, R.	Stevenson, R.	Propagation and Backscatter of Green Light in Gasbag Targets
8:30	P1-3	Still, B	Still, B	PIC Simulation of LPI over an entire speckle volume in three dimensions
8:30	P1-4	Tsung, F.	Tsung, F.	Particle-in-Cell Simulations of 2wp instabilities in a single hot spot
8:30	P1-5	Bradley,D.	Bradley,D.	Measurements of preheat and laser-plasma interactions at irradiances close to 1016 W/cm2
8:30	P1-6	Hittinger,J.	Hittinger/Dorr	Theoretical Model and Numerical Simulation of Energy Transfer Between Crossing Laser Beams in an Expanding Plasma
mv to 05-7	P1-7	Froula, D.	Froula, D.	Search for SBS saturation processes with Thomson Scattering experiments on Ion-Acoustic Waves in Beryllium Plasmas
8:30	P1-8	Eder,D.	Eder,D.	NIF Shrapnel Issues: Modeling of Rear Surface Fragmentation Following Laser or X-Ray Loading
8:30	P1-9	Braun,D.	Braun,D.	Heat Transport in 2D Simulations of HighIntensity, Direct Drive Ablation
8:30	P1-10	Casanova,M.	Casanova,M.	Laser-plasma interaction studies in the context of the LIL facility
8:30	P1-11	Colombant,D.	Colombant,D.	Comparison between direct-drive target designs with radiation preheat and shock heating+
8:30	P1-12	Gardner,J.	Gardner,J.	Numerical simulation of deuterium equation of state experiments on the Nike laser facility
8:30	P1-13	Schroeder,C.	Schroeder,C.	Raman scattering and seeding by short-pulse chirped lasers
8:30	P1-14	Wu, J.	Antonsen,T.	pulse splitting and off axis guiding in Tenuous Argon
8:30	P1-15	Afeyan, B.	Afeyan, B.	The Two Plasmon Decay in an Inhomogeneous plasma and a Laterally Confined Laser Field Profile: Theory and Simulations
8:30	P1-16	Silva. L.	Silva. L.	Proton shock acceleration in ultraintense laser-thin target interactions
8:30	P1-17	Maksimchuk,A.	Maksimchuk,A.	High Energy Proton Generation

Oral Session 2 — Tuesday, July 23, 2002 — 9:00 - 12:20 AM

Time	Paper No.	First Author	Presenter	Title
9:00 AM	O2-1	Aglitskiy,Y.	Aglitskiy,Y.	Hydrodynamic Experiments on Nike. Shooting Campaign of YY2001-2003.
9:20	O2-2	Delettrez,J.	Delettrez,J.	Numerical Investigation of Recent Laser Absorption and Drive Experiments of CH Spherical Shells on the OMEGA Laser
9:40	O2-3	Goncharov,V.	Goncharov,V.	Adiabat Shaping of Direct-Drive Inertial Confinement Fusion (ICF) Implosions Using a High-Intensity Picket
10:00	O2-4	Li, C.	Li, C.	Effects of Fuel-Shell Mix upon Direct-Drive, Spherical Implosions on OMEGA
10:20	O2-5	Petrasso, R.	Petrasso, R.	Capsule Areal Density Nonuniformities and Evolution Inferred from 14.7-MeV Proton Line Structure in OMEGA D3He Implosions
10:40	**Break**			**Kahuku Foyer**
11:00	O2-6	Metzler,N.	Metzler,N.	Laser imprint reduction with a short shaping laser pulse incident upon a foam-plastic target
11:20	O2-7	Amendt,P.	Amendt,P.	Modified Bell-Plesset effect with compressibility: Application to double-shell ignition targets for the National Ignition Facility
11:40	O2-8	Regan,S.	Regan,S.	Experimental Investigation of Expansion Velocity and Gradients in Long-Scale-Length Plasmas on OMEGA
12:00	O2-9	Schroen, D.	Schroen, D.	Overview of Foam Target Fabrication in Support of Sandia National Laboratories.
12:20 PM	**LUNCH**			**at 21° North**

Review Session 2 — Tuesday, July 23, 2002 — 7:30-8:30 PM

7:30 PM	R2	HINKEL, D.	HINKEL, D.	Energetics of high temperature hohlraums

Poster Session 2 — Tuesday, July 23, 2002 — 8:30-11:00 PM

Time	Paper No.	First Author	Presenter	Title
8:30 PM	P2-1	Ruhl,H.	Ruhl,H.	Properties of transport of high currents in near solid density plasma
8:30	P2-2	Watt, R.	Watt, R.	Further investigations of indirectly driven double shell capsule implosions at the Omega laser
8:30	P2-3	Silva, L.	Silva, L.	Tilted filamentation of relativistic electron beams
8:30	P2-4	Smalyuk,V.	Smalyuk,V.	Measurements of Heat Propagation in Compressed Shells in Direct-Drive Spherical Implosions on OMEGA
8:30	P2-5	Adam,J.C.	Laval, G.	Angular dispersion of energetic electrons generated by the interaction of an ultra-intense laser with an overdense plasma
8:30	P2-6	Rosen,M.	Rosen,M.	Radiation Albedoes in High Z Slabs
8:30	P2-7	Mori, M.	Kitagawa, Y.	Growth and Saturation of Large Amplitude Self-Modulated Wakefield in 60 TW Laser Plasma and Possible Gev Electron Generation
8:30	P2-8	Penano,J.	Penano,J.	Propagation of Chirped Laser Pulses in Plasmas
8:30	P2-9	Schroeder,C.	Schroeder,C.	Short-pulse high-power laser propagation in plasmas channels
8:30	P2-10	Kingham,R.	Kingham,R.	Fokker –Planck codes for self-consistent modelling of electron transport and B-field generation in laser-plasmas
8:30	P2-11	Lasinski,B.	Lasinski,B.	PIC Simulations of Short-Pulse, High Intensity Laser-Plasma Interactions
8:30	P2-12	Miller,M.	Miller,M.	Efficient production of Kr K-shell radiation at the OMEGA laser
8:30	P2-13	Huang, CK.	Huang, CK.	Development of a quasi-static 3d pic code for modeling short pulse laser propagation
8:30	P2-14	Kauffman, R.	Kauffman, R.	Hohlraum drive scaling with 0.53 mm light
8:30	P2-15	Koniges,A.	Koniges,A.	Late-time and 3D hohlraum and halfraum simulations with experimental verification
8:30	P2-16	Langer,S.H	Langer,S.H	Correlations between yield and x-ray line emission in NOVA indirect drive implosions
8:30	P2-17	Marinak, M.M.	Marinak, M.M.	Combined effects of 3D drive asymmetry and hydrodynamic instabilities in NIF ignition targets

Oral
Session 3 — Wednesday, July 24, 2002 — 9:00 - 12:20 AM

Time	Paper No.	First Author	Presenter	Title
9:00 AM	03-1	Narang,R	Narang,R	Guiding of a high Intensity femtosecond laser pulse in a preformed plasma channel
9:20	03-2	Tsung, F	Mori,W.	Three-dimensional PIC simulations of SMLWFA of 35 fs class lasers
9:40	03-3	Leemans, W.	Leemans, W.	Laser driven accelerator research at LBNL
10:00	03-4	Kaluza, M.	Tsakiris, G.	Fast electron generation in underdense plasmas and energy transport through solid targets
10:20	03-5	Ren,C.	Ren,C.	Nonlinear and Three Dimensional Theory for Cross-field Propagating Laser Pulse and Its Wake in Magnetized Plasmas
10:40	**Break**			**Kahuku Foyer**
11:00	03-6	Kitagawa,Y.	Kitagawa,Y.	Petawatt laser heating of imploded plasmas and related studies at ILE, Osaka University
11:20	03-7	Cobbles,J.	Cobbles,J.	Laser-Produced MeV Protons on Trident
11:40	03-8	Teubner, U.	Teubner, U.	High-Order Harmonic Generation with Relativistic Femtosecond Laser Pulses at High Density Plasma Surfaces
12:00	03-9	Madison,K.	Madison,K.	An investigation of fusion yield from exploding deuterium and deuterated methane cluster plasmas produced by 100 TW laser pulses

12:20 PM LUNCH

BANQUET — Wednesday, July 24, 2002 — 7:00 PM

Oral
Session 4 — Thursday, July 25, 2002 — 9:00 - 12:20 AM

Time	Paper No.	First Author	Presenter	Title
9:00 AM	04-1	Afeyan, B.	Afeyan, B.	Optical Mixing Controlled Stimulated Scattering Instabilities in CH and Beryllium targets: SRS Suppression in Weak and Strong Ion Acoustic Wave Damping Regimes
9:20	04-2	Short,R.	Short,R.	A Linear Model of Anomalous Stimulated Raman Scattering and Electron Acoustic Waves in Laser-Produced Plasmas
9:40	04-3	Joshi,C.	Joshi,C.	Possible experimental evidence of the electron acoustic wave
10:00	04-4	Montgomery,D.	Montgomery,D.	Trident single hot spot experiments at high $k\lambda_D$
10:20	04-5	Langdon, A.	Langdon, A.	Nonlinear evolution of stimulated Raman scatter in high temperature plasmas
10:40	**Break**			**Kahuku Foyer**
11:00	04-6	Suter,L.	Suter,L.	Reexamining the possibility of laser based IFE using a ~1micron driver
11:20	04-7	Maximov, A.	Maximov, A.	Nonlinear Propagation of Laser Beams in Plasmas Near a Critical-Density Surface
11:40	04-8	Myatt, J.	Myatt, J.	Modeling Laser-Plasma Interaction Physics Under Direct-Drive Inertial Confinement Fusion Conditions
12:00	04-9	Kingham, R.	Kingham, R.	Non-local magnetic field generation in collisional plasmas

12:20 PM LUNCH

Review Session 3 Thursday, July 25, 2002 7:30-8:30 PM

7:30 PM	R3	SILVA, L.	SILVA, L.	Anomalous absorption processes in astrophysics

Poster Session 3 Thursday, July 25, 2002 8:30-11:00 PM

Time	Paper No.	First Author	Presenter	Title
8:30 PM	P3-1	Velikovich,A.	Velikovich,A.	Oscillatory RM to RT transition and other coherent effects in plastic-foam targets
8:30	P3-2	Weaver,J.	Weaver,J.	Absolute Soft X-ray Emission Measurements at the Nike Laser
8:30	P3-3	Carter, S.	Walsh,T.	Planar Target Fabrication in Support of Nike
8:30	P3-4	Kruer, W.	Kruer, W.	Some Features of Relativistic Electron Transport for Fast Ignition
8:30	P3-5	Fernandez,J.	Fernandez,J.	Using laser-driven MeV/nucleon ion beams to study dense plasmas
8:30	P3-6	Gordon,D.	Gordon,D.	Particle-in-Cell Simulations of Laser-Plasma Interactions in the Exowatt Regime
8:30	P3-7	Karasik, M.	Karasik, M.	Side-on Measurements of Density Profile of High-Z Layers on Planar Plastic Targets Irradiated by a Nike KrF Laser Pulse.
8:30	P3-8	Mason, R.	Mason, R.	A 3-D Ray-Trace model for the AMR Code RAGE
8:30	P3-9	Mostovych,A.	Mostovych,A.	Deuterium Equation-of-State Experiments on the Nike Laser Facility
8:30	P3-10	Pollak, G.	Pollak, G.	Comparison of Calculated and Measured Static and Gated Images for Recent Implosion Experiments
8:30	P3-11	Afeyan, B.	Afeyan, B.	Vlasov Simulations of the Nolinear Evolution of High Frequency Waves Generated by Optical Mixing: Electron Plasma Waves and Trapped Electron Acoustic Waves
8:30	P3-12	Leemans, W.	Leemans, W.	Experiments on controlled laser wakefield excitation and electron acceleration
8:30	P3-13	Esarey, E.	Esarey, E.	Electron trapping and acceleration in laser-plasma accelerators
8:30	P3-14	Schmitt, A	Schmitt, A	Evaluation of the stability of laser direct-drive targets
8:30	P3-15	Narang,R	Narang,R	Simulations on Beat-Wave excitation of plasma waves
8:30	P3-16	Weber,S	Weber,S	Non-Ideal Backlit Implosions (NIBI) on Omega
8:30	P3-17	S.W. Haan	S.W. Haan	Hydrodynamic instability modeling for ignition targets for the National Ignition Facility, and for Omega experiments designed to test that modeling

Oral Session 5 Friday, July 26, 2002 9:00 - 12:20 AM

Time	Paper No.	First Author	Presenter	Title
9:00 AM	O5-1	Jones,O.	Jones,O.	Cocktail hohlraum experiments
9:20	O5-2	Glenzer, S.	Glenzer, S.	Measurements of the absolute Hohlraum Wall Albedo under ignition foot drive conditions
9:40	O5-3	Smalyuk,V.	Smalyuk,V.	Areal-Density Growth Measurements with Proton Spectroscopy in Spherical Implosions on OMEGA
10:00	O5-4	Tobin, M.	Tobin, M.	Experimental Techniques to Measure Shrapnel and Debris Environments Expected for the National Ignition Facility (NIF)
10:20	O5-5	Andiel, U.	Andiel, U.	K-shell spectra from isochorically heated solid aluminum driven by ultrashort laser pulses
10:40	**Break**			**Kahuku Foyer**
11:00	O5-6	Tierney, T.	Tierney, T.	Collective Thomson Scattering Measurements of Moderately Coupled Plasmas
11:20	O5-7	Froula, D.	Froula, D.	Search for SBS saturation processes with Thomson Scattering experiments on Ion-Acoustic Waves in Beryllium Plasmas
12:20 PM	**LUNCH**			

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Monday, July 22, 2002

8:50 AM	Welcome
9:00 AM-12:20 PM	Oral Session 1
12:20 PM	Lunch
7:30-8:30 PM	Review Session 1, Dr. Chan Joshi,

"Laser and Beam Driven Accelerators--Turning John Dawson's Vision into Reality"

8:30-11:00 PM	Poster Session 1

Saturation of crossed beam and SBS interactions by trapping induced frequency shifts.

E. A. Williams, B. I. Cohen, L. Divol, R. K. Kirkwood, M. R. Dorr and J. A. Hittinger

Stimulated Brillouin scattering and crossed beam energy transfer interactions are mediated by ion acoustic waves resonantly driven by the ponderomotive force of the beating electromagnetic waves. The crossed beam experiments of Kirkwood *et. al.*(1) on the Omega laser indicate that these ion acoustic waves respond sub-linearly to increasing pump and probe amplitudes, saturating at quite modest (few percent $\delta n/n$) amplitudes. In the CH_2 plasma of the experiment, these levels are well below the two-ion decay threshold and too small to generate energetically significant harmonics. These amplitudes, however, are sufficient to trap enough ions near the phase velocity to both reduce the Landau damping and the resonant frequency of the ion wave. Using Morales and O'Neil's(2) nonlinear frequency shift, we create a simple 1D three-wave coupling model and show that it reproduces the scaling of the experimental results. We investigate the model analytically and numerically in both homogeneous plasmas and those in which there is a locally linear mismatch gradient. Three interesting features emerge from this analysis.

First, there can be multiple steady state solutions for the ion acoustic response to a given ponderomotive force giving rise to the possibility of discontinuous ion wave amplitudes as a function of space. The resulting ambiguity is resolved by a boundary layer analysis in which the small, but no longer negligible, ion wave group velocity term is retained.

Second, when there is a mismatch gradient there is a possibility of auto-resonance, whenever the direction of the gradient is such that the changing frequency shift of the spatially growing ion wave is of the opposite sign to the linear mismatch. In this situation, crossed beam (or SBS) growth would then depend not only on the gradient of the mismatch, but on its direction.

Third, because of the possibility of auto-resonance effects, the Mach layer in which maximum amplification of the probe occurs can be shifted from the layer where linear resonance occurs.

(1) Observation of Saturation of Energy Transfer Between Co-Propagating Beams In a Flowing Plasma, R. K. Kirkwood, J.D. Moody, A. B. Langdon, B. I. Cohen, E. A. Williams, M. R. Dorr, J. A. Hittinger, R. Berger, P.E. Young, L. J. Suter L. Divol, S.H. Glenzer, O. L. Landen (in process of submission)

(2) G.J. Morales and T.M. O'Neil, Phys. Rev. Lett. **28**, 417 (1972); H. Ikezi, K. Schwarzenegger, A.L. Simons, Y. Ohsawa, and T. Kamimura, Phys. Fluids **8**, 239 (1978).

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.

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Scaling of Energy Transfer Between Crossing Laser Beams with Beam Intensity and Plasma Size and Density

R. K. Kirkwood, P.E. Young, J.D. Moody, A. B. Langdon, B. I. Cohen, E. A. Williams, M. R. Dorr, J. A. Hittinger, R. Berger, L. J. Suter L. Divol, S.H. Glenzer, O. L. Landen
Lawrence Livermore National Laboratory

W. Seka,
Laboratory for Laser Energetics, University of Rochester

Experiments on the Omega laser demonstrate saturation of energy and power transfer between co-propagating, same frequency, beams crossing at a small angle in a plasma with a Mach 1 flow, similar to the conditions expected in in-direct drive hohlraums [1]. The transmission of the two beams is measured when they cross in a plasma produced by a pre-heated exploding foil target. The transmission of the low intensity probe beam is shown to be significantly enhanced when there is a Mach 1 flow in the appropriate direction for resonant energy transfer from the pump. The process is interpreted as amplification of the low intensity probe beam by the stimulated scatter of the high intensity pump beam. The observed probe amplification increases slowly with pump intensity and decreases with probe intensity, contrary to what has been observed in experiments with larger crossing angles [2]. The present observations are indicative of the energy and power transfer being saturated by ion wave non-linearities and localized pump depletion and are consistent with numerical modeling including ion wave non-linearities.

[1] R. K. Kirkwood et al. Phys. of Plasmas 4, 1800 (1997).
[2] K.B. Wharton, et. al. Phys. Rev. Lett. 81, 2248 (1998).

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Prefer oral session

SPECTRAL PROPERTIES OF BACKWARD STIMULATED RAMAN SCATTERING (BSRS) IN THE TRAPPING-SATURATION REGIME

B. Bezzerides, D.F. DuBois[1], H.X. Vu[2] and D.C. Barnes
Los Alamos National Laboratory

In the trapping-saturation regime of strong linear Landau damping (high $k_1\lambda_D$), the BSRS reflectivity consists of an irregular chain of sub picosecond pulses. The peaks of the pulses are enhanced by the lowered Langmuir wave (LW) damping due to electron trapping, and saturated by phase detuning resulting from the trapping-induced frequency shift [1]. The time dependent spectrum, $|E(k,t)|^2$, calculated in 1D RPIC simulations, reveals that k "chirps" as , $k_1 + \delta k(t)$, where k_1 is the initially matched LW wave number. The space and time Fourier spectrum, $|E(k.\omega)|^2$, consists of a "streak" following the instantaneous condition: $-\delta k(t)=V\delta\omega(t)$ where $\delta\omega(t)$ is the trapping frequency shift of the LW. This behavior describes the tendency for the nonlinear system to stay k and ω matched. But V is observed to be somewhat less than the condition for perfect parametric matching: $V=v_s+v_p$, where v_s and v_p are the group speeds of the scattered light wave and LW, respectively. The k, ω streak is consistent with the observation that the scattered light and LW fields consist of wave packets traveling toward the laser. At strong laser intensities, especially at higher $k_1 \lambda_D$, $\delta k(t)$ does not return to zero between pulses due to a persistent modification of the background electron distribution function, even allowing for trapped electron side-loss out of the putative laser hot spot. This memory effect has implications for reduced modeling.

[1] Also supported by Lawrence Livermore National Laboratory
[2] Present address: Electrical and Computer Engineering Department, University of California, San Diego.

[1] H.X.Vu, D.F.DuBois, and B.Bezzerides, PRL 86, 4306 (2001) and PoP to be published June 2002.

THREE-WAVE MODELING OF BACKWARD Stimulated Raman Scatter (BSRS) in the Trapping Regime

D.F. DuBois[1], B. Bezzerides, H.X. Vu[2] and D.C. Barnes
Los Alamos National Laboratory

For BSRS, where the wave number of the primary driven Langmuir wave is large ($k_1\lambda_D$ = 0.25-0.50), the Reduced-Description Particle-in-Cell Model (RPIC) has shown the important role of electron trapping in the growth and saturation of the instability. We have employed a 3-wave temporal envelope model, including a nonlinear frequency shift and damping for the Langmuir wave to model this effect. Various theoretically motivated expressions for the nonlinear frequency shift and damping are employed in the 3-wave model and the results are compared with the RPIC simulation. For certain of these expressions the results compare favorably with the reflectivity of the RPIC simulation. However, other diagnostics, including spectral properties of the Langmuir fluctuations can differ qualitatively from those of RPIC. Our work suggests that the assumption of a damping and frequency shift, local-in-time, is responsible for this difference. For the larger $k_1 \lambda_D$ regime and higher drives, as shown in the previous talk, significant memory effects in the electron velocity distribution function develop. In this regime it is unlikely the effects of particle kinetics can be treated simply in terms of a local-in-time nonlinear frequency shift and damping.

[1] Also supported by Lawrence Livermore National Laboratory
[2] Present address: Electrical and Computer Engineering Department, University of California, San Diego.

TWO-DIMENSIONAL RPIC SIMULATIONS OF LASER-INDUCED INSTABILITIES IN SINGLE HOT SPOTS

H.X. Vu[1], B. Bezzerides, D.F. DuBois[2], and D.C. Barnes
Los Alamos National Laboratory

One and two-dimensional kinetic simulations (with initially-uniform density and temperature plasmas) of NIF-emulation experiments on the Trident laser facility indicate significant backward stimulated Brillouin scattering (BSBS), contrary to experimental data where BSBS is either not present or below the experimental detection threshold. A number of possible physical mechanisms that can reduce the amount of BSBS observed in kinetic simulations include supersonic transverse plasma flows and temperature and density inhomogeneities. These effects are under consideration, and 2D kinetic simulations will be presented. Kinetic simulations in one and two dimensions of the interaction of backward stimulated Raman scattering BSRS and forward stimulated Raman scattering (FSRS) and BSBS will also be presented.

[1] Present address: Electrical and Computer Engineering Department, University of California, San Diego.
[2] Also supported by Lawrence Livermore National Laboratory

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Non-linear behavior of Stimulated Brillouin Scattering in 1D-PIC simulations of 500μm long Be plasma

L. Divol, B.I. Cohen, D.H. Froula, S.H. Glenzer, A.B. Langdon, B.F. Lasinski, E.A. Williams.

University of California Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

Following an experimental campaign on Stimulated Brillouin Scattering (SBS) done at the TRIDENT facility[1] , we performed 1D-hybrid PIC simulations of SBS in long Beryllium plasmas (500μm), using the code Bzohar[2] . These simulations were run for 500 ps (comparable to the interaction beam duration), and show two phases in the non-linear evolution of SBS. The first 200ps exhibit a bursty SBS reflectivity which can reach large values. The Landau damping of the driven acoustic wave is reduced when its amplitude reaches a sizeable value, and the associated trapping-driven non-linear frequency shift detunes the instability, hence the burstiness. This detuning allows for ion-acoustic-wave-decay to occur, which then damps the primary acoustic wave and drastically reduces the SBS reflectivity. After 200 ps, the ion distribution function has been deeply modified, in a spatially inhomogeneous way, and a background of decay products remains. We show that this explains why the SBS reflectivity and the amplitude of the driven acoustic wave remain low for the rest of the simulation.

1] D.H. Froula, L. Divol and S.H. Glenzer, PRL **88**, 105003(2002)
2] B.I. Cohen et al.,Phys. Plasmas **4**, 956 (1997)

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.

Upper bounds on SRS in the large $k\lambda_D$ strong damping regime and failı first order mode coupling model

Harvey A. Rose
Los Alamos National Laboratory

In the strongly damped regime, the convective gain rate for stimulated scatter, κ, is customarily maximized by requiring that, taken together, the laser light wave and the daughter light and plasma waves, satisfy wavevector and frequency matching, and then $1/\kappa \sim \gamma$, the plasma wave damping rate. If the bounce frequency in the daughter plasma wave is large compared to the trapped particle loss rate, it would seem, based on naïve extrapolation of the work by Zakharov and Karpman (V. E. Zakharov and V. I. Karpman, JETP **16**, 351 (1963)) on *decaying* one dimensional (1D)Langmuir waves, that κ may be increased indefinitely by increasing the electrostatic wave amplitude, ϕ, since they calculate that γ varies as $\phi^{-3/2}$. However, for a *driven* plasma wave in a laser speckle—as is appropriate to stimulated scatter in an optically smoothed laser beam in 3D—it has been shown (H. A. Rose and D. A. Russell, Phys. Plasma, **8**, 4784 (2001)) that γ varies more slowly, $\propto \phi^{-1/2}$, and asymptotes to a finite value for large ϕ. This combined with the loss of resonance for ϕ too large, leads to a maximum value for κ as a function of scattered light frequency and ϕ, for given laser and plasma parameters. First order mode coupling models, those with a nonlinear dielectric function and only one time derivative acting on the electrostatic wave amplitude, can always respond resonantly no matter what the wave amplitude or wavenumber, contradicting the impossibility of BGK modes with $k\lambda_D > 0.53$, and the loss of resonance (~wave breaking) at small amplitudes for $k\lambda_D \approx$ 0.53. Such models will qualitatively overestimate the reflectivity in this regime, a regime in which NIF will operate.

Fast Electron Preheat of Direct-Drive Targets due to the Two-Plasmon-Decay Insta

W. Seka, C. Stoeckl, B. Yaakobi, R.S. Craxton, and R. Short
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The two-plasmon-decay (TPD) instability has long been identified as a potential source for energetic electrons that can preheat imploding target cores in direct-drive experiments. The basic theory for TPD was developed long ago along with a number of numerical simulations; however, experimental verification of these predictions has been at best of a qualitative nature. Quantitative predictions for fast-electron generation are only now starting to emerge from simulations and have never been compared with experimental data. Recent long-scale-length OMEGA experiments have used one to six interaction beams at total irradiation levels of up to 3×10^{15} W/cm^2. Preheat of the target due to energetic electrons has been measured using fast scintillators and photomultipliers for x-ray energies in the range of 50 to 500 keV with ~ 100-ps time resolution. These detectors have been cross-calibrated to absolutely calibrated K_{α} spectroscopy using special targets (both of which measure the preheat). The preheat data indicate saturation near 10^{15} W/cm^2 at a fractional hot-electron preheat level (preheat energy/incident laser energy) of ~ 0.1%. The present experiments cannot determine if this saturation is due to an intrinsic saturation of the TPD instability or if hydrodynamics or geometry is responsible for the observed saturation. These experiments also indicate that the hot-electron scaling responds to the total irradiation intensity irrespective of whether one or several beams produce this intensity consistent with observations on earlier OMEGA experiments in spherical geometry. This paper will discuss details of our recent experiments, results on fast-electron production, and 3_/2 harmonic emission.

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Abstract

Temperature and Stimulated Scattering Evolution on Scaled Halfraum Targets using 2ω Light

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Recent experiments at the HELEN laser at AWE have focussed on investigations into the evolution of radiation temperature and stimulated scattering processes for a series of scaled NOVA halfraum targets. These were varied from scale 1 to scale 0.1 and used a single beam at 0.53μm to irradiate the target. Target diagnostics included FRD, PCD, DANTE, SRS and SBS FABS, FXI, HENWAY and NBI. Analyses of the results from this campaign are presented with particular emphasis on the conditions present in the smallest scale halfraums including comparison with calculated performance. This also includes the effects of varying pulseshape and pulselength and in the case of scale 0.3 targets, the use with and without phase plate beam smoothing.

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Review Session 1

Monday, July 22, 2002

7:30-8:30 PM

Laser and Beam-Driven Plasma Accelerators -Turning dawson's Vision into a Reality.

C.Joshi UCLA

In a now classic paper , T.Tajima and J.M.Dawson(P.R.L.43,267,1979) outlined a revolutionary scheme for building a charged particle accelerator using a relativistic plasma wave. The same paper specifically pointed out three ways of exciting such plasma waves.These three methods are now known as the plasma beat wave accelerator,the laser wakefield accelerator and the self-modulated laser wakefield accelerator. Shortly thereafter Dawson and coworkers proposed a plasma wave accelerator driven by an intense but short relativistic particle beam.Because these schemes promised acceleration gradients that were orders of magnitude greater than those achieved in radio frequency machines , plasma accelerators caught the imagination of a generation of young experimentalists including myself.

In this talk I will describe the progress that has been made in this exciting field. Electrons have been accelerated to greater than 200 MeV in a couple of mm using a Forward Raman unstable laser where as using particle beams acceleration of both electrons and positrons over a meter has now been demonstrated. We are on the threshold of witnessing a GeV class laser-accelerator on a bench top whereas an energy doubler for a linear collider based on a plasma afterburner is gaining serious attention.A new class of devices for focusing highly relativistic charged particles and generating tunable radiation are also emerging from this research.

Poster Session 1

Monday, July 22, 2002

8:30-11:00 PM

On the Evolution of Perturbed Shock Waves in Materials with Non-Ideal Equations of State

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32^{nd} Anomalous Absorption Conference, Oahu, Hawaii, July 21-26, 2002

Abstract

In the context of an Eulerian hydrodynamic description, we investigate analytically the effect of first-order perturbations to the propagation of a two-dimensional, steady, planar shock wave. This work has been motivated in part by recent laser-driven equation-of-state (EOS) studies performed at the U.S. Naval Research Laboratory in which the appearance of slightly curved sections of shock fronts complicated the interpretation of some experimental data. The earliest analysis of this problem is likely due to Roberts,[1] who reduced the linearized system of perturbed fluid equations to an integral expression, the evaluation of which yields the time-dependent amplitude of each Fourier component of the initial disturbance. One shortcoming of Roberts' approach, though, is that the presence of entropy perturbations behind the shock front is overlooked, and moreover, results are specialized to the case of an ideal gas. Here, we generalize Roberts' calculation and derive explicit expressions governing the temporal evolution of a rippled shock in a material with an arbitrary EOS. Two popular EOS models for deuterium relevant for inertial confinement fusion (ICF) studies are considered as examples: SESAME[2] and the "linear-mixing model" due to Ross.[3] It is shown that in these cases, the late-time behavior is similar to the ideal gas result in which generic perturbations decay at least as fast as $t^{-1/2}$. The methodology developed herein provides a means of testing the accuracy of the D'yakov-Kontorovich instability criterion[4] derived from a linearized normal-mode analysis, which incorrectly assumes that the temporal dependence of the perturbations is exponential. In the future, it will be desirable to apply these results to the study of the Richtmyer-Meshkov instability for realistic equations of state, and to extend the calculation to incorporate the influence of the non-uniform driving mechanism (*e.g.*, initial target roughness and/or varying laser intensity in the case of direct-drive ICF) that gives rise to a perturbed shock front.[5]

Work supported by the U.S. Department of Energy.

[1]A.E. Roberts, Los Alamos Scientific Laboratory Report No. LA-299, 1945.
[2]G.I. Kerley, Los Alamos Scientific Laboratory Report No. LA-4776, 1972.
[3]M. Ross, Phys. Rev. B **58**, 669 (1998).
[4]L.D. Landau and E.M. Lifshitz, *Fluid Mechanics* (Pergamon, Oxford, 1987), pp. 336-341.
[5]R. Ishizaki and K. Nishihara, Phys. Rev. Lett. **78**, 1920 (1997).

Abstract

Propagation and Backscatter of Green Light in Gasbag Targets

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This paper extends the work presented at the 31st Anomalous Absorption conference, which explored the propagation, backscatter and x-ray generation using 2ω light on gas bag targets at the HELEN laser facility at AWE. The targets have used to date have been filled with C_5H_{12}, CO_2 and Kr. These three targets give very different backscatter, including almost no backscatter from the Kr targets, showing that plasma composition can also be used to minimize backscatter losses. These data also indicate that is possible to produce or quench hot electron production by varying the plasma composition, even near quarter critical density.

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PIC Simulation of LPI over an entire speckle volume in three dimensions

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The 2-D particle-in-cell code Zohar has long been a primary tool for modeling parametric laser-plasma instabilities. The latest incarnation of this tool is a 3-D fully kinetic massively parallel code, dubbed Z3. As a capability demonstration, we used Z3 on 512 processors of the ASCI White machine, to perform a milestone calculation, simulating an entire f/4 speckle volume ($25\lambda_0 \times 25\lambda_0 \times 153\lambda_0$) for a 3ω gaussian beam at 7×10^{16} W/cm^2. We present results including evidence of vigorous Raman scatter in the forward and near forward directions at high T_e. We discuss the calculation and challenges inherent in performing such a large simulation (3.5×10^8 cells, 7.6×10^9 particles).

Preferred format: Poster

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Particle-in-Cell Simulations of $2\omega_p$ instabilities in a single hot spot

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We present 2D and 3D particle-in-cell (PIC) results of the $2\omega_p$ instabilities in a single hot spot.

The ultimate goal of this project is to quantify the entire evolution of the instability, from its onset to the linear phase to the saturation, relaxation and finally, recursion. To this end, we plan to perform simulations . We also plan to show diagnostic tools which identify the two plasmon modes and measure the growth rate for comparisons with linear theory (*). Beyond the linear regime, we wish to characterize the generation of fast electrons from the plasmons, and subsequent saturation due to the modification of the distribution function. We also intend to study ion effects, and the suppression of $2\omega_p$ due to transverse localization.

* For more informations on the theoretical aspects of the $2\omega_p$ instability, please see the poster given by B. B. Afeyan et al in this conference.

Prefer Poster Session

Measurements of preheat and laser-plasma interactions at irradiances close to 10^{16} W/cm^2

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The production of Gbar level shocks using direct-drive on the National Ignition Facility will require drive intensities in the region of 10^{16} W/cm^2 over several ns. At these kinds of intensities there exists the possibility of both energy loss due to stimulated scattering, and sample preheating due to superthermal electron production. Existing data for 351 nm drive top out around 10^{15} W/cm^2, and indicate rising levels of fast electron production, but there are disagreements on the production mechanisms, and it is unknown whether the preheat levels will continue to rise, or saturate with increasing drive intensity.

We have carried out a series of shots on the OMEGA laser using 12 overlapped beams to produce an intensity of 8 x 10^{15} w/cm^2 in a 1 ns pulse. Each beam was focused down to a ~280 μm spot using a supergaussian- profile DPP, designed to produce a circular spot on the target despite the non-normal incidence of the beam. Fast electron energy-deposition and temperature were measured using both K-α fluorescence of buried target layers and by diode measurements of the hard x-ray continuum emitted from the target. Time resolved measurements of the SRS and SBS signals were taken for two incident beam angles, together with measurements of the 3/2 ω spectrum. We will show results from a range of intensities from 1-8 x 10^{15} W/cm^2 for both CH and Be ablators.

*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.

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Turtle Bay HI.
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Theoretical Model and Numerical Simulation of Energy Transfer Between Crossing Laser Beams in an Expanding Plasma

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Two laser beams with identical frequencies crossing in the vicinity of the sonic region of an expanding plasma can excite a three-wave resonance that results in the transfer of energy from one beam to the another. Similar conditions may occur in the vicinity of the NIF hohlraum LEH. As a first step towards the quantitative prediction of this resonant transfer, we have developed an analytical model that is applicable in linear and weakly nonlinear regimes. In these regimes, the model has been compared to results obtained using the laser plasma interaction code ALPS [1]. We subsequently have applied ALPS to more strongly nonlinear problems representative of those being experimentally investigated at the Omega facility.

The analytical model was based on a system of equations for the plasma that were linearized about a background rarefaction solution and linearized wave equations for each beam. An incident pair of beams symmetrically oriented about the Mach 1 flow positions were each described by a light equation that neglected diffraction, refraction due to the background expansion, and beam smoothing. Pump depletion was neglected in the derivation, but the interaction of the pump beam and the ion acoustic perturbation was preserved in the probe equation. The resulting equation for the linear gain was integrated numerically with integration bounds determined by a ray-tracing algorithm, and this quadrature was embedded within an iterative procedure that converged to a self-consistent level of pump depletion.

In addition to the model derivation, we will present a comparison of the model results to those obtained by the ALPS code for a range of transverse velocity scale lengths. Reasonable agreement will be demonstrated for scale lengths comparable to or larger than the beam diameters. Comparisons with crossed beam experimental data will also be presented.

[1] M.R. Dorr, F. X. Garaizar and J. A. F. Hittinger, *J. Comput. Phys.* **177**, 233-263 (2002).

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Search for SBS saturation processes with Thomson Scattering experiments on Ion-Acoustic Waves in Beryllium Plasmas

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We observe saturation of the SBS reflectivity and of the ion-acoustic wave amplitude by both varying the interaction beam intensity and plasma scale length. We further investigate detuning by comparing the relative width of the thermal and driven peaks in the Thomson scattering spectra. Experiments have been conducted using a three-beam configuration at the Trident Laser Facility at Los Alamos National Laboratory to investigate the growth of ion-acoustic waves in beryllium plasmas. These experiments were conducted in well-characterized plasmas that were created using a 2ω heater beam with an intensity of 10^{14} W cm^{-2}. A separate 2ω 1.2-ns interaction beam with intensities up to 5 x 10^{15} W cm^{-2} was used to excite an ion-acoustic wave. The wave number of the excited ion-acoustic wave was matched using a third 3w 200ps Thomson-scattering probe beam. The electron and ion temperatures were measured to be 650 eV and 325 eV respectively. A FABS station was used to measure the SBS and SRS energy and spectra. The electron densities were measured to be $n_e \sim 3\times10^{20}$ cm^{-3}.

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

NIF Shrapnel Issues: Modeling of Rear Surface Fragmentation Following Laser or X-Ray Loading

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The lifetime of the debris shields on the 192-beam National Ignition Facility (NIF) laser is an important cost driver for operations and is directly affected by the number, size, and velocity of shrapnel fragments that strike these final optics. The shrapnel fragments can come from target and diagnostic components that are close to target center but are not completely vaporized. An important class of these components is thin metal plates used for shields, pin-hole arrays, etc. These plates are loaded by laser light or by x-rays from the target. As a result of this impulse loading, a shock is sent into the metal and after reflection from the rear surface fragmentation can occur. Recent experiments on the Helen laser at AWE studied the formation of such fragments. The spatial, size, and velocity distributions of the fragments are measured using aerogel capture. The very low density of the aerogel mitigates the problem of vaporization of fragments on impact with the capture material. We discuss modeling of these experiments using the 2D LASNEX code to calculate energy absorption, shock propagation, and material strength. The calculated strain rates are used to estimate the average size of the fragments, which are combined with calculated density and velocity to give spatial, size, and velocity distributions of the fragments.

***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.**

Heat Transport in 2D Simulations of HighIntensity, Direct Drive Ablation

David Braun, David Bradley, Gilbert Collins, John Edwards and Larry Suter

Abstract Proposed direct drive experiments for the NIF will use high laser intensities (~10^{16} W/cm^2) and large spots (r=1000 μm) to generate high pressure shocks (>100 Mbar) for equation of state measurements. 2D simulations using the rad-hydro code LASNEX have successfully reproduced experimental results at moderate laser intensities ($4*10^{14}$ W/cm^2). These simulations show that 2D effects are important; 2D calculations have distinctly lower values of T_e and pressure than the corresponding 1D simulations. This difference increases with intensity to become more than a factor of two for the proposed NIF experiments. Despite the large spot size used in the NIF design, substantial radial energy transport limits the on-axis coronal temperature and the pressure generated.

In this paper we describe the degree to which the coronal plasma conditions of these NIF targets will differ from those of previous targets, we quantify the radial energy transport, and we explore the sensitivity of T_e and pressure to heat transport physics. In particular, we look at the effects of self-generated magnetic fields and inhibited free-streaming electron heat transport. Scaling studies have shown that T_e increases much more sharply than the pressure when the calculations include magnetic fields or when electron heat transport is increasingly limited. This sensitivity of T_e may limit the experimental pressures that can be used, as the x-ray bremsstrahlung flux produced in the corona increases as T_e^4. This flux penetrates the target and preheats the sample in the equation of state experiment. As a result, successful target design will require validation of the magnetic field and electron heat transport models.

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.

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Laser-plasma interaction studies in the context of the LIL facility

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The first experiments on the LIL facility will be carried out in less than two years. This facility is intended to validate one of the sixty LMJ quadruplets. Although the energy available in this quadruplet is comparable to that of the Nova and Omega facilities, new areas of laser-plasma interaction (LPI) will be accessible with the LIL. Indeed, the duration of the laser pulse may be varied from 1 to 20 ns.

In order to prepare the LPI and cavity temperature measurement campaigns, we have studied a number of targets with different kinds of laser pulses. With long pulses and with a unidirectional irradiation geometry, which is imposed by using only one quadruplet, the hydrodynamics can be very complex. This is confirmed by the numerical simulations performed with the FCI2 code. As a consequence, it will be difficult to create LMJ-like plasmas in LIL experiments. This prevents giving definitive conclusions regarding the impact of parametric instabilities for LMJ-class facilities. The various simulations give a good knowledge of LIL target hydrodynamics that enable us to predict and optimize the targets dedicated to the measurements of cavity temperature. We have studied the different hydrodynamical regimes accessible as a function of the length and the shape of the pulses, and for different kinds of gas-filled cavities with one or two windows. We compare these regimes to the standard known regimes of exploding foils, thick targets, gasbags, cavities, etc...

Laser-plasma interaction will be studied in a simplified way with our PIRANAH post-processor. On the one hand, this post-processor can be used to localize the regions where the Raman and Brillouin instabilities are mainly expected to grow. On the other hand, it can indicate towards which regime, linear or nonlinear, these instabilities will evolve.

Comparison between direct-drive target designs with radiation preheat and shock heating+

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Radiation preheat has been proposed[1] as a way of reducing the growth of the Rayleigh-Taylor instability by tailoring the adiabat. It was accomplished by coating the target outside with a thin high-Z layer. However, the effects of this layer are felt well before the acceleration phase of the implosion when the R-T growth takes place. Another way of including radiation preheat is to add traces of a high-Z material to the ablator. This has the undesired consequence of raising the fuel adiabat, thus lowering the gain. A conventional way of accomplishing the same result is to raise the intensity of the foot of the laser pulse, thus creating a stronger shock, increasing the target stability and degrading its performance at the same time.

The purpose of this work is to start making a comparison between these two very different concepts of stabilizing a target, one using radiation, the other one using shocks. For targets of similar input energy (around 2.5 MJ), a comparison between these two very different approaches will be made by trying to match the fuel adiabats just before the burn. The gain and stability of these targets will be investigated using our 1D target design code.

+ Work supported by USDOE

ж LCP &FD, NRL, Washington, DC
* ARTEP Inc., Columbia, Md

1.S.Bodner, D.Colombant, A.J.Schmitt and M.Klapisch, Phys. Plasmas, 7, 2298 (2000)

Numerical simulation of deuterium equation of state experiments on the Nike laser facility

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Abstract

Recent experiments have been carried out on the Nike Laser facility to readdress the issue of the principal Hugoniot behavior of liquid deuterium in the range of a few mega bar shock pressures. Previous experiments have had contradictory or ambiguous results about the existence of a "knee" in the pressure density curve of the principal Hugoniot. [1-3] Current experiments are aimed at providing additional data to help resolve this discrepancy. One of the issues in the experiment is the effect of special nonuniformities in the driving shock both as the result of using steps in the aluminum driver to determine the shock speed in the aluminum and as a result of the finite spot size of the laser. Curved shock waves tend to accelerate when the shock is concave or focusing in the direction of propagation and decelerate when the curvature is convex. This is a stabilizing influence and causes rippled shocks to oscillate with decaying amplitude. It will also mitigate the effects of shock nonuniformity. We use the Fast Radiation hydrodynamics code to assess both the lateral extent of the influence of the step and the effect of the curvature of the shock front as a result of the finite laser spot size. We find that the there is region of several hundred microns for which there is an essential uniform shock and the influence of the step is less than about 75 microns to either side of the step for the current set of experimental conditions.

Work supported by the U.S. Department of Energy and ONR.

[1] G.W.Collins et.al., Science 281, 1178 (1998)
[2] A.N. Mostovych, et.al. Phys. Rev. Lett. **85**(18), 3870 (2000)
[3] M.D.Knuson, et.al. Phys. Rev. Lett. **87**(22), 225501/1-4 (2001)

prefer poster

Abstract for Poster Presentation
32nd Anomalous Absorption Conference
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Raman scattering and seeding by short-pulse chirped lasers

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Nonlinear frequency chirp effects on laser wakefield acceleration have been experimentally studied by the l'OASIS group at LBNL using > 10^{19} cm^{-3} plasmas and a 10 TW, 45 fs, Ti:Al_2O_3 laser [1]. In these self-modulated laser wakefield accelerator experiments, laser chirp and pulse shape were controlled using a grating pair compressor. Nonlinear chirp was used to generate 75 fs positively (negatively) chirped pulses with fast (slow) rise and slow (fast) fall times of the laser envelope, which can asymmetrically seed the growth of the forward Raman instability. The electron yield produced was significantly enhanced for pulses with positive chirp. We examine Raman scattering of a short-duration frequency-chirped laser pulse of relativistic-intensity propagating in an underdense plasma. The spatiotemporal growth of the scattered light is calculated for a laser pulse with a linear frequency chirp. It is shown that the growth rate increases (decreases) for positive (negative) frequency chirp. Numerical fluid simulations of the chirped-pulse laser-plasma interaction are presented. Seeding of the forward Raman instability by asymmetric laser pulse temporal distributions is examined. Comparisons to experimental results of laser-plasma acceleration using frequency-chirped laser pulses will also be presented.

[1] W.P. Leemans et al., Phys. Rev. Lett., submitted (2002).

This work supported by the U.S. Department of Energy, Division of High Energy Physics and the Office of Biological and Environmental Research.

Pulse Splitting and Off Axis Guiding in Tenuous Argon

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Abstract

We study the nonlinear propagation over long distances of moderate intensity laser pulses in tenuous gases. The dynamics of these pulses will be affected by nonlinear focusing and dispersion due to the background gas, and by plasma induced refraction and dispersion. Laser propagation is studied numerically using the simulation code WAKE. Different phenomena are found for different regimes of peak input power. For powers near the critical power, we see temporal pulse splitting due to phase modulation and group velocity dispersion. For slightly higher powers, we observe plasma generation and the formation of a trailing pulse, which is guided off axis by plasma refraction and nonlinear gas focusing. For even higher powers, we observe trapping and refraction of the laser pulse, which exhibits outgoing waves.

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[1] Also with the Department of Electrical and Computer Engineering.

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The Two Plasmon Decay Instability in an Inhomogeneous Plasma and a Laterally Confined Laser Field Profile: Theory and Simulations

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We present the theory of the $2\omega_p$ instability in an inhomogeneous plasma driven by a laser hot spot whose intensity profile is strongly laterally confined. We motivate this calculation by first showing the distribution of laser hot spots in inhomogeneous plasmas with and without filamentation. We then show the effects on the characteristics of the hot spots of $f/\#$s, initial spot sizes of overlapping beams and density scale lengths at the quarter critical density.

Our analytic and semi-anaytic theoretical results are then compared to results from PIC code simulations (Osiris [*]) of the evolution of $2\omega_p$ in a single laser hot spot. In the simulations, the relative roles of kinetic and fluid modes of saturation are contrasted by comparing the results of runs with and without mobile ions. The roles of Landau damping, wave breaking and electron acceleration are quantified in these rather modest time scale simulations (a few psecs).

Our primary goal is to assess the severity of the $2\omega_p$ instability in direct drive reactor design targets with multiple overlapping beams and to evaluate means of mediating its adverse effects on ignition such as preheat.

*For more information on OSIRIS and larger scale simulation results on $2\omega_{pe}$ see the poster by F. Tsung et al. at this conference.

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PREFER POSTER SESSION

Proton shock acceleration in ultraintense laser-thin target interactions

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Present-day state-of-the-art lasers can deliver ultra-intense ultra-short laser pulses, with intensities exceeding 10^{21} W/cm^2, with very high contrast ratios, in excess of 10^{10}:1. These systems can deliver on target most of the electromagnetic energy in the laser pulses without the spurious formation of pre-pulse generated plasmas, thus opening the way to laser-thin solid interactions.
We have performed one-dimensional and two-dimensional particle-in-cell simulations, using OSIRIS [1], for a wide range of incident ultra high laser intensities and solid target thicknesses. The incident laser pulse launchs an intense electron beam, which recirculates several times [2], and heats the target uniformly. Two acceleration mechanisms are then identified: (i) proton acceleration due to the ambipolar fields arising in the free expansion of the strongly heated electrons in the target, and (ii) proton acceleration in a collisionless electrostatic shock formed at the front of the target which propagates undisturbed across the target. We have observed that for high intensities ($a_0 \sim 16$), and thin targets (1 – 10 μm), the highest energy protons are accelerated by the an electrostatic ion acoustic shock formed at the front at the target, propagating undisturbed across the target with a Mach number $M_s \sim 1.8$. Furthermore, the spectrum of the energetic protons provides a clear signature for proton shock acceleration.

Work partially supported by FCT (Portugal) and DOE.

[1] R. G. Hemker, UCLA PhD Thesis, (2000); R. A. Fonseca et al, Lect. Notes Comp. Sci. **2329**, III-342 (Springler-Verlag, Heidelberg, 2002)
[2] A. J. Mackinnon et al, Phys. Rev. Lett. **88**, 215006 (2002)

HIGH ENERGY PROTON GENERATION

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We report on multy-MeV proton beam generation from the interaction of a 10 TW, 400 fs, 1.053 μm laser focused onto thin foil targets at intensities ranging from 10^{17} to 10^{19} W/cm^2. Proton beam characteristics were studied by changing the preformed plasma scale-length, target material initial conductivity and focal spot diameter. We manipulated the maximum energy of the proton beam and beam divergence by using correspondingly highly absorptive "laser black" and shaped targets. Curved targets were used to produce beams with smaller divergence as compared with flat targets. "Laser black" material deposited on copper film produced a beam with a modified high-energy component. A fully relativistic two-dimensional particle-in-cell simulation modeled energetic ion generation. These simulations identify the mechanism for the hot electron generation at the laser-plasma interface. Comparison with experiments sheds light on the ion-energy dependence on laser intensity, preplasma scale length, and relative ion energies for multi-species plasma. We also studied plasma plume expansion from the rear side of the aluminum and Mylar foils. The use of ambient gas allowed us to observe the focusing and collimation of these plumes.

The work was partly supported by the U.S. National Science Foundation (Grant "FOCUS") and the Russian Foundation for Basic Research (Grant #00-02-16063), INTAS (Grant #233).

32nd Annual
Anomalous Absorption Conference

<u>Tuesday, July 23, 2002</u>

9:00 AM-12:20 PM	Oral Session 2
12:20 PM	Lunch
7:30-8:30 PM	Review Session 2, Dr. Denise Hinkel,

Energetics of High Temperature Hohlraums

8:30-11:00 PM	Poster Session 2

Hydrodynamic Experiments on Nike. Shooting Campaign of YY2001-2003.

Y. Aglitskiy,[1] A. L. Velikovich,[2] M. Karasik,[2] V. Serlin,[2] A. J. Schmitt,[2] S. Obenschain,[2] J. H. Gardner,[3] N. Metzler,[1] J. Varadarajan,[4] T. Walsh,[4] and S. Faulk[4]

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[2]*Plasma Physics Division, Naval Research Laboratory, Washington, DC 20375.*
[3]*Laboratory for Computational Physics and Fluid Dynamics, Naval Research Laboratory, Washington, DC, 20375.*
[4] *Schafer Laboratories, 303 Lindbergh Avenue, Livermore, CA 94550.*

We will present the results of our hydrodynamics experiments on the KrF Nike laser at NRL and simulations that include a detailed study of ablative Richtmyer-Meshkov (RM) instability, feedout-related areal mass oscillations and Rayleigh-Taylor (RT) growth. A key component, which made these observations possible, is our new powerful diagnostic technique, monochromatic x-ray imaging coupled to a streak camera.[1] The talk will cover our current activity as well as our future plans for the years to come. We plan to observe for the first time how a single-mode classical RM interfacial instability growth evolves into the RT growth, which, as simulations and theory predict, involves producing observable large-amplitude areal mass oscillations. Next generation plastic, foam and plastic-foam targets that enhance reliability and reproducibility of our experimental results, will be described.

Work supported by the U. S. Department of Energy.

[1] Y. Aglitskiy *et al.*, Phys. Rev. Lett. **87**, 265001 (2001).

Prefer oral presentation

Numerical Investigation of Recent Laser Absorption and Drive Experiments of CH Spherical Shells on the OMEGA Laser

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In direct-drive inertial confinement fusion, one-dimensional hydrodynamic codes are used extensively to analyze current experiments and to design targets for future experiments including direct-drive ignition on the National Ignition Facility. Hydrodynamic codes contain an important free parameter, the flux limiter, which models the effect of nonlocal transport in the Spitzer–Härm diffusion representation of the thermal electron conduction. The flux limiter affects independently the absorption fraction and the mass-ablation rate and, therefore, the final performance of the target. Experiments were carried out on the OMEGA laser to measure the absorption fraction and the shell dynamics in order to improve the application of the flux limiter. The absorbed energy was obtained from plasma calorimeters and time-resolved measurement of the reflected light, both through the focusing lenses and outside the lenses. Imaging of the shell emission during the implosion and measuring of the neutron production history with the neutron temporal diagnostics (NTD) provided accurate timing of the target implosion. The targets were 15-μm-CH and Si-doped CH shells of 930- and 1100-μm diameters, filled with 15 atm of D_2, irradiated by either 1-ns square pulses or shaped pulses. Simulations were carried out with the one-dimensional code *LILAC*, which includes a ray trace of the actual temporal and spatial shape of the laser pulses and a postprocessor to generate imaging streak images. Sensitivity to zoning and flux-limiting algorithms is presented. Results from simulations with varying flux-limiter values are compared with the experiment.

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.

HARMONIC VS sharp cutoff flux limiter → abs 0.85 vs 0.80
need 100 zones/μm. for 1NS. (shaped pulse 0.83 vs 0.85 & you need 40 zones/μm)

need f=0.05 to match data for abs (f=0.08 gives too much shell)
but " f=0.08 " " NTD data + Trajectory data

Adiabat Shaping of Direct-Drive Inertial Confinement Fusion (ICF) Implosions Using a High-Intensity Picket

V. N. Goncharov, J. P. Knauer, P. W. McKenty, S. Skupsky, T. C. Sangster, R. Betti, and D. D. Meyerhofer

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Hydrodynamic instabilities that develop during the direct-drive implosion of ICF capsules put severe constraints on the achievable compression ratio of the shell. A technique is proposed to reduce the growth of the ablation-front Rayleigh–Taylor instability without compromising the 1-D target performance. The technique uses the adiabat shaping to increase the entropy of the outer portion of the shell that ablates during the implosion, keeping the material of the inner portion of the shell on a lower adiabat. The adiabat shaping is performed using a high-intensity picket in front of the main drive pulse. The picket launches a strong shock that decays as it propagates through the shell. It will be shown that for cryogenic target designs, an adiabat ratio of the front to the back shell material of up to 6 can be achieved. The results of the shaped-adiabat implosions performed on OMEGA laser system will be discussed.

picket (input) amplitude is 10% of no picket case

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.

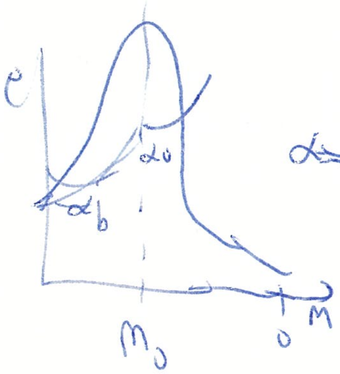
$$\frac{\rho_s}{\rho_0} = \frac{\alpha_s}{\alpha_0} = \left(\frac{t-t_0}{t_{rw}-t_0}\right)^{\sqrt{\frac{2\gamma(\gamma-1)}{2\gamma-1}}}$$

for decaying shot

$$= \left(\frac{t-t_0}{t_{rw}-t_0}\right)^{-0.64}$$

$\gamma = 5/3$ = simulation

t_{rw} is time when rarefaction hits pressure front,



$$\alpha = \alpha_0\left[1.5\left(\frac{m}{m_0}-1\right)+1\right]^{-0.94}$$

$$\alpha_0 = \alpha_b[\quad]^{0.94}$$

m_0 is mass ablated (reached) when pressure is still at full pressure (pre-decay)

Chee Kang

Effects of Fuel–Shell Mix upon Direct-Drive, Spherical Implosions on OMEGA

C. K. Li, F. H. Séguin, J. A. Frenje, S. Kurebayashi, and R. D. Petrasso[a)]

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Cambridge, Massachusetts 02139

D. D. Meyerhofer[b)], J. M. Soures, J. A. Delettrez, V. Yu. Glebov, F. J. Marshall, P. B. Radha, S. P. Regan, S. Roberts, T. C. Sangster, and C. Stoeckl

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Fuel–shell mix and implosion performance are studied for a variety of capsule types in direct-drive experiments at OMEGA. For the first time, the amount of mixing and the size of the mix region are inferred from charged-particle spectrometry data and confirmed with an experimentally constrained model for a wide range of (theoretical) convergence conditions. Data show the relationships between mix and compression reduction, truncation of burn, and reduction of the effective volume of the fusion reaction. Measured yields and convergence ratios CR fall short of one-dimensional predictions, especially for low capsule fill pressures. CR is ~11 for pressures from 3 to 15 atm, in contrast to predictions of ~25 for 3 atm and ~12 for 15 atm.

This work has been supported in part by LLE (subcontract P0410025G) and LLNL (subcontract B313975), and by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300) and under Cooperative Agreement NO. DE-FC03-92SF19460, the University of Rochester, and New York State Energy Research and Development Authority.

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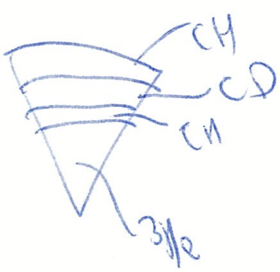
Request oral session

CR_{xpt}	CR_{θ}		
11	25	4 Atm	lots of mix 1D>...
11	12	15 "	NO MIX 1D=...

$D + {}^3He \rightarrow \alpha + p$ (14.7 MeV)

$Y = 2\,10^7$



$Y = 2\,10^6$

Capsule Areal Density Nonuniformities and Evolution Inferred from 14.7-MeV Proton Line Structure in OMEGA D^3He Implosions

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S. Hatchett
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The fusion of D^3He in spherical-capsule implosions results in the copious production of 14.7-MeV protons. As these protons pass out through the hot fuel plasma, and especially through the cool shell plasma (≤ 1 keV), they lose energy. Importantly, this energy loss directly reflects the areal density (ρL) of the plasma transited at that instant of the burn.[1-5] As part of the MIT, LLE, and LLNL collaboration, up to nine proton spectrometers simultaneously view D^3He implosions from different directions.[5] While the burn-averaged and spatially averaged ρL for each implosion is typically between 50 to 75 mg/cm^2 within a group of similar implosions,[6] there are often significant differences in the individual spectra, in both their average implied ρL (±50% about the mean) and in the low-energy tail,[4] the latter a direct measure of the maximum areal density. Differences in the individual maximum—from 60 to 160 mg/cm^2—largely reflect nonuniformities in the shell and, to a lesser extent, in the fuel.[4] [To emphasize the role of nonspherical asymmetries, the notation ρL, rather than ρR, is used.[4,5]] In addition to nonuniformities, time evolution is the other important component to line broadening and spectral shape.[2,3,7] To elucidate this effect, implosions of 24-μm-thick CH capsules were conducted. Importantly, such implosions lead to two distinct peaks: one at first shock coalescence and, 400 ps later (as measured by the neutron temporal diagnostic), a second, larger, more-downshifted peak that results from the compression burn.[7] In this 400-ps period, the spatially averaged ρL changes from ~8 to ~70 mg/cm^2.

This work has been supported in part by LLE (subcontract P0410025G) and LLNL (subcontract B313975), and by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300) and under Cooperative Agreement NO. DE-FC03-92SF19460, the University of Rochester, and New York State Energy Research and Development Authority.

a) Also Visiting Senior Scientist at LLE, Univ. of Rochester.
b) Also Dept. of Mechanical Engineering and Physics and Astronomy, Univ. of Rochester.

1. C. K. Li *et al.,* Phys. Rev. Lett. **70** (20), 3059 (1993).
2. P. B. Radha *et al.*, "D^3He protons as a diagnostic for target ρR", LLE Review, **73,** 15 (1997).
3. C. K. Li, D. G. Hicks, F. H. Séguin *et al.*, Phys. Plasmas **7**(6), 2578 (2000).
4. F. H. Séguin, C. K. Li, J. A. Frenje *et al.*, "Measurements of ρR asymmetries at burn time in inertial-confinement-fusion capsules" accepted for publication in Phys. Plasmas (2002).
5 F. H. Séguin, J. A. Frenje, C. K. Li *et al.*, "Spectrometry of charged particles from inertial-confinement-fusion plasmas", submitted to Rev. Sci. Instrum. (2002).
6. Implosions of 15 to 20 atm D^3He capsules, with shell thicknesses of 20 to 24 μm CH.
7. R. D. Petrasso *et al.*, Bull. Am. Phys. Soc. **46**, 105 (2001).

Request oral session

Laser imprint reduction with a short shaping laser pulse incident upon a foam-plastic target

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[3]*LCP&FD, Naval Research Laboratory, Washington, D.C. 20375*

In our previous work[1] we have shown that a tailored density profile could be very effective in smoothing out the laser beam non-uniformities imprinted into a laser-accelerated target. However, a target with a smoothly graded density is difficult to manufacture. A method of dynamically producing a graded density profile with a short "shaping" laser pulse irradiating a low-density foam layer on top of the payload prior to the main pulse is proposed. We report the results of 2-D hydro simulations demonstrating that the intensity and the duration of the shaping pulse pulse, the time interval between the shaping pulse and the main pulse, and the density ratio between the foam and the payload can be selected so that 1) the strong shock wave driven by the main laser pulse travels all the way to the payload through the graded density profile of the expansion wave immediately following the first shock wave; 2) shock impedance matching between the foam and the payload is achieved (no shock reflection); 3) laser imprint in the main pulse is virtually suppressed. We discuss the requirements to the smoothing of the main and "shaping" laser beams and to the surface finish of the foam-plastic sandwich target.

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

[1]Metzler *et al.*, Phys. Plasmas **6**, 3283 (1999).

Prefer oral presentation

Modified Bell-Plesset effect with compressibility: Application to double-shell ignition targets for the National Ignition Facility

Peter Amendt, J.D. Colvin and H.F. Robey
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The effect of spherical convergence on the fluid stability of collapsing and expanding bubbles was seminally treated by Bell [Los Alamos Scientific Laboratory Report No. LA-1321 (1951)] and Plesset [J. Appl. Phys. **25**, 96 (1954)]. The additional effect of fluid compressibility was considered by Bell but with the restriction to nonzero density on only one side of the fluid interface. A more general extension is presented which considers distinct time-dependent uniform densities on both sides of an interface in a spherically converging geometry. A new form of the fluid velocity potential is introduced that avoids an unphysical divergence at the origin. Two consequences of this reformulation are that an instability proposed by Plesset for an expanding bubble in the limit of large interior density is now absent and application to inertial confinement fusion studies of fluid stability becomes feasible. The model is applied to a proposed ignition double-shell target design [Amendt *et al.*, Phys. Plasmas **9**, 2221 (2002)] for the National Ignition Facility [Paisner *et al.*, Laser Focus World **30**, 75 (1994)] for studying the stability of the inner surface of an imploding high-Z inner shell. Application of the Haan [Phys. Rev. A**39**, 5812 (1989)] saturation criterion suggests ignition is possible. A plausible cutoff in surface perturbation wavenumber is argued based on momentum and mass diffusion across the unstable interface, resulting in a maximum Legendre mode number of nearly 2400 at deceleration onset. Such a modest cutoff allows for the possibility of undertaking direct numerical simulations of a proposed ignition double-shell target for the NIF.

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

modally dependent Atwood #

$$A_n = \frac{n\rho_2 - (n+1)\rho_1}{n\rho_2 + (n+1)\rho_1}$$

compressible $\gamma \approx \frac{1}{10}$ incompressible γ

Experimental Investigation of Expansion Velocity and Gradients in Long-Scale-Length Plasmas on OMEGA

S. P. Regan, R. S. Craxton, J. A. Delettrez, D. D. Meyerhofer, T. C. Sangster, W. Seka, and B. Yaakobi

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Long-scale-length plasmas, which are relevant to direct-drive inertial confinement fusion target designs for the National Ignition Facility, are generated on the 60-beam OMEGA laser system to study the laser–plasma instabilities associated with multiple interaction beams. The plasma conditions created with massive, solid-density plastic targets are characterized with time-resolved x-ray spectroscopy of microdot tracer layers containing either Cl and K or Ca and Ti. The plasma expansion velocity is obtained from a novel diagnostic technique that exploits the Bragg reflection geometry to record the trajectory of the microdot as it is ablated into the blowoff plasma. The He_{α} transition ($1s2p$–$1s^2$) of the intermediate Z microdot radiates over the broad range of electron temperatures and densities that are present between the critical surface and the low-density blowoff plasma and provides a signature point source of x-ray emission to chart the microdot trajectory. The measured trajectories of the ablated microdots are compared with the predictions of the 2-D hydrodynamics code *SAGE* and the 1-D hydrodynamics code *LILAC*. The electron temperature and density profiles are diagnosed with the measured line ratios of the K-shell emissions from the microdot, which are sensitive to variations in the electron temperatures and densities of the plasmas under consideration. The predicted line ratios are calculated with the 2-D hydrodynamics code *SAGE* and the time-dependent *FLY* atomic physics code and compared with the experimental results.

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.

Overview of Foam Target Fabrication in Support of Sandia National Laboratories.

Schroen, D.[1], Collins, P[1]., Droege, M.[2], Faulk, S.[1], Gross, S.[1], Hsieh, E.[1], Motta, B.[1], Streit, J.[1], Youngblood, K.[1]

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Sandia National Laboratories has succeeded in making its pulsed power driver, the Z machine, a valuable testbed for a great variety of experiments. These experiments include ICF, weapons' physics, EOS and astrophysics. The demands of the various experiments have required us to develop and produce a wide range of foams in many densities and geometries. We have produced foams from five foam systems: HIPE polystyrene, resorcinol-formaldehyde aerogel, silica aerogel, divinyl benzene and TPX (poly1-methyl-4-pentene). To produce the requested sizes and geometries, we were required to develop new processes and techniques. We will present an overview of the foam processes, the bulk properties of the foams and examples of targets produced.

Review Session 2

Tuesday, July 23, 2002

7:30-8:30 PM

Energetics of High Temperature Hohlraums*

D. E. Hinkel, M. B. Schneider, A. B. Langdon, L. J. Suter,
R. F. Heeter, and P. T. Springer

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Livermore, CA, USA 94550

Halfraum targets (half of a hohlraum with a back wall) at reduced scales (Nova scale 1/2 – 1/4, 800 μm and 400 μm diameters, respectively) have been designed and fielded on the Omega laser at the Laboratory for Laser Energetics (LLE). Approximately 10 TW of power is incident upon these targets, distributed among three beam cones, each with a spot size of about 80 μm. This provides interactions at moderately high intensities, in excess of 1×10^{16} W/cm^2. These targets are predicted to have a high electron temperature (10 – 20 keV), and exhibit halfraum filling on the time scale of the pulse length (~ 1 ns).

Target filling impacts energetics by reducing the amount of laser energy that couples to material *inside* the target, which in turn reduces the radiation drive. Furthermore, significant levels of plasma density *outside* the target causes filamentation and deflection of the laser beam, reducing further the radiation drive. Simulations and experimental evidence of this will be presented.

Reduced scale targets driven at high intensity produce plasma conditions where novel saturation of backscatter occurs. Under such conditions (high intensity, density, temperature), one-dimensional (1D) particle-in-cell (PIC) simulations show that Raman forward scatter saturates by re-scatter through Brillouin backscatter.[1] Results from the PIC simulations will be presented here and in other contributed talks.[2]

1. A. B. Langdon and D. E. Hinkel, accepted, *Phys. Rev. Lett.*, 2002.
2. PIC simulations will also be presented by A. B. Langdon *et al.*, this conference.

*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.

Poster Session 2

Tuesday, July 23, 2002

8:30-11:00 PM

Properties of transport of high currents in near solid density plasma

Hartmut Ruhl and Paul Parks, General Atomics

Abstract: The concept of laser based Fast Ignition (FI) in Inertial Confinement Fusion (ICF) relies on the generation of large energy flows in plasma by intense laser radiation. The first part of the paper presented at the conference gives results from recent numerical investigations of laser induced mass and energy transport in fully ionized plasma. Processes of self-organization are observed. A prominent example for the latter are magnetically isolated current filaments that penetrate the plasma. Depending on the magnitude of the total current flow the filaments tend to merge and form larger entities. It can be shown that strong magnetic fields at the plasma surface are obtained. The magnetic fields are produced by the low energy part of the electron distribution and inhibit the current and energy flows. The second part of the presentation addresses the transport of highly relativistic electron currents in the MA range in near solid density plasma. Unlike in the first part of the presentation the electrons are injected via a beam injector. Large electron stopping power is observed. Turbulent electric and magnetic fields are excited. The degree of ion background heating is presented. These findings are of relevance for FI in the context of ICF.

Further investigations of indirectly driven double shell capsule implosions at the Omega laser

R. G. Watt, N. D. Delamater, W. S. Varnum*, Los Alamos National Laboratory
P. Amendt, G. Dimonte, H. Robey, Lawrence Livermore National Laboratory

Indirectly driven capsules with two concentric shells (a double shell) separated by a foam region appear to have promise as a non-cryogenic alternative for ignition on the National Ignition Facility. Over the last few years a number of shots have been taken at the Omega laser facility utilizing a double shell target design that has achieved essentially clean one dimensional yield. These designs were a refinement of early designs which removed most or all of the inner capsule material that was sensitive to Au M-band radiation that penetrated the outer ablator and could potentially imprint non-uniformities on the most unstable surface in the capsule, the outer surface of the inner shell. By eliminating the higher Z constituents from the inner capsule, both potential instability growth and the underlying hydrodynamic behavior of the implosion were favorably effected, resulting in values of measured yield divided by clean calculated 1D yield between 0.2 and 1 at convergences up to 40, well above those convergences needed for current NIF double shell ignition designs. Work is continuing on this concept in an attempt to both fully understand the degradation mechanisms of earlier double shell designs, and to find ways to encompass the design aspects of the current Omega capsules in a way which extrapolates well to an ignition design on NIF. This year a series of shots will be taken at Omega intended to both more accurately reflect a shock timing trajectory similar to that anticipated for LLNL NIF ignition double shell designs, and to measure implosion symmetry in a capsule driven by an intentionally enhanced asymmetric M-band drive using backlit imaging. New results from the backlit imaging experiments and plans for the shock timing experiments will be discussed and a short synopsis of prior work will be given.

* Comforce Technical Services, Inc. at Los Alamos National Laboratory

This work was performed under the auspices of the U. S. Department of Energy by the Los Alamos National Laboratory under contract No. W-7405-Eng-36.

Poster Session

Tilted filamentation of relativistic electron beams

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The propagation of relativistic electron beams is a central problem in plasma physics , with repercussions in astrophysical and laboratory scenarios. The fast ignitor concept revived the interest in this subject, and triggered a significant theoretical/numerical work and experimental effort on this subject. In the astrophysical context, recent theoretical results have pointed out the importance of electromagnetic collisionless instabilities for the generation of near-equipartition magnetic fields in gamma-ray bursters, or in the early universe. As first observed in the seminal paper by Lee and Lampe [1], one of the key issues in electromagnetic instabilities of relativistic electron beams in plasmas is beam filamentation, and the nonlinear evolution of the filaments. On these two-dimensional simulations, translational invariance is assumed along the beam propagation direction x_1; this assumption precludes the onset of any longitudinal instability. However, in reality, for relativistic beams the instability will be a mixture of transverse and longitudinal modes, with a longitudinal wave number $k_l \sim \omega_{pe0}/(\beta_1 c)$, and with a typical transverse wave number, determined by the beam temperature, or beam emittance, $k_\perp \sim \omega_{pe0}/c$ Therefore, for relativistic beams the transverse and the longitudinal wave numbers are comparable, and it is necessary to take into account the transverse dynamics as well as the longitudinal dynamics of the beam, in order to describe the multidimensional evolution of the relativistic beam.

In this paper, the multidimensional evolution of relativistic electron beams in plasmas is examined using fully explicit particle-in-cell simulations [2]. The formation of tilted filaments during the linear stage of the electromagnetic filamentation instability is observed for a wide range of conditions, giving rise to to a typical beam spraying angle. An explanation for these tilted filaments is ptovided based on a generalization of relativistic covariant fluid theory including finite temperature effects. In the nonlinear stage of the instability, the presence of these tilted filaments supresses the recombination of the filaments into a single dense beam as well as the formation of ion channels.

Work partially supported by FCT (Portugal) and DOE.
[1] R. Lee and M. Lampe, Phys. Rev. Lett. **31**, 1390 (1973).
[2] R. G. Hemker, UCLA PhD Thesis, (2000); R. A. Fonseca et al, Lecture Notes Computer Science **2329**, III-342 (Springler-Verlag, Heidelberg, 2002).

Measurements of Heat Propagation in Compressed Shells in Direct-Drive Spherical Implosions on OMEGA

V. A. Smalyuk, J. A. Delettrez, R. Epstein, V. N. Goncharov, F. J. Marshall, D. D. Meyerhofer, S. P. Regan, T. C. Sangster, and B. Yaakobi

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The heat propagation in compressed shells is measured with titanium 1*s*–2*p* absorption spectroscopy in spherical implosion experiments. Targets with 20-μm-thick plastic CH shells filled with 4 and 18 atm of D^3He fuel have been imploded on the 60-beam, 30-kJ UV OMEGA laser system. All targets have diagnostic, 1-μm-thick, titanium-doped (2% by atom) layers placed at distances of 1, 3, 5, 7, and 9 μm from the inner surface of the shell. Temporal evolution of titanium 1*s*–2*p* absorption and *K*-edge spectra have been measured with streak cameras, and core images with a narrowband framing camera and gated monochromatic x-ray imager (GMXI). Radiation from the hot core backlights the diagnostic layer, and characteristic titanium *K*-shell line absorption features have been observed from F- to He-like titanium. In addition, a titanium *K*-edge shift to higher energies has been observed simultaneously. Detailed modeling and analysis of the absorption features yield ionization, areal density, temperature, and density conditions in the absorbing layer. The inner part of the shell is heated before peak compression, while the heat wave reaches outer parts of the shell at later times.

This work was supported by U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and New York State Energy Research and Development Authority.

Prefer poster session

Abstract

Angular dispersion of energetic electrons generated by the interaction of an ultra-intense laser with an overdense plasma.

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CNRS, Ecole Polytechnique

In order to study fast electrons generation by ultra-intense laser pulses interacting with an overdense plasma, 2D PIC simulations have been performed in various cases: sharp or smooth density gradients, weakly to strongly relativistic intensities, plane or focused waves. In all cases, fast electrons are emitted with an angular spreading of their velocity which cannot be explained by interface deformations or by the laser beam focusing. It is found that, at least for sharp density gradients, this angular dispersion is linked to a transverse instability which is localized in the vicinity of the skin depth layer. High intensity magnetic fields are produced, leading to trapping and scattering of the energetic electrons.

Radiation Albedoes in High Z Slabs

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Radiation albedoes (x-ray reflectivities) have played a very useful role in systematizing drive studies in laser heated (and Z pinch driven) hohlraums for ICF and HEDP experiments. They are often derived via complex numerical simulations. In this paper we derive analytic formulae for radiation albedoes as a function of drive temperature and time for high Z slabs. We employ a new method (first reported by Hammer & Rosen in BAPS 46, pg. 295 (2001)) of solving the radiation diffusion wave ("Marshak wave"). This approach invokes asymptotic methods of solving the equation in two domains (near the drive input, and near the heat front) and then matching the solutions where the domains overlap. With this basic solution for the heat front shape in place, we then proceed to interrogate that profile in order to solve for the albedo. We will draw distinctions between a global (angle averaged) albedo that should be used with energy conservation arguments, and a specific angle dependant albedo which should be used when interpreting data from a specified x-ray diagnostic line of sight into a hohlraum wall.

Work performed by the Lawrence Livermore National Laboratory under the auspices of the United States Department of Energy under Contact No. W-7405-ENG-48.

Growth and Saturation of Large Amplitude Self-Modulated Wakefield in 60 TW Laser Plasma and Possible GeV Electron Generation

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An 60 TW Ultra Intense Laser[1] was injected into a hydrogen gas jet and has excited a large amplitude self modulated wakefield, which sustains 350 GV/m field over 1.7 mm along the laser axis. As increasing the laser pulse length from 0.45 ps to 1.1 ps, the acceleration field due to the wakefiled grew over the wavebreaking limit and was saturated due to a pump depletion effect. Analysis first explained the growth and saturation of the large amplitude self modulated wakefield. The GEKKO-MII CPA laser produced 25 J at 1.053 μm with 0.45 to 1.1 ps pulse length. The laser beam, of which the size is 140 mm, was focused into the gasjet by an off axial parabola mirror of f/3.8. 68% of the beam energy was focused and the encircled energy was 30% in 18 μ m spot. The intensity was 8×10^{18} W/cm^2 and the field a_0 was 2.2 for 0.45 ps pulse. The prepulse level was 10^{-3}. The gas jet was an electromagnetically switched high speed gas puff. At 2 mm above the puff nozzle of 6 mm aperture, the gas density was 10^{19}/cm^3 over 4 mm long, which encourages us to accelerate electrons over few mm distances. The scale length of the plasma was 1.5 mm.

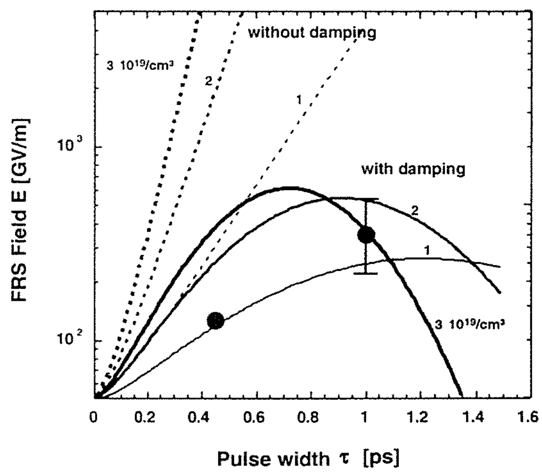

Figure 1: FRS growth as a function of the laser pulse length. Points are experiments. Solid lines are calculated with damping effects for 1, 2, and 3 $\times 10^{19}$ cm^{-3}, respectively. Dashed lines are without any damping. Calculation is in relative unit.

Using the collective Thomson scattering idea, we have obtained the absolute amplitude of the wakefield that the field gradient can overcome the classical wavebreaking limit. The wave amplitude $\delta n/n_0 = 20\%$, or the field = 128 GV/m at the electron density of 1 $\times 10^{19}$/cm^3. We enlarged the pulselength to 1.1 ps and obtained $\delta n/n_0 = 70\%$, or the field = 351 $\pm$151 GV/m at 2 $\times 10^{19}$/cm^3. Including the pump depletion, dephasing and laser diffraction, we simply estimated the FRS wave temporal growth as a function of the pulse length, as shown in Fig.1. Points are the experimental data. Solid lines are FRS amplitude calculated with pump depletion, dephasing and diffraction effects for 1, 2, and 3 $\times$10 19cm^{-3}, respectively. Dashed lines are without any damping. The calculated amplitude is relatively fitted to the experiment.

The analysis says that as either increasing the pulse length or the electron density, the large amplitude FRS grows and saturates around 1 ps and 2 $\times 10^{19}$ cm^{-3} for the present laser intensity. Plasma wave was over 1.7 mm axial length, which can accelerate electrons up to 500 GV/m $\times$1.7 mm =850 MeV.

[1]Y.Murakami *et al.*, Phys. Plasmas **8**, 4138 (2001).

Propagation of Chirped Laser Pulses in Plasmas*

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The propagation of chirped laser pulses in plasmas is analyzed and modeled using 3D computer simulations. Simulations are based on solving coupled fluid equations for the laser pulse envelope and wakefield which include the effects of group velocity dispersion and self-phase modulation in the weakly relativistic regime. The simulations describe the relativistic modulation instability, forward Raman scattering, and self-modulation. The effects of chirp and pulse shape on these various instabilities are investigated and compared with experiments. The modulation of the pump wave, the frequencies of the Stokes and anti-Stokes sidebands, and the width of the sidebands are found to depend upon the sign of the chirp.

* Sponsored by ONR and DOE.

Abstract for Poster Presentation
32nd Anomalous Absorption Conference
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Short-pulse high-power laser propagation in plasmas channels

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Optical guiding of short-pulse high-power lasers in plasmas is beneficial to a variety of applications, including plasma-based accelerators, harmonic generation, x-ray lasers, and laser-fusion schemes. Optical guiding by relativistic effects, ponderomotive effects, and plasma density channels is actively being pursued by the l'OASIS Group at LBNL. To analyze the characteristics of ultrashort high-power laser pulses propagating in plasmas, two unique numerical codes have been developed: a two-dimensional relativistic fluid code [1] and a laser envelope code [2], which solves the nonparaxial laser envelope equations. The 2D fluid code is unique in that the laser time-scale is explicitly resolved. We present simulation results of the propagation of an ultrashort high-power laser pulse in a plasma channel. Solutions to the wave equation beyond the paraxial approximation that include finite pulse length effects and group velocity dispersion are presented. The coupling of the self-modulation and Raman forward scattering of the laser pulse including frequency-chirp is analyzed and growth rates are studied in various parameter regimes.

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This work supported by the U.S. Department of Energy, Division of High Energy Physics and the Office of Biological and Environmental Research.

Fokker –Planck codes for self-consistent modelling of electron transport and B-field generation in laser-plasmas

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We describe two Fokker-Planck codes recently developed to simulate electron transport and magnetic field generation in laser-plasmas. Both codes self-consistently solve the Vlasov-Fokker-Planck equation and Maxwell's equations in 2-dimensions.

One of the codes [1], called IMPACT (standing for Implicit Magnetised Plasma And Collisional Transport), solves the equations in Cartesian geometry using the diffusion approximation $f_e(x,y,\underline{v}) = f_0(x,y,v) + \hat{\underline{v}}.\underline{f}_1(x,y,v)$ and the Lorentz approximation (valid for high Z). Electron inertia is included while e-i and e-e collisions are present in the f_0 and $\underline{f}_1$ equations, respectively. Implicit finite differencing is used in all phase space dimensions x,y,|v| allowing stable operation for timesteps exceeding the characteristic timescales; τ_{ei}, τ_{ee}, $1/\omega_{pe}$ and $1/\omega_{ge}$. This code is ideally suited to modelling electron transport and B-field generation in regimes where the temperature and density gradients are steep enough for classical transport theory (i.e. Braginskii and Spitzer-Härm) to break down. In this limit IMPACT describes non-local effects and effectively, it automatically calculates the appropriate transport coefficients, while in the long scale-length limit it recovers classical transport.

The second code, KALOS, is designed to be able to deal with transport under more extreme conditions, where electrons can become relativistic and where the diffusion approximation is no longer appropriate, e.g. propagation of relativistic electron beams through cold, dense plasma. To achieve this KALOS uses a spherical harmonic expansion in velocity space. The order at which this is truncated can be specified so that beam collimation & pinching by self generated B-fields and other processes involving highly anisotropic velocity distributions can be resolved. Either Cartesian or cylindrically symmetric spatial geometries can be used. This code employs a finite difference scheme that is explicit.
KALOS has the potential to accurately describe both the collisional and collisionless aspects of laser-plasma interactions at high laser intensities and high plasma densities. It offers advantages over existing hybrid transport codes and conventional PIC codes (with collisions included). Unlike hybrid codes which use a Monte Carlo description of the laser-heated, superthermal electrons and a fluid description of the cold, background electrons, this code treats *all electrons* kinetically. In contrast to PIC codes it can be used to simulate solid density plasmas at experimentally relevant temperatures where collisional effects are important.

[1] R.J. Kingham and A.R. Bell, Phys. Rev. Lett. **88**, 045004 (2002)

This work is supported by the EPSRC of the UK.

PIC Simulations of Short-Pulse, High Intensity Laser-Plasma Interactions.

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We continue our studies [1] of short-pulse, high intensity, laser plasma interactions using our modern massively parallel 3D PIC code, Z3. We report on the generation of hot electrons and energetic ions and the associated complex phenomena. Laser light filamentation and the formation of high static magnetic fields are described.

In a complementary study, we investigate the idealized situation of the collisionless energy loss of a relativistic electron beam in a plasma in the context of fast ignitor scenarios. Dramatic beam energy loss to magnetic field generation and plasma kinetic energy has been reported.[2] Here, we show that the beam loses less kinetic energy as the background plasma density is increased and that beam filamentation occurs at longer wavelengths for increasing beam emittance, in agreement with the dispersion relation of Lee and Lampe.[3] We emphasize that electron transport for fast ignitor conditions is much more complex than this simplified model.

1. B. F. Lasinski, A. B. Langdon, S. P. Hatchett, M. H. Key, and M. Tabak, Phys. Plasmas **6**, 2041 (1999); S. C. Wilks, and W. L. Kruer, IEEE Journal of Quantum Electronics **11**, 1954 (1997).
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05-Eng-48.

Efficient production of Kr K-shell radiation at the OMEGA laser

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Efficient production of >10 keV x-rays is important for materials testing, backlighting, and code validation experiments planned for the National Ignition Facility (NIF). Previously reported studies have demonstrated the concept of the underdense radiator for efficient multi-kilovolt emission up to Xe L-shell (4 – 7 keV).[1] Here we report on experiments conducted at the University of Rochester OMEGA laser in which CH cans (1.2 mm long x 1.5 mm diameter) filled with Kr gas and at pressures ranging from 0.5 – 2 atm, were irradiated with 20 kJ of 0.35 μm laser light for the purpose of generating Kr K-shell x-rays (12 – 18 keV). Time-integrated, non-absolutely calibrated spectral measurements were made with the Hard X-ray Spectrometer, a curved-crystal transmission spectrometer sensitive to x-rays in the 12 – 60 keV range. Absolute x-ray emission greater than 10 keV was obtained with a set of filtered diodes. In addition, gated x-ray images and backscatter measurements were obtained. Intense x-ray emission in the >10 keV spectral region was observed and quantified, indicating production of He-like ionization states with efficiencies more than an order of magnitude greater than for comparable solid disk targets. These results are in reasonable agreement with computer simulations, giving some confidence in the ability on NIF to generate x-rays >10 keV with high efficiency, resulting in yields in the 100 – 200 kJ range depending on the number of beams used.

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.

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[1] C.A. Back, *et al.*, Phys. Rev. Lett. **87**(27) 275003 (2001).

DEVELOPMENT OF A QUASI-STATIC 3D PIC CODE FOR MODELING SHORT PULSE LASER PROPAGATION

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Abstract:

Recently Laser Wakefield Acceleration (LWFA) has drawn much attention. In this scheme, intense short laser pulses excite plasma waves. Plasma electrons can be trapped and accelerated to high energy. This process is highly nonlinear and therefore particle models are required to study it. Standard particle-in-cell (PIC) codes such as OSIRIS are CPU-intensive when modeling this phenomenon. We have developed a reduced PIC code called QuickPIC, which makes a frozen field approximation and separates the time scales between how the drive beam evolves and the period of the wakefield oscillation. Thus QuickPIC can be used to study LWFA scheme efficiently. We will review the equations and approximations used in QuickPIC and then describe its algorithms and the parallel object-oriented framework.

Hohlraum drive scaling with 0.53 μm light

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Aldermaston, UK

A significant data base has been developed on the wavelength scaling of laser heated hohlraums on Argus, Shiva, Novette, Nova, and OMEGA. Generally, the scaling shows that shorter wavelength light couples more efficiently with lower levels of fast electrons and plasma instabilities. Most of this data base has been acquired before modern beam smoothing techniques were developed. We report new experiments at the HELEN laser at AWE that investigates hohlraum coupling using 0.53 μm light. The experiments use one beam to irradiate single sided hohlraums with and without a Fresnel phase plate. Drive was measured using a diamond PCD with a pinhole array similar to those fielded on the Omega laser for total energy measurements. Backscattered SBS and SRS light was monitored through the input lens. Preliminary results show that the phase plate increases the coupling slightly compared to without a phase plate. Significant levels of fast electrons were not observed even at the smallest sizes where plasma filling is predicted. Results will be compared to the previous data set from Novette.

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.

Late-time and 3D hohlraum and halfraum simulations with experimental verification

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Target/diagnostic configurations proposed for NIF are predicted to produce sufficient debris and shrapnel to place constraints on the lifetimes of the debris shields. Simulation of debris and shrapnel generation for the proposed target/diagnostic configurations with wide range of driving laser conditions is a very difficult modeling task requiring the hydrodynamic simulations be run out to very late time and in complicated geometries.

New ALE grid motion algorithms have been included into the multi-dimensional simulation code HYDRA to facilitate late-time simulations. We model 0.6 scale NIF hohlraums out to times of 100 ns and beyond.

Halfraums (i.e., cylindrical hohlraums with one laser entrance hole) are irradiated varying the angle of the halfraum to create a truly three-dimensional target configuration. We compare our simulations with recent experiments on the Helen laser to irradiate vacuum halfraums with 2ω light in such 3D configurations. Time-resolved measurements of x-ray re-emission form the interior wall of the halfraum as well as spatial dependence of the ablated material are available for comparison.

This work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

32nd Anomalous Absorption Conference
Turtle Bay Resort, Oahu, Hawaii
July 21-26, 2002

Correlations between yield and x-ray line emission in NOVA indirect drive implosions*

S. H. Langer, H. A. Scott, and O. L. Landen
Lawrence Livermore National Laboratory

Abstract

This talk presents the results of a series of simulations of NOVA indirect drive implosions. The simulations include variations in the initial surface roughness of the capsule and the effects of power imbalance and beam mis-pointing. The simulations compute the fusion yield and the line-strengths from small amounts of argon in the fuel and titanium in the plastic shell. The results of the simulations are compared to experimental data from the HEP-4 campaign on NOVA. The analysis tries to determine if there is any experimental way to distinguish between the effects of surface roughness and drive asymmetry in degrading the performance of ICF capsules.

*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.

32nd Anomalous Absorption Conference
Turtle Bay Resort, Oahu, Hawaii
July 21-26, 2002

Combined effects of 3D drive asymmetry and hydrodynamic instabilities in NIF ignition targets*

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S. M. Pollaine, S. W. Haan
Lawrence Livermore National Laboratory

Abstract

We report the first three-dimensional calculations of the combined effects of drive asymmetry and hydrodynamic instabilities on our baseline NIF ignition target. The 192 laser beams of NIF illuminate the cylindrical hohlraum walls in rings to produce a largely axisymmetric drive. Perfect laser power balance and alignment give significant azimuthal variations associated with the laser spots. The mechanisms responsible for volumetric laser energy absorption are found to be critically important in determining this azimuthal drive variation. The asymmetry is calculated in a 3D HYDRA integrated hohlraum simulation, using realistic radiation transport, and compared with values obtained from a viewfactor code. The integrated simulation, which treats volumetric absorption, emission and wall spot motion self-consistently, gives amplitudes for the Y_{44} and Y_{98} modes that are substantially reduced compared to the viewfactor analysis. We assess the impact of this exact drive asymmetry on target performance by imposing it on a full sphere. The growth of multimode surface perturbations combined with drive asymmetry is examined as well in high-resolution simulations. Representative perturbations initialized on both the inner and outer surfaces encompass the full spectrum of the most dangerous modes.

32nd Annual
Anomalous Absorption Conference

Wednesday, July 24, 2002

9:00 AM-12:20 PM	Oral Session 3
12:20 PM	Lunch
6:30-10:00 PM	Banquet

Guiding of a high Intensity femtosecond laser pulse in a preformed plasma channel

R. Narang, F. Tsung, C. Joshi, W. B. Mori

PIC simulations have been done to model guiding of multi-terawatt femtosecond pulses with a wavelength of 0.8 μm into preformed plasma channels. The goal is to guide the laser over distances much longer than the Rayleigh length, thereby producing a large amplitude wake-field that self-trapped electrons would see for distances on the order of 1 cm. The self-trapped electrons could then be accelerated to energies ~1 GeV. The optimum plasma density in the channel for a given laser pulse-length and amplitude is determined. Simulations have also been done to follow the laser evolution inside of the plasma channel, as well as to estimate the electron energy spectrum that would be produced in an experiment.

Three-dimensional PIC simulations of SMLWFA of 35 fs class lasers

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J.C. Adam
Ecole Polytechnique, France

L.O.Silva and R.A.Fonseca
Instituto Superior Tecnico, Portugal

In the self-modulated laser wakefield regime a laser pulse several to many $2\pi c/\omega_p$ long breaks up via Raman scattering type instabilities producing large wakes. In some cases these wakes can trap background electrons generating a beam of accelerated electrons with a large energy spread. PIC simulations have shown that this process is highly sensitive to the laser intensity, pulse length, and plasma density [K-C.Tzeng et al., PRL 76, 3332 (1996), K-C.Tzeng et al., PRL 79, 5258 (1997)]. There have been some recent experimental results in which 35fs laser pulses have been used. In this case the pulses are at most only a few $2\pi c/\omega_p$ long even for the highest densities ~ 10^{20} cm-3. We report here on 1D, 2D, and 3D PIC simulations using OSIRIS for parameters closely related to the LULI/LOA results. [V.Malka et al., Phys. Plasmas 8, 2605 (2001)]. The simulations show that the self-modulation process depends sensitively on the plasma density. The self-trapped electron spectra obtained from the 3D simulations is consistent with the experimental result in that higher densities leads to few electrons and lower energies.

Work supported by DOE and NSF.

Abstract for Oral Presentation
32nd Anomalous Absorption Conference
Oahu, Hawaii, 21-26 July 2002

Laser driven accelerator research at LBNL

W.P. Leemans, C. Geddes, C. Toth, J. Faure, J. Van Tilborg, B. Marcelis, G. Dugan, P. Catravas, E. Esarey, C.B. Schroeder, G. Fubiani, B.A. Shadwick

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An overview will be presented of the laser driven accelerator research being conducted at the l'OASIS Group of LBNL. At the present time, a multi-beam 10 Hz high power Ti:Al_2O_3 laser system is used for experiments on laser wakefield excitation and electron acceleration. To date, experiments have been carried out in the self-modulated and the standard laser wakefield regime where the laser pulse duration is longer than the plasma period and comparable, respectively. Multi-nC electron beams have been generated and used for the production of radio-isotopes using (γ,n) reactions [1]. Enhancement of electron yield using shaped laser pulse has been observed [2]. Currently we are conducting experiments on laser triggered trapping of electrons using the colliding pulse scheme [3], [4]. Details of the experimental systems and experiments will be shown as well as comparisons with simulations. This work supported by DoE, Division of High Energy Physics and the Office of Biological and Environmental Research. C. Geddes acknowledges support from the Hertz Foundation.

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Fast electron generation in underdense plasmas and energy transport through solid targets

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The generation of relativistic electrons in underdense plasmas using intense laser pulses and the energy transport associated with these electrons through solid targets are two topics of current interest motivated mainly by the concept of the Fast Ignitor scheme for Inertial confinement Fusion [1]. In a series of experiments performed at the Max-Planck-Institut für Quantenoptik using the ATLAS laser system (1 J, 150 fs, 10 Hz) we have addressed these issues. In early experiments using gas-jet targets [2], the mechanism of electron acceleration in underdense plasmas in an unexplored regime of high electron density ($n_e \sim 10$[illegible] cm[illegible]), low laser energy (< 1 J) was investigated and analyzed using 3D-PIC code simulations. Using laser pulses with only 200 mJ energy at 10 Hz, 10^{10} electrons per pulse with mean energy of ~5 MeV were generated. The feasibility of generating positrons using these electrons was also demonstrated [3]. In an ongoing experiment where solid targets are employed, the relativistic electrons are generated by focusing the 1 J / 150 fs laser pulse from the ATLAS laser system into a long scale length preformed plasma produced by a synchronized Nd:glass laser delivering 10 J at 2_ in 3 ns. The fast electron propagation through the overdense plasma is expected to be affected by collective effects due to fields and currents induced by the electron beam itself [4]. Using thin plastic foils as targets, 1D hydrodynamic simulations show the creation of a long underdense plasma with scale length of a ~100 μm. Initial results using time resolved shadowgraphy and interferometry clearly show the formation of a channel in the underdense plasma and Abel inverted interferograms confirm the 1D code predictions for the scale length. Also, electron measurements exhibit the existence of electrons with energies of up to 30 MeV penetrating through the target. Using an electron spectrometer [5], a detailed characterization of the electron spectrum in the energy range of 0.2-12 MeV under different experimental conditions is under way.

This work was supported by the Commission of the EC within the framework of the association Euratom-MPI für Plasmaphysik.

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Nonlinear and Three Dimensional Theory for Cross-field Propagating Laser Pulse and Its Wake in Magnetized Plasmas

C. Ren and W. B. Mori

UCLA

We study the nonlinear and finite spot size effects for short laser pulses propagating across a constant magnetic field in a magnetized plasma (ordinary and extraordinary modes). Starting from a fluid Lagrangian for magnetized plasmas with immobile ions, we derive the envelope equation for the laser and also the equation for the plasma wake in a three-dimensional geometry. The derivation uses quasi-static approximation and assumes the laser pulse length and spot size are much larger that the laser wavelength. The derived equations are similar to the nonlinear Schrodinger equation for the laser envelope and driven harmonic oscillator equation for the plasma wake in an unmagnetized plasma. They show, among other things, the possibility of rotating and deflecting a short and narrow laser pulse in a magnetized plasma.

Petawatt laser heating of imploded plasmas and related studies at ILE, Osaka University

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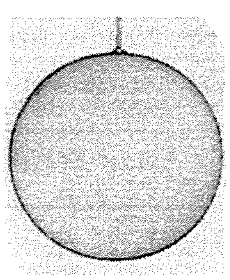
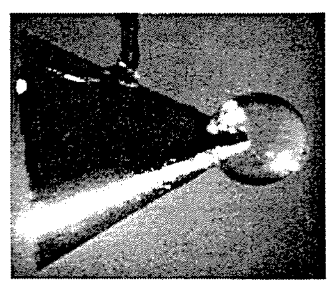
The world biggest Petawatt laser (PW laser) was completed. The beam size was 50 cm to extract 1 PW or 500 J in 0.5 ps from it. The OPCPA in the front end has just suppressed the prepulse as to 10^{-9} times the main pulse peak. A pair of 1-m diffraction gratings, grooved at 1485 lines per mm and set in double path configuration, compressed the pulse length to 500 fs in vacuum. Though the amplifier provides output up to 1.1 kJ, the damage threshold of the grating limits the current output to below 500 J. The focusing system consists of two plain mirrors and a 21-degree off-axial parabola mirror of 3.8 m focal length (f-number is 7.6). A large aperture deformable mirror compensated for phase distortions on the wave front, which permitted the beam to concentrate 30% of the energy into the 30 μm spot. A thin quartz window on the parabola shielded blasts from the targets.

A 1-ns/1-nm chirped light was sliced from the Petawatt laser front end and was injected in front of the GEKKO XII preamplifier. The injected chirped pulse was directly amplified through the GEKKO XII laser system. So that the PW laser beam illuminated the imploded core plasma within $\pm$ 10 ps accuracy.

Now using the Petawatt laser, we have started heating the imploded core plasmas[2]. The targets, used here are a CD shell sphere of 500 μm in diameter without and with cone guide, as shown in figs.(a) and (b), respectively. Simple analysis suggests that as increasing the core areal density from 0.01 gr/cm^2 or 3 times the solid density to 0.3 gr/cm^2 or 100 times the solid, neutrons from the core overcomes those from the peripheral plasmas due to the beam fusion process. The GEKKO XII lasers implode the core up to a 100 times the solid density. Then the Petawatt laser converted hot electrons heat the core up to keV.



(a) CD shell target



(b)Au coned CD shell

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32nd Annual Anomalous Absorption Conference
Turtle Bay, Oahu Hawaii, July 21st – 26th. 2002

Laser-Produced MeV Protons on Trident

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Last summer, 1-J experiments irradiating thin metal foils at > 10^{19} W/cm^2 were performed on the Trident laser. We present basic energy spectra and the angular spread of MeV proton beams emitted from the back surfaces of the targets. The typical energy distribution contains a component with peak energy of 0.6 MeV and a second component of nearly equal population stretching beyond 20 MeV. As foil thickness increases, the half angle of the resulting proton beams decrease to a few degrees. Data indicate a clear difference between Al and Au foils for conversion efficiency, cutoff energy, and beam half angle.

This summer, we begin a second set of experiments with an upgraded Trident short pulse capability – from 1 J to 20 – 50 J. At first, as before, the CPA beam will be compressed in air. In an uncompressed test, a 100 J, 500-ps beam was focused to better than three times the diffraction limit. At the 20-J level, the power flux of the expanded beam is equal to that of last year's beam, which focused to virtually the diffraction limit, and we expect to focus the higher energy beam to a comparable irradiance on target.

Work performed under the auspices of the U.S. D.O.E. by the Los Alamos National Laboratory.

High-Order Harmonic Generation with Relativistic Femtosecond Laser Pulses at High Density Plasma Surfaces

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When a femtosecond laser pulse is focused to relativistic intensity of about 10^{18} W/cm^2 onto the surface of a solid target, a dense plasma builds up rapidly. Due to the large ponderomotive pressure of the light pulse and the high electron density of the evolving plasma, its surface acts as a non-linearly oscillating mirror [1]. Consequently the reflected light contains intensive and coherent harmonics of the fundamental frequency [2]. However, this high-order harmonic generation (HOHG) is not only a method to produce such pulses at short wavelength, but it also provides a promising tool for obtaining information about the laser plasma interaction itself [3].

In a recent investigation, we have extended those previous studies [1-3]. In particular, frequency-doubled 130-fs pulses of the 790-nm laser fundamental were focused to intensities of up to 10^{18} W/cm^2 on both massive and thin foil targets. The contrast ratio exceeded 1:10^{10} and thus high enough to ensure a plasma with a scale length of a few ten nanometers. Besides the observation of the shortest wavelength harmonics from femtosecond-laser solid target interaction reported to date (i.e. the 18-th harmonic of the incident 395-nm light), anomalies have been observed in the harmonic spectra, which appear to depend on target material and thickness of the foil target.

In contrast to the expected well-known continuous „roll-off„ of the high harmonic orders, the harmonic intensity decreases with the increase of harmonic order, but in between shows minima which are significantly less intense than the neighbouring harmonics. Additional numerical kinetic particle simulations show that the physical origin of these modulations is a intricate interplay of resonance absorption and ponderomotive force which leads to a much more complicated surface plasma oscillation than indicated by the simple oscillating mirror model. Furthermore, the experimental observations from the rear side of the 50 to 600 nm thick carbon and aluminium foil targets show that even lower-order harmonics (<6th order) could be well transmitted through the foil. This indicates a high electron temperature (i.e. several hundred eV) and a very rapidly expanding plasma even on the 100-fs time scale of the laser pulse duration.

This work was supported by the Deutsche Forschungsgemeinschaft (grants TE190/2-2, TE190/4-1, FO186/4-3).

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An investigation of fusion yield from exploding deuterium and deuterated methane cluster plasmas produced by 100 TW laser pulses

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When clusters of deuterium are irradiated with an intense, ultrafast laser pulse the clusters explode, generating ions with kinetic energies high enough to produce nuclear fusion events. Here we present experimental measurements of the dependence of the fusion yield of exploding deuterium and deuterated methane cluster plasmas on pulse energy up to the 10 J level for incident pulse durations of 100 fs and 1 ps. These energies correspond to peak vacuum intensities of 2 10^{20} and 2 10^{19} W/cm^2 respectively. We also present measurements of the resulting plasma ion spectra which possess features indicative of a Coulomb explosion and discuss the role of pulse duration and focal geometry on the ion energies and the fusion yield scaling.

32nd Annual
Anomalous Absorption Conference

Thursday, July 25, 2002

9:00 AM-12:20 PM	Oral Session 4
12:20 PM	Lunch
7:30-8:30 PM	Review Session 3, Dr. Luis Silva,

"Anomalous absorption processes in astrophysics"

8:30-11:00 PM	Poster Session 3

32^{st} Annual Anomalous Absorption Conference
Turtle Bay Resort, Oahu, Hawaii
21-26 July, 2002

Optical Mixing Controlled Stimulated Scattering Instabilities in CH and Beryllium targets: SRS Suppression in Weak and Strong Ion Acoustic Wave Damping Regimes

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N. LEGALLOUDEC[3], J. HAMMER[4], R. K. KIRKWOOD,[4]
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We report on experiments conducted on the Omega laser facility at LLE using CH and Beryllium (Be) exploding foil targets. In these experiments, we measured the effects of a large amplitude ion acoustic wave (IAW), generated by the optical mixing of two (close to) counter-propagating high intensity laser beams (155^o apart), a pump and a probe, on the stimulated Raman and Brillouin backscattering of the pump (SRBS and SBBS, respectively). We observed the reduction of SRBS at densities corresponding to the Mach -1 surface of the expanding plasma where we generate a high amplitude IAW via optical mixing. In a series of experiments, we have studied this SRBS reduction as a function of pump and probe intensities (by varying the pump and probe beam energies and the interaction beam DPP and its focal spot diameter) as well as at two IAW damping levels (high and low).

On the theory side, we assess the degree of filamentation expected in our plasmas via 2D simulations of single as well as overlapping f/6.7 beams. We also look at possible nonlinearities that can limit the growth of the ponderomotively driven IAW using Vlasov simulations. Furthermore, we consider models on how such IAWs can degrade the growth of SRS and affect its saturation. Theoretical predictions and simulation results are compared to our large data base of experimental results collected over the last three years via the NLUF program.

Our longer term goal is to find efficient ways to generate large enough (EPW and IAW) disturbances in the plasma so as to control backscattering levels of SRS and SBS in specific regions of large scale plasma.

*This work was performed under the auspices of the U. S. Department of Energy under the grants DE-FG03-99SF21787 and DE-FG03-01SF22231/A001. LANL, NRL and PPPL staff acknowledge the support of their respective laboratories and their DOE contracts. The work by LLNL employees was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

PREFER ORAL SESSION

A Linear Model of Anomalous Stimulated Raman Scattering and Electron Acoustic Waves in Laser-Produced Plasmas

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Anomalous stimulated Raman scattering (SRS) is a long-standing problem in laser–plasma interactions. This short-wavelength emission often dominates SRS spectra, particularly in hot, long-scale-length plasmas used to model conditions in NIF direct-drive targets.[1] According to conventional theory, the plasma waves giving rise to such scattering should be far too heavily Landau damped to account for the observed SRS signal. To resolve this discrepancy, it has recently been proposed[2] that the anomalous SRS actually results from scattering by undamped nonlinear BGK waves. Such waves are predicted to approximately satisfy the Vlasov dispersion relation, which also describes linear electron-acoustic (EA) waves.[3] In plasmas with weaker damping, both SRS and scattering from EA waves are observed[4] and are attributed to nonlinear waves related to the two branches of the Vlasov dispersion relation.

There are, however, several difficulties with the BGK wave interpretation of these observations. BGK waves must satisfy a detailed relationship between the trapped particle distribution function and the form and amplitude of the wave. No model has been proposed by which such a nonlinear wave can arise from thermal noise and be amplified while maintaining this relationship. Moreover, nonlinear waves cannot in general be superposed. It is unclear how a single mode could be selected from the continuous spectrum of noise and amplified without being disrupted by the simultaneous presence and amplification of nearby modes. It is also unclear how a nonlinear EA-like mode could coexist with a much-larger SRS mode, as in the experiments of Ref. 4. Finally, there is much evidence, based on both analysis and simulation, that BGK waves are in general unstable.[5]

Here a simple linear model is proposed that accounts naturally for both anomalous SRS and the observations of EA waves, without invoking BGK waves. It is based on a localized flattening of the electron velocity distribution function in the vicinity of a particular velocity u_0, so that $f'(u_0) = 0$. In the case of anomalous SRS, this flattening results from the Landau damping of the plasma wave associated with SRS, and the SRS matching conditions determine u_0. In the case of EA waves, the flattening arises spontaneously from thermal or other fluctuations in the plasma. It is shown that localized flattening introduces an undamped linear EA mode, unrelated to the usual Landau modes. When this mode satisfies the SRS matching conditions, it is amplified, maintaining the flattening and thus accounting for the observed EA wave scattering.

The linear and nonlinear models have significantly different experimental signatures and consequences; these will be discussed and contrasted.

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Possible experimetal evidence of the electron acoustic wave

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UCLA

There is an on-going debate as to whether the trapped electron acoustic mode can be driven unstable in an actual laser plasma experiment.We have carried out an extensive experimental investigation using a single and two frequency CO2 laser to try to answer this question . We have obtained the frequency resolved backscattered spectrum ,single shot dispersion relation and time resolved spectrum of the density fluctuations in the plasma produced by tunneling ionization of hydrogen gas.

When the plasma is produced by a single frequency laser, we see that the Raman scattering evolves into stimulated Compton scattering . However when the plasma is produced by a two frequency laser such that the beat frequency is equal to the plasma frequency we observe considerable structure on all three diagnostics including a peak at approximately one third the plasma frequency. In addition,a strong signal at the plasma frequency persists in spite of the fact that Raman scattering has evolved into Compton scattering.This latter observation is consistent with counter propagating optical mixing induced by stimulated Brillouin scattering of the pump waves by the plasma.It is tempting to ascribe the lower frequency features to the trapped electron acoustic mode(s) however we have so far been unable to reproduce it in 2D PIC simulations.

32nd Annual Anomalous Absorption Conference
Turtle Bay, Oahu Hawaii, July 21st – 26th. 2002

Trident single hot spot experiments at high $k\lambda_D$

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[2]*University of California, Irvine*
[3]*Massachusetts Institute of Technology*

A large scale length, hot plasma has recently been developed for single hot spot (SHS) experiments on Trident with L ~ 500 μm, T_e ~ 1.5 keV, and $n_e \sim 2 \times 10^{20}$ cm^{-3}. Compared to previous experiments with T_e ~ 0.5 keV, non-local thermal perturbations caused by the SHS beam will be greatly reduced from $\delta T/T \sim 0.3$ to $\delta T/T$ ~ few % ($\delta T/T \sim 1/T^{7/3}$), which is comparable in level to ponderomotive density perturbations. These plasma conditions will allow a study of stimulated Raman (SRS) backscatter with $0.25 \leq k\lambda_D \leq 0.45$ for a 527-nm, f/4.5 SHS interaction beam. The significantly reduced $\delta T/T$ will eventually permit meaningful detailed comparisons to be made between experiment and theory for the SRS reflectivity and Langmuir wave spectra. Preliminary results from recent SHS experiments in these hotter plasmas will be presented.

Work performed under the auspices of the U.S. D.O.E. by the Los Alamos National Laboratory under contract no. W-7405-ENG-36

Nonlinear evolution of stimulated Raman scatter in high temperature plasmas

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For parameters motivated by experiments with small targets and high intensity illumination that produce electron temperatures $T_e > 10$ keV,[1] we find saturation of Raman scatter through novel subsequent Brillouin and Raman re-scattering instabilities. In these processes, rescatter limits the Raman light decay wave, in contrast to saturation by various limitations on the Raman plasma decay wave that are commonly invoked. We discuss consequences of this effect, and present evidence in our Zohar PIC simulations for these conclusions and also for other well-known secondary decays: "Langmuir decay instability" (LDI) and Raman rescatter. To make these identifications, we use synthetic streak spectra of the scattered and transmitted light, and spatial spectra in the plasma of light, Langmuir and sound waves.

1. D. E. Hinkel *et al*, this meeting.
2. A. B. Langdon and D. E. Hinkel, *Phys. Rev. Lett.*, 2002, in press.

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.

Prefer Oral Session, following talk by D. E. Hinkel *et al.*

Abstract

Reexamining the possibility of laser based IFE using a ~1micron driver

Larry Suter, Chris Marshall, LLNL
Kevin Odes, Mark Stevenson, AWE

A leading candidate for laser based IFE is Diode Pumped Solid State Lasers (DPSSLs) which operate most cost effectively at ~ 1 micron wavelength. Unfortunately, experiments in the late 1970's and early '80's indicated that 1 micron lasers often convert a substantial fraction of their energy into superthermal electrons which will preheat an ICF capsule, causing it to fail. This prompted the ICF community to move to 1/3 micron drivers in the late '80's and '90's, a wavelength at which hot electrons are not readily generated. Consequently, current scenarios of DPSSL based IFE assume that the target needs to be irradiated with ~1/3 micron light, requiring the complexity and expense of converting 1micron light to 1/3 micron.

In this talk we present two results that suggest IFE at 1micron might, in fact, be possible. First, are recent experiments on the Helen laser, using 1/2 micron light and smoothed beams. These experiments showed that superthermal electron production can be allowed or inhibited by judicious choice of plasma composition. This control of hot electron production is even observed near 1/4 critical density at incident intensities of $\sim 8x10^{14}$w/cm^2 ($I\lambda^2 \sim 2x10^{14}$w/cm^2). Complementing these experiments are Lasnex analyses of 1 micron IFE targets which support the idea that a 1MJ capsule could be driven at ~220eV in a hohlraum with peak intensity $\sim 8x10^{13}$w/cm^2 ($I\lambda^2 \sim 8x10^{13}$w/cm^2) and coupling efficiency ~28%.

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.

Prefer an Oral Presentation

Nonlinear Propagation of Laser Beams in Plasmas Near a Critical-Density Surface

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Interaction of laser light with plasma near a critical-density surface is a characteristic feature of direct-drive experiments, carried out on the OMEGA laser system at LLE. In particular, laser–plasma interaction (LPI) in the vicinity of critical density determines the balance between absorption and reflection of laser power.

The LPI modeling in a near-critical-density region requires a nonparaxial description for light propagation in order to calculate correctly the reflection from the critical density surface. Paraxial LPI codes, for example pF3D,[1] cannot model light propagation near critical density, where paraxial approximation breaks down. However, pF3D can model LPI in underdense plasma and therefore can provide the boundary conditions for light entering the region near the critical-density surface.

We have studied the nonlinear propagation of laser light near the critical-density surface in two spatial dimensions, using the nonparaxial wave-interaction solver.[2] We have found that for parameters of OMEGA experiments at average laser intensities exceeding few a times 10^{14} W/cm^2, the light reflected from the near-critical-surface region develops a red shift in the frequency spectrum. This frequency shift is due to backward SBS and is consistent with the spectra of backscattered light in experiment.[3]

We have calculated the angular and frequency spectra of light reflected from the near-critical-density region back into the underdense plasma for a single incident beam or a few crossed beams and for different angles of incidence. For an average laser intensity of more than 10^{15} W/cm^2, the self-focusing threshold is exceeded and plasma-induced smoothing[2] increases the incoherence of laser light.

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Modeling Laser–Plasma Interaction Physics Under Direct-Drive Inertial Confinement Fusion Conditions

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Recently pF3D,[1] a parallel, three-dimensional laser–plasma interaction (LPI) code developed at LLNL for modeling indirect-drive plasmas, has been modified for use under direct-drive conditions. Unlike indirect drive, one must deal with inhomogeneous flows and density profiles that include a critical surface. The treatment of the critical surface is particularly problematic as pF3D employs the paraxial approximation for the light waves. Here we present the first results of the recently modified pf3D code.

We report on realistic simulations motivated by long-scale-length exploding-foil experiments conducted on LLE's 60-beam OMEGA laser system and intended to represent future NIF direct-drive conditions.[2] Simulations including backward SBS have been carried out for intensities in the range of 4 to16 × 10^{14} W/cm^2 and for levels of SSD bandwidth up to 1 THz. Light reflected from the critical surface is responsible for the seeding of backscatter SBS, but this occurs at a moderately low level due to strong gradients in the expansion velocity near the sonic point. Weaker gradients occur farther out in the supersonic plasma corona and give rise to blue-shifted SBS light, which is seen in both the experiment and simulations. Implications of these results for the NIF will be discussed.

Larger simulations, without backward SBS, have been used to study the level and the detailed spectrum of enhanced ion-wave fluctuations generated near the quarter-critical surface as a function of laser intensity and SSD bandwidth. Such fluctuations can be generated either through plasma self-smoothing or through SSD. There is experimental evidence[3] that saturation of the TPD instability begins at irradiances of ~ 10^{15} W/cm^2. Such an intensity is well above the threshold for TPD, but close to the threshold for the onset of plasma induced smoothing.[4] We have estimated the saturating effect that such fluctuations would have on TPD[3], either due to dephasing or through the seeding of LDI.

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.

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Non-local magnetic field generation in collisional plasmas

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Existing theories on magnetic field generating mechanisms and instabilities in laser-plasmas typically fall into 2 categories: (1) Local theories based on a fluid description of electrons and classical transport (i.e. Braginskii), which are valid when the characteristic scale-lengths far exceed the electron collisional mean-free-path so that the electron velocity distribution function is very nearly Maxwellian and isotropic. The $\nabla n_e \times \nabla T_e$ mechanism is an example of this. (2) Theories involving highly distorted, non-equilibrium, electron distributions where the electron pressure is strongly anisotropic, e.g. B-field generation from relativistic electron beams propagating through a collisional, thermal background.

Using 2D Fokker-Planck simulations and by analysis of the Fokker-Planck equation for electrons we show that there is a regime between these limits where new B-field generation mechanisms appear. Local theories fail to describe these mechanisms which do not need anisotropic electron pressure and can work under less extreme conditions than is required for the 2nd category above. The new mechanisms are non-local in origin and arise when temperature and density scale-lengths become short enough for transport to compete against electron thermalisation by e-e collisions and thereby distort f_0 (the isotropic part of the distribution) away from (a single) Maxwellian.

One of these mechanisms [1] generates B-fields from an initial, non-uniform temperature profile (or under non-uniform heating) when $\nabla n_e = 0$ and was described at the previous meeting. Here we describe how *planar heating* of a plasma with $\nabla n_e = 0$ but $\nabla Z \neq 0$ also spontaneously generates magnetic fields. We also show how the mechanism that generates B-fields by non-uniform heating is modified in the presence of a density gradient.

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This work is funded by the EPSRC of the UK.

Review Session 3

<u>Thursday, July 25, 2002</u>

7:30-8:30 PM

Anomalous absorption processes in astrophysics

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The designation *anomalous absorption* has been used to describe the interaction of intense electromagnetic waves with plasmas. Identical physical mechanisms are also present in astrophysical scenarios whenever intense fluxes of neutrinos, photons or charged particles propagate in plasmas. I review two of the new directions involving collective processes and anomalous absorption in plasmas pioneered and inspired by John Dawson: electroweak plasma physics and electromagnetic electron-positron plasma instabilities in gamma ray bursters.
Electroweak plasma physics describes the self-consistent interaction of neutrinos with plasmas. Intense fluxes of neutrinos in supernovae can exceed 10^{30} W/cm^2 at 100 km from the core of the exploding star, and for these conditions neutrinos beams can drive electron plasma waves, filament and generate magnetic fields via the electroweak versions of the well know photon/electron beam driven instabilities such as forward Raman scattering or the Weibel instability. Starting from a generalized kinetic theory for neutrinos and electrons, growth rates for the electroweak plasma instabilities are derived, and the astrophysical implications of these instabilities are discussed.
In gamma ray bursters, near-equipartition magnetic fields are required to explain the features of the synchrotron radiation. To probe the full nonlinear dynamics of scenarios involving electron-positron plasmas, we have performed three-dimensional particle in cell simulations of the electron-positron electromagnetic beam plasma instability, for conditions present in internal shocks in gamma-ray bursters. The simulations show that the Weibel instability of electron-positron/ion plasmas can explain the generation of small-scale near-equipartition magnetic fields in gamma-ray bursters.

*in collaboration with R. Bingham, J. M. Dawson, R. A. Fonseca, W. B. Mori, and J. W. Tonge

Work partially supported by FCT (Portugal).

Poster Session 3

<u>Thursday, July 25, 2002</u>

8:30-11:00 PM

Oscillatory RM to RT transition and other coherent effects in plastic-foam targets

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Studies of early-time evolution of hydrodynamic perturbations that form the initial seeds for the Rayleigh-Taylor (RT) growing modes in laser targets is presently conducted at the Naval Research Laboratory. Our simulations and theory reveal many attractive opportunities that can be tested in experiments with advanced foam or foam-plastic sandwich targets. We describe how a classical and non-classical RM instability growth evolves into the RT growth. In plastic-foam sandwich targets with rippled interfaces these processes are shown to be strongly influenced by a coherent interaction of RT and RM modes with rippled shock and rarefaction waves, producing observable areal mass oscillations. We discuss amplification of areal mass oscillations due to impulsive loading of a rippled planar target with a short laser pulse, and equation-of-state measurement implications of this effect. The experimental capabilities now available on the KrF Nike laser at NRL to verify some of the theoretical predictions referring to the above will also be discussed.

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

Prefer poster presentation

Absolute Soft X-ray Emission Measurements at the Nike Laser

J. Weaver, D. Colombant (NRL), U. Feldman (ARTEP), J. Gardner (NRL), G. Holland (SFA), M. Klapisch (ARTEP), A.N. Mostovych, S. Obenschain, J. F. Seely (NRL)

The Nike group at the Naval Research Laboratory (NRL) has an ongoing effort to explore pellet designs for direct drive inertial confinement fusion.[1] Recent experiments have demonstrated that, when a low intensity prepulse (~2% of main laser intensity) is used to heat a thin Au or Pd coating on a planar CH target, the growth of non-uniformities due to laser imprint can be reduced from the growth observed for an uncoated CH target.[2] An absolutely calibrated, time-resolving transmission grating spectrometer and (cross-calibrated) filtered Si photodiode modules were used to monitor the soft x-ray emission ($\lambda \sim$ 1-10 nm) during the laser imprint studies. This poster will present data on the conversion of laser power to soft x-rays in these imprint studies. For the imprint experiments, all measurements were done for a single line of sight for each diagnostic. Recently, measurements of the angular distribution of the emission from unlayered solid targets (Au, Pd, CH) have been made using an array of moveable filtered diode modules. The data from the angular distribution studies will be presented and the implications for the imprint studies and for the comparisons to non-LTE hydrodynamic simulations will be discussed. Future experiments with a new transmission grating spectrometer will also be briefly discussed.

[1] Bodner, et al., Phys. of Plasmas, **7**, 2289 (2000).

[2] Obenschain, et al., Phys. of Plasmas, **9**,2234 (2002).

Planar Target Fabrication in Support of Nike

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We will present an overview of techniques used to fabricate and characterize targets used in hydrodynamics and equation of state experiments on the Naval Research Laboratory's Nike KrF laser. Improved Nike beam quality and more precise diagnostics have necessitated an improvement in target quality. Typical specifications for flat targets include a requirement for less than 1 μm/mm curvature, the necessity that the target be free of defects more than 5 nm peak-to-valley, and overall dimensions characterized to within 0.1 μm. We will present techniques for making targets to these specifications along with current limits and projected improvements.

In addition to increasing target quality requirements, Nike experiments have demanded increasing target complexity. Targets for EOS experiments may have several layers of material including Kapton, micromachined aluminum flats or steps, and witness plates consisting of glass supports, thin polyimide covers, and aluminum stripes. Targets for hydrodynamics experiments consist of various densities of material with patterned surfaces, and metallic coatings. We will present our present capabilities for these kinds of targets and what we foresee as the next generation of plastic and foam targets.

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Some Features of Relativistic Electron Transport for Fast Ignition

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Dan Gordon
Naval Research Laboratory

We are searching for effects which can aid the propagation of ultraintense fluxes of electrons through dense plasmas. One possibility is a magnetic field generated along the direction of the beam. Such a field can be self-consistently generated by azimuthal asymmetry in the electron beam and/or by tailoring the resistivity of the target. 3-D PIC simulations have been carried out to show that energetic electrons produced by ultraintense laser light can have a much greater angular spread in the direction of the electric vector of the light wave than in the orthogonal direction; i.e., an azimuthal asymmetry. Estimates show that this "fan-like" electron flux can lead to a sizeable magnetic field along the beam. We also consider some effects associated with return currents in the background plasma. These currents readily excite drift instabilities which can lead to a significant heating of the dense background plasma.

1. A. R. Bell, J. R. Davis, and S. M. Guerin, Phys. Rev. E 58, 2471 (1998)

Using laser-driven MeV/nucleon ion beams to study dense plasmas*

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In a few months, the Trident laser facility at Los Alamos will be able to provide both high-energy short (~ 0.5 ps) and long (~ 1ns) pulse drive capabilities on the same target. We present plans for various experiments relying on this combined capability aimed at probing the properties of dense plasmas.

High-energy, short-pulse, high-irradiance lasers can subject relatively large plasma volumes to extreme conditions, resulting in exotic phenomena like production of MV/μm electric fields and acceleration of electrons and ions to multi-MeV energies. Conversion efficiency from short-pulse laser energy to a well collimated ion beam in the 5 – 10% range has been demonstrated with both protons [Snavely *et al.*, PRL **85** (2000) 2945] and with ions with higher atomic numbers [B. M. Hegelich, Ph.D. thesis, Ludwig Maximilian Univ., Munich, and *Spectroscopy of MeV Ion Jets from Ultraintense Laser-Plasma Interactions with Thin Foils,* submitted to PRL (2002)]. As a first step in this experimental research program, we intend to increase our understanding of the relativistic laser-matter interactions underlying the ion acceleration. This knowledge will be applied towards producing, optimizing and controlling intense, laser-driven, MeV/nucleon ion beams, including the ability to focus and defocus the beam depending on the application.

These laser-driven ion beams are "neutralized," *i.e.*, electrons co-propagate along with the ions. Charge neutrality allows such beams to greatly exceed the electrical current limits above which conventional ion beams blow up. Thus, these beams are an excellent way to probe the properties of a pre-formed plasma in cases where very intense ion beams or neutralizing electrons themselves are desirable. Even when conventional ion beams would suffice, the co-location of a long-pulse laser drive facility allows to pre-form a plasma above solid density for study with the laser-driven ion-beam probe, which is not easy to do otherwise.

We propose to study beam-dense plasma interactions in regimes of interest for high-energy density physics and for fast ignition. The properties of these plasmas are often very different than those of more rarefied, conventional plasmas. These dense plasmas can be "strongly coupled", *i.e.*, the electrostatic potential energy of the average particle is not negligible compared to its kinetic energy. In these plasmas, particle collisions with large-angle scattering cannot be neglected relative to long-range collisions with small-angle scattering. As a result, important properties such as heat conduction and beam scattering are very different from calculations using conventional models. Beam-plasma interactions are an excellent tool for elucidating some of these important properties. Moreover, once the beam flux exceeds a critical value, the beam-plasma interaction will likely differ from that in the single-particle regime. The interaction of the beam and the background electrons can lead to collective effects and to instabilities that can anomalously scatter the whole beam. We intend to verify the existence of this phenomenon and to understand its implications for ion-driven fast ignition [Roth *et al.*, PRL **86** (2001) 436].

In another class of experiments, the long-pulse Trident beams will be used to pre-form a plasma and subsequently to launch a hydrodynamic shock in it. Simple considerations indicate that, associated with the shock front, there should be an electric field that depends on plasma properties such as collisionality. We will use laser-driven proton beams to radiograph the plasma and thus to diagnose the resulting electric fields.

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Particle-in-Cell Simulations of Laser-Plasma Interactions in the Exowatt Regime

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In recent years the chirped pulse amplification technique has led to the production of laser pulses with powers in excess of 1 PW [M. Perry, *et al.*, Optics Letters **24**, 160 (1999)]. It has been proposed that laser powers as high as 100 PW might be achieved by utilizing a new technique called Optical Parametric Chirped Pulse Amplification [P. Matousek, *et al.*, presented at the 2002 conference on lasers and electro-optics in Long Beach, California]. One way to accurately model the laser-plasma interaction associated with such a pulse is via fully explicit particle-in-cell simulations. The simulations require very high resolution due to the extremely narrow spikes in electron density that result from the interaction. In the one-dimensional case, we find that large numbers of protons are accelerated to GeV energies, and that the laser pulse is absorbed within a few hundred microns. Preliminary two-dimensional results will be discussed.

Work supported by DOE and ONR

Poster

Side-on Measurements of Density Profile of High-Z Layers on Planar Plastic Targets Irradiated by a Nike KrF Laser Pulse.

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Abstract

Large reduction in laser imprint has been observed with targets coated with thin high-Z layers[1]. The mechanism of imprint reduction is thought to be a large-scale buffering plasma formed by x-rays produced by the high-Z layer during the low-intensity foot of the pulse. This mechanism requires most of the laser light to be absorbed by the high-Z layer during the foot. We will present measurements of the density profile of the high-Z layer normal to the target plane during and prior to the foot of the laser pulse. The measurement is performed using side-on monochromatic x-ray imaging using Bragg reflection from curved crystal coupled to an x-ray streak camera.

Work is supported by the U. S. Department of Energy.

[1] S. P. Obenschain *et al.*, Phys. Plasmas **9**, 2234 (2002).

Prefer Poster

A 3-D Ray-Trace model for the AMR Code RAGE

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A new ray-trace algorithm is under development for the modeling of laser-matter-interactions in the 3-D Eulerian Adaptive Mesh Refinement code RAGE[1]. Ray "particles" are tracked on an unstructured mesh, and deflected in refraction by density gradients. The gradients are stored at cell wall centers, calculated "on the fly" at the maximum local uniform refinement level, and area weighted to the particle positions. Energy is absorbed near and at the target by inverse-bremsstrahlung and dump-all. Particle splitting can be employed with mesh refinement. The ray trajectories and target response are rendered in 2-D and 3-D perspective with IDL and ENSIGHT graphics.

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1. R. M. Baltrusaitis, M. L. Gittings, R. P. Weaver, R. F. Benjamin, and J. M. Budzinski, Phys. Fluids 8, 2471 (1996).

Deuterium Equation-of-State Experiments on the Nike Laser Facility

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Abstract

New experiments to measure the primary Hugoniot equation of state of deuterium in the pressure range of 0.5 to 1.5 Mbar are being conducted on the Nike laser facility. Previous experiments[1,2,3] have yielded conflicting data on the nature of the primary shock Hugoniot and extent of compressibility of deuterium at high pressure. Current experiments are aimed at providing data to help resolve this discrepancy. The experiment uses the Nike laser to drive an aluminum pusher plate into liquid deuterium and to launch a steady shock in the deuterium. The primary Hugoniot is determined from the particle and shock velocities in the deuterium sample. Impedance matching between the releasing aluminum and shocked deuterium determines the particle velocity whereas the shock velocity is measured directly. Special targets employ a stepped aluminum pusher to measure the aluminum pressure before release into the deuterium and masked witness plates record the time-of-flight velocity of the deuterium shocks as they travel from the pusher to the witness plate. Velocity interferometry will also be used for the deuterium shock velocity measurements. The latest results will be presented.

1. L.B. DaSilva *et al.*, Phys. Rev. Lett. **78**, 483 (1997).
2. A.N. Mostovych *et al.*, Phys. Rev. Lett. **85**, 3870 (2000).
3. M. D. Knudson, *et al.*, Phys. Rev. Lett. **87**, 225501-1 (2001).

Comparison of Calculated and Measured Static and Gated Images for Recent Implosion Experiments

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A primary goal of laser capsule implosions is to determine pusher-fuel mix with as much spatial and temporal resolution as possible. Continuum emission from low-z elements such as carbon, a ubiquitous component of pushers, is ideally suited to this task, since it is typically stripped well into the k-shell when it is in or near the mix region, and it is in LTE. Both the relative and absolute photon emission are functions of the mix and temperature, but the absolute numbers have a stronger (more non-linear) dependence. Static imagers can be reliably absolutely calibrated, while only relative intensities are available from gated (or streaked) imagers. We present calculations of image line-outs from 1D simulations for various mix prescriptions, and compare them to measured static images. For the more promising prescriptions, a more detailed comparison with measured gated images is made. The capsules considered were direct drive implosions.

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Vlasov Simulations of the Nonlinear Evolution of High Frequency Waves Generated by Optical Mixing: Electron Plasma Waves and Trapped Electron Acoustic Waves

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We will show results of simulations using the Vlasov-Poisson (V-P) and the Vlasov-Maxwell (V-M) system of equations in 1D of ponderomotive force (PF) driven electron plasma (EPW) and trapped electron acoustic waves (TEAW). We compare and contrast the dynamic evolution of these waves driven one at a time as well as their interactions when simultaneously driven. We explore the $k\lambda_{De}$ range where Landau damping of EPWs is severe to where it is not. The ponderomotive forces are turned on gently and left on for a limited duration. The evolution of the waves once driven to large enough amplitudes is tracked past when the ponderomotive forces are turned off. The free evolution and the interaction between these waves in phase space will be demonstrated for weak and strong drive amplitudes and various values of $k\lambda_{De}$.

We will compare the results of V-P and V-M codes in homogeneous as well as parabolic density profile cases. The latter will touch upon so called Blue-Green experiments with exploding foils we have proposed to conduct on Trident at LANL and on Omega at LLE, Rochester.

Our long term goal is to understand the nonlinear evolution of the SRS instability including kinetic effects and distribution function changes. The latter may be diagnosable by the evolution of a PF driven TEAW witnessing the dynamics of an EPW generated by SRS.

*This work was performed under the auspices of the U. S. Department of Energy under the grant DE-FG03-99SF21787.

PREFER ORAL SESSION

Experiments on controlled laser wakefield excitation and electron acceleration

W.P. Leemans, C. Geddes, C. Toth, J. Faure, J. Van Tilborg, B. Marcelis, G. Dugan, P. Catravas, E. Esarey, C.B. Schroeder, G. Fubiani, B.A. Shadwick
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Accelerators based on laser excitation of ultra-high gradient plasma wakes are being considered as alternatives to conventional accelerators. Wake excitation and particle trapping are essential aspects that need to be demonstrated. The l'OASIS Group at LBNL is conducting experiments on the interaction of ultra-short laser pulses with gas targets towards such controlled particle acceleration [1]. Experiments were carried out on the excitation of laser driven plasma wakefields using shaped laser pulses and self trapping of electrons in these wakefields [2]. High power (10 TW, 50 fs) laser pulses from the l'OASIS Ti:Al_2O_3 chirped pulse amplification based laser system were focused onto high density gasjets. Through the use of non-linear dispersion, frequency chirped laser pulses were generated with a non-gaussian temporal profile. For the same peak power, an enhancement (reduction) in electron yield was observed for positively (negatively) chirped laser pulses with a fast (slow) rise time and slow (fast) fall time. Modeling indicates that the growth of the plasma wave is strongly affected by the laser pulse shape and, for the parameters in these experiments, weakly through the intrinsic laser frequency chirp. We also will report on the present status of ongoing experiments on laser triggered injection into a laser wakefield accelerator using the colliding pulse method [3], [4]. This method relies on manipulating background plasma electrons using the beat pattern between two colliding laser pulses to give momentum boost allowing the electrons to catch the plasma wave. Simulations indicate that laser triggered injection could result in ultra-short (fs), low emittance(< 1mm-mrad), low energy spread (few %) electron beams. This work supported by DoE, Division of High Energy Physics and the Office of Biological and Environmental Research. C. Geddes acknowledges support from the Hertz Foundation.

[1] W.P. Leemans et al., Phys. Plasma **8**, 2510 (2001).
[2] W.P. Leemans et al., Phys. Rev. Lett., submitted (2002).
[3] E. Esarey et al., Phys. Rev. Lett. **79**, 2682 (1997).
[4] C.B. Schroeder et al., Phys. Rev. E **59**, 6037 (1999).

Electron trapping and acceleration in laser-plasma accelerators

Eric Esarey, C.B. Schroeder, G. Fubiani, B.A. Shadwick, W.P. Leemans,
and members of the l'OASIS Group
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The l'OASIS Group at LBNL is actively pursuing, experimentally and theoretically, all optical electron acceleration in plasma based on (I) the self-modulated laser wakefield accelerator (SM-LWFA) and (II) colliding pulse injection in a standard LWFA. In the SM-LWFA, the laser pulse duration is long compared to a plasma period and the pulse power is above the critical power for relativistic self-focusing. In this regime, the pulse is violently unstable and a large plasma wave is generated via self-modulation or forward Raman scattering. The self-modulated wakefield grows until it traps and accelerates electrons from the background plasma. The result is a self-trapped and accelerated electron bunch with a large energy spread (100 percent), with most electrons in the MeV range with an exponential tail reaching out to 100 MeV or more, as is observed in several experiments, including those at LBNL. In the colliding pulse injector, an intense pump pulse in the standard LWFA regime (pulse duration equal to the plasma wave) impulsively excites a large amplitude plasma wakefield. Two counter-propagating injection pulses collide some distance behind the pump pulse and generate a beat wave with a slow phase velocity. This slow beat wave can trap background electrons and inject them into the fast wake for acceleration to high energy. This can result in an ultrashort electron bunch (few fs) with a small energy spread (few percent). Another colliding pulse geometry explored is one that uses two pulses (the pump pulse and the backward injection pulse), in which the beat wave is produced by the backward pulse colliding with the pump pulse. Simulations of colliding pulse injection for both the two pulse and three pulse configurations will be presented using test particle and PIC codes. Recent experimental results from the l'OASIS group on self-trapping and acceleration will be presented.

This work supported by DoE, Division of High Energy Physics and the Office of Biological and Environmental Research.

E. Esarey et al., Phys. Plasmas 6, 2262 (1999).
C.B. Schroeder et al., Phys. Rev. E 59, 6037 (1999).
W.P. Leemans et al., Phys. Plasma 8, 2510 (2001).
W.P. Leemans et al., Phys. Rev. Lett., submitted (2002).

Thirty Second Annual Anomalous Absorption Conference
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Evaluation of the stability of laser direct-drive targets*

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In the past few years a variety of target designs have been proposed to produce moderate to high gain when directly driven by lasers[1]. These targets are typically designed with one-dimensional radiation-hydrodynamics codes with their stability projected using ablative RM and RT growth formulæ[2] combined with simple Haan-style saturation effects[3]. Typically, unsaturated growth rates in these targets maximize for perturbations with spherical harmonic mode numbers of order one hundred or larger. Although ablative stabilization is also important in this range, these modes are usually well into nonlinear evolution and saturation well before convergence and stagnation of the fuel shell. The applicability of this quasi-linear analysis is thus suspect over a broad range of modes thought to be important in this problem. We have performed large 2D simulations of some of these targets using the FAST multidimensional radiation hydrocode. These calculations have attempted to address the issue by simulating a wide spectrum of perturbations (e.g., $\ell = 2 - 128$) from the linear through the nonlinear stages. The development of these modes in these multimode simulations is then compared to corresponding single-mode simulations and the previously developed analytic and quasi-analytic theories describing them.

[1] S. E. Bodner, et al, Phys. Plasmas **5**, 1901 (1998); S. E. Bodner, D. G. Colombant, A. J. Schmitt, and M. Klapisch, Phys. Plasmas **7**, 2298 (2000); D. G. Colombant, private communication.

[2]. E.g., R. Betti, V. N. Goncharov, R. McCrory, and C. P. Verdon, Phys. Plasmas **5**, 1446 (1998); V.N. Goncharov, Phys. Rev. Lett. **83**, 2091 (1999).

[3] S. Haan, Phys. Rev. A **39**, 5812 (1989).

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Simulations on Beat-Wave excitation of plasma waves

R. Narang, C.V. Filip, S. Ya. Tochitsky, D.F. Gordon, C.E. Clayton, C. Joshi, W. B. Mori

Current efforts to model Beat-Wave experiments in the Neptune Lab have utilized the PIC code turboWAVE. This code allows one-to-one modeling of the experimental parameters present in the lab. We have modeled laser-plasma acceleration experiments for plasmas produced by focusing a laser pulse with a small f/# optic (specifically from f/2 to f/3) with an intensity of ~10^{15} W/cm^2 in two wavelengths (10.27 μm and 10.59 μm), which are conditions present in the lab. From these simulations we are able to determine the longitudinal wake amplitude, E_x, which allows the estimation of the accelerating gradient present in the plasma for densities on and off resonance (resonance corresponds to n=1.0 at 10^{16} cm^{-3}). Determination of the wake amplitude allows the estimation of the amount of acceleration expected for electrons that are externally injected into the plasma wave. Simulations in 2-D have been done with preformed and laser ionized plasmas with and without mobile ions, as well as for different densities. Simulations have shown that ion motions in the transverse direction, for the short f/# cases, cannot be neglected and that acceleration of electrons would be limited by the shortening of the interaction length due to deviations from the resonant density along the plasma. The peak wake amplitude, at resonance, with ion motions included is ~0.15 at the focus of the laser. Additional simulations have been done to model experiments utilizing a longer f/# (f/18 focusing) to produce longer interaction lengths.

Non-Ideal Backlit Implosions (NIBI) on Omega*

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Lawrence Livermore National Laboratory

Abstract

Asymmetry in a spherically converging system can create a jet, which is a hydrodynamic behavior of general interest. The non-ideal backlit implosion (NIBI) experiment was designed to form a diagnosable jet in a low-convergence implosion. The design is an empty plastic shell of 500 μm inner radius of 60 μm thickness, with a diagnostic dopant (Ge, Br, or Ti) in the inner ~20 μm of the thickness of the shell. The shell was imploded on the Omega laser with direct drive, using 40 beams with a 1 ns square pulse and a 5:1 P_1 intensity asymmetry. The remaining 20 beams, taken from near the horizontal plane, were used to illuminate two area backlighters, Ti for earlier time images, and Fe for later time images. Energies for the other beams in the rings from which backlighter beams were taken were raised to compensate for the missing beams. In this way, illumination uniformity of better than ~3% were preserved, which was adequate for low convergence implosions (CR ~ 2-3 for the capsule radius, but the actual jet feature is smaller).

Images of symmetrically-driven implosions confirm the uniformity of the illumination scheme and validate 1-D understanding of the implosion. Images of asymmetrically-driven implosions exhibited jets and were in qualitative agreement with simulations. A variation of the design employed doping only in a "polar cap", with the doped CH density matched to polyimide for the remainder of the capsule. This design was intended to enhance contrast of the jet. Although higher contrast was seen, the doped region appeared in the late time images as a sector of a circle, and did not exhibit a narrow spike extending from the vertex, which was predicted by the simulations. Detailed comparison between the data and simulations is in progress.

*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.

32nd Anomalous Absorption Conference
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Hydrodynamic instability modeling for ignition targets for the National Ignition Facility, and for Omega experiments designed to test that modeling*

S. W. Haan, T. Dittrich, S. Hatchett, M. Marinak, D. Munro,
S. G. Glendinning, and G. Collins

Abstract

Several topics are presented pertaining to hydrodynamic instability modeling for ignition targets for the National Ignition Facility, and simulations of experiments on the Omega laser. Recent design results include analysis of a target that could be fielded with a less elaborate cryogenics system. For the point design, analysis has been done of diagnostic signatures, including images of core X-ray emission at various energies, and images of down-scattered neutrons. Simulations of Omega experiments will also be discussed, including recent results measuring hydrodynamic instability growth in both planar and imploding spherical geometry.

*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.

32nd Annual
Anomalous Absorption Conference

Friday, July 26, 2002

9:00 AM-12:20 PM	Oral Session 4
12:20 PM	Lunch

Cocktail hohlraum experiments*

O. S. Jones, S. H. Glenzer, L. J. Suter, R. L. Kauffman, R. E. Turner, B. A. Hammel, R. J. Wallace, and O. L. Landen
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Although standard gold hohlraums have proven to be effective for generating soft x-rays for indirect drive ICF experiments, it is possible to make hohlraums more efficient by using mixtures of materials, known as "cocktails". Calculations show that gold is relatively opaque to radiation across a wide range of frequencies, but there are gaps in the opacity that allow radiation in certain frequency ranges to diffuse more rapidly into the wall. By using carefully chosen mixtures of three or four materials, it is possible to fill in these gaps in opacity. In this way, radiation losses through the wall can be reduced, and the hohlraum-capsule coupling efficiency may be improved.

We report on the results of two kinds of experiments on the Omega laser facility to measure the performance of cocktail hohlraums. One type of experiment consisted of a gold half-hohlraum with semi-circular patches of cocktail and gold material placed side-by-side on the endcap of the half-hohlraum. The disk was imaged through the laser entrance hole with a filtered x-ray imaging camera. These measurements show that the relative re-emission intensity of the gold and cocktail materials over different frequency bands agrees with radiation-hydrodynamics calculations.

We also performed experiments in which we measured the radiation drive of hohlraums of different materials and sizes with a filtered x-ray diode array (Dante). Hohlraums tested so far include two different cocktail mixtures, gold, uranium, and cocktails with thin layers of gold liner. Laser backscatter losses measured with FABS are consistently higher for the cocktails than for the gold. However, when the backscatter and laser entrance hole closure are carefully accounted for, the cocktail hohlraums are found to achieve a higher radiation temperature than gold hohlraums.

*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.

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Measurements of the absolute Hohlraum Wall Albedo under ignition foot drive conditions

S. H. Glenzer, O. Jones, L. J. Suter, R. E. Turner, R. L. Kauffman, B. A. Hammel, R. J. Wallace, and O. L. Landen

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We have investigated the soft x-ray re-emission of inertial confinement fusion hohlraums for conditions that are produced during the first 10 ns of a laser ignition experiment when radiation temperatures reach about 90 eV. During this time, the hohlraum wall albedo, which is defined as the re-emitted soft x-ray flux to the incident soft x-ray flux on the wall, is an important quantity because it determines the symmetry of the radiation flux on the fusion capsule. A high hohlraum wall albedo is advantageous because it enhances the emission from the indirectly heated walls relative to that from the laser spots, which makes the radiation symmetry at the capsule less sensitive to laser power imbalance and pointing errors.

Experiments at the Omega laser facility have been performed measuring the absolute hohlraum wall albedo of various type hohlraums. In particular we compare the albedo from so-called cocktail hohlraums that consists of a mixture of U, Nb, Au, and Dy with plain U and plain Au hohlraums. In these experiments, we apply the source radiation from a primary hohlraum to heat a secondary hohlraum and to obtain the albedo from the re-emitted radiation in the secondary hohlraum. The primary hohlraum is heated by 15 beams from the Omega laser with 7.5 kJ in a 1.5 ns square pulse providing a source soft x-ray radiation of 160 eV which is measured with a broadband soft x-ray spectrometer, Dante, and with photo-conductor detectors (PCDs). The secondary hohlraum is heated by the soft x rays from the primary and the radiation temperature achieved in the secondary is a direct measure of the absolute albedo. The initial results suggest that Au hohlraums have an albedo at 90 eV temperatures that is in agreement with predictions based on the STA opacity model. This is a higher albedo than was originally estimated for NIF ignition hohlraums, since a simpler opacity model was used in those design calculations. Moreover, the results indicate that cocktail hohlraums may have a higher albedo than Au hohlraums indicating that an improved radiation uniformity may be achievable in ignition experiments on the National Ignition Facility.

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Prefer oral session

Areal-Density Growth Measurements with Proton Spectroscopy in Spherical Implosions on OMEGA

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The growth of target areal density near peak compression of direct-drive spherical target implosions has been measured with 14.7-MeV deuterium–helium^3 (D^3He) proton spectroscopy on the 60-beam, 30-kJ UV OMEGA laser system. The experiment involves measurements of 14.7-MeV proton spectra (taken from seven different views of the target), neutron production history, and ion temperature. The shape of proton spectra is determined primarily by the target-areal-density evolution. Other effects contributing to the proton spectrum shape are ion-temperature broadening, shell-nonuniformity broadening, and broadening from finite size of the proton source. The geometrical effect of proton-spectrum broadening has been calculated using uniform burn assumption. Assuming that the effect of shell nonuniformities on proton spectra is small, the target areal density grows by a factor of ~10 for time of neutron production before reaching about 150 mg/cm^2 at peak compression in the implosion with a 20-μm-thick plastic CH target filled with 4 atm of D^3He fuel. For more-stable 20-μm-thick-CH shells filled with 18 atm of D^3He fuel, the target areal density grows by a factor of ~8 for time of neutron production before reaching about 120 mg/cm.^{2}

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Prefer oral session

Experimental Techniques to Measure Shrapnel and Debris Environments Expected for the National Ignition Facility (NIF)

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An experimental technique is under development to allow passive measurement of the debris and shrapnel generated by high-intensity laser irradiation. The technique involves using aerogels positioned near a target to trap incident particles of debris and shrapnel. Analyses of post-shot radiography of the aerogel samples at the Stanford Linear Accelerator has provided size distribution and depth of the trapped particles. Calibration experiments have provided the aerogel compaction strength and confirmed scaling of particle depth with initial velocity. Fifteen such aerogels were exposed to a variety of shrapnel and debris environments on the Helen laser. We report the results of the analyses of these aerogels, including average particle size under the various strain rate loadings, radial size distribution, and behavior of laser ablated high-Z material condensed on the aerogel.

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K-shell spectra from isochorically heated solid aluminum driven by ultrashort laser pulses

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Strongly coupled plasma close to solid state density and keV electron temperature can be generated by focusing high contrast ultrashort laser pulses on solid targets, a technique which is called *isochoric heating*. This short living plasma state can by systematically studied by analyzing the spectral properties of the emitted x-rays. The detected K-shell emission serves in our case as benchmark data for a multi-electron radiator code describing the complex behaviour of dense plasma.

For these experiments, the ATLAS Ti:Sapphire laser of the MPQ was used. It delivers frequency doubled laser pulses of high contrast with an energy of about 60mJ and a duration of 150fs at 395nm wavelength. The typical intensity on the target was in the range of 10^{17}-10^{18}W/cm^2.

Time integrated K-shell spectra obtained by 250Å thin Al sample layers burried at different depth (250-4000Å) in solid carbon will be shown. Stark-broadened and red-shifted line shapes as well as high order satellite emission are characteristic features of the detected spectra, which are well reproduced by simulation. Spatial profiles of electron density and temperature are discussed.

Finally, the time history of K-shell lines is investigated at about 1ps time resolution. The emission of layered aluminum targets shows 2-3ps FWHM duration in good agreement with simulation results.

COLLECTIVE THOMSON SCATTERING MEASUREMENTS OF MODERATELY COUPLED PLASMAS

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Collective Thomson scattering has become a widely used technique for density and temperature measurements in laser-plasmas. Weakly coupled scattering theory is expected to break down as the ratio of Coulomb interaction energy to thermal kinetic energy, $\Gamma_{ii} = (Ze)^2/akT$, approaches unity. Accurate modeling is required in order to fit collective Thomson scattering features from ion acoustic waves and determine plasma parameters Z, T_e and T_i. We use the Trident Laser to produce Al, CH, CH_2 moderately coupled, laser-plasmas, where $n_e \sim 10^{20}$ cm^{-3}, T_e ~75-150 eV, and Γ_{ii}~0.1-0.75. A separate 351-nm beam was used as a low intensity probe for Thomson scattering. The Thomson scattered light was recorded using an imaging spectrograph to provide temporally and spatially -resolved profiles of thermal ion acoustic and Langmuir waves. We observed broadening of the ion acoustic waves of the same order of the frequency shift, $\delta\omega_{ia}/\omega_{ia} \sim 1.0$. Using a Collisionless model that incorporates Landau damping, we show that inhomogeneities due to density and velocity gradients are insufficient to solely account for the broadening. We will discuss the effects of ion-ion collisions and moderate ion-ion coupling in analyzing the ion acoustic wave spectrum.

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Search for SBS saturation processes with Thomson Scattering experiments on Ion-Acoustic Waves in Beryllium Plasmas

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We observe saturation of the SBS reflectivity and of the ion-acoustic wave amplitude by both varying the interaction beam intensity and plasma scale length. We further investigate detuning by comparing the relative width of the thermal and driven peaks in the Thomson scattering spectra. Experiments have been conducted using a three-beam configuration at the Trident Laser Facility at Los Alamos National Laboratory to investigate the growth of ion-acoustic waves in beryllium plasmas. These experiments were conducted in well-characterized plasmas that were created using a 2ω heater beam with an intensity of 10^{14} W cm^{-2}. A separate 2ω 1.2-ns interaction beam with intensities up to 5 x 10^{15} W cm^{-2} was used to excite an ion-acoustic wave. The wave number of the excited ion-acoustic wave was matched using a third 3w 200ps Thomson-scattering probe beam. The electron and ion temperatures were measured to be 650 eV and 325 eV respectively. A FABS station was used to measure the SBS and SRS energy and spectra. The electron densities were measured to be n_e~3x10^{20} cm^{-3}.

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