33rd Anomalous Absorption Conference

Technical Program and Book of Abstracts

Hilton Lake Placid Resort
Lake Placid, New York
22–27 June 2003

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33rd Anomalous Absorption Conference
Lake Placid, NY

Hilton Lake Placid Resort
Lake Placid, New York
22–27 June 2003

Hosted by the University of Rochester Laboratory for Laser Energetics

Conference Cochairs:

Valeri Goncharov
Sean Regan

Conference Coordinator:

Jean Steve

Annual Anomalous Absorption Conference

22–27 June 2003

Hilton Lake Placid Resort
Lake Placid, New York

PROGRAM CHANGES

Monday, 23 June 2003

REVIEW TALK: (45 minutes each) **Medallion Ballroom**

7:30 MR1 X-Ray Thomson Scattering on Solid Density Plasmas (**Moved from Thursday**)

S. H. Glenzer, Lawrence Livermore National Laboratory

Tuesday, 24 June 2003

Cancelled

~~9:45 TO4 Model for Hydrodynamic Instabilities of a Fluid Interface Using copuled Conformal Mappings~~

~~*I. V. Sokolov (University of Michigan) and A. L. Velikovich (Naval Research Laboratory)*~~

9:45 TO5 High Resolution Simulations of High Gain Direct-Drive ICF Targets

Andrew J. Schmitt, D. G. Colombant, A. L. Velikovich, S. Zalesak, J. H. Gardner, and D. Fyfe (Naval Research Laboratory)

10:00 Coffee Break

MIXED POSTER SESSION – beginning at 8:15 PM **Lakeview Room**

TP13 Radiation Resonance Emission from Steep Overcritical Plasma Profiles Illuminated by Femtosecond Laser Pulses

R. Ondarza R. (Instituto Nacional de Investigaciones Nucleares)

Thursday, 26 June 2003

REVIEW TALK: (45 minutes each) **Medallion Ballroom**

THR1 Plasma Induced Laser Beam Smoothing: How Do We Understand It (**Moved from Monday**)

V. T. Tikhonchuk, CELIA, University of Bordeaux

Annual Anomalous Absorption Conference

22–27 June 2003

Hilton Lake Placid Resort
Lake Placid, New York

PROGRAM

Sunday, 22 June 2003, 7:30 PM
Lakeview Room

REGISTRATION *7:00–9:00 PM* *Conference Registration and Reception*

Monday, 23 June 2003
Continental Breakfast 7:30 AM
Promenade
Morning Session Begins at 8:30 AM
Medallion Ballroom

Morning Sessions:

ORAL SESSION I ***8:30–10:15 (15 Minutes Each)*** ***S. Craxton (Chair)***

8:30 Introduction and Welcome
S. Regan and V. Goncharov

8:45 MO1 Study of the Effect of Ion Acoustic Wave Damping on Energy Transfer Between Crossing Laser Beams in a Plasma with a Mach 1 Flow

R. K. Kirkwood, A. B. Langdon, B. I. Cohen, E. A. Williams, M. R. Dorr, J. A. Hittinger, J. D. Moody, L. Divol, C. Niemann, and S. H. Glenzer (Lawrence Livermore National Laboratory)

9:00 MO2 Observation of Multiple Steps of Langmuir Decay Instability in Trident Single Hot Spot Experiments

David S. Montgomery, John L. Kline, Ronald J. Focia (Los Alamos National Laboratory)

9:15 MO3 Observation of a Transition From Fluid to Kinetic Nonlinearities for Langmuir Waves Driven by Stimulated Raman Scattering

J. L. Kline, D. S. Montgomery, B. Bezzerides, J. A. Cobble, D. F. DuBOis, R. P. Johnson, H. A. Rose, and H. X. Vu (Los Alamos National Laboratory)

9:30 MO4 Kinetic Electrostatic Electron Nonlinear Waves: Their Generation, Long Time Evolution and Interactions

B. B. Afeyan, K. Won, V. Savchenko, T. W. Johnston, A. Ghizzo, P. Bertrand (Polymath Research Inc.)

9:45 MO5 Electron Acoustic Waves and the Search for a Truly Self-Consistent Large-Amplitude Plasma Response

T. W. Johnston and B. B. Afeyan (INRS-EMT)

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10:00 MO6 Nonlinear Propagation of Crossing Laser Beams in Direct-Drive Target Plasmas

A. V. Maximov, J. Myatt, W. Seka, and R. W. Short (University of Rochester, Laboratory for Laser Energetics)

10:15 Coffee Break

ORAL SESSION II ***10:45–12:00 (15 Minutes Each)*** ***W. Kruer (Chair)***

10:45 MO7 Two-Plasmon Decay, Overlapping Beams, and Electron-Acoustic Waves

R. W. Short (University of Rochester, Laboratory for Laser Energetics)

11:00 MO8 Investigation of the TPD Instability Using Thomson Scattering

W. Seka, H. Baldis, S. Depierreux, R. S. Craxton, S. P. Regan, C. Stoeckl, R. W. Short, A. Maximov, J. Myatt, and R. E. Bahr (University of Rochester, Laboratory for Laser Energetics)

11:15 MO9 Experimental Scalings for the Two-Plasmon-Decay Instability

C. Stoeckl, R. E. Bahr, V. Yu. Glebov, A. V. Maximov, J. Myatt, T. C. Sangster, W. Seka, and B. Yaakobi (University of Rochester, Laboratory for Laser Energetics)

11:30 MO10 Thomson Scattering Analysis of SRS/SBS Interplay in Sub-Picosecond Time-Scale

C. Rousseaux, F. Amiranoff, S. D. Baton, M. Casanova, L. Gremillet, P. Loiseau, H. Popescu, M. Rabec Le Gloahec (CEA, LULI)

11:45 MO11 Quasi-Linear Theory of Non-Local Magnetic Field Generation in Laser-Plasmas

R. J. Kingham and A. R. Bell (Imperial College, Plasma Physics Group)

12:00 Lunch On Own

AFTERNOON ON OWN

6:00 Dinner *Served in Terrace Room 4*

------------------------- Evening Session, Monday, 23 June 2003, 7:30 PM ------------------(E. Williams, Chair)

REVIEW TALK: (45 minutes each) **Medallion Ballroom**

7:30 MR1 Plasma Induced Laser Beam Smoothing: How Do We Understand It

V. T. Tikhonchuk, CELIA, University of Bordeaux

MIXED POSTER SESSION – beginning at 8:15 PM **Lakeview Room**

MP1 Electron Heating Effects on the Generation of Intense Short Light Pulses by Backward Raman Amplification

R. L. Berger, D. S. Clark, E. J. Valeo, and N. J. Fisch

MP2 Measurements of Laser Imprint on Planar Plastic Targets Irradiated by the Nike Laser

Max Karasik, Y. Aglitskiy, A. N. Mostovych, V. Serlin, J. W. Bates, S. P. Obenschain (Naval Research Laboratory)

MP3 Relationship of Secondary Nuclear Production to Implosion Characteristics at OMEGA

S. Kurebayashi, F. H. Séguin, J. A. Frenje, C. K. Li, J. R. Rygg, R. D. Petrasso (MIT, Plasma Science and Fusion Center), V. Yu. Glebov, J. A. Delettrez, T. C. Sangster, J. Soures (University of Rochester, Laboratory for Laser Energetics), S. P. Hatchett, P. A. Amendt (Lawrence Livermore National Laboratory)

MP4 Proton Core Imaging Spectroscopy on OMEGA Implosions

B. Schwartz, J. DeCiantis, F. H. Séguin, J. A. Frenje, C. K. Li, R. D. Petrasso (MIT, Plasma Science and Fusion Center), J. A. Delettrez, J. M. Soures, T. C. Sangster, V. Yu. Glebov (University of Rochester, Laboratory for Laser Energetics)

MP5 Strong Shock Wave and Areal Mass Oscillations Associated with Impulsive Loading of Planar Laser Targets

A. L. Velikovich, N. Metzler, A. J. Schmitt, J. H. Gardner (Naval Research Laboratory)

MP6 Fine-Tuning the Laser Shaping Pulse for Imprint Reduction

N. Metzler, A. L. Velikovich, A. J. Schmitt, J. H. Gardner (SAIC, NRC-N, and Naval Research Laboratory)

MP7 Investigations into the Saturation and Control of Laser Plasma Instabilities

W. L. Kruer, B. Cohen, A. B. Langdon, B. Lasinski, S. C. Wilks, and E. Williams (Lawrence Livermore National Laboratory)

MP8 Comparison of Full PIC and Reduced PIC Results for Low Intensity Laser-Plasma Interactions

B. J. Winjum, F. S. Tsung, W. B. Mori (University of California at Los Angeles), A. B. Langdon (Lawrence Livermore National Laboratory)

MP9 Particle-in-Cell Simulations of the Two Plasmon Decay Instability

F. S. Tsung, W. B. Mori (University of California at Los Angeles), B. B. Afeyan (Polymath Research Inc.)

MP10 A Magnetic Recoil spectrometer (MRS) for ρR_{fuel} and T_i Measurements of Implosions at OMEGA and the NIF

J. A. Frenje, R. D. Petrasso, F. H. Séguin, C. K. Li, J. DeCiantis, S. Kurebayashi, J. R. Rygg, B. E. Schwartz (MIT, Plasma Science and Fusion Center), V. Yu. Glebov, J. Delettrez, D. D. Meyerhofer, T. C. Sangster, C. Stoeckl, M. M. Soures (University of Rochester, Laboratory for Laser Energetics), S. Hatchett, S. Haan, G. Schmid, N. Landen, N. Izumi (Lawrence Livermore National Laboratory)

MP11 Quantitative Comparison Between Reduced-Description Particle-in-Cell (RPIC) and Full PIC Simulations of Laser-Plasma Instabilities

Evan S. Dodd, Dan C. Barnes, Bandel Bezzerides, Don F. DuBois (Los Alamos National Laboratory), Hoanh X. Vu (University of California at San Diego)

MP12 Measurement of the Absolute Hohlraum Wall Albedo Under Ignition Foot Drive Conditions

O. S. Jones, S. H. Glenzer, L. J. Suter, R. E. Turner, K. M. Campbell, E. L. Dewald, B. A. Hammel, R. L. Kauffman, O. L. Landen, M. D. Rosen, R. J. Wallace, F. A. Weber (Lawrence Livermore National Laboratory)

MP13 Fokker-Planck Calculation in the Direct-Drive NIF Design

A. Sunahara, J. A. Delettrez, S. Skupsky, and K. Mima (Institute of Laser Engineering, Osaka University and University of Rochester, Laboratory for Laser Energetics)

Tuesday, 24 June 2003
Continental Breakfast 8:00 AM
Promenade
Morning Session Begins at 9:00 AM
Medallion Ballroom

Morning Sessions:

ORAL SESSION I 9:00–10:15 (15 Minutes Each) D. Haynes (Chair)

9:00 TO1 Hydrodynamic Stability of Undirectly Driven LMJ Capsules

C. Cherfils-Clérouin, D. Galmiche, J. Garnier, L. Masse, P. A. Raviart, and G. Samba (CEA-DIF)

9:15 TO2 On the Bell-Plesset Effects: The Effects of Uniform Compression and Geometrical Convergence on the Classical Rayleigh-Taylor Instability

R. Epstein (University of Rochester, Laboratory for Laser Energetics)

9:30 TO3 Multi-Fluid Interpenetration Mixing in Directly Driven Plastic ICF Capsules

D. C. Wilson, C. W. Cranfill, R. R. Peterson, N. M. Hoffman, Los Alamos National Laboratory), C. K. Li, F. H. Séguin, J. A. Frenje, R. D. Petrasso (MIT, Plasma Science and Fusion Center), and P. McKenty (University of Rochester, Laboratory for Laser Energetics)

9:45 TO4 Model for Hydrodynamic Instabilities of a Fluid Interface Using copuled Conformal Mappings

I. V. Sokolov (University of Michigan) and A. L. Velikovich (Naval Research Laboratory)

10:00 TO5 High Resolution Simulations of High Gain Direct-Drive ICF Targets

Andrew J. Schmitt, D. G. Colombant, A. L. Velikovich, S. Zalesak, J. H. Gardner, and D. Fyfe (Naval Research Laboratory)

10:15 Coffee Break

ORAL SESSION II 10:45–12:00 (15 Minutes Each) W. Manheimer (Chair)

10:45 TO6 Experiments on Hydrodynamic Instabilities in Advanced Plastic and Plastic-Foam Targets

Y. Aglitskiy, N. Metzler, A. L. Velikovich, M. Karasik, V. Serlin, A. J. Schmitt, S. Obenschain, and J. H. Gardner (Naval Research Laboratory)

11:00 TO7 Deuterium Equation-of-State Experiments on the Nike Laser Facility

A. N. Mostovych, J. W. Bates, D. Brown, J. H. Gardner, M. Karasik, J. Oh, A. J. Schmitt, A. L. Velikovich, and J. Weaver (Naval Research Laboratory)

11:15 TO8 Single-Mode Richtmyer-Meshkov Growth in a Compressible, Miscible, Convergent System

M. M. Balkey, J. M. Scott, Cris W. Barnes, S. H. Batha, N. D. Delamater, R. M. Hueckstaedt, J. R. Fincke, N. E. Lanier, and G. R. Magelssen (Los Alamos National Laboratory)

11:30 TO9 On the Applicability of Modern Front=Capturing Methods to the Modeling of Small-Amplitude Instability Growth

Steven T. Zalesak (Naval Research Laboratory)

11:45 TO10 Advanced Target Designs for Direct-Drive Inertial Confinement Fusion

V. N. Goncharov, P. W. McKenty, D. D. Meyerhofer, S. Skupsky, T. J. B. Collins, P. B. Radha, T. C· Sangster (University of Rochester, Laboratory for Laser Energetics)

12:00 Lunch on own

AFTERNOON ON OWN

6:00 Dinner *Served in Terrace Room 4*

------------------------- Evening Session, Tuesday, 24 June 2003, 7:30 PM ----------------- (Y. Aglitskiy, Chair)

REVIEW TALK: (45 minutes each) **Medallion Ballroom**

TR1 Low-Energy-Density Physics at Lucent Technologies: Communication Systems Based on Optical Solitons

C. J. McKinstrie, Lucent Technologies and University of Rochester

MIXED POSTER SESSION – beginning at 8:15 PM **Lakeview Room**

TP1 Design of the Passive Shock Brekaout Diagnostic for the National Ignition Facility

V. Serlin, C· Brown, E. McLean, J. Stamper (Naval Research Laboratory), R. Atkin (Tiger Innovations), C. Duncan (Commonwealth Technology Inc.)

TP2 Damping of and Stimulation Scattering of Light Freom Ion Acoustic Waves in Collisional Multi-Species Plasma

Richard Berger (Lawrence Livermore National Laboratory), Ernest Valeo (Princeton Plasma Physics Laboratory)

TP3 Non-Local Electron Heat Flow in the Presence of Strong Collisional Heating: Effect of Non-Spherical Rosenbluth Potentials

Fathallah Alouani Bibi, Jean-Pierre Matte (INRS-EMT), Magdi Shoucri (Institut de Recherche en Electricite du Quebec)

TP4 Optical Mixing Controlled Stimulated Scattering Instabilities Using Blue and Green Crossed Beams: Experiments, Theory and Vlasov Simulations

B. B. Afeyan, M. Mardirian, K. Won, D. S. Montgomery, M. Albrecht-Marc, J. Hammer, R. K. Kirkwood, A. J. Schmitt, A. Ghizzo, P. Bertrand (Polymath Research Inc.)

TP5 A Reduced Model of Kinetic Effects Related to the Saturation of Stimulated Brillouin Scattering in Long Plasmas

L. Divol, E. A. Williams, B. I. Cohen, A. B. Langdon, B. F. Lasinski (Lawrence Livermore National Laboratory)

TP6 LPI with Polarization Smoothing and SSD on NIF

A. B. Langdon, E. A. Williams, D. E. Hinkel, S. Glenzer, S. Dixit, D. Munro, and J. Murray (Lawrence Livermore National Laboratory)

TP7 Spectroscopic Techniques for the Inference of Fuel-Pusher Mix in Spherical Implosions

D. A. Haynes, Jr., M. A. Gunderson, D. C. Wilson (Los Alamos National Laboratory), S. P. Regan (University of Rochester, Laboratory for Laser Energetics)

TP8 Gas Hydrocoupling in Indirect Drive Experiments at the Omega Laser

E. L. Dewald, S. M. Pollaine, O. L. Landen, R. E. Turner, R. J. Wallace, P. A. Amendt, K. M. Campbell, and S. H. Glenzer (Lawrence Livermore National Laboratory)

TP9 Analytical Solution for the Evolution of Rippled Planar Shock Waves in Real Materials

J. W. Bates (Naval Research Laboratory)

TP10 Measuring Spherical Harmonic Coefficients on a Sphere

S. M. Pollaine and S. W. Haan (Lawrence Livermore National Laboratory)

TP11 Equation of First Order in Time for the Ion Acoustic Wave Generated by Stimulated Brillouin Backscattering in an Inhomogeneous Flowing Plasma

D. Teychenné, D. Pesme, P. Loiseau, S. Hüller, M. Casonova, R. Sentis (CEA/DIF)

TP12 NIF Early Light Designs for Hohlraum LPI Experiments

S. R. Goldman, J. C. Fernández, D. Montgomery, B. Bezzerides, G. D. Pollak, H. X. Vu (Los Alamos National Laboratory)

Wednesday, 25 June 2003
Continental Breakfast 8:00 AM
Promenade
Morning Session Begins at 9:00 AM
Medallion Ballroom

Morning Sessions:

ORAL SESSION I ***9:00–10:15 (15 Minutes Each)*** ***D. Montgomery (Chair)***

9:00 WO1 Crossed-Beam Power Transfer and the NIF Point-Design

E. A. Williams and D. E. Hinkel (Lawrence Livermore National Laboratory)

9:15 WO2 First Experiments on NIF

R. Kauffman, G. Bonanno, P. Celliers, S. Glenzer, C. Haynam, S. Johnson, D. Kalantar, O. Landen, B. MacGowan, B. Remington, H. Robey, M. Schneider, G. Tietbohl (Lawrence Livermore National Laboratory)

9:30 WO3 Two-Dimensional *SAGE* Simulations of Polar Direct Drive on the NIF

R. S. Craxton (University of Rochester, Laboratory for Laser Energetics)

9:45 WO4 Modeling NIF Hot Halfraum Target Bahavior with ALE Rad/Hydro Codes

A. Koniges, M. Marinak, D. Hinkel, M. Schneider, D. Eder, B. MacGowan, M. Tobin (Lawrence Livermore National Laboratory)

10:00 WO5 Nonlinear Raman Scatter in NIF Targets

D. E. Hinkel and A. B. Langdon (Lawrence Livermore National Laboratory)

10:15 Coffee Break

ORAL SESSION II ***10:45–12:15 (15 Minutes Each)*** ***C. Stoeckl (Chair)***

10:45 WO6 Single Beam 2ω Laser Propagation Through Underdense C_5H_{12} Gas Bags

N. B. Meezan, K. Oades, R. M. Stevenson, G. E. Slark, L. J. Suter, M. C. Miller (Lawrence Livermore National Laboratory)

11:00 WO7 "Plan B" 2ω Ignition Hohlraums for NIF

Larry Suter, John Moody, Siegfried Glenzer, Carmen Constatine (Lawrence Livermore National Laboratory), Kevin Oades, Mark Stevenson (AWE)

11:15 WO8 Simulations of Laser-Plasma Interaction in an Early NIF Experiment

Steve Langer and Bert Still (Lawrence Livermore National Laboratory)

11:30 WO9 Effects of Plasma Composition on Green Light Backscatter, Hot Electron Production and Propagation in Underdense Plasmas

R. M. Stevenson, K. Oades, G. Slark, B. R. Thomas (AWE), L. J. Suter, R. L. Kauffman, M. Miller, S. Glenzer, J. Moody, C. Neimann (Lawrence Livermore National Laboratory), J. Grun (Naval Research Laboratory), and J. Davis (Alme & Associates)

11:45 WO10 Filamentation of Laser Beams in Inhomogeneous Plasmas

B. B. Afeyan, A. Kanaev, K. Won, and A. J. Schmitt (Polymath Research Inc and Naval Research Laboratory)

12:00 Business Meeting

12:15 Lunch – On Own

AFTERNOON ON OWN

-------------------------- Evening Session, Wednesday, 25 June 2003 ------------------------------ (S. Regan, Chair)

6:00	Banquet Reception ***Dancing Bears Lounge***
7:00	Banquet Dinner ***Terrace Room 4***
8:00	Boats and Boating in the Adirondacks *Guest Speaker: Hallie Bond, Curator, The Adirondack Museum*

Thursday, 26 June 2003
Continental Breakfast 8:00 AM
Promenade
Morning Session Begins at 9:00 AM
Medallion Ballroom

Morning Sessions:

ORAL SESSION I ***9:00–10:15 (15 Minutes Each)*** ***D. Wilson (Chair)***

9:00 THO1 Hohlraum-Driven Ignition-Relevant Double-Shell Implosion Experiments of Omega: Analysis and Interpretation

Peter Amendt, H. F. Robey, H.-S. Park, R. E. Turner, R. E. Tipton, J. L. Milovich, D. P. Rowley, R. Hibbard, H. Louis, R. Wallace (Lawrence Livermore National Laboratory), W. S. Varnum, R. G. Watt (Los Alamos National Laboratory), W. Garbett, and A. M. Dunne (AWE)

9:15 THO2 The First Spectrometry of Charged Particles From Indirect-Drive Capsule Implosions

C. K. Li, F. H. Séguin, J. A. Frenje, R. D. Petrasso (MIT, Plasma Science and Fusion Center), J. Koch, P. Amendt, S. Haan, N. Izumi (Lawrence Livermore National Laboratory)

9:30 THO3 Proton Temporal Diagnostic for ICF Experiments on OMEGA

V. Yu. Glebov, C. Stoeckl, S. Roberts, T. C. Sangster (University of Rochester, Laboratory for Laser Energetics), J. A. Frenje, R. D. Petrasso (MIT, Plasma Science and Fusion Center), R. A. Lerche, R. L. Griffith (Lawrence Livermore National Laboratory)

9:45 THO4 Measuring ρR Evolution Using a Novel Proton Temporal Diagnostic at OMEGA

J. A. Frenje, C. K. Li, F. H. Séguin, J. DeCiantis, J. R. Rygg, S. Kurebayashi, B. E. Schwartz, R. D. Petrasso (MIT, Plasma Science and Fusion Center), J. Delettrez, V. Yu. Glebov, D. D. Meyerhofer, T. C. Sangster, C. Stoeckl, J. M. Soures (University of Rochester, Laboratory for Laser Energetics)

10:00 THO5 Areal Density Asymmetries and Their Time Evolution in OMEGA Direct-Drive Implosions

F. H. Séguin, J. R. Rygg, J. A. Frenje, C. K. Li, R. D. Petrasso (MIT, Plasma Science and Fusion Center), J. A. Delettrez, J. M. Soures, V. N. Glebov, V. N. Goncharov, J. Knauer, D. D. Meyerhofer, T. C. Sangster, R. L. Keck, P. W. McKenty, F. J. Marshall, V. Smalyuk (University of Rochester, Laboratory for Laser Energetics)

10:15 Coffee Break

ORAL SESSION II ***10:45–11:45 (15 Minutes Each)*** ***A. Velikovich (Chair)***

10:45 THO6 Investigation of Shock-Coalescence Coherence in Asymmetric Direct-Drive Implosions at OMEGA

J. R. Rygg, F. H. Séguin, J. A. Frenje, C. K. Li, R. D. Petrasso (MIT, Plasma Science and Fusion Center), J. A. Delettrez, J. M. Soures, V. N. Glebov, V. N. Goncharov, J. Knauer, D. D. Meyerhofer, T. C. Sangster, P. W. McKenty, F. J. Marshall, V. Smalyuk (University of Rochester, Laboratory for Laser Energetics)

11:00 THO7 Beam Deposition Model for Energetic Electron Transport in Inertial Fusion; Part I: Theory

Wallace Manheimer and Denis Colombant (Naval Research Laboratory)

11:15 THO8 Beam Deposition Model for Energetic Electron Transport in Inertial Fusion; Part II: Initial Results

D. Colombant and W. Manheimer (Naval Research Laboratory)

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11:30 THO9 The Switching Off Of SBS Due to Magnetic Field Generation From Photon Momentum Deposition in Speckle

M. Haines (Imperial College, Blackett Laboratory)

11:45 Lunch—On Own

AFTERNOON ON OWN

6:00 Dinner *Served in Terrace Room 4*

------------------------- Evening Session, Thursday, 18 June 1998, 7:30 PM -------------------- (W. Seka, Chair)

REVIEW TALK: (45 minutes each) **Medallion Ballroom**

THR1 X-Ray Thomson Scattering on Solid Density Plasmas

S. H· Glenzer, Lawrence Livermore National Laboratory

MIXED POSTER SESSION – beginning at 8:15 PM **Lakeview Room**

THP1 Generation of Coherent THz Radiation by Intense Laser-Plasma Interactions

J. van Tilborg, C. B. Schroeder, J. Faure, C. G. R. Geddes, C. Toth, G. Fubiani, E. Esarey, and W. P. Leemans (Lawrence Berkeley National Laboratory)

THP2 Energy Absorption and Transfer for Different Target Geometries in the Fast Ignition Scheme

M· Tzoufras, C. Ren, F. S. Tsung, W. B. Mori (University of California at Los Angeles), S. Amorini, R. A. Fonseca, L. O. Silva (Instituto Superior Tecnico)

THP3 Simulations of High Intensity, Long Pulse, Planar Experiments

Jean-Pierre Matte, Fathallah Alouani Bibi (INRS-EMT), David Braun, John Edwards, Lawrence Suter (Lawrence Livermore National Laboratory)

THP4 Anomalous Plasma Collisionality

K. G. Whitney, J. W. Thornhill, J. P. Apruzese, J. Davis (Naval Research Laboratory), C. Deeney, C. A. Coverdale (Sandia National Laboratories)

THP5 Stimulated Scattering Evolution and Hot Electron Production Using Scaled Halfraum Targets at 2ω

R. M. Stevenson, K. Oades, G. Slark, B. R. Thomas (AWE), R. L. Kauffman, L. J. Suter, M. Miller, M. Schneider, D. Hinkel (Lawrence Livermore National Laboratory)

THP6 Laser Wakefield Acceleration of Auto-Self-Trapped Electrons to ~1GeV in a Plasma Channel

Frank S. Tsung, Ritesh Narang, W. B. Mori, C. Joshi, R. A. Fonseca, L. O. Silva (University of California at Los Angeles)

THP7 Simulation of Indirect Laser-Driven ICF Capsule Implosions

I. E. Golovkin, J. J. MacFarlane, R. C. Mancini, L. A. Welser, D. L. McCrorey, J. A. Koch, P. R. Woodruff (Prism Computational Sciences)

THP8 Experimental Benchmarks for Improved Simulations of Absolute Soft X-Ray Emission from Nike Targets

J. Weaver, M. Busquet, M. Klapisch, D. Colombant, U. Feldman, A. N. Mostovych, J. F. Seely, G. Holland (Naval Research Laboratory)

THP9 Linear Perturbation Computations in a Planar Ablation Flow

Carine Boudesocque-Dubois, Jean-Marie Clarisse (CEA)

THP10 Linear Stability Analysis of a Self-Similar Solution for Ablation Fronts in Inertial Confinement Fusion

Florian Abéguilé, Carine Boudesocque-Dubois, Jean-Marie Clarisse, Serge Gauthier (LMM/CEA)

THP11 Collapsing Radiative Shocks in Xenon Gas on the Omega Laser

A. B. Reighard, R. P. Drake, K. K. Dannenberg, D. J. Kremer (University of Michigan), T. S. Perry, H. A. Robey, B. A. Remington, R. J. Wallace, D. D. Ryutov, J. Greenough (Lawrence Livermore National Laboratory), J. Knauer, T. Boehly (University of Rochester, Laboratory for Laser Energetics), S. Bouquet (CEA Bruyeres), A. Calder, R. Rosner, B. Fryxell (University of Chicago), D. Arnett (University of Arizona), M. Koenig (Ecole Polytechnique)

THP12 Possible Evidence for Suppression of LPI in C_5H_{12} Plasmas by Small Amounts of Dopants

Larry Suter, John Moody, Siegfried Glenzer, N. Meezan, B. J. MacGowan (Lawrence Livermore National Laboratory), Kevin Oades, Mark Stevenson, Gary Slark (AWE)

THP13 Ion Acceleration in High Mach Number Shocks Produced by Overdense Laser-Plasma Interactions

L. O. Silva, M. Marti, J. R. Davies, R. A. Fonseca (Instito Superior Tecnico), J. Fahlen, C. Ren, F. S. Tsung, and W. B. Mori (University of California at Los Angeles)

Friday, 27 June 2003
Continental Breakfast 8:00 AM
Promenade
Morning Session Begins at 9:00 AM
Medallion Ballroom

Morning Sessions:

ORAL SESSION I ***9:00–10:30 (15 Minutes Each)*** ***D. Hinkel (Chair)***

9:00	FO1	Fast-Electron Transport in Dense Plasmas in the Context of Fast-Ignition Studies at LLE *J. Myatt, A. V. Maximov, R. W. Short, J. A. Delettrez, and C. Stoeckl (University of Rochester, Laboratory for Laser Energetics)*
9:15	FO2	Electron Heat Transport in a Cone Target and Prospects for FIREX (Fast Ignition Realization Experiment) *K. Mima, H. Azechi, H. Fujita, Y. Izawa, T. Jitsuno, T. Johzaki, Y. Kitagawa, R. Kodama, N Miyanaga, K. Nagai, H. Nagatomo, M. Nakai, H. Nishimura, T. Norimatsu, S. Sakabe, H. Shiraga, K. Shigemori, T. Takeda, K. A. Tanaka, H. Yoshida, T. Yamanaka (Osaka University, Institute of Laser Engineering)*
9:30	FO3	Transport of Relativistic Electrons for Modeling Fast Ignition in the 2-D Hydrocode *DRACO* *J. Delettrez, S. Skupsky, C. Stoeckl, and P. B. Radha (University of Rochester, Laboratory for Laser Energetics)*
9:45	FO4	Implicit PIC/Hybrid Modeling of Ultra-Intense Laser-Matter Interactions *Rodney J. Mason (Los Alamos National Laboratory)*
10:00	FO5	PIC Simulations for the First Picosecond in the Fast Ignition Scheme *C. Ren, M. A. Tzoufras, F. S. Tsung, W. B. Mori (University of California at Los Angeles), S. Amorini, R. A. Fonseca, L. O. Silva (Instituto Superior Tecnico)*
10:15	FO6	Guiding of Relativistic Laser Intensities in Preformed Plasma Channels *C. G. R. Geddes, C. Toth, J. Faure, J. van Tilborg, C. B. Schreder, B. A. Shadwick, E. Esarey, W. P. Leemans (Lawrence Berkeley National Laboratory)*
10:30		Conclusion

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Monday
23 June 2003

33st Annual Anomalous Absorption Conference
Lake Placid, New York.
June 22-27, 2003

Study of the Effect of Ion Acoustic Wave Damping on Energy Transfer Between Crossing Laser Beams in a Plasma with a Mach 1 Flow

R. K. Kirkwood, A. B. Langdon, B. I. Cohen, E. A. Williams, M. R. Dorr, J. A. Hittinger, J.D. Moody, L. Divol, C. Niemann and S.H. Glenzer,
Lawrence Livermore National Laboratory
(Prefer Oral Session)

Past experiments have demonstrated the saturation of energy transfer between two crossing beams in a flowing CH plasma when the pump and probe beam intensities were increased. The saturation was attributed to the combination of depletion of the pump in localized regions, as well as ion wave non-linearity. The two effects were not independently identifiable in the initial measurements and modeling[1]. Recently we have performed experiments in Al exploding foil plasmas in which the ion wave damping rate is dramatically lower while other plasma parameters are kept similar to the CH experiments. The strong dependence of various ion wave saturation mechanisms on ion wave damping will be used to interpret the results in Al and help identify the saturation mechanisms. When the probe beam intersects the 7 x 10^14 W/cm^2 pump beam at a point where the plasma flow is ~ Mach 1 in the correct direction to excite ion wave resonantly, we find that the probe beam is amplified relative to an experiment in which the flow is oppositely directed and the ion wave resonance is de-tuned. Experiments with probe beam intensities varying from ~ 0.3 to 0.02 times the pump beam intensity, show the measured probe amplification changes during the 1 ns time period of the interaction in all cases, consistent with the relatively narrow resonance layer moving into the interaction volume late in time. Analysis of the peak amplification observed shows that amplifications are higher in Al than in CH, and there is evidence of saturation at high probe intensity in both cases. The results will also be compared with models of ion wave non-linearity and pump depletion.

[1] R. K. Kirkwood et. al. Phys. Rev. Lett. **89**, 215003-1 (2002).

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LA-UR-03-3166

33rd Annual Anomalous Absorption Conference
Lake Placid, NY, June 22nd – 27th, 2003

Observation of Multiple Steps of Langmuir Decay Instability in Trident Single Hot Spot Experiments

David S. Montgomery, John L. Kline, Ronald J. Focia[1]

Los Alamos National Laboratory
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Experiments using the single hot spot technique have observed a cascade of up to five unambiguous steps of Langmuir Decay Instability (LDI) driven by the daughter Langmuir wave from stimulated Raman backscattering (SRS). The experiments are performed using the 527-nm diffraction-limited beam at Trident to drive backward SRS in a CH plasma with $T_e \approx 500 - 700$ eV, and $k\lambda_D \leq 0.3$ for the SRS daughter wave. Waves co-propagating with the SRS daughter Langmuir wave (Stokes) are detected using collective Thomson scattering from a 351-nm probe beam. Waves in the counter-propagating direction (anti-Stokes) are also detected, and their detection is attributed to frequency-upshifted self-Thomson scattering of the 527-nm interaction beam from counter-propagating Langmuir waves with a finite $k_\perp$. The Thomson scattering detection provides both time-resolved spectra and angle-resolved spectra so that the (ω, k) dispersion may be determined. The (ω, k) spacing of the Stokes Langmuir waves is consistent with LDI kinematics, and the number of detected waves is consistent with the angular acceptance of the 351-nm Thomson scattering system. The frequency spacing of the anti-Stokes Langmuir waves are consistent with LDI, but their k-spectra and the number of waves detected can only be understood if the 527-nm single hot spot beam, acting here as the Thomson probe, undergoes some self-focusing to decrease its effective f-number.

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

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33rd Annual Anomalous Absorption Conference
Lake Placid, NY, June 22nd – 27th, 2003

Observation of a Transition from Fluid to Kinetic Nonlinearities for Langmuir Waves Driven by Stimulated Raman Scattering

J.L. Kline, D.S. Montgomery, B. Bezzerides, J.A. Cobble, D. F. DuBois
R.P. Johnson, H.A. Rose, and H.X. Vu

Los Alamos National Laboratory

Single hot spot experiments provide a means to carefully investigate the nonlinear behavior of Langmuir waves driven by stimulated Raman scattering (SRS). An f/4.5 lens is used to focus a λ = 527-nm interaction beam to a nearly-diffraction-limited spot with a peak intensity 10^{15} – 10^{16} W/cm^2. The focal spot size (fλ ~ 2.5 µm, $7f^2\lambda$ ~ 80 µm) is much smaller than the background plasma gradient-scale-lengths, which produces extremely homogeneous initial conditions within the interaction volume. The single hot spot beam drives SRS in a preformed CH plasma with T_e ~ 700 eV and $0.025 \leq n_e/n_{cr} \leq 0.07$ ($0.27 \leq k\lambda_d \leq 0.38$). Thomson scattering was used to detect the associated Langmuir wave spectrum. At higher densities, multiple waves were observed consistent with Langmuir decay instability (LDI) cascade. At lower densities, a frequency-broadened spectrum was observed consistent with frequency detuning by electron trapping. The observed spectral broadening has been compared to a simple theoretical model for frequency broadening by electron trapping, and the trend with $k\lambda_d$ is consistent with the model. The measurements show the transition between the fluid and kinetic regimes occurs at $k\lambda_d$ ~ 0.32 which is greater than 1-D collisionless theory predicts.

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

33^{rd} Annual Anomalous Absorption Conference
Hilton Lake Placid Resort, Lake Placid, NY
22-27 July, 2003

Kinetic Electrostatic Electron Nonlinear Waves: Their Generation, Long Time Evolution and Interactions

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T. W. JOHNSTON[2], A. GHIZZO[3], P. BERTRAND[3]

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We present results using 1D Vlasov-Poisson simulations and theory on Kinetic Electrostatic Electron Nonlinear (KEEN) waves driven by the ponderomotive force generated by two counterpropagating electromagnetic waves (EMW) in a hot uniform plasma. We study the evolution and stability of such modes long after the driving fields are turned off.

We find that for a wide range of frequencies at a given driver wavenumber, and for sufficiently large drive amplitudes, stable long lived nonstationary states persist. These nonlinear modes have no linear theory limit nor a fluid theory one. Strong modifications of the electron velocity distribution function (e^- VDF) are required before they can be *self-consistently* formed starting with a Maxwellian. The number of spatial and temporal harmonics which are essential and unignorable elements of these coherent states is at least three. The response of the plasma at the harmonics of the driver field are phase locked much before the e^- VDF's nonoscillatory component reaches its steady state. Time asymptotically, we observe that the spatial harmonics of the density or electrc field have set relative average amplitudes. These ratios constitute an unambiguous observable by which to identify a given KEEN wave.

The frequency ranges in which KEEN waves can be excited is not limited to electron acoustic waves (EAWs), which were recently discovered experimentally by Montgomery et al., and postulated theoretically by Schamel, Dorning et al. and Rose et al., among others [See the next paper by Johnston and Afeyan for further details]. The large band gap that was thought to exist between EPWs (electron plasma waves) and EAWs, when these linear or very weakly nonlinear theories were the currencies of the analysis, may be populated instead by KEEN waves.

We compare simulation results to a truncated set of "coupled modes in phase space" theory and show how the zero order or non-oscillatory component of the distribution function, once the KEEN wave is formed, can be used to predict the ratio of mode amplitudes between the harmonics that make up KEEN wave nonstationary final states. We will also show how two of these waves, driven staggered in time, at two distinct frequencies, interact and fuse together *differently* depending on the order in which they are driven. Additional experimental signatures will be discussed.

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PREFER ORAL SESSION

33rd Anomalous Absorption Conference, Lake Placid NY June 22-27 2003

Electron Acoustic Waves and the Search for a Truly Self-Consistent Large-Amplitude Plasma Response

T.W. Johnston[1], B.B. Afeyan[2]

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We examine theories that have been invoked in connection with the recent experimental observations by Montgomery et al. [1] on Electron Acoustic Waves (EAW) and their stimulated scatter (SEAS) in laser-plasma interactions. We begin with the BGK [2] like modes studied by Schamel [3] and Krapchev [4] and then by Holloway and Dorning [5] referred to as undamped plasma waves, recalling and examining their relationship to the long standing problem of nonlinear (and long time behavior of) Landau damping Brunetti et al.[6] and nonlinear dispersion relations which arise due to so called hole equilibria. After some remarks on their superpositions, as studied by Buchanan and Dorning [7] (also discussed by Brunetti et al. [6]) on the traveling wave solutions in the same setting found by Lancellotti and Dorning [8], we relate these studies to those presented by Rose and Russell [9] as a self-consistent trapping model of driven electron plasma waves (EPW) which is related to the interpretation used in [1]. Finally, we compare and contrast these studies to the recent findings of Afeyan et al. [9] on Kinetic Electrostatic Electron Nonlinear (KEEN) waves.

[1] D.S. Montgomery et al., PRL **87**, 155001 (2001)
[2] I.B. Bernstein et al., Phys.Rev. **108**, 546 (1957)
[3] H. Schamel, Phys. Scr. **20**, 336 (1979), Phys. Rep. **140**, 161 (1986), Phys. Plasmas **7**, 4831 (2000)
[4] V.B. Krapchev, PRL **42**, 497 (1979), also with A.K. Ram, Phys. Rev. A, **22**, 1229 (1980)
[5] J.P. Holloway and J.J. Dorning, Phys. Lett. A **138**, 279 (1989) and Phys. Rev. **A 44**, 3856 (1991)
[6] M. Brunetti, et al., Phys. Rev. **E** 62, 4109 (2000)
[7] M. Buchanan and J.J. Dorning, PRL **70**, 3732 (1993), Phys. Rev. **E 50**, 1465 (1994) and Phys. Rev. **E 52**, 3015 (1995)
[8] C. Lancellotti and J.J. Dorning, J. Math. Phys. **40**, 3895 (1999)
[9] H. A. Rose and D. A. Russell, Phys. Plasmas **8**, 4784 (2001)
[10] B. B. Afeyan et al., manuscript in preparation and preceding talk.

The work of BBA was performed under the auspices of the U. S. Department of Energy under grant number DE-FG03-NA00059.

Prefer Oral Session BEFORE THURSDAY and IMMEDIATELY FOLLOWING Afeyan et al. *(Kinetic Electrostatic Electron Nonlinear Waves: Generation, Long Time Evolution and Interaction Physics))*

Nonlinear Propagation of Crossing Laser Beams in Direct-Drive Target Plasmas

A. V. Maximov, J. Myatt, W. Seka, and R. W. Short

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In direct-drive inertial confinement fusion experiments on the OMEGA laser system, targets are irradiated by multiple laser beams, crossing at various angles. Incident laser beams are usually randomized in space (through distributed phase plates) and in time (through smoothing by spectral dispersion). The nonlinear propagation of crossing randomized laser beams in the plasmas of direct-drive targets has been studied using the non-paraxial model of light propagation.

In the plasmas characteristic of OMEGA experiments, the strongest interaction between crossing laser beams through ion-acoustic density perturbations occurs at higher plasma densities close to the critical-density surface. Our model allows the calculation of the angular distribution and the correlation properties of laser radiation in the near-critical-surface region. The influence of the nonlinear interaction between crossing beams on laser absorption is studied.

Crossed-beam irradiation also determines the characteristics of the two-plasmon-decay (TPD) instability in the region near quarter-critical density. We demonstrate the difference between the TPD instability driven by randomized crossing beams from the usual three-wave TPD model.

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Prefer oral presentation

Two-Plasmon Decay, Overlapping Beams, and Electron-Acoustic Waves

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Experimental observations of two-plasmon decay (TPD) in multibeam experiments on OMEGA have shown that in general it is the total, overlapped beam intensity that determines the level of TPD activity, as measured by the hard x-ray signal.[1] This is in contradiction to conventional theory, which predicts that for the parameters of these experiments pumps differing in angle by more than a few degrees should not resonantly drive the same decay plasmons. This is a consequence of the fact that when the decay wave vector corresponding to the change in pump angle is substituted into the Bohm–Gross dispersion relation, the resulting frequency mismatch exceeds the TPD growth rate. To account for these results, it appears necessary to introduce new modes of the plasma, not satisfying the Bohm–Gross relation. This talk proposes that these new modes are related to electron-acoustic waves.[2] These linear modes are introduced as a consequence of local flattening of the distribution function in velocity space. This flattening in turn results from the beat between a second pump wave and one of the resonant plasma waves produced by the TPD decay of the first pump. The ponderomotive force of this beat flattens the distribution function near the beat wave phase velocity through a process analogous to the Landau damping of a plasma wave. The new mode introduced by this flattening couples the second pump to the resonant plasma wave produced by the first pump, so that both pumps can now drive this wave. A similar model can be applied in the case of multiple pumps. In general the new modes will not exactly satisfy the electron-acoustic dispersion relation, and so will have a finite damping. The effects of these modes on TPD thresholds and growth rates will be discussed.

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1. C. Stoeckl *et al.*, Bull. Am. Phys. Soc. 47, 288 (2002).
2. T. H. Stix, *The Theory of Plasma Waves* (McGraw-Hill, New York, 1962), p. 218.

Prefer oral presentation

Investigation of the TPD instability Using Thomson Scattering.

W. Seka, H. Baldis,[2] S. Depierreux,[3] S. R. Craxton, S. P. Regan,
C. Stoeckl, R. W. Short A. Maximov, J. Myatt, and R.E. Bahr

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Abstract

Recent long-scale-length plasma interaction experiments on OMEGA focused on Thomson scattering from electron plasma waves generated by the TPD instability. Several different scattering configurations permitted scattering off plasma waves from decays with $0.14 > k\lambda_{De} > 0.3$. Single and multiple interaction beams experiments showed that the plasma wave amplitudes scale nonlinearly with the number of interaction beams present. The experiments also showed that Landau damping prevents the generation of plasma waves with $k\lambda_{De} > 0.3$ thus suppressing the TPD instability involving these waves. In addition, the Thomson scattering data allowed obtaining a rough estimate of the plasma wave spectrum generated by this instability.

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.

Experimental Scalings for the Two-Plasmon-Decay Instability

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Preheat from energetic electrons produced by the two-plasmon decay (TPD) instability may prevent the requisite conditions for ignition from being attained in laser direct-drive inertial confinement fusion (ICF). Since the theoretical analysis of realistic experiments using multiple beams with randomized phase and spectral bandwidth is very difficult, and not well developed, a series of experiments have been performed to find the intensity scaling of the energetic electron production under typical ICF conditions.

The TPD instability was studied by measuring hard x rays in the range of 50 to 500 keV generated by the energetic electrons, which are recorded in a four-channel, time-resolved spectrometer. The optical signature of TPD at $3\omega/2$ of the incident laser was measured with streaked optical spectroscopy.

A wide variety of parameters were explored in both spherical and planar geometry. The number, intensity, and angle of multiple overlapping beams was varied in planar geometry, showing that TPD scales predominantly with the total overlapped intensity. Experiments with different spectral bandwidths [smoothing by spectral dispersion (SSD)] in spherical geometry showed a small effect on the TPD instability. The effect of the electron-density scale length was probed in spherical geometry using different materials.

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Prefer oral session

Thomson scattering analysis of SRS / SBS interplay in sub-picosecond time-scale

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Laser-plasma experiments using short laser pulses can significantly help in understanding the saturation mechanisms of stimulated Raman (SRS) and Brillouin (SBS) scatterings because (i) the laser pulse duration and the growth time of the parametric instabilities are of the same order of magnitude, and (ii) the calculation time needed by kinetic codes is compatible with the simulation of a whole experiment. Moreover, the quick change of the kinetic features of the irradiated plasmas most probably plays a major role in these saturation mechanisms. They should be experimentally studied with the help of picosecond resolution optical diagnostics which are yet marginally available. Thus, sub-picosecond Thomson analysis could become a promising way to explore these topics.

In this presentation, preliminary results will be shown from experiments performed in pre-ionized He plasmas using the 100-TW laser facilities (LULI-Ecole Polytechnique). A 3ω, short (300 fs) pulse diagnostic probed the electron plasma wave (EPW) and the ion acoustic wave (IAW) respectively driven by stimulated Raman and Brillouin backscatterings generated in the 1.5 ps, ω laser interaction. Space-resolved and time-resolved Thomson spectra have been obtained, from the rising part of the main pulse to the final quenching of the EPW/IAW. Regarding the front part of the plasma where SRS and SBS are predominant, it is shown that the EPW first develops ; about 2 ps later, the IAW starts to grow in the same area, however less rapidly. As the IAW reaches its saturation level, the EPW suddenly disappears, while IAW can be measured several tens of picosecond after the main pulse.

Space-resolved Thomson spectra along the laser propagation have also been obtained, showing wider EPW spectra inside the He plasma. These preliminary results will be discussed in relation with the strong heating of the plasma that may follow the EPW/IAW saturation in the focal spot volume.

Oral presentation preferred.

Quasi-linear theory of non-local magnetic field generation in laser-plasmas

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Recently a new magnetic field generation mechanism in laser-plasmas was reported [1]. This non-local mechanism, first seen in FP simulations, works in a regime that is intermediate between completely collisional (e.g. $\nabla n_e \times \nabla T_e$) and collisionless (e.g. Weibel and ponderomotive mechanisms). Here we present a new, analytic model of this non-local B-field source.

Previously, 2D Fokker-Planck simulations using IMPACT [1] showed that a strong magnetic field spontaneously arises when a uniform density plasma is strongly heated by non-uniform laser-irradiation. Since the electron pressure was isotropic the B-field source was clearly not a Weibel type mechanism, as is seen when beams of fast electrons are present. The $\nabla n_e \times \nabla T_e$ mechanism, which is based on classical transport and uses the local approximation (i.e. $f_0 = f_M$, where f_0 is the isotropic part of the distribution), could not explain these fields either.

Instead the B-fields were attributed to a non-local analogue of $\nabla n_e \times \nabla T_e$ that arises when non-local transport distorts f_0 from Maxwellian. A simplified model that could predict the non-local B-field generated by arbitrary initial T_e, n_e and Z profiles (n_e & Z non-evolving), with f_0 starting as a single temperature Maxwellian, was presented at last year's conference. It showed that $\ddot{B} \propto -\nabla T \times \nabla(\nabla^2 T)$ and $\ddot{B} \propto (\nabla Z \times \nabla T)\nabla^2 T$ act as non-local sources.

The new model employs a quasi-linear like approach and complements & improves over the previous model in several important ways: (1) it is valid over a much longer timescale, and (2) it includes thermalisation by e-e collisions. The model elucidates several features of the B-field mechanism seen in the FP simulations. For a pair of Fourier modes δT_1, δT_2 to generate non-local B, $\underline{k}_1$ and $\underline{k}_2$ must be non-parallel and of different magnitude. Crucially, $k > 2\pi/100\lambda_{ei}$ (where λ_{ei} is the mean-free-path of a thermal electron) is required for the mechanism to "turn on". Finally it highlights the role of e-e collisions.

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

This work is funded by the EPSRC of the UK.

Plasma induced laser beam smoothing: how do we understand it

Thursday

V. T. Tikhonchuk

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Recent years have brought us more understanding of the physical processes that control the propagation of the laser beams in plasmas. In particular the temporal beam smoothing has been measured and characterized in great details with various experimental techniques at relatively small laser energies at LULI. We will review and analyze these results from the point of view of applications to the future large-scale experiments at NIF and LMJ.

We have been using a recently developed three-dimensional laser-plasma interaction code PARAX-MPL to investigate fundamental physics issues related to plasma-induced laser beam smoothing effects. The plasma response in this code accounts for nonlinear density perturbations, plasma flow velocity and nonlocal thermal transport in the plane perpendicular to the laser beam axis. Two typical configurations have been considered: mono-speckle and multi-speckle incident laser beams.

Mono-speckle simulations are necessary for the understanding of formation and stability of laser filaments, their long-term behavior and the characteristic temporal and spatial scales involved. In our simulations the hose-like instability has been identified as the dominant mechanism of plasma smoothing effect at sufficiently high laser intensities. A long time scale dynamics of this instability is responsible for the self-supported, non-linear oscillations of the laser speckle that lead to spectral and angular spreading of the transmitted light. We will consider the coherent properties of the transmitted light and their variations in function of the incident laser intensity and plasma parameters. The effect of temporal beam smoothing due to the filament instability has been verified in multi-speckle simulations and have been compared with recent experiments.

The temporal beam smoothing has also been observed well below the self-focusing threshold. This is due to the multiple scattering of the laser beam off the self-induced density fluctuations. This effect cannot be reproduced in single-speckle calculations. It requires a multi-speckle incident beam and a sufficiently long plasma. We will discuss the physical backgrounds of temporal beam smoothing and their manifestations in experiments.

Electron heating effects on the generation of intense short light pulses by backward Raman amplification. R.L. Berger, D.S. Clark, E.J. Valeo, and N.J. Fisch

In the backward Raman amplification process for producing short intense laser pulses, a moderate intensity pump laser propagates across a pre-ionized plasma before a short (<100fs) seed is launched into the plasma just as the front of the pump exits. During this interval, the pump is subject to the usual instabilities that plague ICF. These considerations lead to plasma and laser parameters, for example, L = 7mm, T_e =50eV, n_e = .007n_c, Z=2, and $I_l = 5.5\times10^{13}$ W/cm^2 for a laser with wavelength λ_0 =1.053μm. The pump is weakly absorbed by the sub-critical density plasma and heats the electrons. Helium and hydrogen ions form the plasmas of choice for which inverse bremsstrahlung is as weak as it can be. In our example, the temperature increases from 50eV to 115 eV over the 45 ps during which the pump and seed cross the 7mm plasma and interact. For 50eV, $k\lambda_{de}$ = .23 where $k=2k_0 =4\pi/\lambda_0$ for which value Landau damping is on the edge of being important. When the temperature doubles, it is important. The temperature increases more where the pump enters the plasma and heats the plasma longer and is smallest at the seed entrance. Two possibly important effects from the electron heating that reduce the amplification of Langmuir wave noise are the temperature gradient and the increased damping of the plasma wave. Although it is a stabilizing effect, we find the temperature gradient is not enough by itself to stabilize the growth from noise.

If carefully controlled the increased damping can help control the premature depletion of the laser pump energy by keeping the spontaneous SRS below the absolute threshold. Then chirping of the pump frequency or density gradients can be designed to control spontaneous SRS. We will show examples. These estimates assume that the electron distribution retains a Maxwell-Boltzmann shape during the collisional heating. At 40 eV, Z=2, and .007n_c, the electron-electron scattering relaxation time is 2ps and the ratio of the heating rate to this relaxation rate, $Z(v_0/v_e)^2$ ~0.4. At 100eV, the relaxation rate is 7ps but $Z(v_0/v_e)^2$ ~0.2. We will also show when heating leads to nonMaxwell-Boltzmann distributions for which the Langmuir wave damping would be less than used in our fluid simulations.

Measurements of Laser Imprint on Planar Plastic Targets Irradiated by the Nike Laser.

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Abstract

Accurate quantitative simulations of laser imprint are important in predicting performance of direct-drive ICF targets. In order to benchmark such simulations, we are carrying out experiments on imprint on planar plastic targets under controlled laser conditions, such as the uniformity of the foot of the laser pulse and the bandwidth for induced special incoherence (ISI) smoothing. Measurements of the resulting Raleigh-Taylor amplified areal mass non-uniformity are made by face-on x-ray radiography using Bragg reflection from a curved crystal coupled to an x-ray streak camera. We will present the experimental results and comparisons with 2D simulations using FAST hydrocode.

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

Prefer Poster

Relationship of secondary nuclear production to implosion characteristics at OMEGA

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Ratios of secondary neutron (or proton) yield to primary neutron yield (Y_{2n}/Y_{1n} or Y_{2p}/Y_{1n}) have widely been used to infer fuel areal density (ρR_{fuel}) of D_2 filled inertial confinement fusion capsules for both direct-drive and indirect-drive experiments. Two simple models, hot-spot and uniform models, are commonly used to relate Y_{2n}/Y_{1n} or Y_{2p}/Y_{1n} to ρR_{fuel}. However, values inferred from secondary neutrons have often been larger than values from secondary protons for medium to high ρR_{fuel} capsules (thick, ~ 20 μm, CH shell and cryogenic capsules which result in ρR_{fuel} ~ 10 to 50 mg/cm^2 inferred by secondary neutrons). Saturation of secondary proton yield due to total energy loss of ^3He in the fuel, non-linear temperature dependence of secondary neutron yield, and limitations of models being used are thought to cause the disagreement of inferred ρR_{fuel}. To test the secondary nuclear processes at the high temperature and low ρR_{fuel} limit where the above effects are negligible, several thin-shell (2.1 to 3.3 μm SiO_2) capsules were imploded in recent experiments at the 60-beam OMEGA laser facility at the University of Rochester. Results from these experiments show that proton inferred values of ρR_{fuel} agree better with neutron inferred values for thin-shell implosions than for thick-shell and cryogenic implosions. Monte Carlo code was developed and various radial profiles of temperature and density were used to study profile effects on primary and secondary nuclear production. In addition, spectra of secondary protons from the Monte Carlo simulation were compared with measured spectra to study structures within the spectra.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300 and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

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A poster presentation is preferred.

Proton Core Imaging Spectroscopy on OMEGA Implosions

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Multiple pinhole cameras are being used to image the burn regions in implosions of both thin (~2 μm-glass) and thick (~20 μm-CH) shell capsules on OMEGA. Because the pinholes are generally much larger than the burn region, information about the proton source (i.e. size, shape, and symmetry) can be extracted from the "penumbra" of the resulting images. Capsules with D^3He and DD fills have been studied with Proton Core Imaging Spectroscopy (PCIS). For thin-shell capsules, experimental differences in the burn regions between DD and D^3He reactions will be explored, contrasted, and compared to 1-D calculations. Particularly intriguing is the situation for thick shell implosions. At first shock coalescence, the escaping charged particles sample a relatively small ρR. At bang time (a few hundred ps after shock coalescence), however, only the energetic 14.7-MeV protons escape, since they sample a much larger ρR (~70 mg/cm^2). Comparisons of the shock and compression burn regions will be made.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300 and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

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A poster presentation is preferred.

Strong shock wave and areal mass oscillations associated with impulsive loading of planar laser targets

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When a rippled surface of a planar target is irradiated with a short (sub-nanosecond) laser pulse, the shock wave launched into the target and the mass distribution of the shocked plasma will oscillate. These oscillations are found to be surprisingly strong compared, for example, to the case when the laser radiation is not turned off but rather keeps pushing the shock wave into the target. Being stronger than the areal mass oscillations due to ablative Richtmyer-Meshkov instability and feedout in planar targets, which have recently been observed at NRL [1], these oscillations should therefore be directly observable with the same diagnostic technique.

Irradiation of a target with a short laser pulse represents a particular case of an *impulsive loading*, a fast release of finite energy in a thin layer near the surface of a target. Renewed interest to the impulsive loading in the area of direct-drive laser fusion is due to the recent proposals of using a short pulse prior to the drive pulse to make the target more resistant to laser imprint and Rayleigh-Taylor growth [2]. Impulsive loading produces a shock wave that propagates into the target and is immediately followed by an expansion wave, which gradually reduces the shock strength. If the irradiated surface is rippled, then, while the shock wave propagates through the target, its modulation amplitude grows, exceeding the initial ripple amplitude by a factor of 2 or more. The oscillating areal mass reaches the peak values that exceed the initial mass modulation amplitude (density times ripple height) by a factor of 5-7 or more, and reverses its phase several times after the laser pulse is over. The oscillatory growth is more pronounced in fluids with higher shock compressibility and is probably related to the Vishniac's instability of a blast wave [3]. Frequency of the oscillations is determined by the speed of sound in the shocked material, and could be used as a tuning fork to probe its equation of state. The analytical theory and numerical simulations describing such oscillations are reported, and the opportunities available for their experimental observation are discussed.

This work was supported by the U.S. Department of Energy, Defense Programs.

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Fine-tuning the laser shaping pulse for imprint reduction

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In our previous work [1] we have introduced the principle of Laser Shaping Pulse (LSP). Namely, dynamically producing a graded density profile with a short laser "shaping" pulse irradiating a target prior to the drive pulse. For a target with a low-density foam on top of a solid plastic payload, we have demonstrated in our simulations [1,2] that the LSP could be effective in smoothing out the laser beam non-uniformities imprinted into a laser-accelerated target as an alternative to using a target with a tailored density profile, which was shown to be very imprint-resistant [3], but is difficult to manufacture. Moreover, the shaping of the target adiabat produced by the LSP, or the short "picket" pulse preceding the drive pulse (the outer and inner layers of the target are set at high and low adiabat, respectively), was shown to slow down the RT instability growth [4] in the target accelerated by the drive pulse. However, the LSP is seen to induce sonic oscillations in the shocked plasma, which pre-amplify the mass variation amplitude. This causes the LSP to suppress imprint less effectively than a target with a pre-fabricated tailored density profile.

In this work we investigate options to minimize the effect that sonic oscillations induced by the LSP have on laser imprint reduction. This could be done by the proper choice of the target foam layer, LSP as well as the drive pulse parameters, and timing.

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

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Investigations into the Saturation and Control of Laser Plasma Instabilities

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Some mechanisms for the saturation and control of laser-driven plasma instabilities are explored. Particular attention is given to the effects of electron trapping in ion sound waves on stimulated Brillouin scattering (SBS) and on the cross talk between SBS and stimulated Raman scattering (SRS). We also consider some multi-dimensional effects, such as nonlinear Landau damping of ion waves on the ions and long wavelength density modulations due to ponderomotive and thermal filamentation of laser light and ponderomotive filamentation of electron plasma waves. For example, thermal filamentation is a candidate for explaining the low levels of SRS observed in experiments with Kr and Xe targets irradiated with both .35μm and .53μm light.

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

Comparison of Full PIC and Reduced PIC Results for Low Intensity Laser-Plasma Interactions

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Unraveling the combination of nonlinear yet subtle kinetic physics that saturates stimulated Raman scattering (SRS) under NIF type conditions is a great challenge. One key tool needed to meet this challenge are fully kinetic simulation models. The hope is that insight gleaned from fully kinetic models can be integrated into nonlinear fluid codes. Currently there are two types of kinetic models, full PIC and reduced PIC, where the laser's frequency is averaged out. Recently, results from reduced PIC [H. X. Vu *et al.*, PRL **86**, 4306 (2001)] indicated that backward SRS (BSRS) saturated at higher than expected levels due to a reduction in the Landau damping rate from particle trapping. The trapping leads to a nonlinear frequency shift which eventually detunes the BSRS in combination with the Langmuir decay instability (LDI). There has been little work using full PIC models to study this physics due to the belief that such codes would be prohibitively noisy and expensive with regard to computer time. We report on preliminary full PIC results using the codes OSIRIS.framework and ZOHAR. The preliminary results show both similarities and differences with the published reduced PIC results. In the full PIC simulations, the Langmuir wave spectrum is broader and the backscatter bursts appear broader with a longer period for recurrence. The electron distribution flattens and LDI does occur.

Work supported by DOE & NSF.

PARTICLE-IN-CELL SIMULATIONS OF THE TWO PLASMON DECAY INSTABILITY

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A particle-in-cell code (OSIRIS) is used to investigate the linear and nonlinear evolution of the two-plasmon decay instability in a nonuniform density profile. Our studies show good agreement between the simulation and linear inhomogeneous plasma theory by Afeyan et al. (Phys. Plas. **4**, 3827, 1997.) By varying the lateral width of the laser drive, as would occur in a laser hot spot, for example, the two-plasmon decay instability can be controlled and even suppressed and our simulations have verified this. As the simulation progress, the plasmons will accelerate electrons, some of which are relativistic. The temperature of the fast electrons appears to follows Coffey's wave breaking prediction (T. Coffey, Phys. Fl. **14**, 1402, 1972.) We wish to understand the fast electrons' role in the saturation and recurrence of the two-plasmon instability. Ion effects will be included. On a longer timescale, the nonlinear interaction of plasmons can move ions and subsequently change the saturation level and the temperature of the hot electrons.

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MP10

A magnetic recoil spectrometer (MRS) for ρR_{fuel} and T_i measurements of implosions at OMEGA and the NIF

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A method to determine ρR_{fuel} of cryogenic deuterium-tritium (DT) plasmas is to measure the energy spectrum and yield of elastically scattered primary neutrons. As is the case for complementary methods to measure ρR_{fuel} [C. K. Li *et al*, Phys. Plasmas **8**, 4902 (2001)], minimizing the effect of the background is critical for successful implementation. To accomplish this, a novel spectrometer for measurements of neutrons has been designed for OMEGA and the NIF. Scattered neutrons in the energy range (7-10 MeV) will be used to measure ρR_{fuel}, while primary neutrons will be used to measure T_i and perform final characterization of the spectrometer. The instrument is based on a magnetic spectrometer with a conversion foil for production of charged particles at nearly forward scattered angles. In its initial, and perhaps final, phase of implementation, a thin CH-foil in combination with CR-39 track detectors positioned in the focal plane of the spectrometer will be used to detect recoil protons, produced by 14.1-MeV primary neutrons, with high spatial resolution. The CR-39, operated in coincidence mode, will facilitate a highly accurate ρR_{fuel} and T_i measurements, and accurate energy calibration of the system. In the later implementation, current mode detectors, such as CVD-strip detectors or scintillators, might be used for detection of deuteron recoils for ρR_{fuel} measurements. The spectrometer has a large dynamic range (>10^6), and can operate at yields as low as 10^{12}. This will allow ρR_{fuel} measurements of warm and cryo DT targets at OMEGA, and fizzle and ignited cryo DT targets at the NIF. Using LASNEX and neutron transport calculations, the signal-to-noise (S/N) ratio is estimated to be of the order 100 for measurements of cryo DT targets at OMEGA and the NIF, irrespective detection scheme.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy (contract No. W-7405-ENG-48 with the University of California Lawrence Livermore National Laboratory, Grant number DE-FG03-99DP00300, and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

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Quantitative Comparison Between Reduced-Description Particle-in-Cell (RPIC) and full PIC Simulations of Laser-Plasma Instabilities.

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RPIC is a reduced-description particle-in-cell code designed to investigate laser-plasma instabilities in physical systems with vastly-different time scales prevalent under Inertial Confinement Fusion (ICF) conditions [1]. Such time scales include the laser, Langmuir, and ion acoustic time scales. In past literature, laser-plasma instability phenomena involving these disparate scales have mostly been studied with the extended Zakharov model. Recently, comparisons between the extended Zakharov model and the RPIC model were presented in a series of papers, Ref. [2-4], in which quantitative agreement between these two models are obtained in the fluid and quasi-linear regime. However, in the kinetic regime where electron and/or ion trapping is important, significant differences were found. These findings enunciate the importance for accurate modeling of kinetic processes such as trapping.

The RPIC model itself has some limitations, such as, the frequency harmonics of Langmuir waves are neglected. Our goal is two fold in comparing RPIC with full PIC. First, the various advantages of RPIC over full PIC will be quantitatively assessed, e.g., number of particle/cell required for similar noise spectra. Second, it is expected that for sufficiently strong laser drives, RPIC may not capture laser-plasma instability physics accurately due to the lack of frequency harmonics in the Langmuir waves. We would like to establish the regime of validity for RPIC, and to assess quantitatively if the physical regimes where RPIC fails is of interest to the conventional ICF indirect drive implosion scheme. Our current study is confined to one spatial dimension.

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MP12

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Measurement of the absolute hohlraum wall albedo under ignition foot drive conditions

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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 are approximately 80-100 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 helps to determine the symmetry of the radiation pressure 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 done to measure the absolute wall albedo of hohlraums made from various elements or mixtures of elements. In particular we measure the albedo at 80-100 eV of hohlraums made from Au, U (alloyed with Nb), and a mixture (or "cocktail") of U, Nb, Au, and Dy. In these experiments, we use a laser-heated primary hohlraum to heat a secondary hohlraum and then infer the albedo from the re-emitted radiation in the secondary hohlraum, which is measured with a broadband soft x-ray spectrometer, Dante, and with photo-conductor detectors (PCDs). In this experiment the flux incident upon and re-emitted from the secondary hohlraum wall are measured by the same instrument, resulting in a measurement error in the albedo of only +/- 0.05.

We find that measured albedos for the Au and cocktail hohlraums agree quite well with radiation hydrodynamics modeling that uses opacities from the super transition array (STA) model. This is significant because the capsule symmetry calculations that were used to set the NIF laser power imbalance specifications used Au albedos calculated using the XSN average-atom model, which significantly underestimates the albedo for Au at radiation temperatures that are characteristic of the foot of an indirect drive ignition pulse (80-100 eV). Longer duration experiments using the NIF Early Light (NEL) laser are proposed that could improve the accuracy of this type of experiment.

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Fokker-Planck Calculation in the Direct-Drive NIF Design

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We have studied the nonlocal electron transport in the laser implosion. The design of NIF direct-drive scheme requires both of the higher intense laser irradiation up to 10^{15} W/cm^2 and a lower isentrope implosion [1], where preheating the shell is crucial issue for the implosion performances. To estimate the thermonuclear gain accurately, we have to consider the nonlocal electron transport in NIF direct condition. To calculate the implosion with NIF direct-drive scheme, we use the Fokker-Planck code combined with the 1-D Lagrangian hydrodynamic code LILAC. We found that the time dependent flux-limiter is required for the accurate estimation of the electron heat flux at the critical surface as well as the current experimental implosion. However we have not observed the direct preheating the ablation surface caused by the fast electron. Also, the thermonuclear gain obtained by the Fokker-Planck model is same to that with Spitzer-Harm calculation in LILAC simulation. From these comparison of FP with the flux-limited SH model, we found the robustness of the current NIF direct design.

Reference:

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Poster is preferred.

In the presentation, the first author will be replaced by co-author as a speaker.

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Tuesday 24 June 2003

TO1

Hydrodynamic stability of indirectly driven LMJ capsules

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During the capsule implosion in Inertial Confinement Fusion, the perturbations on the target, seeded by several sources of non uniformity, grow because of the hydrodynamic instabilities and can reduce the target yield. Numerical simulations are the only way to investigate completely such a complex flow. In indirect drive, the most important source of non uniformity in the high modes range is the surface roughness of the different interfaces of the capsule. We will present detailed ALE simulations of multimode perturbed capsules done with the two-dimensional hydro-rad code FCI2. To get confidence in our stability analysis, it is compulsory to have a strong coupling between theoretical studies and computations. We have then developed a weakly non linear model for the ablation front instability. This model is based on the sharp boundary model of Masse and Clavin, where density and thermal conductivities are assumed to be constant on both sides of the isotherm modeling the ablation front. This model will be discussed and compared to simulations in the planar geometry.

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TO2

On the Bell–Plesset Effects: The Effects of Uniform Compression and Geometrical Convergence on the Classical Rayleigh–Taylor Instability

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The classical Rayleigh–Taylor (RT) instability of an accelerating fluid interface is examined considering the effects of compression and geometrical convergence. Both effects occur in the implosion of inertial confinement fusion capsules. We consider incompressible perturbations of an interface separating two homogeneous compressible fluid layers of different mass densities. Planar, cylindrical, and spherical interfaces are considered. The formulation presented, based upon the perturbation mass amplitude introduced by Bell [G. I. Bell (Los Alamos Scientific Laboratory, LA-1321, Los Alamos, 1951)], makes a clear formal and physical distinction between perturbation growth under acceleration–the Rayleigh–Taylor instability–and modifications of perturbation behavior by compression and geometrical convergence–the Bell-Plesset effects [M. S. Plesset, J. Appl. Phys. **25**, 96–98 (1954)]. The perturbation equations obtained for all three simple geometries appear only slightly modified from the simple second-order linear equation governing the classical RT instability. The Bell–Plesset effects exhibited by the general solution vary widely in their nature and importance, depending on the initial conditions and on the rates of Rayleigh–Taylor growth, relative to the rates of geometrical convergence and uniform compression. Interesting special cases are examined, including limits where density and radius scaling of perturbation amplitudes are obtained. In the scaling limit where Rayleigh-Taylor growth is much faster than the compression and

of the spatial amplitude of the perturbation of an interface surrounding a uniformly compressing constant spherical or cylindrical mass

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Prefer oral presentation

Multi-Fluid Interpenetration Mixing in Directly Driven Plastic ICF Capsules

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The multi-fluid interpenetration mix model of Scannapieco and Cheng (Phys. Lett. A., **299**, 49, 2002) is tested against data from directly driven plastic ICF capsules of Li *et al.*, PRL **89**, 165002 (2002). The mix model well approximates the degradation of yield compared to an unmixed calculation as the deuterium gas pressure is reduced from 15 to 3 atm. Observed ion temperatures derived from the Doppler broadening of the neutron energy are consistently about 0.5 to 1 keV higher than calculated, even with mix. The mix calculations reproduce the decrease of the fuel "rho-r" with fill gas pressure. The diagnostic actually measures the number of neutron-deuterium collisions in a capsule with a CH plastic shell. The observations are simulated using a neutron transport calculation of the implosion and noting the total number of n-d collisions. These are normalized to the "rho-r" of a clean calculation. Likewise observations of the number of high energy protons created in neutron-proton collisions are simulated in a post-processing neutron transport calculation. The shell rho-r inferred in a similar way shows little change with gas fill pressure, agreeing with the observations and differing from the increase calculated for an unmixed implosion. The decrease in inferred fuel rho-r is due to DT fuel moving outward through the shell as it implodes, giving a core with less DT and more shell. However the amount of shell mixing in the fuel is small, leading to little change in the shell rho-r. The NTD burn history is simulated by post-processing a calculation to model the neutron energy deposition in 1 mm thick scintillator foil located 2.5 cm from the capsule. This signal is then normalized to the observed yield, as in the observation, to give an inferred "burn history". The post-processed simulation shows a rise in burn rate with mixing similar to that without mix, then a decrease as mixing grows, leading to no yield in the later portion of the unmixed calculated pulse. Modeling simultaneously the D-He3 proton yield and the DD neutron yield from CH targets with CD shells and He3 gas fills shows that atomic mix is present, but that the mix model is making errors especially in the capsules with CD layers offset outward by 1 μm.

Model for Hydrodynamic Instabilities of a Fluid Interface Using Coupled Conformal Mappings.

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The development of hydrodynamic instabilities at the interface between two fluids of different densities is one of the major limiting factors in the Inertial Confinement Fusion. To study this effect, the incompressible fluid model is widely used for describing the motion near the interface separating the two fluids (see Refs. 1, 2 and references therein).

We obtain a new set of 1D partial differential equations, which fully describe the 2D dynamics for such fluid interfaces. To achieve this we found, for any instant of time, a pair of conformal mappings which map the highly distorted interface contour into a simpler domain, for which a boundary value problem can be easily solved. These equations are convenient for numerical solution, they describe the linear and non-linear Richtmyer-Meshkov (RM), Rayleigh-Taylor (RT) and Kelvin-Helmholtz instabilities in incompressible without any additional simplifying assumptions. This approach can be also generalized for the instabilities of the ablation front, as well as for the MHD instabilities

To verify the model we performed numerical simulations for the RM and RT instabilities. For the particular case of the RM instability at Atwood# =1, we compare the new results with the predictions of the analytical theory [1], for other cases – with the results obtained using the vortex method [3].

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TO5

Thirty-third Annual Anomalous Absorption Conference
Lake Placid, NY — 23-27 June 2003

High Resolution Simulations of High Gain Direct-Drive ICF targets*

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We have designed targets that produce moderate to high gain when directly driven by lasers. These designs are initially produced with one-dimensional hydrocodes that give "clean 1-D" yield predictions for given laser pulse and target parameters. This yield is expected to degrade once multidimensional hydrodynamic instability effects are considered. The intrinsic sensitivity of these targets to hydro instabilities can be predicted using ablative RM and RT growth formulae combined with simple Haan-type saturation modeling and Bell-Plesset convergence effects. The resulting instability growth rates for these targets typically maximize for perturbations with spherical harmonic mode numbers of $\ell > 100$. Although ablative stabilization is important for these modes, they typically evolve to nonlinearity and saturation before convergence and stagnation occurs. Thus, the applicability of such quasi-linear modeling is limited. Furthermore, this stability analysis cannot be used to predict the instability-induced degradation of the target yield which occurs after nonlinearity develops.
Large, high-resolution 2D simulations are used to generate these yield degradation predictions. Simulations of these pellets using the FAST radiation hydrocode cover a wide wavelength range of perturbations (e.g., $\ell = 2 - 256$ in 2D) from the linear through the nonlinear stages. The development of the perturbations in these multi-mode simulations is compared to corresponding single-mode simulations and the quasi-linear models and analysis used in the earlier 1-D designs. Growth during the shell acceleration is in good agreement with these models up to the point that the perturbations become fully nonlinear. The relatively mild Richtmyer-Meshkov-type growth during the early pellet compression phase is typically the most challenging part of the simulation owing to the extremely small modal amplitudes (of order 10Å) at this time; we rely upon analytic ablative Richtmyer-Meshkov theory and well-resolved single-mode calculations to constrain the code in this regime. The growth of the resulting perturbations during acceleration due to Rayleigh-Taylor and Bell-Plesset effects in the simulation agrees fairly well with the simple models during their linear phase. These simulation results suggest that the NIF direct-drive point design is expected to give about half of its 1-D clean yield for nominally expected beam and pellet imperfections. Preliminary simulations of high-gain pellets, using advanced imprint suppression and Rayleigh-Taylor growth mitigation techniques (e.g., shaping "picket" pulses and/or thin high-z layers), also show robustness of some high-gain designs, with acceptable (> 100) gains possible even after accounting for significant pellet and laser perturbations.

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

Experiments on Hydrodynamic Instabilities in Advanced Plastic and Plastic-Foam Targets

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This is a progress report on our continuing efforts to benchmark computer codes in cases that allow *ab initio* stimulations [1]. We will present the results of our hydrodynamic experiments on the KrF Nike laser at NRL and simulations that include a detailed study of the ablative Richtmyer-Meshkov (RM) instability, feedout-related areal mass oscillations and Rayleigh-Taylor (RT) growth. The advanced step targets were used in order to remove the experimental uncertainty due to shot-to-shot variation. Large field-of-view of our x-ray imaging diagnostics allows for comparison of perturbation growth at different wavelengths, initial amplitudes, and target thicknesses on the same target in the same shot. This enhances reliability and reproducibility of our experimental data. Next generation plastic-foam targets will be used to observe a transition of a single-mode classical RM interfacial instability (both in light-to-heavy and heavy-to-light configurations) into the RT growth.

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

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Prefer Oral Session

T07

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

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Abstract

Experiments to measure the primary Hugoniot equation of state of deuterium in the pressure range of 0.3 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 the extent of compressibility of deuterium at high pressure. Current experiments are aimed at providing data to help resolve this discrepancy. New data are able to reach into the low-pressure range of previous gas gun experiments, where all theories agree rather well, while also reaching the higher pressures of previous laser driven experiments, where there is more disagreement. 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. Data are analyzed assuming SESAME aluminum release curves and the measured Hugoniot curve appears to be well represented by the SESAME Eos.

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"Single-mode Richtmyer-Meshkov growth in a compressible, miscible, convergent system"

M. M. Balkey, J. M. Scott, Cris W. Barnes, S. H. Batha, N. D. Delamater, R. M. Hueckstaedt, J. R. Fincke, N. E. Lanier, and G. R. Magelssen

As shock waves generated during inertial confinement fusion (ICF) implosions propagate toward the center of the capsule, they encounter an interface between materials with different densities, such as between the ablator and the DT fuel. A shock wave traversing a large density discontinuity is unstable to the Richtmyer-Meshkov (RM) instability which can lead to the mixing of the materials at the interface (mix), and a consequent decrease in fusion burn. There is no widely accepted theoretical or computational model for the growth and saturation of the RM instability in compressible, convergent, miscible plasmas. An experimental campaign is under way to study single-mode RM growth in ICF implosions. In this campaign, the growth of single-mode perturbations machined into a radiographically opaque marker layer is measured during a cylindrical implosion. Single-mode experiments are desirable because they are the simplest case for understanding the physics of the RM instability in a convergent system. The machined surface is embedded away from the ablation surface, and is not subject to RT instability or growth. Experimental results from the OMEGA laser are presented for implosions of targets with single-mode perturbations of azimuthal mode numbers m = 28, 16, and 8, and amplitude Ai = 1.0, 2.5 and 3.0 microns. Experimental results are compared with computational results obtained using the RAGE code and theoretical models. Simple analytic models based on planar geometry predict that the growth of the instability scales with mode number, while both the experimental data and RAGE simulations show that growth of the instability is independent of mode number, for these low-m perturbations.

This work performed by the Los Alamos National Laboratory under the auspices of the United States Department of Energy under contract No. W-7405-ENG-36.

On the Applicability of Modern Front-Capturing Methods to the Modeling of Small-Amplitude Instability Growth*

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Modern front-capturing methods, such as flux-corrected transport (FCT) methods, total variation diminishing (TVD) methods, and high order Godunov methods (e.g., MUSCL, PPM, ENO, WENO, discontinuous Galerkin methods), were developed to address the numerical difficulties that one encounters when attempting to solve problems where discontinuities or near-discontinuities are expected to form in the quantities being modeled, or in one or more of their derivatives. Such methods are usually described as being inherently "nonlinear." While true, this statement does not adequately describe the nature of such methods, for they are often not even differentiable with respect to small perturbations in the solution. This is not usually a problem for stable flows, but when the flows of interest are unstable, and when one is interested in the evolution of small perturbations to those flows, the use of such numerical methods would appear to be quite risky.

We describe experiments we have conducted investigating such methods, and some alternatives to such methods, in the context of evolving Rayleigh-Taylor and Richtmyer-Meshkov instabilities.

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

Advanced Target Designs for the Direct-Drive Inertial Confinement Fusion

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LLE's base-line direct-drive ignition design for the NIF is an "all-DT" design with a 1-D gain of ~45. Recent calculations show that targets composed of foam shells, wicked with DT, can potentially achieve 1-D gains ~100. Current target design research includes exploring the use of adiabat shaping and the possibilities of performing direct-drive ignition experiments in NIF's x-ray drive configuration [Polar Direct Drive (PDD)].

This talk will review new advanced target designs and their relationship to current research.

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Prefer poster session

Low-energy-density physics at Lucent Technologies: Communication systems based on optical solitons

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Current fiber-optical communication systems are required to transmit information at bit rates in excess of 1 Tb/s, over distances of several Mm, with bit-error-ratios that do not exceed 10^{-9}. In this talk I will review soliton systems, which are important in their own right, and which illustrate physics issues that are relevant to all systems.

For single-channel bit rates of 10 Gb/s, the signal pulses can only propagate about 0.1 Mm before dispersive spreading causes bit errors. In ideal (lossless) fibers (nonlinear) self-phase modulation (SPM) balances dispersion and allows solitons (pulses of constant shape) to form. In real (lossy) fibers, the pulse powers decrease with distance. The pulses must be amplified regularly (by Erbium-doped fiber amplifiers) to restore their (common) power. If the path-averaged SPM compensates dispersion, quasi-solitons can form. Unfortunately, all amplifiers produce noise, which is undesirable for two reasons: First, it reduces the received signal-to-noise ratio. Second, it produces soliton amplitude and frequency jitter, and the latter is converted into arrival-time jitter by dispersion. These phenomena all limit the error-free transmission distance. Noise-induced impairments can be reduced by the use of optical filters or distributed (Raman) amplification.

Single-channel transmission at 10 Gb/s, over transoceanic distances, has been achieved. However, transmission at 1 Tb/s requires the simultaneous use of 100 frequency channels. Multi-channel systems are limited by the effects of inter-channel pulse collisions: cross-phase modulation produces frequency and time jitter, and four-wave mixing (FWM) produces amplitude jitter.

Current systems are made from an alternating sequence of fiber sections, whose dispersion coefficients have opposite signs. In such dispersion-managed (DM) systems the local dispersion is high, which reduces inter-channel FWM, whereas the global (path-averaged) dispersion is low, which reduces noise- and collision-induced time jitter. Quasi-solitons can exist in such systems if the path-averaged SPM balances the path-averaged dispersion. Several companies have DM soliton systems ready to be installed.

Design of the Passive Shock Breakout diagnostic for the National Ignition Facility*

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Abstract

The passive shock breakout (PSBO) diagnostic is an optical imager that projects an image of a target surface onto the slit of a UV-sensitive optical streak camera. It relies on shock luminescence to produce the signal. It can measure shock velocities by detecting the breakout times of a shock propagating through a stepped or a wedge-shaped target sample. This diagnostic will make measurements of shock breakout across witness plates and ablator samples for hohlraum driven targets. Hohlraum drive temperatures will range from approximately 100 eV up to 300 eV or more. These measurements are needed to characterize the hohlraum drive quality and to characterize ablator materials. Accurate characterization of hohlraum drive strength and drive history is an essential need of the inertial confinement fusion program and of the high energy density science program. The current design calls for an F/10.2 Cassegrain telescope, with the primary mirror 42cm in dia. and the secondary mirror placed 45cm from the primary and 4m from the NIF target chamber center (TCC). The telescope image is recorded by an optical streak camera placed outside the target chamber. The Cassegrain telescope is diffraction limited to 7.2 um at TCC; however, the streak camera will limit the actual resolution at TCC to about 12 um at magnification 4.9. The system will be capable of selecting 4 discrete fields-of-view by changing the overall system magnification with the help of additional lenses placed in front of the detector (streak camera). The Cassegrain telescope will have pointing capability, so it can view +/-5 cm at TCC. The system will operate at the main wavelength of 280 nm and it will be protected from the main NIF wavelengths at 351 nm, 527 nm and 1053 nm. The filtering needs to reduce the scattered radiation at those wavelengths by 12-15 orders of magnitude.

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Damping of and Stimulation Scattering of Light from Ion Acoustic Waves in Collisional Multi-species Plasma

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The dispersion properties of ion acoustic waves (IAW) are sensitive to the strength of electron-ion acoustic collisions[2] and to ion-ion collisions, especially in the latter case, in multi-species plasma in which the different species have differing charge-to-mass ratios[3]. Here we consider the two different effects: 1. the modification of the growth rate of stimulated Brillouin scattering (SBS) when the electron-ion mean free path is of the same order as the IAW wavenumber and 2. the modification of the frequency and damping of the fast and slow acoustic modes in a plasma composed of light (low Z) and heavy (high Z) ions. In the fluid limit, $\kappa\lambda_{ei} << 1$, the friction between the two species causes the damping whereas, in the collisionless limit, Landau damping of the light ions provides the dissipation. Collisions between light and heavy ions also affect the nonlinear response [4]. We examine the effects of collisions on the non-linear evolution of SBS in two-dimensional simulations, using a δf model with evolving background[5], including the effects of collisions of light on heavy ions within the Lorentz model. The calculated effect of a small number of high Z ions on SBS in low Z Plasmas will be compared with experimental results.

[1]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 and U.S. D.O.E. Contract No. DE-AC02-76-CHO-3073.

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33rd Anomalous Absorption Conference, Lake Placid, NY, June 22-27, 2003

Abstract

Non-local electron heat flow in the presence of strong collisional heating: effect of non-spherical Rosenbluth potentials. Fathallah Alouani Bibi and Jean-Pierre Matte INRS-EMT, Université du Québec, Varennes, Québec, Canada ; Magdi Shoucri, Institut de Recherche en Électricité du Québec, Varennes, Québec, Canada.

Nonlocal electron heat transport in presence of strong collisional heating (Inverse Bremsstrahlung or IB) has been investigated with our electron kinetic, Fokker-Planck code FPI, and it was shown that the modifications to the thermal conductivity greatly change the growth rate of the thermal filamentation instability [1]. We will report on improvements in the code – adding non-spherical Rosenbluth potentials, *i.e.* taking into account the anisotropy of the electron distribution function in the electron-electron Fokker-Planck collision operator. The effect of this improvement on the calculation of the propagators for non-local heat flow, and on a few simulations of strongly non-local transport in low Z-plasmas will be presented.

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TP4

Optical Mixing Controlled Stimulated Scattering Instabilities Using Blue and Green Crossed Beams: Experiments, Theory and Vlasov Simulations

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We report on experiments conducted on the Omega laser facility at LLE using crossed blue and green beams in CH exploding foil targets. In these experiments, we measured the effects on the Green beam's stimulated backscattering of a large amplitude Electron Plasma Wave (EPW) generated by the optical mixing of nearly counterpropagating blue and green beams as the exploding foil passed through the proper density for resonant three wave interaction. We explored various plasma creation or heater beam configurations and different thickness CH targets guided by LASNEX simulations. We also deployed the only available DPP for the Green beam at the time of the experiment which produced considerable filamentation while traversing the plasma. We will show variations in Green beam SRS and SBS as well as the SRS and SBS backscatter of a third beam (BL 30) which witnessed the crossing beams and whose SRS backscatter was diminished significantly only when a large amplitude EPW was created via optical mixing of the counterpropagating Blue and Green beams.

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 blue and green beams. We also have performed Vlasov-Maxwell simulations of the evolution of the nonlinear EPW created by the crossing blue and green beams. The effects of trapping and electron acceleration in these experimental conditions are assessed based on these kinetic simulations.

Our longer term goal is to find efficient ways to generate externally excited (EPW and IAW) disturbances in the plasma so as to control backscattering levels of SRS and SBS in specific regions of large scale plasma such as those that will be created on the NIF.

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Prefer Poster Session

A reduced model of kinetic effects related to the saturation of Stimulated Brillouin Scattering in long plasmas

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We present a model for Stimulated Brillouin Scattering that consists of the classic 3-coupled-wave equations, where the equation for the driven acoustic wave includes a nonlinear frequency shift related to modifications of the ion distribution function by kinetic effects. This frequency shift is calculated in a quasilinear way from the locally averaged modifications of the ion distribution function, described in this model by a single parameter related to the width of the plateau. This parameter evolves according to an additional differential equation that describes the acceleration, advection and diffusion of ions around the phase velocity of the ion-acoustic wave. The behavior of this model will be discussed and compared to hybrid-particle-in-cell simulations performed with BZOHAR.

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.

LPI with polarization smoothing and SSD on NIF*

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Principal beam conditioning measures for amelioration of laser-plasma interaction (LPI) instabilities are continuous phase plates (CPP), smoothing by spectral dispersion (SSD) and polarization smoothing (PS). Here we extend earlier modeling[1] of theoretical benefits of PS and SSD, toward implementation decisions on polarization smoothing (PS) options for NIF early light (NEL), and planning for NEL experiments. Scaling of filamentation and beam spray is modeled; with CPP and PS, these are primarily determined by a normalized intensity, which is the filamentation gain per speckle length. With SSD there is an additional dependence on the bandwidth vs sound frequencies. We consider a new implementation of PS that is located in the converging (focused) beam, as well as previous variants, the "wedge" and "checkerboard".

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

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Spectroscopic Techniques for the Inference of Fuel-Pusher Mix in Spherical Implosions

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Spectroscopy provides an essentially non-interfering probe into the dynamics of spherical ICF relevant implosions. We propose two uses of spectroscopy for the inference of the time-dependence of fuel-pusher mix in spherical implosions to complement the published method of Regan, et al. (Phys. Rev. Lett. 89, 085003 (2002)). Both uses are examined in the context of ~20 micron thick, 450 micron OD microballoons filled with 3-20 Atm of H-isotope fuel. The first technique relies on a thin (sub-micron) Ti-doped CH layer initially at the fuel pusher interface. In the absence of fuel-pusher mix, the Ti does not reach temperatures required for the emission of H-like resonance lines. Thus, the time dependence of H-like Ti line emission is an indicator of the evolution and amount of fuel-pusher mix. Detailed analysis of the Ti line spectra will yield emissivity weighted, time-dependent temperatures and densities for the mix region. The second proposed technique takes advantage of the plasma-composition dependence of the ion microfield. Doping the fuel with a small (~0.25 atomic percent) of Ar has been shown (most recently in Regan, et al. as referenced above) to be an essentially non-interfering probe into the dynamics of CH plastic surrogates. The atomic admixture of C ions into the fuel modifies the ion microfield experienced by the Ar K-shell radiators in the mix region. This modification leads to observable changes in the Ar K-shell line shapes, especially the β- and γ-lines. This work was performed under the auspices of the Department of Energy, DOE contract No. W-7405-ENG-36.

Gas hydrocoupling in indirect drive experiments at the Omega Laser*

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Ignition hohlraum designs use low Z gas fill to slow down the inward progress of high Z ablated plasma from the hohlraum walls which would otherwise lead to unacceptably large laser spot motion and compromise the capsule drive symmetry [1]. On the other hand, the localized laser heating of the gas fill may produce an early pressure spike on the target axis that may couple to the capsule. This gas hydro-coupling to a fusion capsule in an indirect drive hohlraum is presently being assessed in smaller-scale experiments with gas filled hohlraums and low density foamballs at the Omega laser facility at LLE. Our experiments measure the effects of this pressure spike on a foam ball capsule surrogate for various gas fill densities using x-ray backlighting. In addition, the gas hydrodynamics is studied side-on and end-on using L-shell x-ray emission (4-5 keV) imaging from a low concentration (0.4%) Xe dopant and x-ray framing cameras with V filters.

The self-emission pictures show at late times also the capsule compression, similar to backlighting,. Moreover, the wall material stagnation on the hohlraum axis, observed in the vacuum hohlraums is replaced in the gas filled ones by a slower gas stagnation that is proportional with its pressure. For this reason, for vacuum and for 0.5 to 2.4 mg/cc gas fill pressure, the foamball compression asymmetry measured by backlighting increases with the gas pressure.

The performed experiments are important for assessing the viability of proposed design improvements for inertial confinement fusion targets seeking to optimize the choice of the gas fill pressure and the hohlraum wall material.

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Analytical solution for the evolution of rippled planar shock waves in real materials

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We investigate the temporal evolution of small two-dimensional perturbations to an isolated planar shock wave propagating through a material with an arbitrary equation of state (EOS). Following the work of Roberts (Los Alamos Scientific Laboratory Report No.~LA-299, 1945), it is shown that at least two classes of damped oscillatory solutions exist for initial disturbances localized in the neighborhood of the shock front. The two classes share the same late-time asymptotic behavior (in which the envelope of shock front oscillations decays as time to the minus three-halves power), but differ in the degree of damping that the oscillations experience initially. The determination of which class is physically applicable to a particular perturbed-shock system depends on the strength of the front, and the EOS properties of the material through which it propagates. Theoretical predictions agree well with FAST2D simulation results for several examples derived from the CALEOS library. This new theory provides a useful series of test problems for benchmarking the performance of hydrodynamic-based inertial-confinement-fusion (ICF) codes. An effort is underway to extend the results of this work to incorporate the effects of realistic driving mechanisms (*e.g.,* non-uniform ablation surfaces in ICF scenarios) that can give rise to rippled shock fronts.

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Measuring spherical harmonic coefficients on a sphere

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The eigenfunctions of Rayleigh-Taylor modes on a spherical capsule are the spherical harmonics $Y_{l,m}$ These can be measured by measuring the surface perturbations along great circles and fitting them to the first few modes by a procedure described in this article. For higher mode numbers, it is more convenient to average the Fourier power spectra along the great circles, and then transform them to spherical harmonic modes by an algorithm derived here.

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Equation of first order in time for the ion acoustic wave generated by stimulated Brillouin backscattering in an inhomogeneous flowing plasma

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In the stimulated Brillouin scattering (SBS) process, a part of the incident laser wave momentum is transferred to the plasma ions. This momentum transfer may modify the local flow velocity and, consequently, changes the interaction physics [1,2].

We consider SBS in the standard decay regime. Firstly, we derive an equation of first order in time describing the evolution of the ion acoustic wave (IAW) driven by SBS in the case when the plasma density and the flow velocity are inhomogeneous. Then, we write a set of equations describing self-consistently the coupling of the transverse waves with the SBS-generated IAW, together with the evolution of the flow. Momentum conservation is proved to be conserved by this reduced set of equations in three spatial dimensions. Finally, we solve this reduced set of equations by means of the HERA code in order to quantify the effect of the plasma flow modification due to SBS on the SBS reflectivity.

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NIF Early Light Designs for Hohlraum LPI Experiments

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A substantial part of Los Alamos Inertial Confinement Fusion activities at the National Ignition Facility (NIF) in the next several years will be channeled through the organization of the NIF Hohlraum Integrated Experimental Team (IET). Initially the Hohlraum IET will seek to anticipate laser plasma interaction behavior in the NIF at full (192 laser beam) energy through experiments with the first 4 available beams (first quad). Our hohlraum designs utilize the hydrodynamic tamping from the sidewalls of a relatively elongated, gas-filled half hohlraum to obtain quasi-homogeneous plasmas greater than 1 mm in size, with electron densities of order one-twentieth to one-tenth of the critical density. The electron temperature is above 3 keV, ensuring that the ponderomotive plasma response dominates over the thermal response. The expected ion to electron temperature ratio is of order one-half. These conditions are appropriate for studying LPI processes in gas-filled NIF hohlraums at the peak of a full-energy pulse.

Radiation resonance emission from steep overcritical plasma profiles illuminated by femtosecond laser pulses

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A radiation resonance effect observed in the reflection spectra from overdense plasmas illuminated by femtosecond laser pulses at normal incidence is reported from particle-in-cell simulations. Harmonic emission at multiple orders of the fundamental is found to exhibit resonance phenomena, with the number of resonances and power emitted depending on the electron plasma density. For relatively low laser intensities the reflected light at the laser frequency shows prominent resonant emission around specific values of the plasma density, mainly at 4, 16 and 36 times critical. For increasing laser intensities, strong harmonic emission around 4 and 16 times critical dominates the reflection spectra. In the case of the third laser harmonic, the emission is found to be resonant about those densities and presents, additionally, a distinctive resonant region around 9 times critical. A simple radiation model for the power of the third harmonic was proposed confirming a resonant effect dependent on the electron plasma density. For higher harmonic numbers, weak radiation resonances persist in the emission spectra, with their number increasing with order. The resonance effect reported in this paper is found to occur at densities that approximately satisfy n_e/n_c=4 n^2, where n_e and n_c are the plasma and the critical density, respectively, and n is an integer. For the third harmonic, the second resonance corresponds to n=1.5.

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Wednesday 25 June 2003

Crossed-beam power transfer and the NIF point-design.

E. A. Williams and D. E. Hinkel, LLNL

Laser beams intersecting in plasma can exchange energy via the Stimulated Brillouin Scattering (SBS) process if the ponderomotive force from their interference pattern resonantly drives an ion acoustic wave. When the laser beams have the same frequency this requires the plasma flow component in the direction of the beat ion wave to be sonic, Doppler-shifting the ion wave to zero frequency in the lab frame.

In the National Ignition Facility ICF point design, there will be multiple crossing beams entering the hohlraum through the laser entrance holes (LEH). Simulations using Lasnex and Hydra show that the plasma accelerates to supersonic speeds as it leaves the LEH. Transfer of power from the inner to the outer beams by this process could spoil the delicately tuned implosion symmetry of the target capsule.

The most vulnerable time is when the inner beams reach peak power at 12.5ns. Because at this time the NIF laser is at its design power limit, power transfer could not then be compensated for by a change in temporal pulse shape. A detailed analysis, using the NIF beam geometry shows that the beam-crossing region misses the resonant surface. However, despite this, beam to beam power transfers of up to 25% are predicted using a theory that accounts for pump depletion

The non-resonantly driven ion waves responsible for the scattering are small amplitude, with $\delta n/n < 1\%$. Trapped particle frequency shifts, which appear to play a role in current crossed beam experiments are not expected to be effective, because of the lack of resonance and their small size. Slowing of the flow by deposition of light momentum is too slow a process to limit power transfer.

If other non-linearities fail to come to the rescue, a relatively small (2Å) redshift of the inner beams relative to the outer is sufficient to reduce the predicted power transfers to <6%. The effects of SSD are problematical.

First Experiments on NIF*

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The first four beams of the National Ignition Facility (NIF) are beginning to deliver energy to target chamber center for target shots. The first experiments are planned to develop experimental capabilities for the facility. The first diagnostics, a Static X-ray Imager (SXI), a Diagnostic Instrument Manipulator (DIM) and a DIM based Streaked X-ray Diagnostic (SXD), have been commissioned. These diagnostics are being used on the initial shots measuring the beam timing synchronization and pointing. Additional diagnostics and capabilities are planned to do experiments on direct drive planar hydrodynamics, equation of state, material dynamics, laser-plasma instabilities, and hohlruam physics. Present status of the facility and plans to develop its capabilities will be discussed.

*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.

Two-Dimensional *SAGE* Simulations of Polar Direct Drive on the NIF

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Preliminary simulations have been carried out for asymmetric direct-drive configurations on the NIF. Designs have been considered in which the four rings of beams (at $\theta = 23.5°$, 30°, 45.5°, and 50°) are repointed toward the equator by varying amounts. Elliptical phase plates are used for some of the repointed beams to reduce the energy loss as the target implodes and improve the uniformity.

The simulations are run in spherical geometry using the 2-D Eulerian code SAGE with (r, θ) coordinates. Laser energy deposition is calculated using 3-D ray tracing for all the beams, with the deposited energy averaged in the azimuthal direction. Two simulations are presented of the "all-DT" design[1] (a 340-μm cryogenic DT layer of outer radius 1.69 mm driven with 1.5 MJ of laser energy). One (the "symmetric" design) uses the direct-drive rings ($\theta = 23.5°$, 45.5°, and 77.45°) while the other (the "polar" design) uses the four indirect-drive rings with appropriate repointings and phase-plate ellipticities. The simulations focus on the early stages of the implosion (up to the end of the laser pulse), with particular attention paid to uniformity in the θ direction.

The polar design performs almost as well as the symmetric design. Given that many parametric variations have yet to be explored, this result is encouraging for the prospect of polar direct drive on the NIF.

1. C. P. Verdon, "High-performance direct-drive capsule designs for the National Ignition Facility," Bull. Am. Phys. Soc. **38**, 2010 (1993).

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Prefer oral presentation

Modeling NIF Hot Halfraum Target Behavior with ALE Rad/Hydro Codes*

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In the early stages of operation of the National Ignition Facility (NIF) several of the experiments will be hot halfraum targets, using the first quad of up to 4 beams pointed directly towards the target. It is important to understand the late-time physics behavior of these targets so that we can predict the effects on the target chamber optics as the NIF experiments advance and more beam configurations are possible. To make these calculations, we have implemented a program of applying radiation/hydrodynamic codes to new late-time regimes. For the problem of chamber impacts, both three-dimensional effects as well as extremely late time (up to 100 times pulse length) are extremely demanding of rad/hydro code technology.

One of these codes, Hydra, uses an ALE treatment to allow the solution to adapt to the problem. We discuss some of the innovations required in the ALE method including accurate numerical treatment of the laser entrance hole (LEH) region[1] and weighting of the ALE zones to gain accuracy in regions where the laser-ionized target can have the largest impact on surrounding optics. The ALE treatment of the LEH region may also be useful for early-time physics calculations. Since Hydra can be run in three dimensions, we can study configurations that break the standard cylindrical symmetry. Three-dimensional modeling is important for chamber physics since the target disruption is not isotropic, and for laser plasma interaction effects when the laser is not directed normally on the back wall of the halfraum. We benchmark our simulation results with experimental data from halfraum experiments shot on the HELEN laser and make predictions for NIF early light experiments planned for the near future.

[1]A. Koniges, M. Marinak, and R. Tipton, "A New Numerical Treatment of Hohlraum Boundaries for ALE Rad/Hydro Codes, **IFSA** (2003).

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Airmesh technique? →

Nonlinear Raman scatter in NIF targets*

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Ignition targets for the National Ignition Facility (NIF have been designed at several different radiation temperatures. This current work analyzes and compares the Raman scatter in the point design (at 300 eV[1]) to that of the 350 eV design[2]. In the former target a radiation temperature of 300 eV is achieved using 410 TW of peak power with an input energy of 1.3 MJ and a pulse length of 18 ns, and the yield is 18 MJ. The 350 eV target is 75% the size of the 300 eV target, and uses 600 TW of peak power with an input energy of 1.4 MJ and a pulse length of 13.5 ns, yielding 5.4 MJ of energy. The yield is lower than in the 300 eV design because of the relatively smaller fuel mass, but this target is of interest to the ignition community because it tolerates larger Rayleigh-Taylor density fluctuations than does the point design.

The smaller scale and higher power of the 350 eV ignition target make the plasma density, electron temperature, and laser intensity higher than that of the 300 eV design. Nonetheless, both targets are predicted to have nonlinearly high levels of laser scatter. To assess the nonlinearities associated with laser scatter in these targets, 1D full-PIC simulations have been performed using Zohar[3]. In these simulations, both designs show Langmuir wave saturation through re-scatter via either Brillouin[4] or Raman scatter, depending on the density. Moreover, the Langmuir wave associated with Raman scatter shows additional saturation through the Langmuir decay instability. Results from these simulations will be presented and analyzed.

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

[1] Designed by S. M. Pollaine et al., 1995.
[2] Designed by D. E. Hinkel and S. W. Haan, 1999.
[3] A. B. Langdon and B. F. Lasinski, in *Methods in Computational Physics* (Academic Press, New York, 1976), Vol. 16, pp. 327-366.
[4] A. B. Langdon and D. E. Hinkel, *Phys. Rev. Lett.* **89**, 015003 (2002).

Single Beam 2ω Laser Propagation through Underdense C_5H_{12} Gas Bags

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Recent single beam green light (2ω) experiments on the Helen laser studied propagation and backscatter as a function of gas density. Neopentane (C_5H_{12}) gas bags were shot to produce long (~ 2 mm), low density, low-Z plasmas similar to what might be encountered in a NIF ignition hohlraum. Electron thermal conduction appears to be the critical physical process in these experiments. Simulations using the radiation-hydrodynamics code HYDRA were compared to experimental fast x-ray (FXI) images showing stable laser propagation across the bags at low densities ($n_e \leq 0.16n_c$). Although the simulations capture many aspects of the data, there are detailed differences that we think can be attributed to non-local transport. The simulations were run with two values of the electron flux limiter f, where $q_{max} = f \times$ (free stream limit). Synthetic images from simulations with the "standard" f=0.05 showed the beam burning through slightly earlier than experiment. There were also differences in the shapes of the simulated and experimental images: The simulated emission closely tracked the expansion of the f#/3 beam through the bag, whereas the experimental images show the lateral extent of the emission decreasing across the bag.

Simulations with f=1.0 better matched the experiments, especially at high density ($n_e \geq 0.16n_c$); however, for the lower density cases ($n_e \leq 0.12n_c$), the simulations still over-predicted the width of the emission. We propose non-local electron transport as an explanation for this discrepancy. Non-local thermal conduction can decrease the sharpness of density peaks and the steepness of temperature gradients in the lateral wave driven by the laser. This changes where the laser absorbs, affecting the entire time-evolution of the hydrodynamics. While filamentation might also help explain the experimental images, time-resolved spectra of the stimulated raman backscatter showed little filamentation for the low intensity, low density cases. These experimental results should prove extremely valuable for validating non-local electron transport models in the near future.

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.

"Plan B" 2ω Ignition Hohlraums for NIF

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Kevin Oades, Mark Stevenson, Mark Stevenson AWE

For several years we have been exploring the possibility of using green light for indirect drive ignition on NIF. The rationale for this work is the possibility of extracting significantly more energy from NIF in green light, as compared to blue. The principal direction of this work, to date, has been to see if green light could be substituted for blue in otherwise unchanged ignition designs. Recently, because of the large amount of energy potentially available with 2ω, we decided to more aggressively explore green light for ignition. This includes exploring alternative, or "Plan B" hohlraum designs aimed specifically at increasing the likelihood of successfully using 2ω for ignition. In this paper we present the results of 2D Lasnex simulations of "Plan B" hohlraum designs which attempt to capitalize on recent experimental findings on 2ω LPI. In particular:
*Experiments on the HELEN laser at AWE, corroborated by additional experiments on Omega, which indicate that 2ω laser-plasma instabilities and the concomitant losses can be suppressed by judicious choice of plasma composition.
*Omega 2ω intensity scaling showing backscatter from CH plasmas drops significantly at $3x10^{14}$w/cm^2 and below.
Our hohlraum simulations indicate it is possible to replace the He-H in the beam path with a wide variety of plasma compositions while still maintaining hohlraum drive and implosion symmetry. This includes potentially buildable designs based on foam fills (eg SiO2) or based on mid-Z liners. We also find it is plausible that 250eV ignition designs could operate at an intensity of $<3x10^{14}$w/cm^2 for the outer cone beams and $<1.5x10^{14}$ for the inner cone beams.

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

Simulations of Laser-Plasma Interaction in an early NIF Experiment

Steve Langer and Bert Still
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We used pf3d to simulate a gasbag experiment that is planned for NEL (NIF Early Light) this summer. The gasbag is roughly 4x4x5mm and is filled with neo-pentane gas. The conditions were chosen to yield significant backscattered light so that the experiment can be used to check out the backscatter diagnostics on NEL. We simulated the central 1x1x5 mm on 1920 processors of the new Pentium Linux MCR cluster at LLNL. The nominal laser intensity was 10^{15} W/cm^2 of 0.35 μm light, but speckles have intensities up to ten times higher than that. We used a speckle pattern obtained from the laser designers. The simulation used 6.8 billion zones (zones can be only slightly larger than the laser wavelength) and ran for 10 days. The simulation computes the absorbed and transmitted laser light and the strength of SRS and SBS.

This simulation produced a number of interesting results. Approximately 17% of the laser light is transmitted, 60% is absorbed, and 23% is backscattered as SRS. SBS was very weak in this simulation. The simulation lacked good models for SRS and SBS saturation, and the gains for both instabilities are well above the expected levels for saturation, so we expect some differences between simulation and experiment. Nevertheless, the predicted levels are consistent with prior gasbag experiments on NOVA, Helen, Omega, etc. so we believe the results from this simulation can provide useful guidance in preparing for the experiment.

The NEL laser has 4 beams in a 2x2 grid. The FABs detector will measure light that is scattered back through the 4 final focus lenses. The simulation shows that approximately 33% of the SRS falls on the lenses and the remainder falls either between the lenses or outside of them. This result has stimulated discussions as to whether additional detectors can be used to verify the prediction from the simulation. The simulation also predicts the spatial distribution of the transmitted light. This is of interest in checking that the levels of light falling on various optical surfaces during the experiment will be within the specifications.

The simulation also produced some results that are interesting to theorists. Side-on volume visualizations clearly show many bursts of SRS that have a fairly short extent in the laser direction (roughly half the length of an f8 speckle). Each burst starts from a small volume of plasma and increases in transverse extent as it propagates back through the plasma. In most cases, a single "seed point" dominates each SRS burst, but in some cases two seed points contribute significantly. We are investigating the conditions that make a region a seed point candidate and investigating why the SRS bursts have a spatial extent shorter than a speckle.

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

Effects of Plasma Composition on green light backscatter, hot electron production and propagation in underdense plasmas

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Abstract

This paper extends the work presented at the 32nd Anomalous Absorption conference, which explored the propagation, backscatter and x-ray generation using 2ω light on gasbag targets at the HELEN laser facility at AWE.

The targets described previously were filled with C_5H_{12}, CO_2 and Kr. While the C_5H_{12} and CO_2 targets showed the expected trade-off of Raman for Brillouin, a few experiments with Kr targets surprised us by producing low Brillouin as well as low Raman backscatter. This suggested that plasma composition could be an important LPI control mechanism.

Here we report findings from a recent series of HELEN experiments that more broadly investigated the effect of plasma composition on backscatter, hot electron production and propagation. Our expanded studies included gasbags filled with Nitrogen, Neon, Ar, Ar+Kr, Ar+Xe, Ar+Kr+Xe, Kr, and Xe gas. Of all the gasses, we find that only the C_5H_{12} gas produces significant amounts of Raman.

Brillouin, on the other hand, is efficiently produced by N_2, CO_2 and Ne, but then begins to drop off rapidly with increasing Z. The drop in Brillouin was not anticipated because the higher Z gasses still have very low ion damping. The drop in Brillouin backscatter in higher Z plasmas was recently confirmed by Ar and Xe gasbag experiments on Omega. Complementing the Helen backscatter data are measurements of hot electron production and x-ray framing camera images. These images show the formation of a compact emitting column across the bag and suggest propagation is about as expected from hydrodynamic simulations.

Oral presentation
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33^{rd} Annual Anomalous Absorption Conference
Hilton Lake Placid Resort, Lake Placid, NY
22-27 June, 2003

Filamentation of Laser Beams in Inhomogeneous Plasmas

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We present results from simulations and theory of the time evolution of the nonlinear propagation of laser beams in an inhomogeneous plasma. The (2+1)D simulations show that chaotic nonstationary interactions occur between incoming and outgoing portions of a beam near its turning point. We study various instantaneous nonlinear models of the dependence of ion response to the ponderomotive field including the standard unsaturated cubic model as well as Gaussian and Lorentzian saturable nonlinearity models.

We have varied the propagation length inside the plasma, the source field spot size, its initial amplitude and its angle of incidence and charted out stable, metastable and chaotic regimes of evolution. We have also studied crossing laser beams as well as beams with distributed phase plates (DPP) and temporal incoherence (ISI or SSD).

On the more theoretical side, we have idenitified the interesting prospect of stopping light in such (model) plasmas and to extract multiple short intense pulses of light emanating from the reflection surface. This is due to the incident (single soliton like) field being squeezed down and amplified near its turning point as diffraction is minimized while nonlinearity continues to concentrate the wave energy. One to N soliton transitions take place, where the area of the Airy surface near the turning point and on both sides of it are used to feed the nonlinear reflection process. The connection between these new and unexpected results and older (1+1)D models of resonance absorption in an inhomogeneous plasma where resonantly driven solitons interact chaotically just near the critical density is highlighted.

The implications of these new phenomena to direct drive and to crossing laser beams in inhomogeneous steep density gradient plasmas such as those found in short pulse high intensity laser-plasma interaction (LPI) experiments will be given.

**This work was performed under the auspices of the Naval Research Laboratory.

Prefer Oral Session but not on Friday

Thursday 26 June 2003

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33rd Anomalous Absorption Conference, Lake Placid, NY
June 22-27, 2003

Hohlraum-driven ignition-relevant double-shell implosion experiments on Omega: analysis and interpretation*

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Abstract

An experimental campaign to study hohlraum-driven ignition-like double-shell performance using the Omega laser facility is underway. These targets are intended to incorporate as many ignition-like properties of the proposed NIF double-shell ignition design [1] as possible, given the energy limitations of the Omega laser. In particular, this new generation of Omega double-shell is theoretically constrained to produce over 99% of the (clean) DD neutron yield from the compressional or stagnation phase of the implosion as in the NIF ignition design. By contrast, previous double-shell experience on Omega [2] has been restricted to cases where a significant fraction of the observed neutron yield was produced during the earlier shock convergence phase where the effects of mix are deemed negligibly small. These new targets are designed to have optimized fall-line behavior for mitigating the effects of pusher-fuel mix after deceleration onset and thereby providing maximum neutron yield during the stagnation phase. Recent experimental results from this initial Omega ignition-like double-shell implosion campaign will be reported and compared with preliminary simulation studies.

[1] P. Amendt, J.D. Colvin, R.E. Tipton *et al.*, Phys. Plasmas **9**, 2221 (2002).

[2] W.S. Varnum, N.D. Delamater, S.C. Evans *et al.*, Phys. Rev. Lett. **81**, 5153 (2000).

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33rd Anomalous Absorption Conference
Lake Placid, NY, June 22-27, 2003

The First Spectrometry of Charged Particles from Indirect-Drive Capsule Implosions

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Recent experiments have resulted in the first spectrometry of charged particles from indirect-drive capsule implosions; High-resolution spectra were obtained and used for characterizing areal density (ρR) and/or ρR asymmetry. Four range-filter spectrometers were used to measure 14.7 MeV protons from capsules filled with 10- or 50-atm D^3He gas. Two spectrometers looked through the equator of the hohlraum, and two looked through the laser entrance holes (LEH). A total ρR ~ 42 ± 9 mg/cm^2 was obtained for the imploded capsules, and ρR ~ 40 ± 15 mg/cm^2 was found for the hohlraums. No large capsule ρR asymmetries were observed (variations were within statistical errors). It is shown that charged-particle spectroscopy can be an important diagnostic method for the indirect-drive ICF program.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48, and has been supported in part by LLNL subcontract No. B313975, the U.S. Department of Energy Office of Inertial Confinement Fusion under Grant No. DE-FG03-99DP00300, and under Cooperative Agreement No. DE-FC03-92SF19460.

Oral presentation preferred

Proton Temporal Diagnostic for ICF Experiments on OMEGA

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We have developed a proton temporal diagnostic (PTD) to record the fusion-reaction-rate history of protons generated from the thermonuclear burn of D^3He-fueled capsules on OMEGA. The detector is based on a fast scintillator (BC-422) that acts as a proton-to-light converter protected by a thin (~100-μm) tantalum foil against x-ray and direct laser illumination. A sophisticated optical system transfers the scintillator light to a high-speed optical streak camera for recording. A simultaneously recorded optical fiducial provides a reference for accurate timing with respect to the incident laser pulse. The instrumental time resolution of 25 ps is sufficient for simultaneous measurements of the shock coalescence and compression peaks of D^3He implosions with proton yields greater than 10^5. For the case of D_2 implosions, the PTD can also measure the secondary protons and primary neutron timing from which ρR can be inferred. Additionally PTD can operate as a hard-x-ray temporal diagnostic with a time resolution of 20 ps and an x-ray cutoff energy range of 10 keV to 100 keV. The first experimental results utilizing PTD will be presented.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Prefer oral session

Measuring ρR evolution using a novel proton temporal diagnostic at OMEGA

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Proper assembly of capsule mass in inertial confinement fusion (ICF) implosions is of fundamental importance for achieving ignition, and experimental information about implosion dynamics is crucial both for understanding how assembly occurs and for critically evaluating numerical simulations. Without carefully tailored assembly of the fuel, hot-spot ignition planned for the National Ignition Facility (NIF) and the Laser Mega Joule (LMJ) Facility will fail. Hot spot ignition relies on shock coalescence to "ignite" the hot spot, followed by propagation and burn of the compressed "shell" material. The relationship between these events must be understood to ensure the success of ICF ignition. To elucidate these issues, we report the first measurements of the D^3He reaction burn history using a novel proton temporal diagnostic (PTD). These measurements were conducted on OMEGA laser facility, and accomplished through use of 14.7-MeV protons generated by the fusion of the fuel constituent's deuterium (D) and helium (^3He), in imploding capsules with various shell thicknesses. To improve our understanding of the physical processes and to test the validity of 1-D and 2-D hydrodynamic simulations in realistic circumstances, we show comparisons of simulated and measured spectral and temporal D^3He proton data. Effects that will be addressed are: behavior of the flux limiter, propagation of the shock waves through the capsule for different types of implosions.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300 and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

[a)] Also Visiting Senior Scientist at LLE.
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An oral presentation is preferred.

THO5

Areal density asymmetries and their time evolution in OMEGA direct-drive implosions

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Charged-particle spectrometry has been used to study the areal density (ρR) of imploding "spherical" capsules as a function of angular position and time during direct-drive experiments at OMEGA. ρR is determined by measuring the energy losses of D^3He protons (produced in the compressed fuel) due to slowing while passing out of the capsule. Angular resolution comes from the simultaneous use of many spectrometers, while time resolution is possible for certain classes of implosions that produce clearly-separated proton energy peaks at two times (first shock coalescence and compression burn, which occur several hundred ps apart). Deviations from spherical symmetry are often observed and can be quantified for a given implosion by the ratio $\langle \delta\rho R\rangle/\langle \rho R\rangle$, where $\langle \rho R\rangle$ is the average over all angles and $\langle \delta\rho R\rangle$ is the rms value of deviations about $\langle \rho R\rangle$. A clear correlation has been seen between measured ρR asymmetries and asymmetries in laser illumination. The largest asymmetries appear in experiments that involve offsets of the capsule from the nominal center of illumination, where the primary angular structure has mode number 1. It has been shown experimentally that $\langle \delta\rho R\rangle/\langle \rho R\rangle$ in these cases is proportional to the rms variation of on-target laser intensity $\langle \delta I\rangle/\langle I\rangle$ with an amplification factor of ~ ½(Cr-1), largely due to the effects of capsule convergence (Cr). The time evolution of these asymmetries is being studied through comparison of measured angular structures at the times of shock coalescence and compression burn. The value of $\langle \rho R\rangle$ grows by about a factor of 7 between these times; the amplification and phase coherence of $\delta\rho R(\theta,\phi)$ during the same time interval is being studied and will be discussed.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300 and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

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An oral presentation is preferred.

THO6

Investigation of shock-coalescence coherence in asymmetric direct-drive implosions at OMEGA

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Ignition of ICF capsules on the NIF will be critically dependent on the quality of hot-spot heating due to converging shock waves. If the ingoing shocks are sufficiently asymmetric, there is a possibility that their coalescence near the center will be insufficiently coherent to heat the hot-spot. A series of experiments where the capsules were offset from target chamber center (TCC) was recently done on OMEGA to investigate the sensitivity of the shock quality on shock symmetry. The TCC offset of the capsule results in a perturbation to the illumination intensity on the target primarily of mode number 1, which launches an asymmetric shock front. Charged-particle spectrometry was used to measure D-D and D-^{3}He protons emitted during the "shock flash" at the coalescence of these aspherical shocks. The results of these experiments will be discussed.

This work was performed in part at the LLE National Laser Users' Facility (NLUF), and was supported in part by the U.S. Department of Energy Office of Inertial Confinement Fusion (Grant number DE-FG03-99DP00300 and Cooperative Agreement number DE-FC03-92SF19460), LLE (subcontract P0410025G), LLNL (subcontract B313975). (Petrasso: Visiting Senior Scientist at LLE.)

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BEAM DEPOSITION MODEL FOR ENERGETIC ELECTRON TRANSPORT IN INERTIAL FUSION; Part I: THEORY

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A new model is proposed for calculation of the effect of energetic electron transport in inertial fusion. Preheat may not be well described in a fluid treatment because the electron temperature may be so high, and the gradient scale length L_T so short, that the mean free path λ is longer than L_T. Then some of the electron energy in the heat front may be deposited nonlocally. We explore in this paper what seems to be a new approach to the problem. The basic idea is to treat the energetic electrons with a steady-state beam deposition model. The beam is produced by a large temperature gradient and it is absorbed by electron electron collisions. All of this occurs very rapidly compared to hydrodynamic time scales, so this model uses a steady state approximation. For long λ this model is equivalent to Spitzer Harm thermal conduction. As λ decreases it calculates corrections to preheat and flux limitation. This paper discusses other attempts to model the problem including flux limitation, Fokker Planck simulations and other nonlocal fluid models; and it shows how our model fits into these. A companion paper will give results of the model.

THO8

Beam Deposition Model for Energetic Electron Transport in Inertial Fusion; Part II: Initial results

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A new model for non local deposition of energetic electrons has been proposed[1]. When the electron mean free path is longer than the temperature gradient scale length, the fluid approximation breaks down and electron transport occurs non-locally. The model described in the previous paper is proposed as a replacement to the use of a heat conduction flux-limiter which has only a phenomenological basis.

In order to validate this new model, a comparison with a Fokker-Planck calculation[2] has been made. Results from this comparison will be shown. The model is then applied to our current Mega Joule laser class targets. Results will also be shown and the effects of this new flux inhibition will be discussed.

Work supported by DOE.

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The Switching Off Of SBS Due to Magnetic Field Generation From Photon Momentum Deposition in Speckle

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It has long been a puzzle as to why stimulated Brillouin back-scatter (SBS) suddenly switches off to be replaced by stimulated Raman back-scatter (SRS). This paper proposes an explanation in which the development of SBS in a speckle of the incident laser beam leads to the deposition of linear momentum in the electrons through absorption and reflection (back-scatter) of the incident laser light. The resulting charge separation produces a longitudinal electric field locally. But this field falls off in the transverse direction, i.e., it has a non-zero curl. Therefore, through Faraday's law, an azimuthal magnetic field is generated, caused essentially by the localised deposition of photon momentum. In turn this affects the electrostatic ion acoustic wave, converting it into a compressible magnetosonic wave which is electromagnetic. But because the magnetic field is spatially very non-uniform (it is proportional to the radial distance from the speckle axis close to the axis) the fast magnetosonic wave velocity also increases away from this axis. Thus the original planar ion acoustic wave fronts which acted like a grating in causing the SBS are changed into a spatially dispersive set of waves, unable to cause coherent back-scatter of the laser light. The magnetic field however has very little effect on electron plasma waves which were earlier inhibited in their growth by the density gradients associated with the ion acoustic waves; with the demise of the parametrically-driven ion acoustic waves the plasma waves and associated SRS can grow.

Abstract for 33rd Anomalous Absorption Conference
Lake Placid, NY 22-27 June 2003

X-ray Thomson scattering on solid density plasmas*

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We have recently succeeded measuring the temperature and ionization balance of a previously unexplored regime of high-density matter with a proof-of-principle experiment at the Omega laser facility at LLE, U. Rochester. We used spectrally-resolved 4.75-keV x-ray scattering from solid-density beryllium and carbon plasmas. The source is provided by a highly ionized resonance K-line from a Ti plasma. The sample is heated volumetrically by x-rays from another set of mid-Z plasmas produced by 10^{15} W/cm^2 laser beams. Spectrally resolved x-ray scattering provides for the first time detailed information on electron densities, temperature, and velocity distributions. In our experiments, we observe the Compton-downshifted spectral line that is broadened by the thermal motion of the electrons in the plasma indicating temperatures of up to T_e = 50 eV at densities of 3 x 10^{23} cm^{-3}. These are the first measurements from a solid-density plasma close to the Fermi degenerate state that is a fundamental state of matter occurring in many high energy density laboratory experiments.

We compare our results with calculations of the ionization balance using several ionization state models. In this regime, we find that the experimental data test models of electronic properties at high density. These results also suggest that the full range of dense plasmas, from Fermi degenerate, to strongly coupled, to high temperature ideal gas plasmas will now be accessible. For example, as the temperature is increased, the electron velocity distribution as measured by inelastic scattering transitions from a density-dependent parabolic Fermi distribution to the traditional Gaussian Boltzmann distribution. The technique has wide applications, ranging from studying the adiabat and compression of ICF fuels, to temperature measurements for radiatively heated foams. In addition, by accessing the collective scattering regime, basic dense plasma wave physics can be studied.

In collaboration with G. Gregori, F. J. Rogers, S. W. Pollaine, S. Kuhlbrodt (U. Rostock, Germany), G. Faussurier (CEA, France), and O Landen

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Generation of coherent THz radiation by intense laser-plasma interactions

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The l'OASIS group at LBNL has recently observed the production of THz radiation in the interaction of high-power laser pulses (10 TW, 50 fs) with underdense plasmas (gas jet targets).[1] In these experiments, the THz emission was produced via coherent transition radiation when a fs electron bunch crossed the plasma-vacuum boundary. The electron bunches were produced by a laser wakefield accelerator operating in the self-modulation regime and contained several nC of charge.[2] In these proof-of-principle experiments, the THz energy per pulse within a limited 30 mrad collection angle was several nJ and scaled quadratically with bunch charge, consistent with coherent emission. Modeling indicates that this broadband source produces nearly a μJ per pulse within a 100 mrad angle, and that the emission is limited due to the narrow transverse width of the laser generated plasma.[3] By increasing the transverse size of the plasma to the mm scale (e.g., by using additional pre-ionizing laser pulses), this source could provide more than 100 μJ/pulse, some two orders of magnitude beyond conventional laser-based methods of THz generation. This mechanism is also a convenient diagnostic for the electron bunch length, since coherent emission only occurs for wavelengths longer than the electron bunch length. In addition to laser-gas jet interactions, coherent transition radiation should also be observed in laser-solid interactions when the accelerated electrons emerge from the back side of the target.

This work supported by DoE, Division of High Energy Physics, under contract number DE-AC03-76SF00098.

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Energy absorption and transfer for different target geometries in the fast ignition scheme.

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We have used 2-1/2D particle in cell (PIC) simulations by the code OSIRIS to study the fast ignition. Targets of size 50μm and bulk density $40n_c$ (critical density) were placed in a box 100μm×100μm. The resolution was chosen $0.33c/\omega_p$ (skin depth) which resulted to a grid 12032×12032 with 4 particles per cell for both electrons and ions. The total simulation time is 1psec. Both s and p polarizations were simulated to infer the 3D effects and diverse geometries (circular with a ramp up region with and without a cone and square with a sharp boundary) for the target have been studied to provide insight to the mechanisms that affect the laser-plasma interface physics.

We will present results for the energy absorption, the energy distribution, the fast electron beam divergence angle and the flow pattern for the simulation geometries. Filaments are seen to form in the fast electron current but it will be argued that the Weibel instability is not the underlying mechanism. The filaments are found not to coalesce to a single current jet. The laser light also filaments influencing both the absorption and the transfer of the energy (that is the current flow) inside the overdense region. The energy distribution of the fast electrons is found to be approximated by a power law.

This work is supported by DOE and NSF.

POSTER

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33rd Anomalous Absorption Conference, Lake Placid, NY, June 22-27, 2003

Abstract

Simulations of high intensity, long pulse, planar experiments.
Jean-Pierre Matte and Fathallah Alouani Bibi, INRS-EMT, Université du Québec, Varennes, Québec, Canada ; David Braun, John Edwards and Lawrence Suter, Lawrence Livermore National Laboratory, Livermore, California.

Experiments on the ablation of solid plastic targets by long (1 nanosecond), high intensity (10^{16} W/cm^2) pulses were recently undertaken at LLNL, and LASNEX simulations of these were performed, which indicated that non-local transport was an issue. To assess this, comparative simulations of a related idealized problem (pure, fully ionized carbon, 100 eV initial temperature) were performed with both LASNEX and our electron kinetic code FPI. FPI uses the profiles computed by LASNEX at 100 psec as a staring point to avoid simulating the initially infinite density gradients. We find that FPI results indicate a greatly increased ablation rate, due to non-local heat flow. We have also begun to simulate this problem with an Eulerian fluid code using our new model of non-local electron heat flow [1].

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ANOMALOUS PLASMA COLLISIONALITY

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ABSTRACT

In a variety of experiments conducted at Sandia National Laboratories on the Saturn pulsed-power generator, operated in a long current-risetime mode, an exceptionally large amount of x-ray emission was observed. Canonical MHD modeling of these experiments, which utilizes Braginskii transport coefficients, is incapable of providing an energy input to the wire loads that were used in the experiments that is greater than or even equal to the energy seen in the x-ray output. The energy input is deficit by factors of between $1\frac{1}{2}$ to 3. The only way to achieve the energy inputs needed to explain the energy outputs is to assume that the experimental plasma has an anomalously large electrical resistivity brought on by an anomalously large collisionality. It has long been known that elastic scattering in a plasma medium is different from electron-electron and electron-ion scattering in free space because of the long range nature of the Coulomb force[1]. The consequences of this shielded scattering formalism have yet to be exploited, however. We show that the Rutherford scattering cross section is modified by the purported shielded potential in a way that enhances the plasma collisionality but does not shield the Coulomb interaction potential. Several orders of magnitude of collisional enhancement are found to be possible. This finding is in conformity with the amount of resistivity enhancement that is needed to explain the Sandia experiments.

Work supported by Sandia National Laboratoies and DTRA

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Stimulated Scattering Evolution and Hot Electron Production using Scaled Halfraum Targets at 2ω

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Abstract

A major factor limiting the radiation temperature achievable in a hohlraum, at a given laser energy and pulse length, is the onset of parametric instability growth for hohlraums below a certain threshold size. Target design has been guided by the belief that ensuring that plasma filling of the hohlraum void does not occur until the end of the laser pulse can reduce such instability growth and the associated deleterious production of energetic electrons.

Traditionally, x-ray driven experiments have used conservative hohlraum designs whose size is sufficient to ensure that the electron density is maintained below $0.1n_c$ (critical electron density for the wavelength used) for the duration of the laser pulse. The potential for instability growth has also guided laser facility operation into the near-UV, as the thresholds scale with both focused intensity, I, and wavelength, λ, as $I\lambda^2$ [1]. We contend that both of these directions, whilst effective, are based on limited evidence and may be overly constraining future exploitation of large laser facilities such as the National Ignition Facility (NIF).

Recent experiments at the HELEN laser at AWE have focussed on investigations into the evolution 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. The first stages of this experimental campaign were reported on at the 32nd Anomalous Absorption.

Analyses of the results from this campaign are presented with particular emphasis on the conditions present in the smallest scale halfraums and shows that beam smoothing using a phase plate has a significant effect on the stimulated backscatter and the hot electron production.

Poster Presentation
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Laser Wakefield Acceleration of auto-self-trapped electrons to ~1GeV in a plasma channel

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The auto-self-trapping and laser wakefield acceleration of electrons is studied in three-dimensions using the particle-in-cell (PIC) code OSIRIS.framework. The simulations model a 50fs, 16.5 TW, .8μm laser propagating through a leaky plasma channel with a minimum density of 3 10^{18} cm^{-3}. The initial wake is not large enough to trap background electrons. However, the self-consistent evolution of the laser due to photon acceleration and deceleration, group velocity dispersion, and transverse self-focusing results in larger wakes and a transverse dephasing of the electrons orbits leading to self-trapping. This first group of particles beam loads and eventually stretches the wake, leading to the trapping of a second bunch of electrons. The first bunch eventually reaches 480 MeV (with a beam distribution), while the second bunch approaches 840MeV(with a continuous distribution). We will discuss the evolution of the laser, the auto-self-trapping, the acceleration mechanism, the modification to the beam as it exits the plasma and the difference between 2D and 3D simulations. The simulations followed particles on 3600 x 256 x 256 grids for

Work supported by DOE and NSF. The simulations were performed on the IBM SP @ NERSC under the SciDAC allocation.

Simulation of Indirect Laser-Driven ICF Capsule Implosions

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We present results of simulations of indirect-drive, Ar-doped ICF implosions at OMEGA. These simulations are carried out to aid in the study of Ar K-shell spectra and monochromatic images being obtained in series of OMEGA experiments led by U. Nevada-Reno.

To predict the radiation field seen by the capsule, we perform 3D view factor simulation using *VISRAD.* The view factor simulations take into account the OMEGA laser pointings, the laser beam spatial and temporal profiles, and are used to estimate the time- and frequency-dependent radiation field seen by the capsule. This information is used to specify the incident radiation field for 1D radiation-hydrodynamics simulations of the capsule implosion carried out using the *HELIOS* code. *HELIOS* is a user-friendly radiation-hydrodynamics code which is currently being upgraded to perform inline collisional-radiative calculations so that the radiative cooling from the Ar-doped core can be simulated in greater detail. Plasma core temperature and density distributions from the hydro code are then used to compute Ar emission spectra and core images. To this end we utilize a multi-dimensional collisional-radiative, spectral analysis code, *SPECT3D*, which computes synthetic monochromatic images and detailed spectra emanating from the Ar-doped core. We will discuss details of the calculations and compare our results against experimental data.

Experimental Benchmarks for Improved Simulations of Absolute Soft X-ray Emission from Nike Targets

J. Weaver*, M. Busquet**, M. Klapisch **, D. Colombant *, U. Feldman**, A. N. Mostovych*, J. F. Seely***, G. Holland****

The Nike laser group has an ongoing effort to improve and benchmark the radiation hydrodynamic simulations used to develop pellet designs for inertial confinement fusion. A new non-LTE postprocessor, Virtual Spectro [1], has been added to the FAST code suite [2] for detailed simulation of spectra, including radiation transport effects. Virtual Spectro uses atomic data from HULLAC [3] and SCROLL [4] to treat both low-Z and high-Z ions. This new combination enhances our ability to predict the absolute emission of soft x-rays (hν ~0.1-1.0 keV). An extensive database of time-resolved, absolutely calibrated measurements of soft x-rays has been collected at the Nike laser facility using filtered diode modules and transmission grating spectrometers. The recent addition of a new absolutely calibrated, time-resolving transmission grating spectrometer has provided higher spectral resolution and further knowledge of the angular dependence of emission from planar targets. Comparison between these observations and results from Virtual Spectro and FAST1D will be presented. Good agreement (within factor of ~2) for the absolute emission has been found for CH targets at laser intensities of ~10 TWcm^{-2}.

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*** Space Science Division, NRL, Washington, DC
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Poster presentation requested

LINEAR PERTURBATION COMPUTATIONS IN A PLANAR ABLATION FLOW

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This work pursues an investigation initiated in [1]. Namely, linear perturbations about a self-similar planar ablation flow are computed with the help of the linear perturbation code SILEX. The physical model assumes ideal gas dynamics and electronic heat conduction for a semi-infinite slab of perfect gas. For vanishing initial temperature, the self-similar ablation flow results from imposing time power-laws for boundary pressure and incoming heat-flux. This configuration is representative of the early stage of the laser irradiation of a target in inertial confinement fusion. Perturbations are here initiated by introducing external surface defects at $t = 0$, thus allowing us to study the so-called "ablative Richtmyer-Meshkov instability" [4, 3]. Both the mean flow and linear perturbations initial and boundary value problems are solved with SILEX. The numerical methods are based on a finite-volume formulation combining, through operator splitting, explicit Godunov-type schemes with semi-implicit iterative/direct methods. The qualitative findings previously obtained [1] with the first order version of these numerical methods are here corroborated by second order accurate results. In particular, both the shock-wave front and the ablation front are created with significant perturbation amplitudes. Shock-wave front perturbations appear to decrease asymptotically as $t^{-\alpha}$ (where $\alpha = 4/3$ is the self-similar exponent of the mean flow), while oscillating with a pseudo-period which scales like $t^{-\alpha-1}/k_{\perp}$, where $k_{\perp}$ is the transverse wavenumber. (Note that these behaviors differ from the classical steady strong-shock results [2].) Ablation front perturbations oscillate about zero and are damped as time increases.

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Linear Stability Analysis of a Self-Similar Solution for Ablation Fronts in Inertial Confinement Fusion

THP10

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The stability of an ablative flow is of importance in inertial confinement fusion. Here we exhibit a family of self-similar solutions of gas dynamics equations with nonlinear heat conduction for semi-infinite slabs of perfect gases. Such self-similar solutions arise for particular but realistic initial and boundary conditions—boundary pressure and incoming heat flux are given by time power-laws—and are representative of the early stage in the ablation of a pellet heated by a laser. Following [1], these solutions which satisfie a fourth order ordinary differential equation depending on three parameters, are numerically obtained using a dynamical multidomain Chebyshev pseudo-spectral method. Wide variety of ablation configurations may be obtained. Linear stability analyses of such solutions are performed by solving initial and boundary value problems for linear perturbations. The numerical methods release on a dynamical multidomain Chebyshev pseudo-spectral method and operator splitting between hyperbolic and parabolic equations. Here we focus on boundary heat flux perturbations. Space-time evolutions of characteristic perturbations of the flows—density, velocity, pressure, entropy and vorticity—for different wavenumbers will be presented. These results indicate that, for large time and large wavenumber, all perturbation amplitudes in the ablation zone decrease for sufficiently large times, and more rapidly as the transverse wave number increases.

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THP11

Collapsing Radiative Shocks in Xenon Gas on the Omega Laser

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A number of astrophysical systems involve radiative shocks that collapse spatially in response to energy lost through radiation. Supernova remants are an example of systems that cool enough to radiatively collapse, resulting in a shell-type remnant. This is believed to produce thin, dense shells that are Vishniac unstable. This type of instability may be responsible for the convoluted structure of supernova remnants such as the Cygus Loop. We are conducting experiments on the Omega laser intended to produce such collapsing shocks and to study their evolution. The experiments use the laser to accelerate a thin slab of driving material (beryllium) through 1.1 ATM of xenon gas (~6 mg/cc) at ~100 km/sec. 1D radiation-hydrodynamic simulations predict a collapsed layer in which density will reach > 20 times the initial density, and whose thickness will approach 100 μm as the distance traveled reaches ~ 2 mm. The simulations also predict that the dense layer will be pushed ahead of the dense Be or plastic by the leading edge of the expansion of this material. The experiment is diagnosed in two ways. X-ray radiography has detected the presence and thickness of the dense shocked layer. These data indicate that the shock velocity is ~ 100 km/s and that the layer is compressed to < 1/15 its initial thickness. A unique, side-on application of the VISAR (Velocity Interferometer System for Any Reflector) technique is used to detect frequency shifts from ionization and any reflections from the edge of the dense shocked layer. The timing of signals attributed to the dense shocked layer confirms the radiographic measurements of shock position. Future experiments using a plasic target instead of beryllium will be outlined.

Work at Michigan supported by the U.S. Department of Energy under grants DE-FG03-99DP00284, DE-FG03-00SF22021, and other grants and contracts.

Possible evidence for suppression of LPI in C_5H_{12} plasmas by small amounts of dopants

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The C_5H_{12} gasbag experiments shot on Helen in November, 2002 differed from previous shots through the addition of a very small amount of Kr dopant to allow x-ray imaging. The amount of Kr was about 1% partial pressure or 0.06% atomic. Comparison of the results from these shots with results from previous, undoped C_5H_{12} gasbags shows several marked differences. First, the overall level of raman backscatter as a function of fill density was noticeably lower. Second, the raman backscatter spectrum was much narrower at higher densities, suggesting there was less filamentation. Finally, the hard x-ray spectrum, indicative of hot electron production, was below the threshold of detection whereas with the undoped gasbags there was a very strong hard x-ray signal.

Although, at this point, these results are hardly stronger than anecdotal, it is possible to find other instances where small amounts of dopants may have had a surprising effect. This includes some Omega gasbags which had trace amounts of Xe in C_5H_{12} and the first Nova C_5D_{12} gasbag that was fired without Ar dopant giving “weird results; lots of hard x-rays fogging the film”. All subsequent Nova C_5D_{12} gasbags had Ar dopant.

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Prefer a Poster Presentation

Ion acceleration in high Mach number shocks produced by overdense laser-plasma interactions

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The possibility of proton acceleration from laser-solid interactions has been explored in various experiments, but there is still debate about whether the protons originate at the front or rear surface of the target and about the acceleration mechanisms. In these experiments a thin metal target, such as Aluminum, is used. The protons come from a layer of impurities on the surface of the target. To isolate the acceleration mechanisms, we have recently examined proton acceleration using the particle-in-cell model OSIRIS.framework. This is a parallelized, multi-dimensional (2D/3D), relativistic, fully electromagnetic, PIC code. A series of simulations were done for various laser intensities, target thicknesses, and target densities. These simulations identified two distinct acceleration mechanisms: i) proton acceleration due to the time dependent ambipolar electric fields arising from the free expansion of the strongly heated electrons off both the front and rear target surfaces, and ii) proton acceleration in a collisionless, electrostatic shock formed at the front of the target. The formation of strong high-Mach number (2-3) electrostatic shocks by laser pulses incident on overdense plasma slabs is observed in particle-in-cell (PIC) simulations for a wide range of intensities, pulse durations, target thicknesses, and densities. The shocks propagate undisturbed across the plasma, accelerating the ions. Protons with energies approaching 150 MeV were observed. We find that a plateau in the ion spectrum could provide a direct signature for shock acceleration. We will also present preliminary results on the acceleration of high Z ions to see if the shock can accelerate these ions to energies in excess of 1 GeV.

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Friday
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Fast-Electron Transport in Dense Plasmas in the Context of Fast-Ignition Studies at LLE

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One of the central issues of the fast-ignitor (FI) approach to inertial fusion is the possibility of propagating an intense relativistic electron beam over distances in excess of 100 μm from its origin near the critical surface to the dense compressed core. Motivated by future integrated FI experiments with the OMEGA EP laser system, we have studied the penetration of an intense electron beam into an overdense plasma with the hybrid 3-D electromagnetic particle-in-cell code LSP.[1] The simulations were compared with the predictions of a simple two-fluid model. We have assumed prescribed parameters for the electron beam at the critical surface and a plasma profile consistent with OMEGA implosions.

We have determined the relative roles of resistive electric and magnetic fields and collisional stopping in determining the penetration of the hot electrons over a parameter space that will likely be encountered in future FI studies at LLE. We have explored the degree to which the simple model, which is similar in spirit to analytical models of Ref. 2, reproduces the LSP simulations. A reduced model of electron transport is required for integration into hydrodynamic inertial confinement fusion (ICF) codes.

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Electron heat transport in a cone target and prospects for FIREX(Fast Ignition realization Experiment)

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Recently, the PWM laser was upgraded to peta watt level. In PW laser experiments, it is found that the neutron yield increased from 10^5 to 10^7. The neutron yield enhancement, the neutron energy spectrum and X-ray spectrum of the core plasmas indicate that the temperature increased from 300eV to about 0.8keV. The experimental results were simulated with the hydrodynamic code 'PINOCO", PIC code ,and Fokker Planck code and are well reproduced.[1][2]

In the cone target, a ultra-intense laser light is partially reflected on the cone surface wall and focused to the top of the cone while the relativistic electrons are generated on the side wall of the cone and the top wall. Since the electrons are accelerated along the laser propagation direction, strong current is driven along the cone axis and the relativistic electron flows are pinched to the top of the cone. The guiding of the relativistic electron is due to the strong magnetic field generated by the electron acceleration along the surface of the cone. These characters of the laser interaction with cone contribute to enhance the coupling efficiency of short pulse laser to the core plasmas.

We also carried out Fokker Planck simulations on the cone target experiment for predicting the neutron yield. In the simulation, the relativistic electron energy spectrum was taken from the cone target PIC simulation where the spectrum has two slope temperatures which are 0.5MeV and 2.0 MeV. The 0.5 MeV slope temperature is related to the cone side wall Brunnel absorption, where the laser intensity is lower than the top of the cone, since the laser is focused toward the top of the cone. The Fokker Planck simulation shows that the plasma heating and the neutron yield depend on the 0.5 MeV electron heating.[3] This softening of the electron spectrum is also one of the advantages of the cone guide target.

If the coupling efficiency is higher than 25%, the required heating laser energy for break even experiment (Fast Ignition realization Experiment I; FIREX-I) is estimated to be 10kJ for 1500 times solid density DT plasmas and 30μm spot diameter. According to the simulation and fundamental experiment results, the relativistic electron heat flow is expected to be confined by the self-generated magnetic field in the 30μm spot diameter. From the above understandings on the cone target performance, we started to construct the FIREX-I in this year.

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FO3

Transport of Relativistic Electrons for Modeling Fast Ignition in the 2-D Hydrocode *DRACO*

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To simulate fast ignition in direct-drive inertial confinement fusion, a simplified fast-electron transport model has been introduced in the multidimensional hydrodynamic code *DRACO*. In the first iteration of the model, the electrons are introduced at the pole of a 2-D simulation at an appropriate thermal electron density and are transported in a straight line toward the target core. The energy deposited in the background plasma is calculated using slowing formulas by Deutsch.[1] The fast-electron model is applied to an OMEGA cryogenic target designed to reach 1-D fuel ρR of 500 mg/cm^2 in order to assess the effect of a fast-ignitor beam from the proposed high-intensity, short-pulse OMEGA EP (extended performance) laser. Sensitivity to timing, the source spectrum, and energy of the electron beam will be presented.

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Prefer oral presentation

FO4

Implicit PIC/Hybrid Modeling of Ultra-Intense Laser-Matter Interactions*

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The ANTHEM Implicit hybrid simulation code was used in the earliest studies[1] of intense laser-matter interaction in application to the Fast Ignitor approach to ICF. The basic model has treated the background plasma in a laser target as a pair of collisional ion and cold electron fluids. Laser energy is propagated across the computational mesh to the critical surface, where it converts some of the background electrons into a third, relativistic hot electron fluid. The hot electrons spread throughout the target, scattering off the ions and dragging against the electrons. They draw a resistive cold electron return current through resultant self-consistent electromagnetic fields. The fields are calculated implicitly by the Moment Method, enabling the practical study of super-compressed plasmas (10^3 x critical) with no time-step limits from the plasma period. Near gigagauss magnetic fields at critical have been predicted through the action of the ponderomotive forces at $\geq 10^{19}$ W/cm^2 laser intensities[1]. We will report on recent model refinements, including the mixed use of fluid and particle ion and electron components. The particles permit a more accurate treatment of relativistic effects. In 2D Weibel instability can be studied as a function of the hot electron source distribution. In application to transport in dense (200 x critical), thin (~10 μm) foils ANTHEM shows strong magnetic field generation on the foil's back side surrounding a directed column of the hot electrons, correlated with the strongly focused emission of fast ions.

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PIC Simulations for the First Picosecond in the Fast Ignition Scheme

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We study the fast ignition scheme using two-dimensional (2-1/2 D) particle-in-cell (PIC) simulations with the code OSIRIS. The simulations are performed in a 100 μm×100μm box with a target size of 50 μm to reduce the influence of the box boundary conditions. The target consists of fully-ionized plasma with a bulk density of 40 n_c (critical density). The largest simulations use a grid of 12032×12032 with a grid resolution of 0.33 c/ω_p (skin depth) and we use 4 particles/cell for both electrons and ions. The laser intensity used is about 10^{20} W/cm^2 and the pulse length is about 1 ps. Both s- and p-polarization are used to infer any three-dimensional effect. Various target geometries have been studied, including square, circular and circular with a cone, and with a sharp boundary or ramped-up plasma density. We will present the results from these simulations, including the laser absorption rate, fast electron beam divergence and energy flux, and target boundary influence on the current flow pattern.

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(Oral presentation preferred.)

Abstract Submitted to the
33rd Anomalous Absorption Conference
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Guiding of relativistic laser intensities in preformed plasma channels

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The l'OASIS group at LBNL has recently demonstrated the guiding of laser pulses with relativistic intensities ($> 10^{18}$ W/cm^2) in preformed plasma channels.[1] In these experiments, four synchronized pulses (an ignitor pulse, a heater pulse, a high intensity main pulse, and a probe pulse for interferometry) from a 10 TW, 50 fs laser system were incident on a gas jet target. The plasma channel was created over the width of the gas jet plume (few mm) by the ignitor-heater method.[2] First, a short pulse ignitor beam of intensity $\sim 10^{14}$ W/cm^2 is used to ionize the region about the central axis of the gas jet. Secondly, a long pulse (200 ps) beam of intensity $\sim 10^{13}$ W/cm^2 is used to heat the centrally ionized region. A plasma channel forms as the hot plasma region expands into the neutral gas region. The channel properties are measured with side-on interferometry. A few ns after heating, the high intensity $> 10^{18}$ W/cm^2 main pulse is injected down the axis of the channel and the transmitted energy and modal properties of the pulse at the channel exit are measured. Approximately 40% of the beam energy is transmitted through the channel over a distance on the order of tens of Rayleigh lengths. At the channel exit the pulse radius is approximately 8 μm and the intensity exceeds 10^{18} W/cm^2. Recent theoretical results on the propagation of short, intense laser pulses in plasma channels will be presented, including results from envelope and fluid codes. Progress towards the realization of a 1 GeV single-stage of a channel-guided laser wakefield accelerator will be discussed.

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