25th Annual Anomalous Absorption Conference

Aspen Institute
Aspen, Colorado
27 May - 1 June, 1995

Los Alamos

25th Anomalous Absorption Conference Agenda

May 28, 1995 Sunday Morning 8:30-12:15
Oral Session 1, Laser Plasma Interactions , Paepcke Auditorium
Donald DuBois, Chair

8:30 Introduction and Welcome
Doug Wilson

8:45 1O1 Enhancement of the Saturation Level of Stimulated Brillouin Scattering of a Laser by Seeding a Plasma with an External Light Wave
J. C. Fernández, K. S. Bradley, J. A. Cobble, P. L. Gobby, and R. G. Watt, LANL

9:00 1O2 Experimental Dependence of Stimulated Brillouin Scattering Reflectivity on Focusing Optic F Number in a Long Scale Length Plasma
R. G. Watt, J. Cobble, D. F. DuBois, J. C. Fernandez, and H. A. Rose, LANL
R. P. Drake and B. S. Bauer, LLNL

9:15 1O3 Generalization of the Multidimensional Theory of Stimulated Brillouin Scattering to Include Pondermotive Filamentation and Inhomogeneous Flow Profiles
B. B. Afeyan, R. L. Berger, T. B. Kaiser, and W. L. Kruer, LLNL

9:30 ~~1O4~~ 1O12 Effects of the Anti-Stokes Wave on Stimulated Brillouin Scattering
C. J. McKinstrie and J. S. Li, Univ. of Rochester

9:45 1O5 Study of Stimulated Side-Scattering using Multiple Interaction Beams
C. Labaune, H. A. Baldis, E. Schifano, N. Renard, and A. Michard, Ecole Polytechnique
W. Seka, Univ. of Rochester
J. Moody, K. Estabrook, LLNL

10:00 1O6 Do SBS and SRS Care About Large Plasmas?
H. A. Baldis, C. Labaune, B. Quesnel, N. Renard, E. Schifano, and A. Michard, Ecole Polytechnique

10:15 1O7 Phase-Conjugated SBS in Laser-Produced Plasmas
R. W. Short, Univ. of Rochester

10:30 Coffee Break

10:45 1O8 Nonlinear Frequency Shifts and Harmonic Generation in Finite Amplitude Ion Acoustic Waves
E. A. Williams, LLNL

11:00 1O9 ↓ 3O15 Angular Distribution of SRS from Nova Gasbag Plasmas
D. S. Montgomery, R. K. Kirkwood, B. J. MacGowan, J. D. Moody, C. A. Back, S. H. Glenzer, D. H. Kalantar, B. B. Afeyan, R. L. Berger, and D. H. Munro, LLNL
D. Desenne, A. Richard, and C. Rousseaux, CEA

11:15 1O10 ↓ 3P24 Novel Techniques to Control Stimulated Raman and Brillouin Scattering in Laser Plasmas
W. L. Kruer and S. C. Wilks, LLNL

11:30 1O11 Anomalous High Energy Electron Emission from Laser Plasma
V. V. Ivanov, A. K. Knyazev, A. V. Kutsenko, A. A. Matzveiko, Yu. A. Mikhailov, V. P. Osetrov, A. I. Popov, G. V. Sklizkov, A. N. Starodub, P. N. Lebedev Physical Institute
M. Klapisch, Artep, Inc.

11:45 ~~1O12~~ 1O4 Thermal Filamentation of Laser Beams
J. S. Li and C. J. McKinstrie, Univ. of Rochester
C. Joshi and K. Marsh, UCLA

12:00 1O13 Return Current Instability in Laser Heated Plasmas
V. T. Tikhonchuk and W. Rozmus, Univ. of Alberta
V. Yu. Bychenkov, P. N. Lebedev Physics Institute
C. E. Capjack, Univ. of Alberta
E. Epperlein, Univ. of Rochester

May 28, 1995 Sunday Evening ~~7:30 - 8:30~~
Invited Talk, Paepcke Auditorium
Don DuBois, Chair

7:30 1I1 Experiments for Fusion and Physics Using Trident
R. P. Drake and R. G. Watt

May 28, 1995 Sunday Evening 8:30 - 9:00 Dining Room
25 th Anniversary Celebration
B. Kruer Master of Ceremonies

May 28, 1995 Sunday Evening 9:00 - 10:30
Mixed Posters Session 1, East and West Seminar Rooms

1P1 Plasma Flow Effects in Beam Pointing
H. A. Rose and D. F. DuBois, LANL

1P2 Laser Propagation in Underdense Plasmas
M. D. Feit, J. C. Garrison, and A. M. Rubenchik, LLNL

1P3 Numerical Simulations of High-Frequency Parametric Instabilities, Brillouin Scattering and Beam Crossing in the Gas-Bag Experiment Context
G. Bonnaud, C. Bouvet, A. Chiron, and A.Bers, CEA
B. B. Afeyan, and R. L. Berger, LLNL
F. Bouchut, Univ. d'Orleans

1P4 Relativistic Self-Focusing of a Multi-Terawatt Laser Pulse in a Underdense Plasma: Experimental Observation and Simulations
A. Chiron , A. Dulieu, G. Bonnaud, J.L. Micquel, G. Malka, M. Louis-Jacquet, CEA Limeil
G. Mainfray, CEA, Saclay

1P5 Numerical Simulations of Stimulated Raman Scattering in Laser Hot Spots and Speckles
B. B. Afeyan, R. L. Berger, C. D. Decker, W. L. Kruer, A. B. Langdon, C. W. Still, and T. B. Yang, LLNL
G. Bonnaud, CEA

1P6 Propagation of Intense Laser Beams in Underdense Plasmas in the Presence of Stimulated Brillouin Scattering and Filamentation
V. Eliseev, I. Ourdev, W. Rozmus, V. T. Tikhonchuk, and C. E. Capjack, Univ. of Alberta
P. E. Young, LLNL

1P7 Effects of Long-Wavelength Density Fluctuations on Stimulated Brillouin Scattering
A. Maximov, W. Rozmus, and V. T. Tikhonchuk, Univ. of Alberta
D. F. DuBois , E. M. Gavrilov, and H. A. Rose, LANL
A. M. Rubenchik, LLNL

1P8 Electron Temperature Measurements of a Laser-Produced Plasma Using Simultaneous UV Thomson Scattering and X-Ray Spectroscopy
J. F. Camacho, UC-Davis & LLNL
S. M. Cameron, J. L. Porter, L. E. Ruggles, and R. B. Spielman, SNL

1P9 A Spatially Imaging Broadband Streaked Spectrograph
J. Cobble, S. Evans, J. Fernández, R. Watt, and B. Wilde, LANL

1P10 Time Resolved Measurements of the Angular Deflection of an Electron Beam by a Tunnel-Ionized Plasma
D. Gordon, A. Lal, K. Wharton, C. E. Clayton, M. Everett, and C. Joshi, UCLA

1P11 Imaging of Near to Back Scattered Light in Gas Target Plasmas
R. K. Kirkwood, C. A. Back, K. G. Estabrook, D. H. Kalantar, B. J. MacGowan, D. S. Montgomery, and J. D. Moody, LLNL

1P12 Energy Transfer Between Crossing Laser Beams
W. L. Kruer, S. C. Wilks, R. Kirkwood, and B. Afeyan, LLNL

1P13 Relation Between N-Body Lyapunov Exponent and Transport Coefficient in One Component Strongly Coupled Plasmas
K. Nishihara and Y. Ueshima, Osaka University
D. M. Barnett and T. Tajima, Univ. of Texas-Austin

1P14 Excitation of Accelerating Wakefields in Inhomogeneous Plasmas
G. Shvets, PPPL
J. S. Wurtele, MIT
T. Chiou and T. Katsouleas, UCLA

1P15 Measurements of the Beatwave Dynamics in Time and Space
K. Wharton, A. Lal, D. Gordon, C. E. Clayton, M. Everett, and C. Joshi, UCLA

1P16 Adaptive Mesh Refinement Simulation of Linear-Nonlinear Instability Growth (U)
R. P. Weaver, M. L. Gittings, and R. M. Baltrusaitis

May 29, 1995 Monday Morning 8:30- 12:30
Oral Session 2, Hydrodynamics ,Paepcke Auditorium
John Gardner, Chair

8:30 2O1 Theoretical and Experimental Studies of Hydrodynamic Stability Related to Start Up Problem
K. Nishihara, R. Ishizaki, T. Endo, K. Shigemori, H. Azechi, A. Nishiguchi, K. Mima, M. Sato, M. Nakai, A. Ando, and K. A. Tanaka, Osaka University

8:45 2O2 Target Imprinting by Laser Intensity Nonuniformities
J. P. Dahlburg and J. H. Gardner, NRL
R. J. Taylor, Blackett Laboratory
A. J. Schmitt, NRL

9:00 2O3 Laser Imprint Smoothing in Foam-Buffered Targets
R. J. Mason, R. A. Kopp, and H. X. Vu, LANL

9:15 2O4 X-Ray Laser Backlighting Applied to Measure Laser Imprint
D. H. Kalantar, L. B. DaSilva, S. G. Glendinning, M. H. Key, F. Weber, and S. V. Weber, LLNL
J. P. Knauer, Univ. of Rochester

9:30 2O5 NIF Direct Drive Capsule Design Studies
S. V. Weber, S. Dalhed, and D. Eimerl, LLNL
M. H. Key, Rutherford Appleton Lab
C. P. Verdon, Univ. of Rochester

9:45 2O6 The Nike KrF Laser and Target Facility
S. P. Obenschain, S. E. Bodner, K. A. Gerber, R. H. Lehmberg, E. A. McLean, C. J. Pawley, M. S. Pronko, V. Serlin, J. D. Sethian, J. A. Stamper, and C. A. Sullivan, NRL
A. V. Deniz, J. Hargrove, and T. Lehecka, SAIC

10:00 2O7 Initial Target Results from the Nike Laser
A. V. Deniz, D. A. Garren, and T. Lehecka, SAIC
S. E. Bodner, Y. Chan, D. Colombant, J. P. Dahlburg, J. H. Gardner, K. A. Gerber, K. J. Kearney, M. Klapisch, R. H. Lehmberg, E. A. McLean, S. P. Obenschain, C. J. Pawley, M. S. Pronko, A. J. Schmitt, V. Serlin, J. D. Sethian, J. A. Stamper, and C. A. Sullivan, NRL

10:15 2O8 The Knock-On's Diagnostic in Laser ICF Targets Revisited
S. Cremer, S. Skupsky, C. P. Verdon, and J. A. Delettrez, Univ. of Rochester

10:30 Coffee Break

10:45 2O9 Richtmyer-Meshkov Experiments and Simulations
G. Dimonte, E. Frerking, M. Schneider, and B. Remington, LLNL

11:00 2O10 Experimental and Computational Analyses of Rayleigh-Taylor Growth in Cylindrical Implosions
J. B. Beck, W. W. Hsing, and N. M. Hoffman, LANL

11:15 2O11 NOVA High Growth Factor Implosion Experiments and Analysis
C. J. Keane, O. L. Landen, B. A. Hammel, M. Cable, R. Cook, T. Dittrich, S. Haan, S. P. Hatchett, R. McEachern, T. Murphy, M. Nelson, L. Suter, and R. Wallace, LLNL
R. Chrien, J. Colvin, N. Hoffman, W. Hsing, and G. Pollak, LANL

11:30 2O12 A Mix Model in LILAC for the Linear and Weakly Nonlinear Regime of the Rayleigh-Taylor Instability
J. Delettrez, D. K. Bradley, and C. P. Verdon, Univ. of Rochester

11:45 2O13 Growth Rate of the Rayleigh-Taylor Instability for Indirect-Drive ICF
R. Betti, V. Goncharov, R. L. McCrory, and C. P. Verdon, Univ. of Rochester

12:00 2O14 The Effect of Finite Thermal Conduction on the Ablative Rayleigh-Taylor Instability
V. Goncharov, R. Betti, R. L. McCrory, and C. P. Verdon, Univ. of Rochester

12:15 2O15 The Effect of Surface Perturbation Spectrum in Unstable ICF Implosions
N. M. Hoffman, D. C. Wilson, W. S. Varnum, and F. J. Swenson, LANL

May 29, 1995 Monday Evening 7:30 - 8:30
Invited Talk, Paepcke Auditorium
Nelson Hoffman, Chair

7:30 2I1 Prospects for Direct and Indirect- Drive ICF on the OMEGA Laser
R. S. Craxton, LLE

May 29, 1995 Monday Evening 8:30 - 10:30
Mixed Posters Session 1, East and West Seminar Rooms

2P1 The Anomalous Absorption of Short-Pulse High-Intensity Lasers in Underdense Plasmas
K. C. Tzeng, W. B. Mori, and T. Katsouleas, UCLA
C. D. Decker, LLNL

2P2 Collisionless Electron Heating by a UHI Laser Pulse at Normal Incidence
E. Lefebvre and G. Bonnaud, CEA

2P3 Transparency of an Overdense Plasma Induced by Relativistic Effects
E. Lefebvre and G. Bonnaud, CEA

2P4 Stimulated Raman Scattering in High Intensity Short-Pulse Laser Plasmas
F. I. Gordon, H. C. Barr, T. J. M. Boyd, and S. J. Berwick, Univ. of Essex

2P5 Harmonic Generation in Picosecond Laser-Plasma Interaction
L. Zhao, G. Kulcsár, F. W. Budnik, and R. S. Marjoribanks, Univ. of Toronto

2P6 Light Pressure Effects on a Preformed Plasma"
Z. Jiang, J. C. Kieffer, H. Pépin, A. Ikhlef, C. Y. Coté, M. Chaker, T. W. Johnston, and J. P. Matte, INRS-Énergie et Matériaux

2P7 Propagation of High Intensity Lasers Through Large Scalelength Plasmas
J. D. Moody, B. J. MacGowan, R. K. Kirkwood, D. S. Montgomery, D. Desenne, C. Rousseaux, R. L. Berger, D. H. Kalantar, and D. Munro, LLNL

2P8 Self-Trapped Electron Acceleration from Wakefields Generated by Short-Pulse Lasers
W. B. Mori, K. C. Tzeng, and C. E. Clayton, UCLA
C. D. Decker, LLNL
A. Modena, Rutherford Appleton Lab

2P9 Intense Beam Channeling in Underdense Plasmas
M. D. Feit, J. C. Garrison, and A. M. Rubenchik, LLNL

2P10 Optical Probing of a Dense Plasma Created by a Femtosecond Laser Produced Shock Wave
R. Evans, T. A. Hall, A. D. Badger, and M. Mahdieh, Univ. of Essex
P. Audebert, J. C. Gauthier, and J. P. Geindre, Ecole Polytechnique
A. Mysyrowicz and A. Antonetti, Laboratoire d'Optique Appliquée

2P11 Mass Resolved Time Flight Observations of Ions Produced by 140 fs Laser Pulses on Buried Layer Targets
G. Guethlein, M. Foord, D. Price, J. Bonlie, B. Young, R. Sheperd, and R. Stewart, LLNL

2P12 Optical Guiding of High Intensity Laser Pulses in Long Plasma Channel Formed by a Slow Capillary Discharge
A. Zigler and Y. Erlich, Hebrew University
J. Krall and P. Sprangle, NRL

2P13 Collisionless Absorption of Light Waves Obliquely Incident on Overdense Plasmas with Sharp Density Gradients
T. Y. B. Yang, W. L. Kruer, A. B. Langdon, and R. M. Moore, LLNL

2P14 Experimental Investigation of the Interaction of 1μ, 0.7 Psec, 10^{19} W/cm^2 Laser Pulses with Solid Targets
C. Darrow, G. Hay, Y. Zakharenkov, H. Nguyen, B. Hammel, and M. D. Perry, LLNL

2P15 Energetic Ions, Produced in Short-Pulse-Laser Interaction with Solid Targets
Y. A. Zakharenkov, U. of California - Davis
R. G. Hay and C. B. Darrow, LLNL
A. P. Fews, U. of Bristol
B. A. Hammel, H. Nguyen, and M. D. Perry, LLNL

2P16 Pulsewidth Control of Bright Ultrashort X-Rays from Intense Subpicosecond Laser-Plasma Interactions
A. Maksimchuk, D. Umstadter, J. Workman, X. Liu, and S. Coe, Univ. of Michigan

2P17 Low Entropy Material Compression Using the Nike KrF Laser
D. G. Colombant and S. E. Bodner, NRL

2P18 Hydrodynamic Efficiency Dependence on Atomic Number in High-Gain Targets
D. G. Colombant, A. J. Schmitt, S. E. Bodner, J. H. Gardner, and M. Klapisch, NRL

2P19 Direct Drive NIF Capsule Studies in 1 and 2-D
C. Fontes, LANL

2P20 High Gain Direct-Drive Target Designs for KrF Lasers
A. J. Schmitt, D. Colombant, J. P. Dahlburg, and J. H. Gardner, NRL

2P21 ~~Hydrodynamic Instability Analysis of an NIF Target Design~~
D. C. Wilson and N. M. Hoffman, LANL

2P22 Measurement and Calculation of Nickel-Like Soft X-Ray Laser Spectra
H. Daido, Y. Kato, K. Murai, S. Ninomiya, R. Kodama, and H. Takabe, Osaka Univ.
F. Koike, Kitasato Univ.

2P23 Effect of ISI Imprinting on Planar and Spherical Targets
J. H. Gardner, J. P. Dahlburg, R. H. Lehmberg, and S. E. Bodner, NRL

2P24 Quantitative Experimental Evaluation of a Foam Buffer Target Design for Spatially Uniform Ablation of Laser Irradiated Plasmas
M. Dunne, Atomic Weapons Establishment
M. Borghesi, A. Iwase, M. W. Jones, R. Taylor, and O. Willi, Imperial College of Science
R. Gibson, S. R. Goldman, J. Mack, and R. G. Watt, LANL

2P25 Two-Dimensional Lasnex Simulations of Foam-Mitigated Direct Drive Experiments on Trident
R. A. Kopp and H. X. Vu, LANL

2P26 Tetrahedral Hohlraums for the OMEGA Upgrade and the National Ignition Facility
J. D. Schnittman and R. S. Craxton, Univ. of Rochester

2P27 1-D Vlasov Simulations of Electron Acceleration by Radiation-Driven Langmuir Turbulence in the Ionosphere
D. L. Newman, J. G. Wang, and M. V. Goldman, Univ. of Colorado

2P28 Observed Langmuir Turbulence During Ionospheric Modification Experiments in the Presence of Irregularities
E. Helmersen, D. F. DuBois, E. Mjolhus

2P29 Propagation of Intense Electromagnetic Waves in Self-induced Turbulence
D. F. DuBois, H. A. Rose, LANL
D. Russell, Lodestar
A. Hanssen, U. of Tromso, Norway

May 30, 1995 Tuesday Morning 8:30-12:15
Oral Session 3, Hohlraum Physics , Paepcke Auditorium
Bernhard Wilde, Chair

8:30 3O1 Shocked Witness Foam-Ball Diagnostic for NOVA Hohlraum Time-Dependent Drive Asymmetry
P. Amendt, S. G. Glendinning, B. A. Hammel, O. Landen, and L. J. Suter, LLNL
S. Laffite and J. P. Jadaud, CEL-V

8:45 3O2 Studies of Radiation Transfer and X-Ray Conversion Efficiency in Thin Laser-Irradiated Targets
B. N. Bazylev, G. S. Romanov, and V. I. Tolkach, A. V. Lykov Institute of Heat and Mass Exchange
V. V. Gavrilov, A. Yu. Goltsov, I. A. Kargin, and N. G. Kovalsky, Troitsk Institute for I nnovation and Fusion Research
M. O. Koshevoi and A. A. Rupasov, P. N. Lebedev Physical Institute

9:00 3O3 Radiative Heating of Low-Z Solid Plastic Foils
K. Eidmann, I. B. Foldes, T. Lower, J. Massen, R. Sigel, G. D. Tsakiris, and S. Witkowski, MPI, Garching
H. Nishimura, Y. Kato, T. Endo, H. Shiraga, M. Takagi, and S. Nakai, ILE, Osaka

9:15	3O4	Symmetry Experiments in Gas Filled Hohlraums at NOVA N. D. Delamater, E. L. Lindman, G. R. Magelssen, A. A. Hauer, B. H. Wilde, and R. Chrien, LANL T. J. Murphy, L. V. Powers, S. M. Pollaine, L. J. Suter, R. L. Kauffman, M. B. Nelson, M. D. Cable, J. B. Moore, and R. J. Wallace, LLNL A. L. Richard, CEA K. Gifford, GA
9:30	3O5	Modeling of Drive-Symmetry Experiments in Gas-Filled Hohlraums at Nova E. L. Lindman, G. R. Magelssen, D. H. Delamater, A. A. Hauer, and B. H. Wilde, LANL S. M. Pollaine, T. J. Murphy, L. V. Powers, L. J. Suter, and R. L. Kauffman, LLNL
9:45	3O6	Interface Motion in Gas-Filled and Ch-Lined Laser-Heated Hohlraums J. M. Foster and P. A. Rosen, Atomic Weapons Establishment T. J. Orzechowski, T. D. Shepard, and W. K. Levedahl, LLNL
10:00	3O7	Interface-Motion Modeling for Nova Gas Hohlraums T. D. Shepard, T. J. Orzechowski, T. J. Murphy, and L. J. Suter, LLNL N. D. Delamater, LANL A. L. Richard, Centre d'Etudes de Limeil J. M. Foster and P. A. Rosen, Atomic Weapons Establishment
10:15	3O8	Energetics of Gas-Filled Hohlraums T. J. Orzechowski, R. L. Kauffman, R. K. Kirkwood, H. N. Kornblum, D. S. Montgomery, L. V. Powers, G. F. Stone, L. J. Suter, and R. J. Wallace, LLNL
10:30	Coffee Break	
10:45	3O9	Analysis of Effect of Gas Fills on Nova-Scale Hohlraum Dynamics and Energetics L. V. Powers, L. J. Suter, S. G. Glendinning, R. L. Kauffman, R. Kirkwood, D. S. Montgomery, T. J. Murphy, T. J. Orzechowski, S. M. Pollaine, D. B. Ress, and T. D. Shepard, LLNL N. D. Delamater, A. A. Hauer, E. L. Lindman, and G. R. Magelssen, LANL
11:00	3O10	Power Balance and Radiation Production in Laser Heated Hohlraums L. J. Suter, S. M. Pollaine, and L. V. Powers, LLNL
11:15	3O11	Robustness Studies and Beam Angles for the National Ignition Facility S. M. Pollaine, S. W. Haan, P. A. Amendt, J. C. Moreno, and A. S. Wan, LLNL
11:30	3O12	Experimental Evidence of Interpenetration and High Ion Temperature in Plasma Collisions O. Rancu, P. Renaudin, C. Chenais-Popovics, H. Kawagoshi, and J. C. Gauthier, Ecole Polytechnique M. Dirksmöller, T. Missalla, I. Uschmann, and E. Förster, Friedrich-Schiller Universität O. Larroche and O. Peyrusse, Centre d'Etudes de Limeil E. Krousky and O. Renner, Academy of Sciences of the Czech Republic H. Pépin, INRS-Energie et Matériaux T. Shepard, LLNL
11:45	3O13	Kinetic MC-PIC Simulations of Axially Stagnating Plasma P. W. Rambo, LLNL
12:00	3O14	Electron Temperature Scalings of Gasbag Targets C. A. Back, S. H. Glenzer, K. Estabrook, B. J. MacGowan, D. S. Montgomery, D. H. Munro, T. D. Shepard, and G. F. Stone, LLNL

3O15

May 30, 1995 Tuesday Evening 7:30 - 8:30
Invited Talk 3, Paepcke Auditorium
Juan Fernández, Chair

7:30 3I1 The Study of Parametric Instabilities in Large Scale-Length-Plasmas on Nova
B. MacGowan, LLNL

May 30, 1995 Tuesday Evening 8:30 - 10:30
Mixed Posters Session 1, East and West Seminar Rooms

3P1 Numerical Simulations of Two-Dimensional Stimulated Raman Scattering in an
T. Kolber and C. J. McKinstrie, Univ. of Rochester

3P2 Collective Thomson Scattering Measurements of the Langmuir Wave Spectrum Driven by Stimulated Raman Scattering
K. L. Baker, R. P. Drake, B. S. Bauer, and K. G. Estabrook, LLNL
C. Labaune, H. A. Baldis, N. Renard, S. D. Baton, E. Schifano, and A. Michard, Ecole Polytechnique
W. Seka and R. E. Bahr, Univ. of Rochester

3P3 Simulations of the Interaction of Filamentation with SRS and SBS
R. L. Berger, B. B. Afeyan, G. Bonnaud, A. B. Langdon, B. F. Lasinski, C. W. Still, and E. A. Williams, LLNL

3P4 Parametric Instabilities Driven by Short Intense Laser Pulses in Preformed Underdense Plasmas
M. Casanova, G. Malka, J. L. Miquel, and C. Rousseaux, CEA
P. Mounaix, Ecole Polytechnique, Centre de Physique Théorique
F. Amiranoff, S. D. Baton, and V. Malka, Ecole Polytechnique, Laboratoire pour l'Utilisation des Lasers Intenses

3P5 Excitation of Raman Instability by a Multi-Beam Pump
P. N. Guzdar, Univ. of Maryland
R. H. Lehmberg, NRL

3P6 Nonlinear Aspects of SBS in Multi-Species Plasmas
S. C. Wilks and W. L. Kruer, LLNL

3P7 Parametric Excitation of Electron Bernstein Waves in Laser-Produced Plasma
A. Simon, Univ. of Rochester (Requests Poster)

3P8 Numerical Simulation of Filamentation and its Interplay with SBS in Underdense Plasmas
S. Hüller, P. Mounaix, and D. Pesme, Ecole Polytechnique

3P9 More on Leaky Pulsating Filaments
T. W. Johnston and F. Vidal, INRS-Énergie et Matériaux

3P10 SBS Backscatter and Filamentation in a Single Hot Spot
T. B. Kaiser, B. B. Afeyan, R. L. Berger, B. I. Cohen, and B. F. Lasinski, LLNL

3P11 Convective Gain in Laser Produced Plasmas
K. L. Baker, LLNL

3P12 An Adiabatic Fluid Electron Particle-In-Cell Code for Simulating Ion-Driven Parametric Instabilities
H. X. Vu

3P13 First Experimental Detection of Ion Plasma Waves
B. S. Bauer, R. P. Drake, K. G. Estabrook, and J. F. Camacho, LLNL
R. G. Watt, M. D. Wilke, G. E. Busch, and S. E. Caldwell, LANL
S. A. Baker, EG&G-LAO

3P14 Convective Gain of Stimulated Brillouin Scattering in Long-Scale Length, Two-Ion-Component Plasmas
B. Bezzerides, H. X. Vu, and J. M. Wallace, LANL

3P15 Ion Wave Nonlinearities in Stimulated Brillouin Scattering
B. I. Cohen, B. B. Afeyan, A. B. Langdon, B. F. Lasinski, and E. A. Williams, LLNL

3P16 Ion Wave Modeling in PIC-Fluid Simulations
B. F. Lasinski, B. B. Afeyan, B. I. Cohen, A. B. Langdon, and E. A. Williams, LLNL

3P17 Modelling of Radiation-Driven Hole Closure
C. P. B. Hills, P. A. Rosen, J. M. Foster, Atomic Weapons Establishment

3P18 Radiation-Driven Hole Closure Experiments and Simulations at Helen
P. A. Rosen, J. M. Foster, and C. P. B. Hills, Atomic Weapons Establishment

3P19 Gas Hohlraum Simulations
S. M. Pollaine, L. J. Suter, L. V. Powers, R. L. Kauffman, T. J. Murphy, and T. D. Shepard, LLNL

3P20 Results from Implosion Experiments with Gas-Filled Nova Hohlraums
T. J. Murphy, M. D. Cable, M. B. Nelson, S. M. Pollaine, L. V. Powers, L. J. Suter, and R. J. Wallace, LLNL
N. D. Delamater, A. L. Richard, R. Chrien, A. A. Hauer, E. L. Lindman, G. R. Magelssen, J. B. Moore, and B. H. Wilde, LANL
K. Gifford, GA

3P21 NIF and NOVA Hohlraum Plasma Conditions Correlated to SBS and SRS Measurements
B. H. Wilde, J. A. Cobble, N. D. Delamater, J. C. Fernández, W. J. Krauser, E. L. Lindman, and D. S. Montgomery, LANL

3P22 Update on Time-Dependent Measurements and Theoretical Comparisons of Radiation Symmetry within Nova Hohlraums
G. R. Magelssen, N. D. Delamater, E. L. Lindman, A. A. Hauer, M. R. Clover, J. L. Collins, C. W. Cranfill, and W. J. Powers, LANL

3P23 Nonlinear Eulerian Hydrodynamics in Three Dimensions
C. H. Still, R. L. Berger, A. B. Langdon, and D. S. Miller, LLNL

May 31, 1995 Wednesday Morning 8:30-12:30
Oral Session 4, Laser Plasma Interactions , Paepcke Auditorium
Albert Simon, Chair

8:30 4O1 Beam Steering by Filamentation in Flowing Plasmas
E. A. Williams and D. E. Hinkel, LLNL

8:45 4O2 Beam Steering Induced by Transverse Plasma Flow
D. E. Hinkel, E. A. Williams, R. L. Berger, and L. V. Powers, LLNL

9:00 4O3 Whole Beam Deflection through a Hohlraum Window Plasma
J. D. Moody, B. J. MacGowan, R. K. Kirkwood, D. S. Montgomery, R. L. Berger, D. E. Hinkel, T. D. Shepard, and E. A. Williams LLNL

4O4 Crossed Laser Beam Interactions in Laser Fusion Plasmas
W. Rozmus, A. Eliseev, and V. T. Tikhonchuk, and C. E. Capjack, Univ. of Alberta

9:30 4O5 Observation of Energy Transfer Between Frequency Mis-Matched Laser Beams in a Large Scale Plasma
R. K. Kirkwood, B. B. Afeyan, W. L. Kruer, B. J. MacGowan, D. S. Montgomery, J. D. Moody, and S. C. Wilks, LLNL

9:45 4O6 Observation of Threshold and Saturation of Stimulated Brillouin Scattering
P. Drake, LLNL

10:00 4O7 Acceleration to 44 MeV of Electrons Trapped in Plasma Waves Generated by Forward Raman Scattering and Wakefield Action
A. Modena, Z. Najmudin, and A. E. Dangor, Imperial College
C. E. Clayton, K. A. Marsh, W. B. Mori, and C. Joshi, UCLA
C. B. Darrow, LLNL
V. Malka, Ecole Polytechnique
C. N. Danson, Rutherford Appleton Lab

10:15 4O8 Diffractive Irradiation Patterns Inside the Plasma Corona
R. Grobe and R. W. Short, Univ. of Rochester

10:30 4O9 Ionization Induced Refraction in Recombination X-Ray Lasers
C. D. Decker, D. C. Eder, and R. A. London, LLNL

10:45 Coffee Break

Oral Session 4 Continued
Spectroscopy and Atomic Physics, Paepcke Auditorium
Jill Dahlburg, Chair

11:00 4O10 Debye Screening in Multicomponent Plasmas
A. Decoster, CEA

11:15 4O11 Non-LTE Implementation in an Eulerian Hydrocode
D. A. Garren, SAIC
M. Klapisch, Artep, Inc.
J. A. Gardner, D. Colombant, and J. P. Dahlburg, NRL
M. Busquet, CEA

11:30 4O12 Non-LTE Effects on Radiative Plasma Structures
M. Klapisch, Artep, Inc.
D. A. Garren, SAIC
D. Colombant, J. P. Dahlberg, J. H. Gardner, and A. J. Schmitt, NRL
M. Busquet, CEA

11:45 4O13 Preliminary Extraction of Core/Pusher Capsule Conditions from X-Ray Image and Spectroscopy Data for Hydrodynamically Equivalent Physics (HEP) Shots
G. D. Pollak, LANL

12:00 4O14 Two-Dimensional Models of Emission Line Ratios in ICF Target Implosions
S. H. Langer, C. Keane, H. A. Scott, LLNL

12:15 4O15 Simulations of Time-Dependent Spectral Signatures of Fuel-Pusher Mixing in Laser-Driven Implosions
R. Epstein, J. A. Delettrez, C. P. Verdon, D. Shvarts, and B. Yaakobi, Univ. of Rochester

May 31, Wednesday Evening 5:00
BarBaQue T-Lazy -7 Ranch

June 1, 1995 Thursday Morning 8:30-12:00
Oral Session 3, Short Pulse Laser Interactions , Paepcke Auditorium
William Kruer, Chair

8:30 5O1 The Generation of High Harmonics using a Short Pulse KrF Laser
J. S. Wark, S. G. Preston, M. Zepf, W. Blyth, C. Smith, M. H. Key, K. Burnett, and A. Sanpera, Univ. of Oxford
D. Neely, Rutherford Appleton Laboratory
A. Offenberger, Univ. of Alberta

8:45 5O2 Second Harmonic Generation and Extreme Broadening of Stimulated Raman Scattered Light from High Intensity Laser Interaction in Underdense Plasmas
A. Ting, A. Fisher, and C. Manka, and E. Esarey, NRL
K. M. Krushelnick, Cornell Univ.
H. R. Burris, Research Support Instruments, Inc.

9:00 5O3 Fast Ignitor Plasma Physics Issues
S. C. Wilks, W. L. Kruer, B. Hammel, J. Hammer, M. Tabak, and P. E. Young, LLNL

9:15 5O4 Ponderomotive and Magnetic Effects under Bright Source Laser Illumination
R. J. Mason, LANL

9:30 5O5 Kinetic Simulations of Intense Ultra-Short-Pulse Laser Light on Thin Targets
W. S. Lawson, P. W. Rambo, D. J. Larson, and S. T. Brandon, LLNL

9:45 5O6 Hydrocode Simulation of Sub-Picosecond Laser Interaction with Solid-Density Matter
S. Hüller, K. Eidmann, and J. Meyer-ter-Vehn, Max-Planck-Institute für Quantenoptik

10:00 5O7 Laser Absorption, Plasma Evolution, and X-Ray Emission in Solid Targets Heated by Femtosecond Lasers
R. S. Walling, R. M. More, W. E. Alley, M. E. Foord, and A. L. Osterheld, LLNL

10:15 5O8 Two-Dimensional Stimulated Raman Scattering of Short Laser Pulses
↓ E. J. Turano and C. J. McKinstrie, Univ. of Rochester
1P17 R. E. Giacone, LANL

10:30 Coffee Break

10:45 5O9 Time-Resolved Reflectivity Measurements of Electron Heat Conduction and Hydrodynamics in an Ultra-Short Pulse Plasma
↓ D. M. Gold and R. Walling, LLNL
1P18

11:00 5O10 Dynamics of Femtosecond-Laser-Pulse-Produced Plasmas in Transparent Solids by Electron Thermal Transport
B. T. V. Vu, A. Szoke, O. L. Landen, and R. W. Lee, LLNL

11:15 5O11 X-Ray Spectrum by Femtosecond Laser-Produced Plasma from Periodically Modulated Targets
P. Audebert, J. P. Geindre, S. Bastiani, and J. C. Gauthier, Ecole Polytechnique
G. Grillon, R. Evans, and A. Mysyrowicz, Laboratoire d'Optique Appliquée
J. C. Adam and A. Héron, Ecole Polytechnique
K. Neuman, T. Donnely, M. Hoffer, and R. W. Falcone, UC-Berkeley
R. Shepherd, D. Price, and B. White, LLNL

11:30 5O12 Observation of Relativistic Quiver Effects and Multiphoton Compton Scattering During High-Intensity Laser-Electron Interactions
D. D. Meyerhofer, J. P. Knauer, S. J. McNaught, and C. I. Moore,Univ. of Rochester

11:45 5O13 Hose-Modulation Instability of Laser Pulses in Plasmas
E. Esarey, P. Sprangle, and J. Krall, NRL

ORAL SESSION 1

LASER PLASMA INTERACTIONS

Donald F. DuBois, Chair

Sunday, May 28

LAUR-95-1562

Enhancement of the Saturation Level of Stimulated Brillouin Scattering of a Laser by Seeding a Plasma with an External Light Wave

Juan C. Fernández, K. S. Bradley,[1] J. A. Cobble,
P. L. Gobby, and R. G. Watt

Los Alamos National Laboratory, Los Alamos, NM, USA

April 14, 1995

The reflectivity of a laser due to Stimulated Brillouin scattering (SBS) has been recently studied [J. C. Fernández *et al.*, R. G. Watt *et al.*, submitted to Phys. Rev. Lett.] in various plasma conditions approaching those expected within laser-driven cavities (hohlraums) capable of driving a fusion capsule to ignition with X rays. It is normally seen that the reflectivity saturates once the laser intensity exceeds a certain "critical" value [H. A. Rose and D. F. DuBois, Phys. Rev. Lett. 72 (1994) 2883]. It is shown in this paper that the saturation level can be significantly enhanced by the introduction of an electromagnetic seed (external to the plasma being probed) at a wavelength near that of the resonant SBS that would normally grow from the noise in the probed plasma. This effect appears to be important in determining the observed SBS reflectivity from Nova hohlraums. In these relatively complex hohlraum plasmas, seeding sources of the required magnitude, apparently from regions other than that with the highest SBS gain, enhance the SBS reflectivity.

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[1]Present address: Lawrence Livermore Nat. Lab., Livermore, CA, USA

[2]This work sponsored by the US DOE

Experimental dependence of stimulated Brillouin scattering reflectivity on focusing optic F number a long scale length plasma*

R. G. Watt[1], J. Cobble[1], R. Paul Drake[2], Bruno S. Bauer[2], D. F. DuBois[1], J. C. Fernandez[1], and Harvey A. Rose[1]

(1) Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545
(2) Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94551

The onset of stimulated Brillouin scattering (SBS) has been examined by varying the F number (lens focal length/beam diameter) of the optical system used to irradiate a preformed 1 mm-long, 5% n_c, 1 keV, uniform CH plasma. Experiments were done using the Trident laser at Los Alamos National Laboratory at 527 nm wavelength, for intensities in the 10^{14}-10^{15} W/cm^2 range, using a static RPP conditioned probe beam, to determine the onset intensity for SBS at F/6, F/8.6, and F/14.5. SBS onset occurs at higher average laser intensity for smaller F number, in qualitative agreement with theory. The thresholds for onset at each F number are very clearly defined, but the onset occurs for intensities approximately a factor of 2 higher than anticipated from the theory of Rose and DuBois [3]. Details of the experiment, along with reflectivity plots and spectral content will be shown. Implications for the National Ignition Facility will be discussed.

*Work performed under the auspices of the U.S. Department of Energy by the Los Alamos National Laboratory under Contract W-7405-Eng-36 and by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

3. Harvey A. Rose and D. F. DuBois, Phys. Rev Lett. **72,** 2883 (1994).

Generalization of the Multidimensional Theory of Stimulated Brillouin Scattering to Include Ponderomotive Filamentation and Inhomogeneous Flow Profiles †

B. B. Afeyan, R. L. Berger, T. B. Kaiser, and W. L. Kruer

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Livermore CA, 94551

An explicit integral representation of electromagnetic sideband amplitudes interacting with an ion acoustic wave and seeded by a spatially localized pump source is derived and evaluated in certain distinguished limits. We compare the efects of source geometry, anisotropic gain, and pump-strength dependent ray trajectories in the 2-D evolution of amplifying light waves traversing the pump beam. The effects of RPP on Brillouin scattering and filamentation are examined and the transition from SBS to filamentation as the scattering angle goes to zero is identified. These results are compared to F3D simulations where realistic overlappingg-beam geometries are analyzed.

In addition, the gain of crossed-beam seeded SBS including the effects of inhomogeneous velocity profiles is calculated in order to assess the relative roles played to detune the instability by the inherent frequency mismatch between the crossing laser beams and the flow gradients in the background plasma. These results are applied to the conditions of the NOVA crossed-beam SBS experiments recently conducted by R. K. Kirkwood et al., and presented at this conference.

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

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Effects of the Anti-Stokes Wave on Stimulated Brillouin Scattering

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ABSTRACT

In stimulated Brillouin scattering (SBS), the Stokes process is the decay of the incident light wave into a frequency-downshifted, or Stokes, light wave and an ion-acoustic wave. The anti-Stokes process is the production of a frequency-upshifted, or anti-Stokes, light wave by the incident light wave and the ion-acoustic wave. Because the anti-Stokes process consumes phonons, the anti-Stokes wave reduces the growth rate of SBS whenever it participates strongly in the instability. In near-forward SBS[1] the anti-Stokes wave is driven near resonantly and must be included in the analysis of SBS.

The linearized equations governing the initial evolution of near-forward SBS are solved analytically and numerically. Two paradigms are considered: Stokes amplification, in which an externally generated Stokes wave is amplified as it propagates through the plasma, and Stokes generation, in which the Stokes wave is generated by ion-acoustic fluctuations within the plasma. Although the spatiotemporal evolution of near-forward SBS is complicated, there exist simple criteria that determine if the anti-Stokes wave is important.[2]

1 K. Marsh, C. Joshi, J. S. Li, and C. J. McKinstrie, *Bull. Am. Phys. Soc.* **39**, 1585 (1994).
2 J. S. Li, C. J. McKinstrie, C. Joshi, and K. Marsh, *Bull. Am. Phys. Soc.* **39**, 1584 (1994).

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.

25th Anomalous Absorption Conference

Aspen - Colorado, 27 May- 2 June 1995

Study of stimulated side-scattering using multiple interaction beams

C.Labaune, H.A. Baldis, E. Schifano, N. Renard, A. Michard
(LULI, Ecole Polytechnique, France)
W. Seka *(Laboratory for Laser Energetics, Rochester, USA)*
J. Moody, K. Estabrook *(Lawrence Livermore National Laboratory, USA)*

The characterization of Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS) in directions other than backscatter have been rather limited in the past, in spite of their importance in plasmas inside cavities (Holraums). We have extended our studies of ion acoustic waves (IAW) and electron plasma waves (EPW) associated with these instabilities to include scattering in different directions.

The principal diagnostic was Thomson scattering, using an array of spectrometers and streak cameras in different configurations, to include frequency, time and space resolution of the waves. A preformed plasma was produced by exploding thin CH disk targets. The wavelength of the interaction beam and of the Thomson scattering probe beam were 1.05 and 0.35 μm respectively.

Three different beams were individually used, that allows to perform side-scatter measurements with the same optical configuration for Thomson scattering, as well as the study of seeding between two interaction beams. Spectral, spatial and temporal characterization of IAW and EPW has been done, as well as measurements on the backscattered and sidescattered SBS waves

A new technic for multiplexing the streak cameras made possible by the first time the direct correlation of behavior of plasma waves at different locations within the interaction region in the plasma. We will discuss the temporal evolution of IAW and EPW at multiple locations in the plasma.

SBS and SRS care about large plasmas ?

H.A. Baldis, C. Labaune,
B. Quesnel, N. Renard, E. Schifano, A. Michard

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Direct measurements of the location of ion acoustic waves (IAW) and electron plasma waves (EPW) associated with stimulated Brillouin and Raman scattering (SBS and SRS) have been performed using space resolved Thomson scattering. The overall experimental arrangement was the same as described in the previous paper. Information about the localization of SBS and SRS is an important issue for the proper interpretation of results based on existing theoretical work. Estimation of growth and reflectivities need to assume an interaction length for the instability, and lacking anything better, the scale length of the plasma is often use, which is very likely an overestimation.

The study was performed using complimentary Thomson scattering configurations, that provided detailed temporal evolution of the waves along the full length of the plasma and along the direction of the interaction beam. The observed IAW and EPW were always confined to small regions in the plasma, short compared to the plasma dimensions. IAW were observed to start first, moving rapidly towards the interaction beam, and ending about the time of the onset of the EPW. The EPW on the other hand, showed a brief evolution towards the summit of the plasma. Simultaneous recording of both IAW and EPW for the same laser shot showed the relative location of the waves.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Phase-Conjugated SBS in Laser-Produced Plasmas

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ABSTRACT

When a plasma with strong ion-wave damping and/or inhomogeneity is irradiated by a random phase plate ("speckled") beam, it can be shown[1] that stimulated Brillouin scattering (SBS) strongly favors the amplification of a scattered mode (the "specklon") that closely approximates the phase conjugate of the pump beam. The conditions under which this process may play an important role in laser-fusion plasmas are determined, and possible signatures of the process in observed SBS spectra are discussed.

1. B. Ya. Zel'dovich, N. F. Pilipetsky, and V. V. Shkunov, *Principles of Phase Conjugation* (Springer-Verlag, Berlin, 1985).

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.

25th Anomalous Absorption Conference, Aspen, Colorado.

Nonlinear frequency shifts and harmonic generation in finite amplitude ion acoustic waves.

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We investigate analytically the effects of particle trapping on finite amplitude ion acoustic waves in mixed ion-species plasmas. Following Andreev and Tikhonchuk[1], we calculate the particle distribution functions in the presence of a periodic potential by solving the appropriate kinetic equation for a time long compared to the trapping time, but short compared to a collision time. The resulting distributions are flattened in the vicinity of the ion acoustic phase velocity and have trapped and untrapped components. Expressions for the perturbed charge density are obtained by integrating over velocity space and expanding in powers of $(e\phi/T)^{1/2}$. Substituting these in Poisson's equation gives an amplitude dependent dispersion relation and harmonic generation coefficients.

From this one can derive a candidate model for the saturation of SBS ion-acoustic waves.

(1) A. A. Andreev and V. T. Tikhonchuk, Sov. Phys. JETP, 68, 1137 (1989)

(2) Work performed under the auspices of the United States Dept. of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Angular distribution of SRS from Nova gasbag plasmas *

D.S. Montgomery, R.K. Kirkwood, B.J. MacGowan, J.D. Moody,
C.A. Back, S.H. Glenzer, D.H. Kalantar, B.B. Afeyan, R.L. Berger, D.H. Munro

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D. Desenne, A. Richard, C. Rousseaux

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We report measurements of stimulated Raman scattering from large scale length plasmas. The plasmas were created using nine beams of the Nova laser to heat a C_5H_{12} gas-filled target which produced a large uniform plasma ($L_n \geq$ 2 mm) with 0.1 n_{cr} density and 3 keV electron temperature. A high intensity 351 nm interaction beam was used at f/8 with various intensities and beam smoothing conditions to study SRS. The SRS light was temporally and spectrally resolved in the backscatter and near-backscatter directions. The angular distribution of SRS into the f/8 lens and near the lens was imaged which gave a nearly continuous measurement out to 18° from direct backscatter. Discrete time and spectrally integrated measurements were made out to 27°. For laser intensity < 10^{15} W/cm^2 a narrow SRS spectra was observed at about 560 nm, corresponding to the average plasma density. At higher intensities, the spectra broadened to shorter wavelengths. The angular distribution is strongly peaked in the backscatter direction for all these cases. SRS levels of several percent were observed at the highest laser intensities. We will present the experimental results and will compare the SRS spectra and angular distribution to modeling and theory.

* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

1010

Novel Techniques to Control Stimulated Raman and Brillouin Scattering in Laser Plasmas*

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Several novel techniques to control stimulated Raman and Brillouin scattering of intense laser light are considered. We show that scattering levels can be significantly reduced if the transport of energetic particles is lowered from free-streaming values usually modeled in particle simulations. Physically, the instability is then choked by strongly-enhanced damping on the self-consistently heated particles. In some cases, the "reduced" transport might simply be obtained from a modeling of collisional effects. In other cases, the reduced transport might be intentionally induced in various ways. Examples are given.

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

V.V. Ivanov, A.K. Knyazev, A.V. Kutsenko, A.A. Matzveiko
Yu.A. Mikhailov, V.P. Osetrov, A.I. Popov, G.V. Sklizkov, A.N. Starodub.
[P.N. Lebedev Physical Institute, Leninsky Pr. 53, Moscow, Russia]

An original method based on direct measurements of electron emission has been proposed and experimentally realized at the installation "PICO" for the study of high energy electrons generation in high density high temperature laser plasmas. The method allows to record both time-resolved current integral value and energy spectrum of fast electrons.

Nd-glass laser (1.06 μm, t = 2ns, energy varied from 0.1 to 30 J, a = 1.4×10^{-4} rad, flux density from 10^{12} to 8×10^{13} W/cm^2) has been used to heat a plane cylindrical target (Cu and Al, 12 mm length and 5 mm dia.). The target is positioned inside coaxial capacitor connected with transmitting line.

The energy of fast electrons experimentally has been observed up to the value of 200 keV at current flux density up to 10^5 A/cm^2. The dependencies of electron energy on radiation flux density as well as current density corresponding to cut off boundary of electron energy have been measured in the range of plasma temperatures from 70 to 200 eV evaluated from absorbing filter procedure. A strong dependence of maximum electron energy on laser radiation flux density (at the level of 2 A probe sensitivity) has been observed (more than the second power of heating flux).

It is observed that a hydrodynamics instability leads to sharpening electron current pulse front at energy of 100 keV. Sometimes we have observed a pause of the current during laser action. In the range of 1 - 10 keV the value of electron current more than 2 kA has been recorded. In this case, current pulse duration is a few times more than laser pulse, and the pulse front is comparable with laser one.

25th Annual Anomalous Absorption Conference, Aspen, Colorado, 27 May–1 June 1995

Thermal Filamentation of Laser Beams

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University of California at Los Angeles

ABSTRACT

Recent experiments have observed whole-beam thermal focusing and have demonstrated that the total laser intensity required for two counterpropagating laser beams to focus is less than for one laser beam.[1] Because whole-beam effects are difficult to model analytically, a series of probe-beam experiments has been made to elucidate the physics of thermal filamentation. Theory predicts that a resonant transient (near-forward stimulated Brillouin scattering) will dominate the initial evolution of the one-beam instability and that anti-Stokes loss will suppress this transient in the two-beam instability.[2] These predictions are consistent with the results of the probe-beam experiments.[3]

1. L. S. Ingraham, K. A. Marsh, A. Lal, C. Joshi, and C. J. McKinstrie, Bull. Am. Phys. Soc. **39**, 1584 (1994).

2. K. Marsh, C. Joshi, and C. J. McKinstrie, Bull. Am. Phys. Soc. **39**, 1585 (1994).

3. J. S. Li, C. J. McKinstrie, C. Joshi, and K. Marsh, Bull. Am. Phys. Soc. **39**, 1584 (1994).

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.

Return current instability in laser heated plasmas.

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Department of Electrical Engineering, University of Alberta, Edmonton, Canada
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Laboratory for Laser Energetics, University of Rochester, Rochester, USA

The localized heating of an underdense plasma by a focused laser beam involves two processes which occur simultaneously: nonlocal energy transport by hot electrons and the return current of cold electrons which may excite the ion acoustic instability. Usually these two processes are studied separately, although initial estimates suggest that the return current instability can only be excited under conditions of inhibited heat transport. We report results of the first self-consistent study of the ion acoustic instability produced by the localized inverse bremsstrahlung heating of an underdense plasma.

An electron kinetic Fokker-Planck code has been used to obtain the electron temperature profile, radial electron heat flux, and electron distribution function in a plasma heated by a cylindrical Gaussian laser beam. The growth rate for the return current instability has been calculated by using the electron distribution function in the ion acoustic dispersion relation. Fokker-Planck simulations show an inhibition of the electron heat flux across the laser beam, which results in a high temperature plasma in the centre region. We have recovered these results from hydrodynamical flux limited calculations. An analysis of the dispersion relation demonstrates that the heat flux inhibition does not interfere with the excitation of the return current ion acoustic instability. It does not depend on the electron heat flux, but rather on the magnitude of a temperature gradient which becomes even larger when the electron heat flux is inhibited. We discuss conditions for instability excitation and a possible effect of ion acoustic turbulence on electron heat transport.

* *On leave from Russian Academy of Sciences, Moscow, Russia.*
** *Present address: City Bank Canada, Toronto, Ontario.*

INVITED TALK 1

Experiments for Fusion and Physics Using Trident

by

R. P. Drake and R. G. Watt

Sunday, May 28

Don DuBois, Chair

Experiments for Fusion and Physics Using Trident*

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ABSTRACT

Waves, instabilities, and turbulence impose definite constraints on the applications of laser plasmas. For laser fusion, they will limit maximum performance that may be obtained from any laser fusion facility, such as the proposed National Ignition Facility, through reduced efficiency, loss of symmetry via scattering, or hot-electron production. As another example, x-ray lasers will be constrained by electron heating or ion heating. Waves, instabilities, and turbulence are also of interest in the context of basic plasma physics, as their theoretical properties often remain unconfirmed experimentally and in some cases observed phenomena appear to be at odds with theory.

Small, versatile laser facilities have the potential to accomplish high-quality experiments that greatly increase our understanding of such phenomena. Work on such facilities in recent years has permitted substantial progress in the study of the four standard three-wave instabilities as well as the first observation of ion plasma waves. The Trident laser system in particular includes two beams that can produce ~ 200 J of 527 nm light and a third probe beam capable of 50 J of 527 nm light in a 1 ns pulse. This permits plasma production to be separated from pumping and probing the waves and turbulence. The system has good geometric flexibility and the high-energy beam can be split as needed. A variety of pulse shapes are possible and the shape of the probe can be controlled independently. We will discuss in some detail the results of several recent experiments: (1) A controlled-flow, high ZT_e/T_i plasma was used to make the first observation of ion plasma waves. (2) An experiment using separate "seed" and "amplifier" plasmas observed the seeding of stimulated Brillouin scattering (SBS), which is relevant to scattering in hohlraums. (3) The scaling with f/number of the onset of SBS in a long, uniform plasma confirmed recent theory regarding the critical onset of SBS. (4) Scaling studies of SBS in an inhomogeneous plasma found the anticipated critical onset behavior and unanticipated evidence of very "hard" saturation behavior.

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

MIXED POSTER SESSION 1

Sunday, May 28

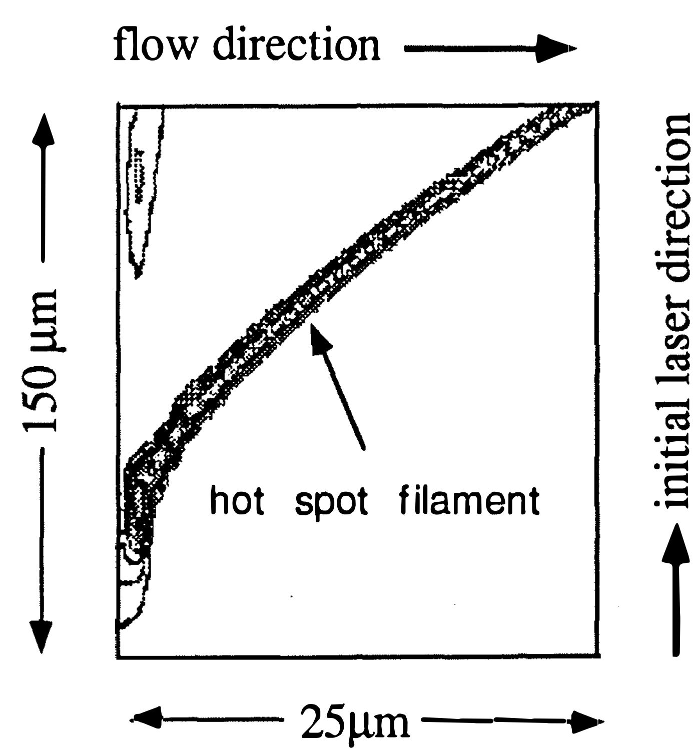
Plasma Flow Effects Beam Pointing*

Harvey A. Rose and D. F. DuBois
Los Alamos National Laboratory

In general we find that the plasma density response to a laser beam's ponderomotive (and thermal) force is locally shifted in the direction of a transverse flow, which in turn deflects the laser beam in that direction. This overall deflection is in part due to the cumulative effect of the deflection, $\Delta\theta$, of the light from individual hot spots and their associated filaments, which rapidly increases with hot spot power, Phot. $\Delta\theta$ also increases with the acoustic damping rate and flow Mach number. If Phot exceeds the hot spot filament threshold, then $\Delta\theta$ grows with propagation distance, otherwise $\Delta\theta$ is independent of the system length once it exceeds a speckle length. In current gas filled hohlraum experiments, the magnitude of this effect is consistent with the experimental observation of asymmetric backscatter SBS (it is shifted in the direction opposite to the plasma flow) and may be large enough to influence macroscopic beam pointing and symmetry of a capsule implosion.

The figure shows intensity countours of a slice of a 3d simulation of an isolated hot spot of a Random Phase Plate conditioned laser field, with f/8 optics, which is allowed to ponderomotively self focus. The flow has Mach #=1/2, and dimensionless acoustic damping coefficient 1/4. The hot spot has 3 times the critical power for explosive self focusing.

*Research supported by USDOE



Laser propagation in underdense plasmas

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Abstract

Propagation of an intense laser pulse in an underdense plasma is modelled by treating the electrons as a cold relativistic fluid. For sufficiently short pulses, the ion motion is negligible. The disparities between the optical, plasma, and propagation length scales are dealt with by using a multiple scales technique to derive approximate equations averaged over successively larger length scales. This argument does not require the quasistatic approximation (QSA) often used in earlier work, and it shows that, in the coordinate system moving with the pulse, the fluid will exhibit transient (initial layer) behavior in time. Asymptotically, i.e., for times long on the plasma scale, the transient solution approaches the QSA. The problem of matching the transient (inner) solution to the asymptotic (outer) solution is solved by means of a uniformly valid, two-time expansion. The QSA is shown to suffer from instabilities which could cause serious problems for numerical simulations of long pulses, and an "improved-QSA", suggested by the inner-outer analysis, is demonstrated. An analytical solution for a planar, weak-field model is presented which explicitly displays the initial layer behavior of the fluid. For a short, cylindrically symmetric, weak-field pulse numerical simulations which include relativistic self focusing, forward Raman scattering, and ponderomotive forces show the importance of the transient effects in a more realistic case.

Numerical simulations of high-frequency parametric instabilities, Brillouin Scattering and beam crossing in the gas-bag experiment context †

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A numerical code (RHEA) has been designed to solve the coupling of the fully nonlinear hydrodynamical equations of the electron and ion fluids to the Maxwell equations in both 1-D and 2-D planar geometry. Firstly, we report on Brillouin scattering efficiency in a drifting plasma ; its dependence on the reflected wave is quantified ; comparison is provided between the results from RHEA-1D and the 1-D PIC code EUTERPE. Secondly, we present results from simulations performed with RHEA-2D in Raman scattering ; side-scatter and back-scatter are compared when the hot spot size is varied ; the results are compared to those of the SRS SOFTSTEP code. Finally, we show some results from a stationary paraxial equation that simulates the propagation of two beams in a gas-bag; their capacity to stay independent or to coalesce is exhibited.

†The work of B. B. A. and R. L. B. was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

25th Anomalous Absorption Conference *Aspen (Co), May 27-June 1 1995*

RELATIVISTIC SELF-FOCUSING OF A MULTI-TERAWATT LASER PULSE IN A UNDERDENSE PLASMA : EXPERIMENTAL OBSERVATION AND SIMULATIONS

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We report on experimental images of the side-scattering of a plasma, created by the propagation of a sub-picosecond laser pulse, which exhibit clear dependence on both jet gas pressure and laser irradiance. The laser used in the present experiment is the P102 laser that operates at 1.058 μm wavelength, which can deliver 0.4 ps FWHM pulses with a peak power up to 10 TW. Two- and three- dimensional simulations of wave propagation, based on stationary paraxial equation, within laser and plasma density conditions close to the experimental ones have been performed to reproduce the Thomson radiation from the plasma electrons. By introducing the laser-driven nonlinear effects bound to the relativistic electron mass increase and ponderomotive electron expel, we pinpoint various propagation behaviors : electron cavitation induced by the beam focusing, self-focusing, self-guiding, beam smoothing of initial nonuniformities and, at larger power, beam filamentation. Simple Bremsstrahlung model with account of tunnel ionization and electron temperature for a Gaussian cylinder beam provides estimates of the plasma emission background. The detailed comparison of the experimental images to the Thomson emission and Bremsstrahlung patterns from simulation let us confidently interpret the experimental observation as the laser-pulse self-guiding for laser power and plasma density conditions around 10 TW and 5 10^{18} cm^{-3}, respectively.

Numerical Simulations of Stimulated Raman Scattering in Laser Hot Spots and Speckles †

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SRS SOFTSTEP is a fluid code that treats Raman scattering in multiple dimensions in the presence of density inhomogeneities and nonuniform laser profiles. It is used to study the properties of SRS in speckles and density channels where kinetic effects are not dominant. The angular distribution of the scattered light, as well as its space-time evolution are calculated and compared to RHEA 2D, a nonlinear fluid code developed in CELV-Limeil.

The effects of nonuniform and fluctuating density profiles as well as possible transitions from convective to absolute growth are examined at various densities by solving the initial value problem for SRS.

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

Numerical Simulations of Stimulated Raman Scattering in Laser Hot Spots and Speckles †

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We have studied the evolution of the stimulated Raman scattering (SRS) instability in laser hot spots and speckles using both fluid and PIC simulations. In speckles which correspond to an f/4 focusing lens, we have examined the SRS instability in both homogeneous and inhomogeneous plasmas, in one and two dimensions. We have concentrated our efforts on understanding the angular distribution of the scattered light as well as the nonlinear saturation mechanisms in various cases where the density is low ($0.1n_c$ or below) and the temperatures high enough that one is in the strong damping regime, or when the density is high (around $0.2n_c$) where the instability is resonant and Landau damping does not play a significant role. The interplay between SRS and SBS has also been explored by allowing for mobile ions. This work was motivated by recent experiments on NOVA, at the Lawrence Livermore National Laboratory where SRS measurements were made on gasbags and hohlraums at various angles and different smoothing schemes (see the paper by D. Montgomery et al.). The Compton regime is explored further in an accompanying paper by Berger et al., where regions large compared to a single speckle are needed to achieve significant gain.

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

Propagation of intense laser beams in underdense plasmas in the presence of stimulated Brillouin scattering and filamentation.

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We present an interpretation of experimental results [1] related to the propagation of intense laser beams in underdense plasmas. Our numerical results obtained from a 2-dimensional nonparaxial wave interaction code [2] confirm previous experimental and theoretical findings [1] regarding beam channeling and spreading due to filamentation. However, contrary to earlier studies [1] our model includes stimulated Brillouin scattering (SBS) and more accurately describes the non-Gaussian beams used in experiments. Both effects are crucial because of the large measured reflectivity in the backward direction (on average 15 %) and the important role that is played by non-Gaussian beams in the competition between SBS and the filamentation instability. In order to reproduce the experimental laser intensity distribution at the best focus position, our simulations use a superposition of two co-axial Gaussian beams with different f/numbers (e.g. f_1=18 and f_2=3). We have found that the density channel produced by the self-focusing of the narrow beam component enhances density fluctuations for the filamentation instability of a broad Gaussian. This enhancement allows filamentation to effectively compete with SBS. It limits SBS reflectivity and causes beam spreading. The role of kinetic effects in limiting SBS reflectivity will be discussed by comparison with PIC simulations [3].

[1] S. Wilks, P. E. Young, J. Hammer, M. Tabak, and W. L. Kruer, Phys. Rev. Lett. **73**, 2994 (1994).
[2] V. Eliseev, W. Rozmus, V. T. Tikhonchuk, and C. E. Capjack, Phys. Plasmas, **2** (5) (1995).
[3] S. C. Wilks and W. L. Kruer, this conference.

* *On leave from Russian Academy of Sciences, Moscow, Russia.*

Effects of long-wavelength density fluctuations on stimulated Brillouin scattering.

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We have investigated nonlinear effects of long-wavelength density perturbations on stimulated Brillouin scatering (SBS) by using a one dimensional model, which includes a system of the Korteweg-de Vries (KdV) and Maxwell equations. We have found two important effects:

- Harmonic generation of long-wavelength density perturbations enhances the spectral density of ion acoustic fluctuations over a wide range of k-vectors, including SBS resonant sound waves. This results in enhanced nonthermal noise levels for SBS.
- Nonlinear interaction of the SBS produced ion-acoustic wave with long wavelength density perturbations leads to the formation of ion acoustic wave satellites, and results in additional damping and frequency shift. This effect can significantly lower the value of the SBS gain and reflectivity.

Long-wavelength ion-acoustic perturbations decrease the SBS reflectivity most strongly when the ion-acoustic wave damping is weak, and has a value close to the electron Landau damping value. Even small levels of long-wavelength fluctuations can reduce the SBS reflectivity more dramatically than short-wavelength harmonics produced by the SBS driven nonlinear sound wave [1]. The close relationship of this effect to the broad bandwidth theory of parametric instabilities (cf. e.g.[2]) will be also demonstrated.

Intensity hot spots of random phase plate (RPP) laser beams might provide a natural source for such long-scale density perturbations. A reduction of SBS by these fluctuations could be considered as a plasma-induced beam smoothing, which enhances the influence of RPP on scattering instabilities.

[1] J. Candy, W. Rozmus, and V. T. Tikhonchuk, Phys. Rev. Lett. **65**, 1889 (1990).
[2] J. J. Thomson, Nuclear Fusion, **15**, 237 (1975).

* *On leave from Russian Academy of Sciences, Moscow, Russia.*

Twenty-Fifth Annual Anomalous Absorption Conference
Aspen, Colorado
27 May – 1 June 1995

Electron Temperature Measurements of a Laser-Produced Plasma Using Simultaneous UV Thomson Scattering and X-Ray Spectroscopy*

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We are producing plasmas using 1-ns, 532-nm laser pulses incident on various solid metal targets (*e.g.*, Al, Mg, Ti). Laser energies are ~ 1 J, and intensities on target are estimated to be $\sim 10^{13}$ W/cm^2. Our initial goal is to characterize the soft x-ray emission from these plasmas. Current diagnostics include an x-ray diode, an x-ray pinhole camera ($M = 11.57$, 20-μm source resolution), and a time-integrated soft x-ray spectrometer with an energy resolution of $E/\Delta E \approx 30$ at 1 keV. The detector used for the pinhole camera and spectrometer is an x-ray CCD array. Preliminary measurements from Al targets indicate an x-ray spot size of about 40 μm FWHM with approximately 150 J/cm^2-sr of K-shell x-ray intensity. Spectroscopic measurements of the free-bound recombination continuum yield an electron temperature estimate of $T_e \approx 400$ eV.

Our next step is to perform electron temperature measurements using collective Thomson scattering at $\lambda = 266$ nm and x-ray spectroscopy simultaneously. The Thomson scattering spectra will be collected with an 0.8-m double monochromator. We will use a CCD camera to detect the scattered light and obtain spatially resolved, time-integrated spectra. We will acquire temporally resolved spectral data with the use of a streak camera. The electron temperatures deduced from these data will be compared with the temperature estimates based on x-ray spectroscopy in order to cross-check our measurements. Our ultimate goal is to use this suite of complementary optical scattering and x-ray emission diagnostics to characterize heat transport and radiation hydrodynamics in our laser plasmas.

*This work was performed under the auspices of the U. S. Department of Energy by Sandia National Laboratories under Contract DE-AC04-94AL85000 and by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

A Spatially Imaging Broadband Streaked Spectrograph

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A new instrument is employed to study broadband laser scattering from ICF targets with spatial discrimination. On NOVA, it uses a Cassegrain telescope to image scattered light from a laser plasma onto a field stop. The telescope magnification and the stop aperture provide spatial discrimination of target plane scatter. On Trident, the spatial discrimination derives from the laser spot size. In either case, the < 200-μm resolution allows local diagnosis of long scale length plasmas.

On NOVA, a UV lens relays the image to a 0.25-m spectrograph which is lens coupled to a streak camera with an extended-UV S-1 photocathode. Optical signals encompassing SBS, SRS, and the 3/2-ω signature of two plasmon decay are captured in the 200 - 700-nm bandwidth of the system. On Trident with its 527-nm drive, a grating adjustment permits data collection of backscatter from 500 - 1100 nm. On both systems, the streak output is imaged onto a CCD camera. In its 512x480 pixel array, the CCD covers the spectral range with 4-nm resolution. The sweep speed is variable with full window values of 30, 12, 6 ns, and faster. An optical fiducial provides a spectral and temporal marker.

On the NOVA laser, this instrument has been used to determine spatial density in gas-filled hohlraums from SRS signals. At Trident, it has been employed for similar measurements with long scale length plasmas in SBS and SRS seeding experiments. It has proven to be a versatile tool for studying the physics of laser-generated plasmas and has helped in target design issues for control of experiments.

Abstract for the 25th Annual Anomalous Absorption Conference
May 27-June 1, 1995
Aspen, Colorado

Time Resolved Measurements of the Angular Deflection of an Electron Beam by a Tunnel-Ionized Plasma

D. Gordon, A. Lal, K. Wharton, C.E. Clayton, M. Everett and C. Joshi

Department of Electrical Engineering

UCLA

We report on time resolved measurements of the transverse interactions between a tunnel-ionized plasma and a longitudinally-probing relativistic electron beam. There are a variety of effects which will ultimately couple fields in such a plasma to the probing electron beam. In vacuum, the ponderomotive force of the laser will de-focus the electron beam, but in plasma the radial electric fields set up by the ponderomotive force can actually confine the electron beam. In the case of plasma wave excitation via the beatwave mechanism, the thermalization of the plasma electron distribution function can lead to large-scale magnetic fields via the Weibel instability. A novel probe is used which uses a solenoidal lens after the interaction region to map angular deflection into x-y space on a 2-D Cherenkov probe. The Cherenkov light is streaked in time providing $A(x,y,t) \rightarrow A(\theta_x,\theta_y,t)$ where $A(x,y,t)$ is the measured intensity on the streak camera and θ_x and θ_y are the inferred deflection angles.

This work is supported by DOE grant number DE-FG03-92ER40727.

25th Annual Anomalous Absorption Conference, Aspen CO, May 27 - June 1 1995

Imaging of Near to Back Scattered Light in Gas Target Plasmas*

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A measurement of all of the light energy scattered from the target is necessary to determine the energy balance in NIF like targets. Stimulated processes direct the most intense scatter toward the focusing lens (back scatter), but in strongly non-uniform or strongly filamenting plasmas substantial light can be scattered just outside the lens cone (near to back scatter). We have developed a system to measure the total back scattered energy in experiments with f/4.3 and f/8 probe beams in gas filled target plasmas. Two absolutely calibrated, time integrated, cameras image the light near the laser wavelength (351 nm ± 5 nm) scattered 1) through the lens onto a diffuser plate and 2) on to a plate lying between 7.8° and 18.5° outside the f/4.3 lens. A single image is constructed using the measurements of both cameras which provides a measure of the energy flux over nearly all of the region inside of 18.5°. Arrays of 10 fiber optic pick offs and 12 photo-diodes provide time resolution of the energy flux and independent measurements of the time integrated energy density at various locations inside 18.5°. A second pair of cameras and a diode array make measurements of long wavelength light (400 to 700 nm). In experiments with symmetric plasmas ('gas bags') we find that the energy scattered outside the lens is comparable to that scattered into the lens and that the scattering is fairly symmetric about the beam axis. In experiments with gas filled hohlraums, in which the laser enters the plasma at 50° w.r.t. the plasma gradient, the scattering is asymmetric about the beam axis. The scattering of long wave length light is found to be peaked in the direction toward the plasma gradient (hohlraum axis) while the short wavelength light is peaked in the opposite direction. Results will be discussed from experiments carried out with f/8 beams, in which intensity, smoothing technique (4-color, or SSD), and target geometry are varied.

[1]D. S. Montgomery et. al. this conference

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*This work was performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W7405-ENG-48

Energy Transfer Between Crossing Laser Beams*

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Induced scattering between crossing laser beams is considered in theory and simulation. This fundamental process can impact the choice of beam-smoothing techniques for laser-driven hohlraums. Allowing independent variation of the intensity and frequency separation of the crossing beams, study of this process is an ideal way to quantify stimulated scattering instabilities.

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

Relation between N-body Lyapunov exponent and transport coefficient in one component strongly coupled plasmas

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We have measured the seperation rate between two adjacent trajectories in 6N-dimensional phase space for strongly coupled ion one component plasmas with the use of 3-d particle code SCOPE. We conjecture that the instantaneous Lyapunov expansion rate in phase space can provide a useful window on microscopic evolution system, because of its connection to phase space mixing and loss of initial state information.

In the SCOPE , the particle-particle particle-mesh (PPPM) method is employed, namely a short-range force is computed by using a direct particle-particle summation, and long range force is calculated by the particle-in-cell method.

The time averaged Lyapunov exponent $< \lambda > / w_p$ is found to be proprotional to $\Gamma^{-2/5}$ and $(D/w_p a^2)^{2/5}$ for the ion coupling constant $1 < \Gamma < 150$, where D , w_p and a are the diffusion constant, plasma frequency and ion sphere radius. A lage jump of the time averaged Lyapunov exponent appears near $\Gamma = 160$, corresponding to phase transition. Those results suggest that the phase-space expansion rates are related to tranport coefficients. Chaotic behavior of instantaneous Lyapunov exponent is also observed. Its time spectrum consists of the three different phases, plateau, f^{-2} and f^{-1}.

Excitation of Accelerating Wakefields in Inhomogeneous Plasmas

G. Shvets[1], *J. S. Wurtele*[2], *T. Chiou*[3], *and T. Katsouleas*[3]

The excitation of the wakefields in a transversely inhomogeneous plasma by a short laser pulse is investigated theoretically. A general equation for the wake excitation is derived and applied to plasma channels. The wakes in an idealized hollow channel which has a step-function density are found. A more realistic model, in which the transition between the evacuated channel and the homogeneous surrounding plasma occurs over a finite radial extent, is then analyzed. It is shown that the excited channel mode interacts resonantly with the plasma electrons at that radial location where the local plasma frequency equals the wake frequency. This leads to secular growth of the electric field and, eventually, results in wavebreaking and the dissipation of the accelerating mode. We introduce an effective quality factor Q for the hollow channel laser wakefield geometry. This resonance limits the number of electron bunches that can be accelerated in the wake of single laser pulse.

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Abstract for the 25th Annual Anomalous Absorption Conference
May 27-June 1, 1995
Aspen, Colorado

Measurements of the Beatwave Dynamics in Time and Space

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Department of Electrical Engineering

UCLA

We report on continuing experiments on the Plasma Beat Wave Accelerator which uses an intense, two-frequency CO_2 laser pulse to resonantly drive up a large amplitude, relativistically-propagating electron plasma wave suitable for electron acceleration. Previously, collective scattering of a probing laser beam has allowed us to measure $\tilde{n}(\omega_m,t)$ where $\omega_m=m\omega_p$ and m=1,2 corresponds to the fundamental and second harmonic of the large-amplitude plasma wave. The ratio of these harmonics allowed us to determine $\tilde{n}/n_0$ = 38± 5%. Also, $\tilde{n}(\omega_m,k)$ has been measured up to the third harmonic.[1] This powerful Thomson scattering technique has now been extended to measure $\tilde{n}(z,t)$ at $\omega=\omega_p$ and $k=\omega_p/c$, where z is the coordinate along the CO_2 propagation direction. Preliminary results show a coherent beatwave, extending for at least 9mm along the z axis. Spatial structure smaller than the Rayleigh length of the laser is observed, possibly because nonlinear dynamics such as relativistic detuning and ponderomotive effects complicate the longitudinal amplitude profile and coherence. Supporting diagnostics include the energy spectrum of the accelerated electrons, and the corresponding $\tilde{n}(\omega,k)$ spectrum near $k=2k_0$.

This work is supported by DOE grant number DE-FG03-92ER40727.

1. M.J. Everett et al., Nature 368, 527 (1994)

Adaptive Mesh Refinement Simulation of Linear-Nonlinear Instability Growth (U)

R. P. Weaver, M. L. Gittings, and R. M. Baltrusaitis (X-2)

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Hydrodynamic instabilities, turbulence and mixing are difficult to simulate. However, direct numerical simulation of the growth of perturbations is becoming feasible with recent advancements in computer hardware and software. We have developed an Adaptive Mesh Refinement code that optimizes the use of memory by successively refining the zone size of the mesh in an adaptive fashion. This adaption of the zoning allows the smallest zones (highest resolution) to track interesting hydrodynamic features of the simulation such as shocks, material interfaces or significant density or pressure gradients. This code currently runs in 1D, 2D, or 3D and incorporates a nonequilibrium radiation diffusion package for all dimensions.

We have applied this code to several experimental applications in order to study the direct numerical simulation of hydrodynamic instabilities through the linear growth phase and into the nonlinear/fully turbulent phase. 2D and 3D simulations of the Linden, Redondo and Youngs Rayleigh-Taylor instability experiments are being modeled. Growth of the turbulent mixing zone will be shown. The Mach 1.2 shock-induced Richtmyer-Meshkov hydrodynamic instabilities generated by the Los Alamos DX-13 shock tube experiment also have been simulated. The three general classes of data that result from three differing initial conditions of a thin SF_6 layer in air in these shock tube experiments have been successfully modeled using this new technique. We present here the methods used for these simulations and the results of the simulations.

ORAL SESSION 2

HYDRODYNAMICS

John Gardner , Chair

Monday, May 29

1A Sued/cc/Oe25

Theoretical and experimental studies of hydrodynamic stability related to start up problem

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When ablation pressure is first applied on an ICF target wtih surface ripples, a rippled shock wave is launched in accordance with the target surface. Once a shock front is rippled, the phase of the ripple tends to oscillate as the shock propagates. The oscillation of the rippled shock would amplify target perturbations and determine the initial condition on the Rayleigh-Taylor instability after shock breakout. The dynamics of the rippled shock is investigated theoretically,computationally and experimentally.

In addition to the propagtion of the rippled shock,a new hydrodynamic instability is found to be derived when the rippled shock propagates through a contact surface. The instability can be understand as a gravitational hydrodynamic instability due to a gravity of a damping oscillation. Thus the amplitude of the velocity perturbation of the unstable contact surface is depend on the phase of the oscillating shock at

Target Imprinting by Laser Intensity Nonuniformities

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Robert J. Taylor
The Blackett Laboratory, Imperial College, UK
and Andrew J. Schmitt
Plasma Physics Division, Naval Research Laboratory, Washington, DC

It has long been recognized that the ablative Rayleigh-Taylor instability is seeded on laser-accelerated targets both by target mass nonuniformities and also by nonuniformities in the incident laser beam. The latter gives rise to ablation pressure nonuniformities which can imprint the target. The effect of imprinting is particularly deleterious at early times, before a sufficient corona has developed to shield the target and smooth out variations in the driving pressure.[1]

We are examining a variety of schemes to reduce imprinting while maintaining the viability of low-isentrope high-gain direct-drive pellet designs for KrF systems.[2] Part of our effort to achieve this goal includes semi-empirical modeling of the laser imprint as a function of incident laser intensity parameters and target materials. Results from a series of simulations of planar targets accelerated by a laser provides input for the model. The spatial profile of the laser is modulated by a single-mode nonuniformity. In the simulation study, we varied (a) the laser spatial modulation wavelength and amplitude, (b) the temporal length of the modulation, (c) the contrast ratio, and the temporal history shape, and (d) the target materials. The parameter regimes and laser intensity temporal histories primarily investigated are those suggested by successful one-dimensional KrF pellet designs. We describe progress in this work and its immediate application to a set of imprint experiments[3] recently performed by Taylor and others on the Vulcan laser at RAL, as well as modeling for future Nike experiments.

Work supported by USDOE and USONR and Imperial College, UK.

[1]M. H. Emery, J. H. Gardner, R. H. Lehmberg, & S. P. Obenschain, *Phys.Fluids B* **3**, 2640 (1992);"Chapter 29: Start-up Imprint and Shock Dynamics," M. H. Emery, in *Nike KrF Laser Facility Annual Report August 1993*, NRL/PU/6730-94-264 (1994).

[2]A. J. Schmitt, *et al.*, this conference.

[3]R. J. Taylor, *et al.*, (in preparation, 1995).

Laser Imprint Smoothing in Foam-Buffered Targets*

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We have used LASNEX to examine energy deposition in foam-buffered plastic foil laser targets in support of experiments performed on LANL's TRIDENT glass laser system by O. Willi (Imperial College). In the experiments, a 200 Å Gold layer deposited on 200 μm of $C_{10}H_4 0_8$ of 50 mg/cm^3 foam, and covering a 10μm CH foil, was exposed to 3×10^{14} W/cm^2 illumination over 1.1 ns. Early imprinted disturbances from the laser non-uniformity were significantly smoothed by the presence of the foam and gold as compared to the density evolution with deposition directly onto the plastic. In scoping calculations, we have run LASNEX studies of 200 μm radius cylindrical system illuminated with a 1.2 ns 110 J trapezoidal pulse. We see pre-explosion of the CH foil when simple 3T radiative diffusion is used. With multi-group and LTE the CH still explodes. But with multi-group and NLTE we see only slight pre-expansion of the CH foil and a strong laser driven shock passing through the foam, hitting the foil in 1 ns, in agreement with experiment. The 1-D shock penetration history is very nearly the same with or without the gold layer; but the gold broadens the shock.

*Work supported by the USDOE.

UCRL-JC-120244 ABS

X-ray laser backlighting applied to measure laser imprint*

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For direct drive ICF, a capsule is imploded by directly illuminating the surface with laser light. The beam smoothing and uniformity of illumination affect the seeding of instabilities at the ablation front and affect the overall stability of the implosion.

Measurements of the effect of laser imprint on a flat CH foil have previously been made by recording the perturbation amplitude during the phase when it is dominated by Rayleigh-Taylor growth. This measurement is a convolution of laser imprint and the Rayleigh-Taylor growth, and it does not give any information about a time history of the imprint. The effect of imprint is expressed in terms of an equivalent surface perturbation amplitude.

We have developed a new technique for studying the imprint of a laser beam on a thin foil. We use an Yttrium x-ray laser as a XUV backlighter. This is relayed via multilayer optics onto a thin Si foil. The foil is then imaged onto a CCD camera to measure the optical depth modulation due to laser imprint when the shock breaks out. By using an XUV backlighter to image a Si foil, we are able to measure small fractional variations in the foil thickness, so we can measure modulations due to laser imprint during the imprint phase.

We recorded images due to imprint from a 5×10^{12} W/cm^2 3ω drive beam incident on a 3 μm Si foil. We show the modulation at the time of the shock breakout corresponds to a 4% RMS modulation in the initial thickness of the foil. We compare the cases of narrow bandwidth and broad bandwidth laser drive and compare both with Lasnex simulation.

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

NIF Direct Drive Capsule Design Studies*

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The National Ignition Facility (NIF), a 1.8 MJ, 500 TW neodymiumglass laser system, is being redesigned to add the capability to implodedirect drive ignition capsules, as well as the main line indirect drive targets. Thismay be accomplished by steering a fraction of the beams to additional ports on asingle target chamber which provide a more nearly spherically symmetric illuminationpattern. The baseline direct drive capsule is an LLE design which uses a picketpulse shape to implode a DT shell on an adiabat which has three times the Fermidegenerate pressure. This capsule must be irradiated with an illuminationasymmetry of less than ~1% rms in modes l = 1-20, which the NIF will be able to deliver. Beam smoothing must also be good enough to give less than an additional1% rms intensity modulation, time-averaged over about 1 ns, in modes l = 21-500. This level of beam smoothing requires more bandwidth than is needed forindirect drive, which reduces the deliverable laser energy and peak powersomewhat. The target still has enough ignition margin for significant gain to beprobable for laser output within the achievable range.

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

The Nike KrF Laser and Target Facility

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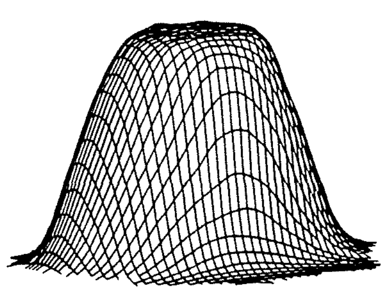
Nike is a 56 beam KrF laser and target facility that is now being activated for regular laser-target experiments. The primary goal for the laser system is to obtain >2 kJ of laser energy on planar targets in 4 nsec pulses with focal profiles that are uniform and controlled enough for high-gain direct-drive fusion. In addition we expect to have 800 J available for x-ray backlighting targets.

The Nike optical system images an aperture that has been uniformly illuminated by diffuse, broad bandwidth, KrF light. The focal profile is highly uniform when averaged over times long compared to the laser coherence time (0.5 - 1 psec). We have obtained individual 4-nsec beam focal profiles through the entire amplifier system that deviate only 1% rms from the desired top-hat shape over the center 50% of the beam's FWHM diameter. A sample focal profile measured by a cooled CCD camera is shown below. By overlapping many beams on target we expect to obtain even further improvements in the focal uniformity than has been obtained with the individual beams. The final amplifier has demonstrated 5 kJ output in 56 beams.

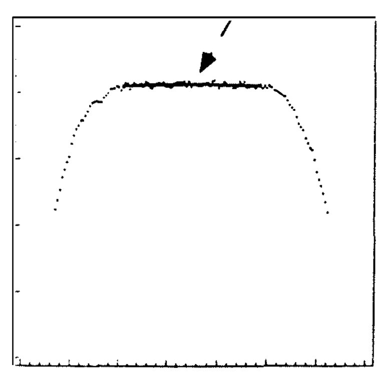
Nike will be used to evaluate the laser, target, and interaction- physics requirements for controlling hydrodynamic instabilities sufficiently for high-gain target performance. In this paper we will discuss the laser performance and the facility's unique capabilities for target experiments.

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



Nike laser intensity focal profile

The variation in the laser intensity is 1%



A cross-section of the Nike profile

Initial Target Results from the Nike Laser[1]

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The Nike laser is a 56-beam angularly-multiplexed KrF laser. It is capable of producing a highly uniform flat-topped focal distribution using the echelon-free induced spatial incoherence technique. The focal distribution will eventually consist of 44 flat-topped beams overlapped onto the planar target. Typical parameters are: a focal FWHM diameter of 600 to 1000 μm, an intensity of 1 to 2×10^{14} W/cm^2, and a pulse length of 4 ns.

For the initial target shots, 10 to 30 beams overlapped onto plastic targets. The diagnostics include an optical streak camera and fast photomultiplier tube that observe the target's rear surface luminosity, and an x-ray pinhole camera that observes the front surface soft x-ray emission. The single and double foil experiments will determine the long scale-length pressure uniformity. In addition, measurements of x-ray emission from the front surface will indicate the temperature uniformity of the ablation plasma. The x-ray camera has verified that the beams were correctly overlapped.

Diagnostics being prepared include x-ray side- and back-lighting, x-ray streak and framing cameras, optical framing cameras, and spectroscopy. We expect these diagnostics to be ready later this year.

[1] This work was supported by the U. S. Department of Energy

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25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

The Knock-On's Diagnostic in Laser ICF Targets Revisited

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ABSTRACT

In an attempt to take full advantage of a new design for a charged particle spectrometer,[1] the range of applicability of the knock-on diagnostic[2] to measure fuel ρR is being re-examined. A Monte Carlo computer code, *IRIS*, is being used to calculate the spectrum of the emerging energetic charged particles (knock-on's) produced by the interactions of the 14-MeV fusion neutrons with the compressed target material. Initial results show that both the fuel ρR and the tamper ρΔR can be diagnosed using the high-energy peak of the deuteron and triton knock-on's spectra if $(\rho R) \lesssim 200$ mg/cm^2 and $(\rho R) + (\rho \Delta R) \lesssim 300$ mg/cm^2. For larger values of ρR, which can occur in cryogenic fusion fuel targets, the high-energy peaks are no longer well defined, and interpretation of this diagnostic becomes model dependent. Detailed results from the Monte Carlo simulations are presented.

1. D. G. Hicks, C. K. Li, R. D. Petrasso, K. W. Wenzel, and J. P. Knauer, MIT Report: PFC/RR-94-11, November 1994.

2. S. Skupsky and S. Kacenjar: J. Appl. Phys. **52**, 2608 (1981); S. Kacenjar, S. Skupsky, A. Entenberg, L. Goldman, and M. Richardson; Phys. Rev. Lett. **49**, 463 (1982).

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.

and Simulations*

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The Richtmyer-Meshkov instability is investigated at high compression using the Nova laser. The growth of imposed single wavelength interfacial perturbations as well as the shock compression and velocities are diagnosed with 1D streaked and 2D gated radiographs. Detailed comparisons are made with full hydrodynamic simulations for a variety of wavelengths, initial amplitudes, shock and interface speeds, compressions, and density ratios. For small initial amplitudes, the growth rate is consistent with the Meyer-Blewett impulsive model. For large initial amplitudes, the growth rate is bounded by the difference between the velocities of the transmitted shock and interface.

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore N   nal Laboratory under contract number W-7405-ENG-48

Experimental and Computational Analyses of Rayleigh-Taylor Growth in Cylindrical Implosions*

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The implosion of an inertial-confinement-fusion (ICF) capsule is most efficient if the imploding flow is exactly spherically symmetric. It is well known, however, that real ICF flows are subject to a variety of fluid instabilities that destroy spherical symmetry. Specifically, near the end of the capsule's implosion, the inward-moving high density shell is decelerated by the capsule's hot low-density core. The instability at this stage is most nearly like the classical Rayleigh-Taylor instability.

An experiment has been designed in cylindrical geometry which allows for the study of this unstable regime. The use of cylindrical geometry targets was chosen in order to maintain direct diagnostic access while still creating a physical situation where a decelerational phase exists in convergent geometry. This diagnostic situation allows for the study of an unstable mode's amplitude during the history of the implosion. These experiments have been carried out on the Nova laser facility at Lawrence Livermore National Laboratory. In these experiments, laser beams were used to create a radiation drive inside a hohlraum which then drives the implosion of the cylinder. X-ray backlighting was used along the axis of the cylinder to image an opaque layer. The growth of the unstable mode was visible upon this layer. Several different designs have been experimentally shot during the last few years. The results from these shots will be discussed, along with the rationale for the design modifications. Included in these discussions will be several single mode unstable implosions. Experimental results will then be compared to computational simulations.

*** This work was supported under USDOE contract W-7405-ENG-36**

No show!!

NOVA HIGH GROWTH FACTOR IMPLOSION EXPERIMENTS AND ANALYSIS

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We report on modeling and analysis of recent Nova experiments aimed at understanding the growth of the Rayleigh-Taylor instability in spherical implosions. In these experiments the variation in neutron yield and x-ray line emission from both fuel and pusher dopants is studied as a function of controlled initial capsule outer surface perturbation. Capsules with relatively high instability growth (150-200 linear growth factors @ mode 20) are used so as to test the treatment of saturation effects in current mix models. The RMS of the imposed outer surface perturbations is varied from 0.05-μm to 1.0-μm. Two combinations of capsule fill gas/inner capsule wall are considered, namely DH fill/CH wall and H fill/CD wall. (Here "inner wall" refers to the 3-μm thick region of capsule wall closest to the fuel.) The capsule yield is qualitatively expected to decrease and increase with surface roughness for the DH/CH and H/CD cases, respectively.

In this talk we will first show that Nova high growth factor implosions test many aspects of hydrodynamic instability modeling important to the design of NIF targets. The relative merits of x-ray spectroscopy and yield as diagnostics of mix will then be discussed. The effects of drive asymmetry and inner surface perturbations will also be considered. We compare the results of Nova experiments to date to simulation and discuss the sensitivity of the results to variations in the drive and capsule conditions. Future near term experiments include i) varying the degree of instability growth by modifying the level of pusher doping, and ii) studying near single-mode outer surface perturbations. The important physics aspects and expected results from these experiments will also be discussed.

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

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

A Mix Model in *LILAC* for the Linear and Weakly Nonlinear Regime of the Rayleigh-Taylor Instability

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Modeling of the linear and weakly nonlinear regime of the Rayleigh-Taylor (RT) instability is necessary to complete the analysis of burnthrough experiments[1] and to predict the behavior of high-performance target designs. Complete atomic mix does not occur in that regime, only distortion of the material boundaries. We present a model in which the perturbation of the grid in the 1-D Lagrangian hydrodynamic code *LILAC* is obtained from a multimode treatment of the RT instability.[2] The energy equation is solved in both the radial and the transverse direction on the distorted grid. This provides an accurate description of the heat conduction between regions of material that are brought in close proximity by the instability. The model and its assumptions are described, and the results of simulations of burnthrough experiments are discussed.

1. J. Delettrez, D. K. Bradley, and C. P. Verdon, Phys. Plasmas **1**, 2342 (1994).
2. S. W. Haan, Phys. Rev. A **39**, 5812 (1989).

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.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Growth Rate of the Rayleigh-Taylor Instability for Indirect-Drive ICF

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ABSTRACT

The stability analysis of ablation fronts is carried out for the regimes significant to indirect-drive ICF, where the main mechanism of energy transfer is due to radiation transport. The analysis is self-consistent as the effects of finite thermal conductivity ($K \sim T^{\nu}$) are retained. It is found that, in the large ν regime typical of indirect-drive ICF, the ablative stabilization coefficient is significantly reduced and the density gradient stabilization is enhanced. For wave numbers much less than the cut-off, the ablative stabilization coefficient (β) is approximately unity. Most interesting, it is found that the density gradient stabilization term depends on $(kL)^{1/\nu}$ where L is the density gradient scale length. For large ν the density gradient stabilization can be significant even for large wavelength.

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.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

The Effect of Finite Thermal Conduction on the Ablative Rayleigh-Taylor Instability

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ABSTRACT

The linear stability theory of the ablative Rayleigh-Taylor instability is developed by including the effect of finite thermal conductivity. In inertial confinement fusion (ICF) capsules, thermal conduction is responsible for generating the zeroth-order ablation flow and, therefore, must be included for a self-consistent treatment of the stability analysis. By using the isobaric approximation, the linear system of equations is reduced to a fifth-order differential equation for the density perturbation. The growth rate is determined by asymptotically matching the solution in the overdense portion to the solution in the ablation front and the blow-off region. The equilibrium conditions typical of direct-drive (ICF) and indirect-drive ICF determine two different regimes for the solution of the stability problem. It is found that the magnitude of the ablative stabilization and the density gradient stabilization terms depends on thermal conduction.

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.

The Effect of Surface Perturbation Spectrum in Unstable ICF Implosions*

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Using the technique of direct simulation of the unstable growth of nonlinear multi-mode surface perturbations in imploding ICF capsules, we have examined the effect of variations in the spherical harmonic spectrum of the initial perturbation. We find that the flow retains memory of the initial spectral shape for a National Ignition Facility capsule such as the PT design (1). That is, the flow does not become so turbulent that mode coupling destroys memory of the initial conditions, for the range of perturbation amplitudes we considered. For example, if two initial perturbations on the inner DT ice surface have equal RMS amplitude, but one has a larger relative contribution from high spatial frequencies than the other, then the high-frequency perturbation is more deleterious. We also have investigated the effect of "bandwidth-equivalent-RMS" (BER) spectra. Using a BER spectrum scaled from a 3D perturbation spectrum, each spherical harmonic mode in a 2D calculation makes the same relative contribution to the total RMS amplitude as it does on a real 3D surface with the 3D perturbation spectrum. It is expected that using a BER spectrum in 2D calculations gives a more accurate representation of the influence of higher modes than if the 3D spectrum is used directly.

*This work was supported under USDOE contract W-7405-ENG-36.

1. S. W. Haan, *Bull. A. P. S.* **39**, 1635 (1994).

INVITED TALK 2

Prospects for Direct and Indirect-Drive ICF on the OMEGA Laser

by

R. S. Craxton

Monday, May 29

Nelson Hoffman , Chair

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Prospects for Direct- and Indirect-Drive ICF on the OMEGA Laser

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The upgraded OMEGA laser offers an exciting new capability for investigating key issues related to both direct-drive and indirect-drive ICF. The laser can deliver 30 kJ of 351-nm energy on target in 60 symmetrically disposed beams and will be able to combine this with beam smoothing and versatile pulse shaping.

The primary direct-drive program on OMEGA aims to demonstrate near-ignition conditions in capsules scaled from high-gain NIF designs ($\rho R \gtrsim 0.2$ g/cm^2, T_i ~2–3 keV). Success will depend on progress in two main areas - cryogenic target development and beam smoothing. A key theme is the progressive improvement in experimental implosion results as the on-target irradiation nonuniformity is reduced toward the goal of 1%–2% rms using two-dimensional smoothing by spectral dispersion (SSD) and polarization wedges. The experimental program will be coupled to the development of target designs less susceptible to irradiation nonuniformity. Other major areas of investigation on OMEGA include flat-target stability experiments and long-scale-length plasma physics experiments.

In addition, the OMEGA laser offers a unique capability for indirect-drive experiments. Using 40 out of the 60 beams, pointed onto the inside of a cylindrical hohlraum in four or six rings rather than the two available on Nova, it should be possible to carry out indirect-drive implosions with unprecedented symmetry. Some aspects of "beam phasing" [the use of varying laser powers in the different rings, a key feature of the baseline design for the National Ignition Facility (NIF)] can also be investigated for the first time. In addition, all 60 beams can be used to irradiate a "tetrahedral hohlraum," defined as a spherical hohlraum with four laser entrance holes placed at the vertices of a tetrahedron. Tetrahedral hohlraums offer the potential advantage over cylindrical hohlraums of lower time-varying nonuniformity.

All these experiments are directly relevant to the NIF, especially in view of the proposed redesign of the NIF target area. This redesign would greatly enhance the versatility of the NIF by accommodating both direct-drive targets and tetrahedral hohlraums in addition to the baseline cylindrical hohlraums. This talk will provide an overview of the experiments planned for the upgraded OMEGA laser and will attempt to identify those physics issues that are key to achieving success both on OMEGA and on the NIF.

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.

MIXED POSTER SESSION 2

Monday, May 29

25th Annual Anomalous Absorption Conference
The Aspen Institute, Aspen, Colorado
May 27 - June 1, 1995

The Anomalous Absorption of Short-Pulse High-Intensity Lasers in Underdense Plasmas1

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The ability to propagate a short-pulse high-intensity laser through Rayleigh lengths of underdense plasmas is crucial for laser-plasma accelerators, laser plasma radiation sources and the fast ignitor fusion concept. Such lasers are susceptible to a large number of instabilities such as Raman scattering, self-focusing/filamentation, and self-phase modulation. Using a fully explicit particle-in-cell code, we have studied short-pulse (*80 ~ 600fs* for $\lambda = 1.02\ \mu m$), high-intensity ($Ipeak = 5*10^{17} \sim 5*10^{18}$) lasers propagating through *1 ~ 4% ncr* density plasmas for distances up to *2* Rayleigh lengths. For a wide range of these conditions, we find that typically *50%* of the laser energy is lost from the original focal cone within a Rayleigh length. This loss is due predominantly from a combination of absorption and side scattering from Raman plasma waves. At the higher powers self-focusing and filamentation also occur but the energy losses still occur. Self-phase modulation occurs at the front of the pulse before Raman occurs and laser hosing occurs at the back of the pulse seeded by the residual plasma waves from Raman forward scatter.

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1 Work Supported by DOE Grant No. DE-FG03-92ER40727 and LLNL Grant LLNL PPRI B283617.

COLLISIONLESS ELECTRON HEATING BY A UHI LASER PULSE AT NORMAL INCIDENCE

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Some of the various physical phenomena through which a ultra-intense laser couples to an overdense plasma at normal incidence are still speculative. Among them, electron heating is a crucial aspect, since it governs the foreseeable applications—such as fast ignitor, X-ray sources or ion acceleration. Some possible mechanism have already been identified or suggested:

—j x B heating[1]

—sheath inverse Bremsstrahlung[2]

—heating due to relativistic self-induced transparency[3]

—and also, in two dimensions, surface rippling and the corresponding onset of absorption mechanism usually observed at oblique incidence (resonance absorption and vacuum heating).[4]

For a better understanding of the phenomena and with the hope to obtain improved scaling laws for the temperature and density of the suprathermal electrons, two simple models of wave-particle interaction have been studied.

We first consider the motion of an electron under the simultaneous action of a propagating electromagnetic wave and an electrostatic restoring field[5] . The longitudinal momentum that the particle would gain in vacuum, as well as its excursion length, are then strongly limited by this ambipolar field. This model enables a better understanding of the plasma oscillations driven by the laser at the target surface.

The second situation of interest features an electron originating in the target and incident on the standing wave located at its surface. A somewhat similar configuration has previously been proposed {2} at non-relativistic irradiances: the corresponding results are discussed and generalized. Whereas {2} seems to overestimate heating at low intensity, a potentially very efficient mechanism is identified at relativistic irradiances.

For these two situations, the main characteristics of electron dynamics are reviewed. We also compare the resulting kinetic energies with suprathermal temperatures obtained from PIC simulations.

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[1] W.L. Kruer ann K. Estabrook; *Phys. Fluids, **28**, 430 (1985)*

[2] P.J. Catto and R.M. More; *Phys. Fluids, **20**, 704 (1977)*

[3] E. Lefebvre and G. Bonnaud; *Phys. Rev. Lett.., **74**, 2002 (1995)*

[4] S.C. Wilks;*Phys. Fluids, B, **5**, 2603 (1993)*

[5] J.N. Bradsley, B.M. Penetrante and M.H. Mittleman; *Phys. Rev. A, **40** 3823(1989)*

TRANSPARENCY OF AN OVERDENSE PLASMA INDUCED BY RELATIVISTIC EFFECTS

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The very high irradiances that can now be achieved by tight focussing of a short laser pulse, bring about a renewed interest for the phenomenon of relativistic self induced transparency. An electromagnetic wave of frequency ω is classically allowed to propagate in a plasma up to a so-called critical density: $n_{cr} = \omega^2 m_e \varepsilon_o / e^2$ At that density, the electron current exactly balances the displacement current and prevents further propagation of the wave. When relativistic non-linearities are taken into account, the electron mass shift or the electron velocity saturation increase the critical density, leading to the phenomenon of self induced transparency (SIT)[1]. A classically opaque plasma of density $n_e > n_{cr}$ becomes transparent to waves whose amplitude is above a threshold value $a_o^*(n_e)$.

Extensive simulations of a linearly polarized laser wave in the range $I\lambda^2 \in [10^{18} - 5x10^{19}]$ $W\mu m^2 / cm^2$ normally incident on a slightly overdense plasma $n_e / n_{cr} \in [2-6]$ have been performed with a 1.5D relativistic particle-in-cell code[2]. These kinetic simulations reveal a quite more complicated picture of SIT than what could be expected from analytical work of the 70's.[3,4]

As the wave propagates into the target, it also reflects on the interface between the "transparent" and "opaque" media—i.e. respectively, the parts of the plasma that the fields have or have not already entered. Since this interface is in motion parallel to the propagation direction, the reflected light is strongly redshifted.

The propagation is also accompanied by a strong electron acceleration, apparent on the $x - p_x$ phase space plots. Whereas the transverse electron motion falls back to a small amplitude when the fields are turned off, the longitudinal motion persists and can contain a sizeable fraction of the incident laser energy.

The influence of ion dynamics on SIT has also been considered. When ion motion is allowed, a more stringent condition is imposed on the strength of the laser wave, leading to a higher threshold amplitude than with fixed ions.

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1 A.I. Akhiezer and R.V. Polovin; Sov.Phys. JETP., 3, 696 (1956)
2 E. Lefebvre and G. Bonnaud; Phys. Rev. Lett., 74, 2002 (1995)
3 P. Kaw and J. Dawson; Phys. Fluids, 13, 472 (1970)
4 C.E. Max and F. Perkins; Phys. Rev. Lett., 27, 1342 (1971)

STIMULATED RAMAN SCATTERING IN HIGH INTENSITY SHORT-PULSE LASER PLASMAS

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Stimulated Raman scattering driven by relativistically intense sub-picosecond laser pulses is addressed. The extreme intensities, the pulse duration, the pulse shape and in particular the steep intensity gradients,and also density gradients due to ionization can each have a marked effect on the nature, strength and emission characteristics of the instability. In recent experiments novel results have been observed for both backward and forward scattering [1,2,3]. We use a model which describes the instability in the rest frame of the pulse (Lorentz transformed to the pulse group velocity), includes relativistic effects, obtains convective gain factors but also shows that solutions temporally growing (absolute growth) in the pulse frame exist. The latter arise, for both forward and backward scattering, from the finite levels of mode conversion which occur across the pulse boundaries at both leading and trailing edges, since the dispersion characteristics of modes supported inside the pulse are distinct from those which freely propagate outside the pulse.

(1) Najmudin Z, Dangor A E, Malka V, Marques J-R, Modena A, Norreys P, and Taday P 1994 RAL Annual Report RAL-94-042,23

(2) Darrow C B, Coverdale C, Perry M D, Mori W B, Clayton C, March K and Joshi C, 1992 Phys. Rev. Lett. **69**, 442

(3) Dangor, A E, Modena, A, Najmudin, Z, Danson, C, Norreys, P, Malka, V and Marques, J R, in Proceedings of ECLIM 1994 Conference, 19-23/9/94, St. Johns College, Oxford, UK.

Harmonic Generation in Picosecond Laser-Plasma Interaction

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&
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Harmonic generation is one of the promising methods of producing intense short-wavelength coherent radiation. For laser-plasmas produced from solid targets, it offers an alternative way to diagnose plasma conditions. High-order harmonic generation in these dense plasmas was studied over a decade ago in a series of experiments using CO_2 lasers at $\lambda = 10.6\ \mu m$ [1,2]. The mechanism of generation is believed to depend on steep plasma profiles resulting from pondermotive pressure. Unlike gases, this solid target interaction produces not only odd-order harmonics, but also even-order and half-integer-order harmonics.

In several modelling results [3,4], the interaction of high-intensity picosecond laser pulses with solid targets has also been predicted to produce a range of harmonics; a few experiments conducted have produced apparently null results for harmonics above the second, for various reasons speculated. We describe our observation of weak $3\omega_0$ harmonic emission, and our observed parametric dependences of $2\omega_0$ and $3\omega_0$ harmonic produced from solid-target interaction with 1 ps, $I = 10^{17}$ W cm^{-2}, $\lambda = 1\ \mu m$ pulses. These conditions produce, at this shorter wavelength, the same $I\lambda^2$ scaling factor as in the earlier CO_2 laser experiments.

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1. N.H. Burnett, H.A. Baldis, M.C. Richardson, and G.D. Enright, Appl. Phys. Lett., 31, 172 (1977).
2. R.L. Carman, C.K. Rhodes, and R.F. Benjamin, Phys. Rev. A, 24, 2649 (1981).
3. S.C. Wilks, W.L. Kruer, and W.B. Mori, IEEE Trans. Plasma Sci. 21, 120 (1993).
4. J. Delettrez and G. Bonnaud, LLE Review 58, (University of Rochester), 76 (1994).

25th Anomalous Absorption Conference, Aspen, May 27 - june 1, 1995

Light Pressure effects on a preformed plasma

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Preliminary results are presented on the effects of light pressure on a preformed plasma. An ultra-intense pulse (300 fs, 0.525 μm, 10^{18} W/cm^2) interacts with a plasma preformed by an early pulse (500 fs, 1.053 μm, 10^{16}W/cm^2). We study the evolution of the 0.525 μm backscattered light spectrum as a function of the delay and relative intensity between the two pulses and find clear indication of the inward motion of the critical density surface. Preliminary characterization of the interaction region by dark field imaging will be presented. The behavior of the hot electron population (hot temperature and fraction of laser energy transferred) has been studied as a function of the irradiation conditions with a hard X-ray spectrometer (10-100 keV) and with a crystal spectrometer (K_α spectroscopy).

Twenty-Fifth Annual Anomalous Absorption Conference
Aspen, Colorado
27 May-1 June, 1995

Propagation of High Intensity Lasers Through Large Scalelength Plasmas*

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We describe measurements made in two separate experimental configurations of high intensity laser propagation through a large scalelength plasma. In one case, a 1 ns laser pulse of 351 nm light with intensity ranging from 0.5 to $5 \times 10^{15}\,\mathrm{W/cm^2}$ and various beam smoothing conditions is focused with an f/8 lens onto a preformed gasbag plasma. Laser propagation is measured by observing the angular spreading, temporal, and spectral characteristics of the transmitted light. These measurements provide important information about laser propagation through NIF-like plasmas. We observe significant angular spreading of the transmitted beam for high intensity interactions and only minor angular spreading for low intensity. We also measure the spectral content of the transmitted light near 351 nm and between about 400 and 700 nm. In the second experimental configuration a 1054 nm high intensity 100 ps Gaussian beam ($I \leq 1.1 \times 10^{17}\,\mathrm{W/cm^2}$) converges on an exploded CH foil plasma in an f/8 cone. This experiment studies the formation of a laser channel as part of an ongoing effort to develop fast ignitor schemes. Laser propagation through the plasma is measured with 263 nm interferometry and XUV imaging in addition to a transmitted light scatter plate similar to the gasbag experiments. Interferograms indicate that in most cases the incident beam breaks up in the low density coronal plasma. One case shows possible evidence of a narrow channel through a peak density of about $n_e/n_{\mathrm{cr}} \geq 0.5$ ($\rho r = 0.1\mathrm{mg/cm^2}$). We also observe strong (up to about 60%) broadband SBS extending about 16 nm to the red. We will present the experimental observations and compare with modeling of light propagation through the various plasmas.

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*Work performed under the auspicies of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Self-Trapped Electron Acceleration from Wakefields Generated by Short-Pulse Lasers*

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A short-pulse laser will genrate a wake of relativistic plasma waves as it propagates through a plasma. The wake can be excited by either the resonant wakefied[1] mechanism where the pulse length is half a plasma wavelength long or by the Raman forward scattering[2] (RFS)/ self-modulational instability when the pulse is many wavelengths long. We study the acceletation properties of these wakes using particle-in cell simulations. We find that the RFS generated wakes evolve to amplitudes where a large number of background electrons are self-trapped. At the time of self-trapping the distribution fundtion of the background electrons is already heated due to the earlier wavebreaking Raman backscatter and sidescatter plasma waves. The peak energy of an electron scales roughly with the common scaling law $\varepsilon_{max} = 4\varepsilon\omega_0^2/\omega_p^2$ where ε is the $\delta n/n$ of the wave and ω_0 is the frequency of the laser. The density of the relativistic electrons is nealy 10% of the background density. Results are compared to experimental data from LLNL and RAL.

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* Work Supported by DOE Grant No. DE-PG03-92ER40727 and LLNL Grant PPRIB283617

1 T. Tajima and J.M. Dawson, *Phys. Rev. Lett* , 43, 267 (1979)

2 W.B. Mori et al., *Phys. Rev. Lett.*, 72, 1482 (1994)

3 T. Krall et al., *Phys. Rev. Lett.*, 48, 2157 (1993)
T. Antonsen and P. Mora, *Phys. Rev. Lett.*, 69, 2157 (1992)

Intense Beam Channeling in Underdense Plasmas

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Realization of the "fast ignitor" fusion scheme requires the channeling of an intense laser beam through a long underdense plasma. Not yet well understood is possible beam degradation due to strong self-focusing. Both ponderomotive and relativistic self-focusing are important for the laser pulse parameters contemplated (intensities greater than 10^{17} W/cm^2 and pulselengths on the order of 100 ps). We report here numerical simulations that indicate that relativistic effects tend to suppress catastrophic self-focusing and stabilize the empty channel formed in the plasma.

We developed a model treating both ponderomotive and relativistic self focusing. The equations of the model were derived from a multiple scales expansion of the exact equations for underdense plasmas. There is no restriction to weakly relativistic intensities. These equations include a paraxial wave equation which contains the relativistic nonlinearities in refractive index due to the above effects. In addition, the plasma is treated as a fluid. Since ion motion is highly supersonic at these high intensities, thermal pressure is neglected. Our approach differs from traditional treatments in that ion motion must be taken into account for such long pulses. The simplicity of the model allows implementation of a three dimensional simulation (assuming cylindrical symmetry) on a workstation. Three dimensional modeling is necessary since beam behavior near a strong self-focus differs in one and two transverse dimensions.

Our results demonstrate the onset of catastrophic self-focusing for weakly relativistic fields (intensities on the order of 10^{17} W/cm^2). Relativistic effects become important at intensities an order of magnitude higher than this. For still higher intensities (10^{19} W/cm^2), the relativistic increase in the critical density saturates the self-focusing nonlinearity and arrests the beam contraction. This leads to a wider empty channel through which the laser radiation can be transported.

Optical Probing of a Dense Plasma Created by a Femtosecond Laser Produced Shock Wave.

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Shock waves are produced by 100fs, 580nm laser pulses with energies up to 1mJ, which are focused to a 10μm spot on the front surface of a thin aluminium layer deposited onto a thick silica target. Two 70fs, 530nm probe pulses of ~10μJ are partially focused onto the corresponding rear side of the target to a diameter of ~100μm. The probe pulses are used to perform frequency domain interferometry of the shocked aluminium layer. This technique allows measurement of changes in the phase and amplitude of the reflected probe pulses. By ensuring the changes occur only over part of the area covered by the probe beam, the initial phase and reflectivity can be measured simultaneously with the perturbed values.

The phase results for thin (<500Å) aluminium layers show two main components, firstly at early times, there is a large increase which is thought to be due to the changes in the optical properties of the heated aluminium layer, secondly, at later times there is a slow decrease due to the motion of the shock/ionisation front. Thicker (>1000Å) layers show only the slow decrease stage. The absorption data also shows variations which can be explained due to the changing optical characteristics of the shocked and heated aluminium layer. The onset of the phase change relative to arrival of the pump pulse also gives measurement of the shock transit time.

We gratefully acknowledge the support of the staff at LOA where these experiments were carried out. The work was supported by the European Community under the Large Facilities programme no. CHGE-CT93-0021 and under the Capital and Mobility programme, contract no. CHRX-CT93-0338.

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Submitted for poster presentation.

Mass Resolved Time of Flight Observations of Ions Produced by 140 fs Laser Pulses on Buried Layer Targets†

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Abstract: The plasmas studied here were produced at the Ultra Short Pulse (USP) laser facility at LLNL. The 140 fs (FWHM), 400 nm (2ω, I = 3e17 W/cm^2) light was incident at 22 degrees from the target normal. The target was a solid sandwich of 100 to 5000 Å aluminum over 100 Å MgF_2 over 1 μm of aluminum on top of a common microscope slide. Ions were detected with a magnetically deflected time-of-flight spectrometer.[1] Any given q/m is represented in the resulting 2-dimensional image by a straight line with slope proportional to q/m. As hydrocarbon contamination of the surface is unavoidable, the fastest ions traveling normal to the target surface are protons, followed by highly stripped carbon (q=4 to 6). These are followed closely by less stripped carbon and ions of the target material. Magnesium and fluorine from the buried layer are easily resolved. Observations of the asymptotic expansion velocity as a function of initial depth will be presented. Using LASNEX to model the expansion, the asymptotic velocities from the thinnest 3 layers suggest a peak surface temperature of 760 eV for P polarized light and 600 eV for S polarized light. A simple inverse bremsstrahlung absorption model in LASNEX gives asymptotic velocities which fall off too quickly with initial depth in the target. Including a superthermal component with a few percent of the absorbed energy flattens the dependence upon initial depth sufficiently to match the experimental data.

1. G. Guethlein, RSI 66(1),333 (1995).

†Work performed under the auspices of the U.S. Department of Energy by Livermore National Laboratory under contract number W-7405-ENG-48.

Optical guiding of high intensity laser pulses in long plasma channel formed by a slow capillary discharge

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Plasma-based accelerators have recently been the subject of intense research because of their potential for high accelerating gradients, compact size and low cost. However, the electron energy to be reached in such scheme is limited due to the short acceleration distance, determined by laser beam diffraction limited focusing distance. Optical guiding is necessary in order to propagate a laser pulse over distances larger than the vacuum diffraction length. One of the possible methods for the guiding of high intensity laser pulses is by channel guiding in a performed plasma channel. In plasma channel guiding, one tailors the plasma's transverse density so that its minimum is at the center of the laser pulse.

In this proof of principle experiment we have guide a high power laser beam in a preformed 1 cm long plasma channel formed by a slow capillary discharge.

An electrical discharge heats the capillary plasma that radiates and provides further evaporation of the capillary walls. The created plasma flows into a vacuum cell through a slit in the anode (the anode channel). The plasma density and profile is controlled by varying the discharge parameters. The high plasma jet's homogeneity is obtained by using a long anode channel made out of an alloy with a high thermal conductivity.

The proof of principle channeling experiments were carried out using a high power 100 fs, 30 mJ Ti: Sapphire laser at l=0.8μm. The laser beam was focused with a f/20 lens on the entrance of the plasma jet channel produced by the capillary discharge. The estimated maximum peak intensity was 10^{16} W/cm^2. The laser light transmitted through the plasma channel was reimaged by an optical system on a CCD camera. The beam was guided in one dimension over distance of 1cm, while the other one remained unchanged. This phenomena occur, since the rectangular plasma jet which emerges out of the capillary anode channel has a hollow density profile across the jet's width, but the density is homogenous in the other one (down the jet). The difference between the beam width in those two dimensions provides an evidence for a guiding.

We have performed simulations of laser pulse self-modulation, channel guiding, and wake field generation for laser and plasma parameters corresponding to the experimental values. The simulation shows that the laser pulse remains guided even with significant variations in the on-axis channel density, as long as the on- axis density remains below the density at the outer edge of the channel. The calculated on-axis electric wake field exceeds 50 GV/m.

Collisionless Absorption of Light Waves Obliquely Incident on Overdense Plasmas with Sharp Density Gradients

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Collisionless absorption of laser lights obliquely incident on overdense plasmas with sharp density gradients is studied analytically and numerically. The analytical results are derived under the assumption that the particles are reflected instantaneously at the sharp density gradients, an assumption frequently made for normal incident cases. Numerical results are obtained from particle-in-cell simulations using ZOHAR. The comparison between the analytical and the numerical results indicates that the instantaneous reflection is a reasonable assumption for s-polarized cases, but a very poor one for p-polarized cases. It is found that, due to the interaction of electrons and the normal component (parallel to the density gradient) of the laser electric field in the sheath region, the absorption coefficient of a p-polarized light is much greater than that derived under the assumption of instantaneous reflection.

Experimental Investigation of the Interaction of 1μ, 0.7 Psec, 10^{19} W/cm^2 Laser Pulses with Solid Targets*

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We have experimentally investigated the interaction of 1.05 μm, 0.7 psec, 10^{19} W/cm^2 laser pulses with solid targets on the LLNL 15 TW laser/target facility. The results to be presented include characterization of energetic electrons (several MeV), their transport and energy deposition in the target, and hard x-ray spectra obtained with a 9-channel NaI/filter detector array. (See poster by Y. Zakharenkov for discussion of energetic ion blowoff.) Results concerning the relevance of intentional laser prepulse and polarization will also be discussed.

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

The 25th Anomalous Absorption Conference
May 27 - June 1, 1995
Aspen, Colorado

Energetic ions, produced in short-pulse-laser interaction with solid targets*

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ABSTRACT

Energetic ions (protons with energy 0.2 to 6 MeV) were detected in experiments with a 15 TW short pulse laser [1]. The laser irradiance on target was in the range 5.10^{18} - 10^{19} W/cm^2 (energy up to 7 J, pulselength 650 fs, laser beam diameter in the focal plane of parabolic mirror 10 μm, angle of incidence 45^o). The energy spectrum and angular distribution of fast ion emission were measured with an array of CR-39 plastic track detectors, placed behind a set of foil filters (Al 10-90 μm, Cu 25 μm, mylar 195-390 μm). It was found that ion blowoff occurs in a very narrow (FWHM 20^o) cone of expansion along the normal for a solid Mo target. At the angle of specular reflection of laser beam (45^o to normal) the ion flux was 2 orders of magnitude lower. The ion distribution function, based on the measurements, had characteristic "temperature" of 600 keV. The total energy in the fast ions (above 100 keV) is estimated to be ~1 mJ.

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

Pulsewidth Control of Bright Ultrashort X-Rays from Intense Subpicosecond Laser-Plasma Interactions

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Short-pulse, high-intensity lasers interacting with solid targets make possible the study of a new class of laser-plasma interactions. They are unique because during the ultrashort laser pulse relatively little expansion occurs, and the density scale length remains much less than the laser wavelength. This makes possible the direct deposition of a significant amount of the laser energy at close to solid density. Steep plasma temperature and density gradients subsequently cause rapid cooling, resulting in highly non-equilibrium conditions and the concurrent emission of extremely bright ultrashort x-ray pulses. In this study, the latter are investigated experimentally with temporally and spectrally resolved (simultaneously) soft x-ray diagnostics.

The emitted x-ray spectra from solid targets with various atomic numbers are characterized for a laser with pulse width $\tau_l \sim 400$ fs and over a large range of laser intensities ($I < 5 \times 10^{17}$ W/cm^2). With low contrast (10^5), the x-ray spectrum in the λ = 40–100 Å spectral region is dominated by line emission, and the x-ray pulse duration is found to be characteristic of a long-scale-length, low-density plasma. Bright, picosecond, broadband emission, characteristic of a short-scale-length, high-density plasma, is produced only when a high laser contrast (10^{10}) is used. It is demonstrated experimentally that the pulse width of laser-produced x-ray radiation may be controlled by adjusting the incident ultrashort-pulse laser flux.[2] The x-ray pulse width is shown to vary from a duration of tens-of-picoseconds at high-laser intensity down to the streak-camera limit (the picosecond time scale) at low-laser intensity. The results are found to be in qualitative agreement with the predictions of both a code-independent model of radiation from a collisionally dominated two-level ion and a hydrodynamics code coupled to a detailed-configuration atomic physics package. X-ray film measurements of conversion efficiency, along with pinhole camera measurements of the emission region, reveal very high x-ray brightness.

These ultrashort x rays may be used as (1) a diagnostic of solid-density plasma conditions, (2) a tool for the study of radiation hydrodynamics in a parameter regime that is otherwise inaccessible, and (3) a source for time-resolved diffraction, spectroscopy, or microscopy studies of transient chemical, biological or physical phenomena. Preliminary results of an ultrafast pump-probe x-ray absorption spectroscopy study will also be presented.

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[1]National Science Foundation contract #PHY8920108

[2]D. Umstadter, J. Workman, A. Maksimchuk, X. Liu, C.-Y. Chien, and S. Coe, "Laser-Produced Picosecond Soft X-Ray Continuum Radiation," *Proceedings of LASERS '93*, V. J. Corcoran and T. A. Goldman, Eds. (STS Press, McLean, VA, 1994), p. 165.

Low Entropy Material Compression Using the Nike KrF Laser

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The goal of laser fusion is to uniformly compress and accelerate material on a low isentrope. This methodology may also be useful in materials research, to explore the creation of new alloys.

The Nike KrF laser is an appropriate driver for this type of program because its very uniform and flat laser profile will provide a very uniform compression region. We are studying the compression of materials sandwiched between a thin layer of gold (< 10 μ) and several hundred microns of diamond. The laser shines on the gold side of this sandwich. (Lead and cubic zirconia would be cheaper and less glamorous substitutes). The laser would deliver its few kiloJoules in a shaped 20 ns pulse with a peak intensity of 4×10^{13} W/cm^2. The gold becomes a hot plasma, but with pulse shaping, we find that the target material and the diamond can be kept below 0.1 eV as their pressure rises to 5 Mbar. This would open up a new regime of research for the cold compression of materials.

Hydrodynamic Efficiency Dependence on Atomic Number in High-gain Targets °

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Hydrodynamic efficiency in pellet designs with 0.25μ light has been computed numerically for specific thin shell targets where the mass of the shell has been kept constant while varying the element. Runs have been made for D, DT and T where Z is unchanged and only A varies. It is found that the hydrodynamic efficiency increases with A. Other elements have also been tested, such as CH and CD_2. Scaling is a function of Z/A.

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

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DIRECT DRIVE NIF CAPSULE STUDIES IN 1 AND 2-D

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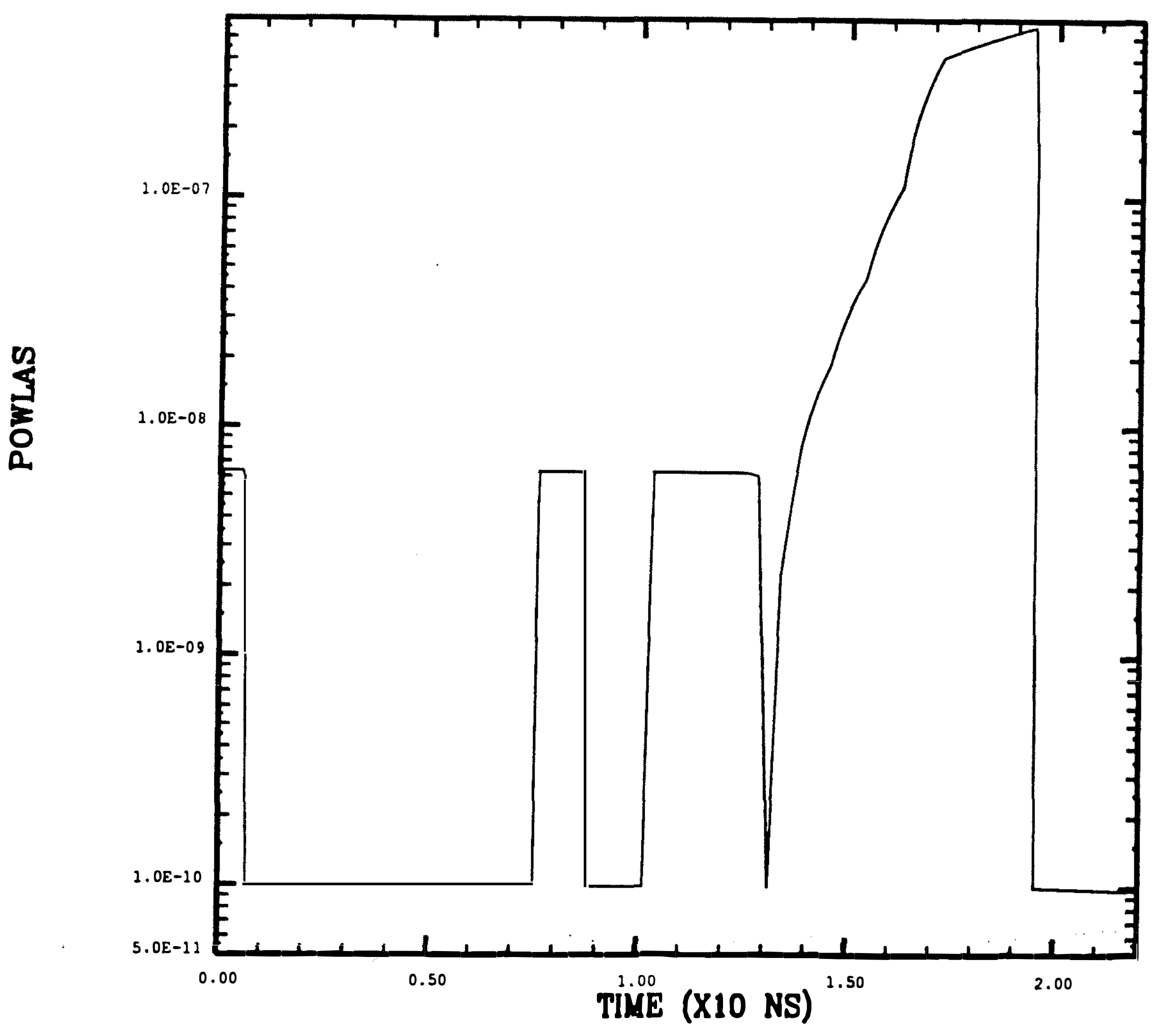
We present LASNEX results of direct drive calculations for an 'all' DT, NIF capsule design proposed by C. Verdon from Rochester (LLE). The 'picket fence' laser pulse shape (sample shown below) is considered, which is designed to keep the outer fuel on a high adiabat in order to minimize instabilty growth. The sensitivity of target performance to changes in several parameters is evaluated. These parameters include: laser profile, laser tuning, DT gas density, and laser rays which are radially focused vs. f20 optics. In addition, the effect of mesh zoning on target performance is studied.



Abstract submitted for the 25th Annual Anomalous Absorption Conference

High Gain Direct-Drive Target Designs for KrF Lasers*

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Abstract

Direct-drive ICF promises high gains for minimal laser pulse energy due to relatively high coupling of laser energy to target energy. However, high gain can only be realized if the concomitant problem of hydrodynamic instability can be solved. One essential contribution is optically smoothed laser drive, which minimizes the seed for hydrodynamic instabilities. It may also be necessary to tailor the isentrope of the target to decrease the growth of hydrodynamic instabilities, but this will inevitably lower the target gain as well. We are developing high-gain target designs that address these issues.

1d hydrocodes[1] are our primary design tool for developing these high-gain direct-drive targets. Stability constraints are calculated by a conventional multimode quasi-linear growth model[2] as well as 2d hydrocode simulations[3].

We present our current high-gain designs for KrF lasers with order MJ energy. These targets explore the tradeoffs between high-gain, hydrodynamic stability, and target fabrication limitations. Pure DT and multilayer designs are considered. We concentrate on designs with an optimally tailored pellet isentrope, an insensitivity to target and drive variations (particularly imprinting problems[4]), and maximal coupling efficiency.

1. A.J. Schmitt, D. Colombant, J.P. Dahlburg, and J.H. Gardner, Bull. Am. Phys. Soc. **39**, 1683 (1994); D. Colombant and A.J. Schmitt, Bull. Am. Phys. Soc. **39**, 1683 (1994).
2. S. W. Haan, Phys. Fluids **B3**, 2349 (1991); H. Takabe, K. Mima, L. Montierth, and R.L. Morse, Phys. Fluids **28**, 3676 (1985).
3. J.H. Gardner, J.P. Dahlburg, S.E. Bodner, A.J. Schmitt, and D. Colombant, Bull. Am. Phys. Soc. **39**, 1697 (1994).
4. J.P. Dahlburg et al., this conference

Sensitivity of a Beryllium NIF Capsule to Surface Perturbations

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Copper doped beryllium is one alternative to high Z doped plastic for the ablator of a National Ignition Facility capsule for the National Ignition Facility. The design we studied has an outer radius of 1.105 mm, and an inner radius of 0.95 mm. Inside this is a layer of DT ice 0.08 mm thick, and, in the center, DT gas in temperature equilibrium with the ice. This capsule is centered in a 9.5 mm long 2.76 mm radius cylindrical gold hohlraum with 1.39mm radius laser entrance holes covered by 1 micron thick plastic foils, and is driven over 20ns by a five step laser pulse with a peak power of 400TW. Integrated calculations of the hohlraum and capsule produce ignition and propagation of DT burn.

Surface roughnesses on both the outer beryllium surface or the DT layer are important potential sources of performance degradation. Two dimensional calculations of non-linear growth of outer surface finish perturbations on both the beryllium and plastic capsules show a cliff in yield at about 50 nm RMS roughness. Combining the effects of a lower final temperature (or laser) pulse and ablator surface roughness results in higher sensitivity to each. If the final temperature is reduced 7% then the cliff is near 1nm RMS roughness. If a 20 nm RMS roughness is applied, then the capsule fails when the final temperature is between 2% and 4% below nominal. With no surface perturbation, it survives a 9% decrease.

The sensitivity of the beryllium and plastic capsules is very different to perturbations on the DT ice surface. Ice surface roughness perturbations of about 2 microns RMS on the plastic capsule prevent ignition. For the beryllium capsule 8 micron RMS roughness still ignites and produces a yield of 4.4 MJ. Since current measurements on DT ice layers show a roughness between 1 and 2 microns, this difference is important.

The difference is not due to the different central gas density (0.5 vs 0.3 mg/cc) in the nominal beryllium and plastic designs. An 8 micron RMS surface perturbation on the beryllium produces yields of 3.3 and 4.4 MJ for central densities of 0.3 mg/cc and 0.5 mg/cc, whereas 0.68 mg/cc (the maximum compatible with a solid layer) produces only 84kJ with a 6 micron RMS perturbation.

Reduced perturbation growth appears soon after the surface moves. When compared at equal imploded radii, the DT ice surface perturbation is several times in the beryllium capsule. Moreover the DT/beryllium interface is much less perturbed than the DT/plastic. The favorable reduction of growth appears related to the extra beryllium (approximately a mass equal to the DT) that is imploded along with the DT. In the plastic design all of the plastic is ablated. A plastic capsule with the same absorbed energy could be designed to leave some plastic unablated, at the expense of DT. A beryllium capsule could be designed to carry more DT and reduce the extra beryllium. The fact that the beryllium ablator is more massive than the plastic, and therefore compresses more mass, may be a fundamental advantage.

*Work performed under the auspices of the U. S. Department of Energy by the Los Alamos National Laboratory under Contract No. W-7405-ENG-36.

Measurement and calculation of nickel-like soft x-ray laser spectra

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we report measurement of soft x-ray spectra from Ni-like soft x-ray laser media[1] with a curved slab target[2,3] and multiple laser pulses[4]. With this technique we have obtained lanthanide soft x-ray lasers with the spectral range between 6 nm and 8 nm. The bent angle of 10 mrad for a 2.5 cm long target, corresponding to a 2.5 m radius of curvature, provided the most intense lasing for the Ni-like Nd soft x-ray laser. The laser beam of 1.053 μm wavelength was focused to a line of 2.8 cm length and approximately 80 μm average width. The laser pulse was composed of two pulses with the individual pulse width of 100 ps separated by 400 ps. The laser energy was approximately 150 J for each 100 ps pulse which is an order of magnitude lower than that of the previous Eu laser experiment [1].

The average irradiance at focus was 6.9 x 10^{13} W/cm^2. A gain coefficient of 3.1 cm^{-1} and a gain-length product of 7.8 for Nd have been achieved at 7.97 nm wavelength. The spectra of the Ni-like Nd(Z=60), Sm(Z=62), Gd(Z=64), Tb(Z=65) and Dy(Z=66) lasers were recorded with a flat field spectrometer and a Q-plate or an x-ray streak camera where Z is the atomic number. Each spectrum is composed of two J=0-1 lines; a longer wavelength line due to (3/2,3/2) to (5/2,3/2) transition and a shorter wavelength line due to (3/2,3/2) to (3/2,1/2) transition. The calculated wavelengths with the atomic physics code (GRASP2) are in good agreement with the experimental results. The intensity ratios of the shorter and the longer wavelength lines will be discussed. We will also report the required pumping conditions for extending the wavelength range with this technique using the plasma hydrodynamic (ILESTA) codes.

REFERENCES

[1] B. J. MacGowan et al., Phys. Fluids B**4**, 2326 (1992).
[2] J. G. Lunney, Appl. Phys. Lett. **48**, 891 (1986).
[3] R. Kodama et al., Phys. Rev. Lett. **73**, 3215 (1994).
[4] H. Daido et al., Opt. Lett. **20**, 61 (1995).

Effect of ISI Imprinting on Planar and Spherical Targets

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We report the results of calculations aimed at elucidating the effects of ISI in providing a seed for the growth of the Rayleigh-Taylor instability in laser accelerated thin targets. We compare the results from low-isentrope simulations of pure DT, plastic [CH], plastic foam saturated with liquid DT [DT-CH], and thin moderate Z overcoated DT-CH targets. In each simulation, the target is accelerated with a $1/4\mu m$ laser light with peak intensity in the mid-10^{14} W/cm^2 range, and intensity temporal profiles that are strongly reminiscent of those developed for high-gain direct-drive KrF designs with contrast ratios between the foot and the main pulse of a few hundred.[1] In the cases where even a modest amount of radiation smoothing is present in the plasma blowoff, ISI provides a seed for Rayleigh-Taylor that is no worse than a few hundred angstrom surface finish nonuniformity.

For these calculations we use a multigroup, variable Eddington radiation transport model with STA opacities coupled to our FAST2D laser matter interaction code. Multiple materials are tracked by a volume fraction model. Laser energy is deposited by means of a ray trace algorithm that emulates the Nike system, and is absorbed by inverse bremsstrahlung. The ISI speckle is modelled by Gaussian-Distributed random field amplitudes with periodic boundary conditions. The number of coherence zones is reduced and the zone sizes increased to maintain the overall f number. To simulate a 2D mode spectrum, the 1D modes are weighted by their absolute amplitudes and renormalized to maintain the quadrature sum of the intensities while maintaining the modal structure. The laser energy is transported to the target surface by two different physical processes. Classical thermal conduction dominates the outer region, transporting the energy to a region of higher density where some fraction of the energy is converted to soft x rays. The x rays are then transported further towards the target by the multigroup transport process to a second absorption front dominated by x-ray absorption. Our goal is to manipulate transport processes in the second region of absorption, to reduce the effects of imprinting while maintaining a low isentrope target to test the viability of high-gain with direct-drive pellets on KrF systems.

Work supported by USDOE and ONR

[1]A. J. Schmitt, *et al.*, this conference.

QUANTITATIVE EXPERIMENTAL EVALUATION OF A FOAM BUFFER TARGET DESIGN FOR SPATIALLY UNIFORM ABLATION OF LASER IRRADIATED PLASMAS

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Experimental observations are presented demonstrating that the use of a simple modification to the design of directly-driven targets can provide efficient smoothing of spatial nonuniformities in a coherent laser drive. Such smoothing is necessary due to the fact that laser-based smoothing techniques have so far proved inadequate in overcoming the imprinting of intensity nonuniformities in the early-time 'start-up' phase of the laser-target interaction. Additional smoothing is desirable whenever it is necessary to accelerate a target over large distances (for example, in directly driven ICF), or when a smooth thermal front in a static target is required (for example, in the production of x-ray laser media, or smoothly varying large-area backlighter emission), or when a uniform shock breakout is required.

Computational analysis of the outstanding imprint problem led us to propose a solution [1] in which a plasma buffer is generated on the surface of the direct-drive target via the passage of a supersonic ionization wave through a low density foam jacket [2]. The critical surface for the laser is in this way separated from the solid target surface by many tens of microns from the start of the interaction. Efficient thermal smoothing through the long-scalelength, supercritical foam plasma buffer is therefore to be expected. The foam buffer is introduced only to influence the initial ($t<500$ps) start-up phase of the interaction. The subsequent target response should remain essentially unchanged from that of a conventional directly driven target.

Experimental evaluation of this proposed scheme is now presented. Face-on and side-on XUV (50Å) radiography is used to diagnose the target response of planar plastic foils driven by a coherent laser. Quantitative measurements of optical density perturbations induced in conventional foils and the novel foam-buffered foils are presented, along with a Fourier analysis of the dominant mode structure. (The plain foils are 10.6μm thick parylene-N, whereas the hybrid targets have an additional 50μm thick overcoat of 50mg/cc foam, itself overcoated with 200Å gold). Over four-fold reductions in the standard deviation of the optical density modulations are observed for the foam-buffered target in comparison to the conventional foil. The hydrodynamic efficiency was shown to remain unaffected by the foam overcoat and parametric instability generation remained at a low level (<5%).

Good agreement with 2D hydrocode simulations has been obtained as regards the general effectiveness of the thermal smoothing and hydrodynamic efficiency of the hybrid targets. Whilst the foam buffer is capable of substantially reducing laser nonuniformity imprint from a coherent beam, a combination of the hybrid target design and some form of laser-based smoothing (e.g. RPP/ISI) may be required to ensure that there remains sufficient thermal smoothing during the steady-state laser-plasma interaction, which is primarily determined by the choice of laser wavelength.

[1] M. Desselberger *et al.*, Phys. Rev. Lett. **74**, 2961 (1995)
[2] T. Afshar-rad *et al.*, Phys. Rev. Lett. **73**, 74 (1994)

TWO-DIMENSIONAL LASNEX SIMULATIONS OF FOAM-MITIGATED DIRECT DRIVE EXPERIMENTS ON TRIDENT

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It has recently been suggested by O. Willi (Imperial College) and co-workers that the use of a low density foam "buffer" in front of a solid laser-target surface may effectively smooth out early-time spatial nonuniformities of the laser beam, which would otherwise imprint themselves onto the target surface. However, the physical mechanism by which this smoothing occurs has yet to be theoretically explained in detail. To this end we have carried out 2D LASNEX simulations of the response of a planar CH-foil target, such as has been employed in recent laser-plasma experiments on Los Alamos' TRIDENT laser system, to a spatially structured laser beam - both with and without a foam buffer ahead of the solid target.

The target and laser properties were chosen to represent typical TRIDENT experimental conditions. Thus, we examine the reaction of a 20-μm thick CH-foil to irradiation by an f/6 laser beam containing 200 J of 2ω light in a 1-ns square pulse, focused to a spot of radius 140 μm. The foil was covered by 50 μm of low density (50 mg/cm^3) $C_{10}H_4O_8$ foam overcoated with a thin (200 Å) layer of gold. The beam intensity in the focal spot was spatially modulated in the radial direction, in such a way as to represent the 30-μm scalelength of intensity fluctuations known to characterize the raw (unsmoothed) beam in the TRIDENT experiments. To study beam smoothing, comparison calculations were done for an identical foil without the foam buffer. In each case the LASNEX calculations were postprocessed via the X-ray image-simulation package TDG to determine the degree of laser "imprint" as revealed by the use of a 200-eV backlighter source at mid-pulse, such as comprised the principal diagnostic tool used in the experiments.

From these calculations we compare the relative efficiencies of various energy transport processes (such as thermal radiation and conduction both along and transverse to the direction of the incident beam) in the foam buffer and/or in the CH corona, for smoothing out the imposed beam nonuniformities and resulting laser imprint on the solid target surface.

**Work performed under the auspices of the U. S. Department of Energy.*

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Tetrahedral Hohlraums for the OMEGA Upgrade and the National Ignition Facility

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ABSTRACT

We are investigating the use of tetrahedral hohlraums for indirect-drive experiments on the OMEGA Upgrade and the National Ignition Facility (NIF). By the term "tetrahedral hohlraum" we mean a spherical hohlraum with four laser entrance holes placed at the vertices of a tetrahedron. This configuration allows all 60 beams of the OMEGA system to be used in indirect-drive experiments, as opposed to only 40 beams available for cylindrical hohlraums. The geometry of the OMEGA laser provides for an exact tetrahedral symmetry on a hohlraum target, eliminating the $l = 1$, 2, and 5 spherical harmonic components.[1] We have developed a similar design for the NIF that uses the same latitudinal (θ) values of the beam ports proposed by Eimerl[2] to optimize direct-drive uniformity, but with an alternate choice of azimuthal (ϕ) angles. This design uses 12 out of the 24 direct-drive ports that are proposed to be added to the NIF.[2] Unlike the OMEGA geometry, the NIF does not possess a true tetrahedral symmetry, but we have designed a hohlraum showing a high radiation temperature and good radiation uniformity.

We have designed tetrahedral hohlraums for the NIF that reach temperatures of 300 eV with an rms nonuniformity of 1.2% and for OMEGA that reach 240 eV with 1.6% nonuniformity. In addition, the variation of the albedo over time has a smaller effect on the nonuniformity than in the cylindrical case. For OMEGA, $\alpha = 0.1$ leads to an rms of 2.1% for a tetrahedral hohlraum and 6.2% for a cylindrical hohlraum, and, for the NIF, 3.8% for a tetrahedral hohlraum, as opposed to 8.7% for the cylindrical case.

The calculations for these designs use a view-factor program called Buttercup, which traces all beam paths, calculates the background radiation temperature, and evaluates the radiation flux at a large number of points on the fuel capsule. The code permits a great deal of tuning and optimization of the hohlraum design, from basic dimensions to individual beam pointings and energy ratios. Buttercup has been used to optimize both cylindrical and tetrahedral designs for OMEGA and the NIF.

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1. D. W. Phillion and S. M. Pollaine, Phys. Plasmas **1**, 2963 (1994).
2. D. Eimerl (private communication).

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.

1-D Vlasov Simulations of Electron Acceleration by Radiation-Driven Langmuir Turbulence in the Ionosphere*

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Electron and ion Vlasov equations are numerically integrated in 1-D, while driven by a constant-amplitude clamped electric field near the plasma frequency.

Plasma and pump parameters are chosen to model typical conditions at and below the critical heater reflection altitude for ionospheric-modification experiments at Arecibo, Puerto Rico. Semi-lossy boundary conditions are employed which model inflow of thermal particles at the boundaries of a locally heated region which is larger that the "box" simulation domain.

Following initial transients, steady state turbulence is attained. Close to the critical altitude the turbulence is characterized by coherent wavepackets, which nonlinearly self-forcus and collapse to small spatial scales, where they transfer energy to electrons—thereby forming a tail on the electron distribution. At lower altitudes there are fewer collapsing wavepacket sites, and transfer of radiation-driven Langmuir wave energy to lower wave numbers occurs via stimulated backscatter cascades, as determined by Hanssen et al,[1] who call this a "coexistence regime."

Both x-space nonlinear wave energy-density time-histories and (k-omega) power spectra are used to diagnose the numerical turbulence. Common power law tails are found both at the reflection altitude and at lower altitudes.

The electron distributions produced by these simulations can be regarded as seed distributions that freely propagate along magnetic field lines outside the heated region to lower altitudes where it has been hypothesized that they excite atomic transitions resulting in observed oxygenic airglow.[2]

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* Work supported by US National science Foundation Atmospheric Physics Division

[1] A. Hanssen, E. Mjolhus, D.F. DuBois, and H.A. Rose, JGR 97, 12073 (1992)

[2] Paul A. Berhardt, Lewis M. Duncan, and C.A. Science 242, 1022 (1988)

Observed Langmuir Turbulence During Ionospheric Modification Experiments in the Presence of Irregularities

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April 26, 1995

Abstract

We show that some simplifying assumptions made in previous numerical simulations may be incorrect for simulating the backscattered spectra from ionospheric heating experiments. The first is the polarization of the heater electric field at EISCAT that may make a large angle to the geomagnetic field. We show that this makes the turbulence unobservable at certain heights in a smooth ionosphere. This has led us to study the effect of small and large scale field aligned irregularities on the observed turbulence in order to explain the observed spectra. The small scale field aligned irregularities can be included in a consistent way into the Zakharov model, and we find that they can help spread the Langmuir waves sufficiently to be observable by the radar. This may also be important at Arecibo where decay–cascade spectra have most likely been observed only in a preconditioned ionosphere containing such irregularities. Theoretical and numerical results show that this inclusion significantly alters the decay–cascade prosess.

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Propagation of Intense Electromagnetic Waves in Self-induced Turbulence

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In hf modification of the ionosphere and in laser plasma interactions a pump wave reflected from the critical surface can form a standing wave pattern. Near critical density the ion acoustic decay instability and the related purely growing instability will be most strongly excited near the peaks of the standing wave.Locally a saturated state of Langmuir turbulence is excited whose correlation lengths and times are small compared to the macroscopic scales of the standing wave pattern.This separation of scales permits a mesoscale approach wherein the ponderomotive pressure of the induced turbulence, which is usually much greater than that of the pump alone, is locally computed using *homogeneous* plasma simulations.This allows us to compute the time evolution of the self consistent pump, turbulence, and density profiles as a function of position in an initially inhomogeneous plasma profile.Here we present preliminary 1D results which can be compared to time and altitude resolved observation of induced ionospheric turbulence. Dramatic dynamical effects are observed even for moderate incident pump powers.The standing wave pattern drops to lower altitude in a quasi periodic fashion because the half wave length induced density depletion grating inhibits the propagation of the pump until these depletions relax.Generally the initial standing wave profile is disrupted on the time scale of and ion acoustic transit time across a pump maximum.

* Research carried out under the LANL Laboratory Directed Research and Development Program supported by the USDOE

ORAL SESSION 3

Hohlraum Physics

Bernhard Wilde, Chair

Tuesday, May 30

Shocked Witness Foam-Ball Diagnostic for NOVA Hohlraum Time-Dependent Drive Asymmetry*

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ABSTRACT

Backlighting of low density SiO_2 aerogel balls in NOVA Au (empty) hohlraums enables indirect imaging of the ablatively-driven shock trajectory versus time. The transmissivity inflection point contour is actually imaged in the experiments, which we show from analysis and simulations to correlate well with the radiation-driven shock trajectory. From the backlighter-imaged distortion of the radially converging shock layer, the time-dependent flux asymmetry near the center of the hohlraum can be inferred. Effects of drive asymmetries are magnified due to an increased shock speed in low density (≈ 0.3 g/cc) foam balls. A goal of the current campaign is to identify to within 100 ps the transition from waist-high flux to pole-high flux as a function of pointing using the 3:1 peak-to-foot contrast ratio pulse shape (ps22). Results are presented for both inner (1150 μm) and outer (1250 μm) pointing, as well as nominal pointing (1200 μm).

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

Studies of Radiation Transfer and X-Ray Conversion Efficiency in Thin Laser-Irradiated Targets.

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Experiments and numerical simulations were accomplished to investigate the radiation transport and X-ray emission generation in a plasma formed by laser irradiation of thin foil targets. The possibilities to control the X-ray conversion efficiency by proper adjustment of initial conditions were also studied. The experiments were carried out in planar geometry on the "Mishen" facility at laser intensity on the target surface of about (1...5)10E13 W/cm2.

Thin Cu and Pb layers and Cu foam coated onto plastic substrata were irradiated. Plasma soft X-ray spectra in the 1...10 nm range with high temporal resolution, X-ray angular isotropy, and conversion efficiency were measured and will be presented.

To support the experimental investigations of X-ray emission from the laser-produced plasma of moderate and high Z materials the radiative-hydrodynamical 1-D and 2-D codes were developed. Two-fluid two-temperature plasma model was used and the energy transfer by electron conductivity mechanism along with the nonequilibrium plasma radiation heat transfer are taken into account.

The results of the comparative analysis of experimental and numerical data will be presented. Among other things it was shown that the radiative heat conductivity seems to be an important mechanism of energy transfer in laser produced plasma under the investigated experimental conditions and that proper choice of initial target parameters allowed one to control the overall yield and spectral intensities of laser-plasma X-rays.

Radiative Heating of Low-Z Solid Plastic Foils

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Abstract

X-ray emission and burnthrough of radiatively heated low-Z plastic foils (C_8H_8, nCH_2 or CF_2) have been investigated in gold cavities of different shape and size which were heated by the Gekko XII laser up to a radiation temperature of $180eV$. The cavity radiation temperatures were obtained spectroscopically as well as from the speed of the shock which is radiatively driven into aluminium. From the carbon burnthrough spectra we derived the scaling of the mass ablation rate at cavity temperatures ranging from $100eV$ to $180eV$. In addition we measured temporally resolved reemission spectra of carbon. The time and frequency integrated reemission was 23% of the gold reemission or 16% when normalized to the driving cavity flux. The measurements are in good agreement with numerical hydrocode simulations based on multi-group radiation diffusion.

Abstract for 25th Anomalous Absorption Conference - Aspen, Co, May, 1995.

Symmetry experiments in gas filled hohlraums at NOVA

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Understanding drive symmetry in gas filled hohlraums is currently of interest because the baseline design of the indirect drive ignition target for the planned National Ignition Facility uses a gas filled hohlraum. We report on the results of a series of experiments performed at the Nova laser facility at Lawrence Livermore National Laboratory with the goal of understanding time dependent drive symmetry in gas filled hohlraums. Time dependent and time integrated symmetry data from implosions, symmetry capsules and reemission balls in gas filled hohlraums will be discussed. The purpose of filling the hohlraum with gas is to tamp the motion of the high-Z material ablating from the hohlraum walls, reducing spot motion and swings in drive symmetry. We have obtained time integrated and time resolved x-ray images of the implosion of plastic deuterium filled capsules, neutron yields, implosion times and spectroscopy of argon emission from the imploded core. Our experiments use gold hohlraums filled with either methane, propane or neopentane gas. The gas is held in the hohlraum by using thin polyimide windows. Preliminary results show that the gas is effective in impeding the motion of the wall blowoff material, and that the resulting implosion performance of the capsule is not significantly degraded from vacuum results. The implosion symmetry differs from vacuum results with similar laser pointing indicating a somewhat hotter drive at the capsule's poles than at the equator. These experiments are relevant to those currently being planned for the National Ignition Facility.

work performed under the auspices of the U.S. D.O.E. under contract no. W-7405-ENG-36.

Modeling of Drive-Symmetry Experiments in Gas-Filled Hohlraums at Nova*

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The experiments are being carried out in scale-1 hohlraums (1650 μm in diameter with lengths between 2000 and 2700 μm) filled with one atmosphere of methane, propane or neopentane. The pointing of the laser beams is adjusted so they enter the hohlraum at the center of the laser entrance holes (diameter 0.75 of the hohlraum diameter) located at the ends of the hohlraum. The gas is held in the hohlraum with either 0.65 μm thick mylar windows or 0.35 μm thick polyimide windows. The experiments are driven with shaped pulses consisting of a 1 to 2 ns foot followed by a 1 ns main pulse with a contrast ratio between 2 and 3 and a total energy of 25 to 30 kJ.

X-ray images of an imploded standard capsule (220 μm fuel radius with a 55 μm thick plastic wall) are used to examine the time-integrated symmetry over the whole laser pulse. Smaller capsules with thinner walls (symcaps) are used to sample the symmetry over the early part of the pulse. X-ray images of the surface brightness of high-Z spheres, which do not implode (re-emission balls), are used to obtain time-dependent data on drive symmetry.

LASNEX calculations of these experiments are being carried out as well. These integrated calculations include the propagation of the laser through the window and gas and the energy deposition in the hohlraum walls and its reradiation as x-rays. Also included are the dynamics of the window, gas, hohlraum walls and capsule.

LASNEX modeling techniques, that were quite successful for predicting capsule-implosion symmetry in evacuated hohlraums, do not give comparable agreement with experiments in gas-filled hohlraums. Comparison of LASNEX modeling with the experimental data will be presented as well as work on mechanisms and missing physics which might explain the observed discrepancies.

* Work performed under the auspices of the U. S. Department of Energy under Contract No. W–7405–ENG–36 at the Los Alamos National Laboratory and under Contract No. W–7405–ENG–48 at the Lawrence Livermore National Laboratory.

INTERFACE MOTION IN GAS-FILLED AND CH-LINED LASER-HEATED HOHLRAUMS

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We describe measurements and calculations of wall motion and stagnation in hohlraum targets heated by the AWE Helen Laser. Simple (un-tamped) cylindrical hohlraum show significant motion of the x-ray source in the neighbourhood of the laser deposition regions, followed by plasma stagnation on the hohlraum axis. Motion of the gold hohlraum wall is considerably reduced by the use of a low-Z tamper. The gas-tamped hohlraums contained (initially) 1-atmosphere pressure of CH_4, C_2H_6 or C_5H_{12}, the CH-tamped hohlraums used a coating of between 0.2 and 1 μm of Parylene-N on the hohlraum wall. These laser targets were illuminated by two beams of the Helen laser, delivering 500-1000J in a pulse of 0.3-1ns duration at 2ω . Emission from the gold wall was diagnosed by viewing along the hohlraum axis with a soft x-ray framing camera. In the case of the taped hohlraums, these emission measurements allowed the position of the gold/tamper interface to be identified and tracked. The experimental data are compared with 2-D LASNEX simulations.

Interface-Motion Modeling for Nova Gas Hohlraums

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Lasnex calculations of radial motion of thermal (hν = 450 eV) wall emission from Nova "Gas-Tamp" gas-filled hohlraums are in excellent agreement with experimental data, as shown in Fig. 1. The quantities plotted are radial emission profiles, where R = 0 represents the hohlraum axis and the wall is at 800 μm. The GasTamp hohlraum is a gold cylinder, 1600 μm long and 1600 μm in diameter, and the experimental profiles were obtained from an axially-viewing soft-x-ray framing camera. The hohlraum was illuminated with all 10 Nova beams interleaved along a single circle at the hohlraum center, to facilitate comparison with 2D Lasnex calculations. The calculations were post-processed to include the effects of opacity and the instrumental filter responses.

In contrast to the thermal emission, Lasnex predicts M-band emission (hν > 2 keV) in the coronal gold which is not observed in the experiments, as shown in Fig. 2. Although the M-band energy is not an important component of the capsule drive, the presence of low-density coronal gold is of interest because of its potential effects on laser absorption and plasma instabilities resulting from the high atomic number of the ion species. We are currently refining the calculations in an attempt to resolve this discrepancy.

We are also studying wall motion in standard Nova scale-1 gas-filled hohlraums, in which experimental data do indicate M-band emission from coronal gold, in contrast to the GasTamp results. The comparison between experiment and calculation for thermal and M-band emission in these hohlraums, and the results of the refined GasTamp calculations, will be presented at the conference.

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

Figure 1
450-eV emission profile

1-atm. pentane fill

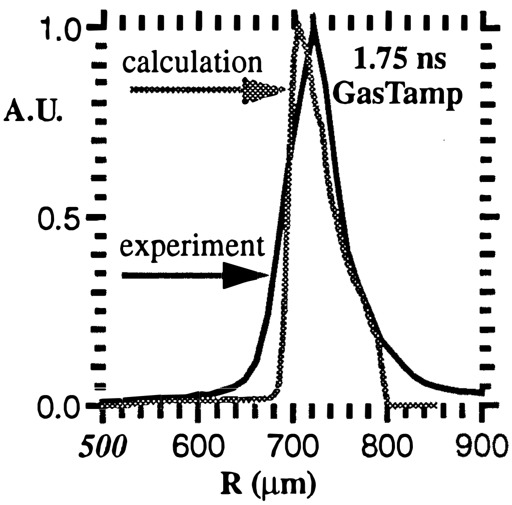
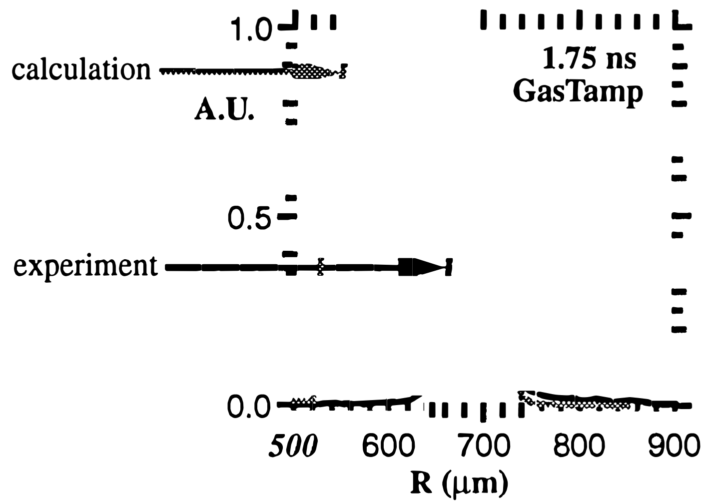


Figure 2
M-band emission profile



ENERGETICS OF GAS-FILLED HOHLRAUMS

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Advanced hohlraum designs for ICF include the use of a low-density ($n<0.1n_c$) plasma, or tamper, to impede the motion of the high-Z hohlraum wall material. The purpose of this tamper is to minimize the motion of the laser deposition region caused by refraction of the laser beam in the plasma resulting from the ablated wall material as well as the time-dependent position of the laser deposition region as the critical density region moves into the hohlraum. This motion of the laser deposition region inside the hohlraum can affect the drive symmetry. We are investigating the effect of the tamper on the energetics of the hohlraum by measuring the time dependent drive inside the hohlraum for different hohlraum configurations and gas fills. To account for the over-all energy balance, we measure the scattered laser light and subtract this from the incident laser energy to model the hohlraum performance. We find that the tamped-hohlraum temperature is reduced about 5 to 10% due to the energy expended in ionizing and heating the tamping material.

This work was performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-ENG-48

Analysis of Effect of Gas Fills on Nova-Scale Hohlraum Dynamics and Energetics

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In current indirect drive target designs for the National Ignition Facility (NIF), low-Z gas fills provide control of time-dependent symmetry variations by reducing wall expansion. Experiments to assess the effect of gas fills on hohlraum dynamics, energetics and symmetry have been performed on Nova over the past year. We relate these data to calculations of plasma evolution, energy partitioning, and radiation symmetry from LASNEX and other models, and discuss the relevance of these experiments to the parameter regime of interest for NIF.

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

POWER BALANCE AND RADIATION PRODUCTION IN LASER HEATED HOHLRAUMS*

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Two complementary techniques allow us to estimate radiation production in laser heated hohlraum simulations. One gives us both the total radiation production as well as the radiation budget. The other provides us with both total radiation production as well as with insight into why the radiation production is what it is. In this talk we describe the techniques and discuss our findings for a variety of laser heated hohlraums.

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* This work was performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

ROBUSTNESS STUDIES AND BEAM ANGLES FOR THE NATIONAL IGNITION FACILITY*

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We are designing hohlraums for the National Ignition Facility (NIF), a frequency-tripled 192 beam 1.8 MJ glass laser. Our hohlraum simulations are integrated in the sense that in one calculation, a laser source produces x rays in the hohlraum wall, which then drives a capsule that subsequently ignites and burns. In the past year, we did robustness studies that show that the capsule should still ignite and burn in the presence of expected fluctuations in laser beam power and pointing.

We have found laser beam angles that work with indirect drive in a standard cylindrical hohlraum, and are also compatible with indirect drive in a spherical hohlraum with tetrahedral symmetry,[1] and direct drive.[2]

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1. D.W. Phillion and S.M. Pollaine, "Dynamical Compression of Irradiation Nonuniformities in a Spherical Hohlraum Illuminated with Tetrahedral Symmetry by Laser Beams," *Phys. Plasmas 1* (9), pp. 2963-2975 (1994)
   J.D. Schnittman and R.S. Craxton, "Tetrahedral Hohlraums for the OMEGA Upgrade and the National Ignition Facility," 25th Annual Anomalous Absorption Conference, Aspen, CO, May 27-June 1, 1995.

2. D. Eimerl, Lawrence Livermore National Laboratory, private communication

* This work was performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

Experimental evidence of interpenetration and high ion temperature in plasma collisions

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(5) INRS-Energie et Matériaux, Université du Québec, C.P. 1020, Varennes, Québec, J3X1S2 Canada
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** permanent adress: PNC, Tokai, Japan*

Experiments involving the collision of two thin aluminum (or Al versus Mg) foils accelerated by a 2ω, 600 ps FWHM laser pulse have been performed for various values of the laser intensity (3 to 6 x 10^{13} W/cm^2) and initial foil separation (450 to 900 µm). The thickness of the foils was chosen, with the help of standard hydrodynamical simulations, so that the foils would become fully ablated at collision time, leading to a thickness of 0.8 to 1 µm in the case of Al and Mg respectively.

Using the collisionality parameter ζ of Rambo and Denavit [1], we checked that these sets of parameters were sampling the medium to low collisionality regime, corresponding to the case of lowest intensity and shortest separation and the case of highest intensity and largest separation respectively. Thus a transition from collision to interpenetration of the foils was expected to occur.

To observe this transition, we used several spectroscopic diagnostics, leading, among other things, to time-integrated space-resolved spectra in the 5.5 to 7 Å region, and time-integrated high-spectral-resolution records of the Al He_β and Mg Ly_δ lines. The former enabled us to directly check that interpenetration of Al and Mg over a distance of about 300 µm did show up in the less collisional case, while the latter provided us with a means of measuring the ion temperature at midplane. Values of the electron density n_e, electron and ion temperatures T_e, T_i and the transverse dimension of the plasma were then deduced by fitting the observed spectra with results from the collisional-radiative code FLY [2].

The interpretation of the measured values was performed with the help of multifluid simulations of the experiment with our eulerian code MULTIF, post-processed by the atomic physics package TRANSPEC [3]. This provided us with a reconstruction of the space- and time-resolved spectra emerging from the system.

Typical results from these simulations are shown in fig. 1. One can see that spectroscopic diagnostics based on the Al He_β line sample the early part of the collision process. In the interpenetrating case, stagnation, i.e. maximum T_i and zero velocity at midplane, occurs much later than the maximum of n_e, T_e and He_β line emission.

The measured ion temperature values are consistent with the simulated temporal behavior and, together with the direct evidence mentioned above, allow us to conclude that plasma interpenetration occurs in this sytem, and seems unimpeded by other processes like ion-acoustic turbulence excited by a possible two ion-stream instability.

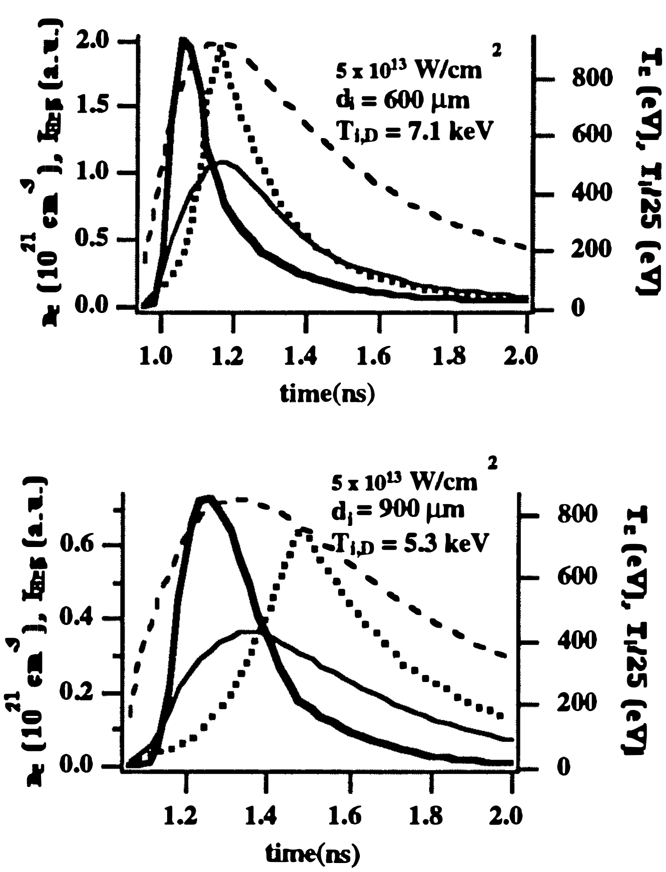

Figure 1: Numerical simulation of the plasma parametersat midplane, for a laser intensity of 5x10^{13}W/cm^2 and an intertaget distance of 600 µm (a) or 900 µm (b); thin full line: n_e ; thin dotted line : T_e ; thick dotted line : T_i ; thick full line: He_β emission.

[1] P.W. Rambo and J. Denavit, *Phys. Plasmas* 1, 4050, (1994).
[2] R.W. Lee, B.L. Whitten and R.E. Strout, *J. Quant. Spect. Radiat. Transf.*, 32, 91 (1985).
[3] O. Peyrusse, *Phys. Fluids* B 4, 2007 (1992).

Kinetic MC-PIC Simulations of Axially Stagnating Plasma*

P. W. Rambo

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The expansion, interaction, and subsequent stagnation of the plasma blow-off inside ICF hohlraums is an important issue for capsule symmetry and laser absorption. Single fluid models do not allow interpenetration, resulting in immediate stagnation with complete conversion of the ion streaming energy to thermal energy. Although multifluid models are applicable in simple geometries, a kinetic treatment is necessary to properly model plasma conditions near the axis. Our kinetic modeling makes use of particle in cell (PIC) techniques with binary Monte Carlo (MC) particle-particle collisions that are equivalent to a Fokker-Planck collision operator. One and two dimensional calculations relevant to NOVA and NIF hohlraums are presented. One dimensional azimuthally symmetric calculations show much larger density near the axis compared to calculations performed in the adiabatic fluid limit, but with smaller axial ion temperature; the axial pressure is comparable for the two cases.

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

Electron temperature scalings of gasbag targets*

. A. Back, S. . Glenzer, K. Estabrook, B. J. MacGowan, D. S. Montgo ry, D H. Munro, T. D. Shepard, and G. F. Stone

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Gas-filled targets can be laser-irradiated to create mm-size uniform plasmas. They are unique laser-produced plasmas because variations in the gas fill or laser parameters allow a controlled variation of the plasma conditions. To enable these plasmas to serve as testbeds to study physical processes, it is important to characterize them by measuring the range of temperature and density variations for different target types. In particular, temperature variations may be affecting the SRS data obtained on some shots.

Experiments in the past year at Nova have used gasbags to produce plasmas that attain electron temperatures of up to 3 keV for laser-plasma interaction studies relevant to laser fusion studies. Thin gasbags are formed by inflating two 3500 Å polyimide membranes and irradiated by 10 laser beams that deliver a total of ~ 2500 J of energy in 1 ns. In these experiments, the laser conditions were varied to create plasmas having electron temperatures in a range of ~ 1.5 - 5 keV, and electron densities of 5×10^{20} to 1×10^{21} cm^{-3}.

In this paper, we present measurements that characterize these large-scale plasmas by spectroscopy. X-ray spectroscopic diagnostics of high temperature underdense plasmas have been developed using spectra from gas dopants and coated fibers. Mid-Z elements from Cl to Cr have been used to diagnose electron temperature by line intensity ratio measurements. Here we report on recent refinements that have enabled us to obtain higher spectral resolution and reduce source size. Higher spectral resolution is obtained by using a different Bragg crystal configuration. Broadening due to source size is reduced by mounting a space-resolving slit between the gasbag and the spectrometer. Coupled together, these allow us to eliminate overlaps between spectral lines and examine the intercombination line and satellites to the Ar He-like n=2-1 resonance line as a function of time and space.

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

INVITED TALK 3

The Study of Parametric Instabilities in Large Scale-Length-Plasmas on Nova

by

Brian MacGowan, LLNL

Tuesday, May 29

Juan C. Fernández , Chair

THE STUDY OF PARAMETRIC INSTABILITIES IN LARGE SCALE-LENGTH-PLASMAS ON NOVA*

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Understanding laser scattering by parametric instabilities continues to be important for indirect drive ICF. The hohlraum designs for the National Ignition Facility (NIF) present particular problems due to the large scale and homogeneity of the plasmas within them. Experiments at Nova over the last 18 months have studied laser plasma interactions within large scale length plasmas that mimic many of the characteristics of the NIF hohlraum plasmas. The control of filamentation and scattering of laser light by SBS and SRS have been investigated as a function of beam smoothing and plasma conditions, this talk will review the results.

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

MIXED POSTER SESSION 3

Tuesday, May 30

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Numerical Simulations of Two-Dimensional Stimulated Raman Scattering in an Inhomogeneous Plasma

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ABSTRACT

The evolution of stimulated Raman scattering in time and two spatial dimensions is examined. It has been observed in previous studies[1,2] that the propagation of the idler wave can affect the saturation levels of weakly damped homogeneous systems. The effect such propagation has on an inhomogeneous plasma is investigated numerically and compared with one-dimensional theoretical predictions.

1 C. J. McKinstrie, R. Betti, R. E. Giacone, T. Kolber, and J. S. Li, Phys. Rev. E **50**, 2182 (1994).

2 T. Kolber, C. J. McKinstrie, R. Betti, and R. E. Giacone, "Paradigm of a Two-Dimensional Parametric Instability," in preparation for submission to Physics of Plasmas.

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.

Collective Thomson scattering measurements of the Langmuir wave spectrum driven by stimulated Raman scattering

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C. Labaune, H.A. Baldis, N. Renard, S.D. Baton, E. Schifano, and A.Michard
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Collective Thomson scattering was used to measure frequency versus wave number of the Langmuir wave spectrum resulting from stimulated Raman scattering (SRS). A 1,053 nm pump beam was used to drive SRS in a preformed, underdense CH plasma and the resulting Langmuir waves were measured by collective Thomson scattering using a 351 nm probe beam. The scattering geometry allowed for the detection of Langmuir waves traveling both parallel and antiparallel to the pump. Therefore, the relative energy difference between oppositely directed plasma waves was measured and the results of these measurements will be discussed.

Some of this work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract no. W-7405-Eng-48.

Simulations of the interaction of filamentation with SRS and SBS*

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C. W. Still, and E. A. Williams

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We have developed models for the time and space evolution of the backscattered light driven by stimulated Brillouin (SBBS) and Raman (SRBS) instabilities in our 3D filamentation code F3D[1]. The laser light propagation includes models for random phase plates and SSD, smoothing-by-spectral-dispersion. We have shown that the SBBS light grows over regions much larger than a laser hot spot length such that, above threshold, the reflectivity is weakly dependent on f-number[2]. We also show that, for equal steady-state amplification exponents, the reflectivity is a decreasing function of ion acoustic damping rate. SSD is also shown to be effective in reducing the SBBS levels. SRBS behaves differently in the two limits where the plasma wave is strongly damped (stimulated Thomson or Compton) and where it is not. In the former case, the wave amplifies over many hot spots; in the latter, it may be localized in single hot spots. This single hot spot regime is studied more fully in an accompanying paper at this conference by Afeyan et al.

*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.
§Centre d`Etudes de Limeil-Valenton, 94195 Villeneuve-St.-Georges, France

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[1]R. L. Berger et al., Phys. Fluids B 5, 2243 (1995)
[2]R. L. Berger et al., submitted to Phys. Rev. Lett. Jan 1995; UCRL-JC-119259

25th Annual Anomalous Absorption Conference
The Aspen Institute, Aspen, Colorado, USA
May 27 - June 1, 1995

PARAMETRIC INSTABILITIES DRIVEN BY SHORT INTENSE LASER PULSES IN PREFORMED UNDERDENSE PLASMAS

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Ph. Mounaix[b)]
F. Amiranoff[c)], S. D. Baton[c)], V. Malka[c)]

Experiments have been performed at P102 laser facility (CEA-Limeil) to study stimulated Raman and Brillouin scatterings (SRS and SBS) in short pulse interactions. SRS and SBS reflectivities have been investigated as a function of the laser intensity by irradiating large underdense plasmas (≈ 1mm) with short laser pulses (≈ 500fs at 1.06 μm). Forward Raman scattering has also been measured at high laser intensity (> 10^{17} W/cm^2). Spectra of SBS and backward and forward SRS are presented.

For what concerns backward SRS and SBS, it is seen that, unlike SBS, the linear theory of SRS from thermal equilibrium noise is in good agreement with experimental data. Beyond the analytical studies, several 1-D simulations based on the envelope equation approximation have been performed. The effects of pulse shaping, pump depletion and nonlinear shifts are investigated. Reflectivities, transmitted light and spectra are compared with experimental data.

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EXCITATION OF RAMAN INSTABILITY BY A MULTI-BEAM PUMP*

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R. H. LEHMBERG
NAVAL RESEARCH LABORATORY
WASHINGTON D. C.

The presence of multiple beams with finite angles between the beams is a more realistic geometry for present-day laser target studies. One such operating facility is the NIKE laser system at the Naval Research Laboratory. In our earlier work we had investigated the threshold for the Raman instability in which the phases of each of the beamlets was assumed to be completely independent and that the laser intensity in the far field was uniform. We now model the beams more realistically which allows for far field interference patterns with hot spots and re-evaluate the threshold for the Raman instability as a function of the number of beams as well as the angle between the beams.

* Work Supported by the PPD, NRL Contract N0014-93-K-2019

Abstract for the 25th Anomalous Absorption Conference 1995

Nonlinear Aspects of SBS in Multi-Species Plasmas*

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For many parameters relevant to ICF plasmas, SBS is predicted to be in, or very near, a nonlinearly saturated state. An important tool in the study of the nonlinear state of this instability is computer simulation. There are numerous approximations that can be made for various parameter regimes, which can significantly ease the complexity of the calculations, but at what expense to the physics? We will compare various methods, and try to assess their strengths and weaknesses in their respective regions of validity. We start by looking at the effects of major approximations (like assuming less than three dimensions), and proceed to more subtle issues, such as fluid[1] versus kinetic treatment and $k\lambda_{De}$ effects. We will compare the result of large 2-D, mobile ion, particle electron PIC simulations to 1-D particle ion, fluid electron simulations. In addition, we will look at a specific example of a CH-Au interface, and see how the present of the gold affects the SBS reflectivity from a long (~200μm) underdense (1/10 n_{cr}) plasma.

1. V.V. Eliseev*, W. Rozmus* and V. T. Tikhonchuk*, this conference.
Department of Physics, University of Alberta -
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*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Parametric Excitation of Electron Bernstein Waves in Laser-Produced Plasma

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ABSTRACT

The current difficulty in reconciling theory and experiment for SBS encourages one to consider alternative mechanisms. If strong magnetic fields, of the order of 100 kG, are present in laser-produced plasma, then parametric excitation of electron Bernstein waves (BW) could mimic SBS. The absence of Landau damping (whenever the plasma wave vector is nearly perpendicular to **B**) could result in low onset thresholds.

We have derived the dispersion relation (for backscatter perpendicular to **B**) and solved it numerically for parameters typical of CH plasma experiments. We have also obtained a new analytic expression for the BW growth rate and shown it to be in excellent agreement with the numerical results. The resulting BW thresholds are then shown to be comparable with that for SBS when B = O(100 kG) and for moderate densities [n/n_c = O(0.1)], or when B = O(10kG) and for low density [n/n_c = O(0.01)]. The first regime would mimic SBS, while the second is of the order of the fine structure that has been observed in some experiments.

Tables of numerical results for growth rates and thresholds, for a variety of values of B and n, will be presented. In the absence of any detailed measurements of magnetic field structure in current experimental plasmas, no attempt was made to estimate actual reflectivities that might result from this mechanism, but it seems unlikely that this mechanism could account for the very high values that have been observed.

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.

Numerical simulation of filamentation and its interplay with SBS in underdense plasmas

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We present results of a new code, recently developed at Ecole Polytechnique, which models the interaction of intense electromagnetic beams with the low-frequency dynamics of the plasma fluid in two or three spatial dimensions. The light propagation is treated according to the slowly varying envelope approximation in time, but without the restriction of the paraxial optics approximation. The low-frequency plasma dynamics is treated using the linearized hydrodynamic equations of the ion fluid. The numerical scheme is based on spatial discretization in the direction along the axis of the incident laser light whereas the transversal directions are treated spectrally.

The interplay between SBS and filamentation is very sensitive to the plasma parameters and the initial noise level. To describe the ion fluid dynamics, we use the damping coefficients derived from linear kinetic theory and noise sources chosen so as to reproduce the thermal equilibrium level of ion density fluctuations in the absence of coupling with laser light. Although we focus on ponderomotive filamentation and its interplay with SBS, the action of thermal effects enhancing long-wavelength contributions can also be included in a phenomenological way.

The specific cases we show refer to conditions recently investigated experimentally where ion acoustic waves causing SBS are expected to be heavily damped. Focussing a Gaussian laser beam with $f/2$ into the plasma, we clearly observe the onset of filamentation as well as the "beam spreading" caused by the refraction of laser light from ion density modulations that terminate the channel-like depression.

Abstract for the 25th Anomalous Absorption Conference
May 27-June 1, 1995, Aspen CO

More on Leaky Pulsating Filaments

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General NonLinear Schrödinger Equation (GNLSE) circularly symmetric filaments with "saturating" nonlinearities (i.e. ones where the nonlinearity is not infinite even if the field becomes indefinitely large) are usually discussed with the assumption that they "contain" an invariant amount of power (I_1, i.e. "number" (of quanta)) and often other conserved integrals (such as I_2, often called "Hamiltonian", especially if derived from an appropriate Lagrangian). While such integrals are indeed conserved, the integrals extend over all space, rather than being localized to the filament, so the question of filament losses to radiation remains open. In fact, many simulations, such as in the classic paper of Zakharov et al. [1], have produced gradually decreasing oscillations (around what appears to be an asymptotic limit), although it was not clear whether during the decrease in modulation, power was being lost from the filament or merely being re-distributed within it. Recent unpublished work by the authors has clearly shown the role of a slow leak in energy from such pulsating filaments. Since most Initial states with negative values for the Hamiltonian lead to such decaying pulsation (typically after an initial burst of outward radiation), rather than a single steady well-confined filament *ab initio*, it is important to understand this problem. Leak rates, coupling mechanisms and related topics will be discussed, including the relation with the Cartesian 1D case of Cubic NLSE (CNLSE) as presented by Kath and Smyth [2].

[1] V.E. Zakharov, V.V. Sobolev and V.C. Synakh, Soviet Phys. JETP 33(1) 77-81 (1971).

[2] W.E. Kath and N.F. Smyth, Phys. Rev. E 51(14), 1484-92 (1995) (February).

SBS Backscatter and Filamentation in a Single Hot Spot†

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and B. F. Lasinski

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We have used the three-dimensional fluid simulation code F3D to study the effect of pump depletion on SBS backscatter, and the influence of SBS backscatter on filamentation, in a single hot spot. Both 2D and 3D simulations were performed. We found that without pump depletion the driven plasma was linearly absolutely unstable inside the hot spot for sufficiently small acoustic damping, with a temporal growth rate that was independent of position along the hot-spot axis and slightly lower than the infinite-medium growth rate at the peak intensity. Pump depletion saturated the instability even at small damping. We also observed a dramatic effect of SBS backscatter on filament growth via pump depletion: filaments that would otherwise have grown to large magnitude were extinguished due to the removal of backscattered light from the laser beam, effectively weakening the pump strength.

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

3P11

Convective gain in laser produced plasmas

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The convective gain of parametric instabilities is derived using the homogeneous coupled equations in conjunction with the inhomogeneous dispersion relations. This prescription allows for the determination of the parameter dependence of the Rosenbluth gain for an arbitrary $(x)^n$ phase mismatch, correctly reproducing the previous WKB results for linear and parabolic phase mismatches with no damping. This approach results in a different damping correction to the gain factor for a linear phase mismatch than previously reported. The effect of this damping expression on Raman and Brillouin experiments will be discussed. The parameter dependence of the gain for a parabolic phase mismatch, including damping on both daughter waves, is found which is applicable to forward stimulated Raman scattering from a parabolic profile.

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

An Adiabatic Fluid Electron Particle-in-Cell Code for Simulating Ion-Driven Parametric Instabilities

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A hybrid particle-in-cell method is presented in which the electrons are modeled as an adiabatic fluid with an arbitrary ratio of specific heats γ. The electromagnetic field model is based on a temporal WKB approximation. The method is a new tool for simulating ion-driven parametric instabilities which often exist in laser-produced plasmas. The method is general, and does not depend on the number of spatial dimensions. The method will model the plasma behavior correctly even in situations where the electron Debye shielding is not negligible. Test simulations of ion Landau damping and of Stimulated Brillouin Scattering in both one and two dimensions are performed, and the results are in excellent agreement with linear Vlasov theory.

First Experimental Detection of Ion Plasma Waves†

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R. G. Watt, M. D. Wilke, G. E. Busch, and S. E. Caldwell
Los Alamos National Laboratory

S. A. Baker, *EG&G-LAO*

The first experimental detection of ion plasma waves is reported. While Tonks and Langmuir derived the dispersion relation of this purely-electrostatic ion wave in 1929, it escaped unambiguous observation for 65 years. This short-wavelength ($k\lambda_{De} > 1$), non-quasineutral, dispersive ($\omega \approx \omega_{pi}$) mode is important in plasmas with high-ZT_e/T_i. Examples of such plasmas include the multiply-ionized plasmas used in x-ray lasers and inertial confinement fusion, and some gas-discharge plasmas. Pioneering attempts to observe ion plasma waves, by driving them with a wire-mesh grid in a singly-ionized ($Z = 1$) plasma, were not successful, because the ion plasma waves were strongly ion-Landau damped, and were obscured by grid-excited ballistic modes. Our experiment succeeds in detecting ion plasma waves by eliminating these two problems. First, weak ion plasma wave damping ($\gamma \approx 10^{-3}\omega_{pi}$) is obtained, by employing a highly-ionized ($\bar{Z} = 22$), laser-produced plasma, with $ZT_e/T_i \approx 30$. Second, plasma-immersed solid wave drivers and diagnostics are avoided, by using resonant laser scattering to measure the frequency and wavenumber of *undriven* or *optically-driven* ion waves. The density, temperature, flow, and ionic composition of the long-scalelength ($L \approx 10^4 k^{-1}$) plasma are also measured, with a variety of diagnostics, and the flow profile is adjusted to minimize the Doppler broadening of the ion wave frequency measurement. The dependence of ion wave frequency on plasma density is observed, unclouded by Doppler shifts, nonuniform density, or ion species inhomogeneity. The observation of ion plasma waves serves as a reminder that it can be important to include sub-electron-Debye-length structures ($k\lambda_{De} > 1$) in descriptions of plasma turbulence and in plasma computer modeling.

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

CONVECTIVE GAIN OF STIMULATED BRILLOUIN SCATTERING IN LONG-SCALE LENGTH, TWO-ION-COMPONENT PLASMAS

1995 Annual Anomalous Absorption Conference

The Aspen Institute Aspen, Colorado

May 27-June 1, 1995

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ABSTRACT

In both present and future ICF designs, SBS is expected to operate in the convective regime, since the intensity of incident light generally will exceed the convective threshold, but will be below the threshold for absolute gain. The spatial gain coefficient Q has been used in these designs to give some information on the important scaling parameters of the SBS. Recent experiments on gas-filled hohlraum have explored the possibility of reducing the Brillouin reflectivity by introducing mixed species gases. In this paper we present a formulation of Q in a two-ion-species plasma. An efficient calculational scheme has been developed which can determine Q over the entire spatial grid of a given hydrodynamics calculation. The procedure relies on earlier work which established the complete structure of ion acoustic waves in a two-ion plasma.* Using this method we present results for a foam CH target, including spectral information on the backscatter and predictions of the model on the scaling of the backscatter with species concentrationand incident laser intensity.

* H. X. Vu, J. M. Wallace, and B. Bezzerides, Phys. Plasmas **1** (11), 3542 (1994).

25th Anomalous Absorption Conference

ION WAVE NONLINEARITIES IN STIMULATED BRILLOUIN SCATTERING *

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Ion wave nonlinearities can provide a mechanism for limiting the reflectivities associated with stimulated Brillouin backscattering (SBBS). Experiments with the NOVA facility at the Lawrence Livermore National Laboratory have observed SBBS reflectivities generally lower than those predicted by both analytical and numerical calculations. A more complete, multi-dimensional theory of the role of ion-wave nonlinearities in SBBS including beam smoothing and multiple ion species effects should lead to a better understanding of the experiments. With this as motivation, we have undertaken analytical calculations in support of numerical simulations to determine the influences of ion trapping and wave steepening on ponderomotively driven ion waves.

When there is only one ion species that can be resonant with an ion wave, there is a formal equivalence to electron trapping in an electron plasma wave with its associated nonlinear frequency shift and dissipation, an area in which there has been much previous theoretical work. We show how nonlinear frequency shifts and dissipation can be diagnosed in the case of ponderomotively driven ion waves in one and two-dimensional simulations with our hybrid code BZOHAR presented here and in an accompanying paper by B. F. Lasinski, *et al.* We derive an energy conservation law for the two-dimensional hybrid simulation model and show how this can be used to deduce an effective ion-wave dissipation rate associated with linear or nonlinear wave diffraction or scattering out of a spatially localized region in which the wave is driven. We are investigating the dependences on the physical parameters of the competing mechanisms that can limit the amplitudes of the ponderomotively driven ion waves.

* Work performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

ION WAVE MODELING IN PIC-FLUID SIMULATIONS.*

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Our major goal is to understand the levels of Stimulated Brillouin Scattering in NIF-like plasmas. We are developing additional packages for the electromagnetic PIC code, ZOHAR, to take advantage of the disparate scales involved in SBS: Boltzmann electrons, $c_s \ll v_e$, and low-frequency ordering. We retain the kinetic description for the (multispecies) ions and the complete Poisson's equation to provide the correct dispersion and ion Landau damping for the ion wave phenomena. This 2-D implementation, our hybrid code BZOHAR, is described. We both isolate and compare kinetic and hydrodynamic effects in the nonlinear evolution of ponderomotively driven ion waves, as discussed both here and in an accompanying presentation by B. I. Cohen *et al.*

* Work performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

MODELLING OF RADIATION-DRIVEN HOLE CLOSURE

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Calculations of hohlraum diagnostic-hole closure were performed for a variety of wall thicknesses and slit widths, using the AWE 2-D Lagrangian radiation hydrodynamics code NYM, which uses an implicit scheme for the Monte-Carlo radiation transport. These calculations were then x-ray ray-traced by solving the transfer equation through the calculational mesh, and the results compared with experiments conducted on the Helen laser, (described in a companion paper—P. A. Rosen et. al.). Various modelling issues are addressed.

RADIATION-DRIVEN HOLE CLOSURE EXPERIMENTS AND SIMULATIONS AT HELEN

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We have carried out experiments to study closure of, and radiation transport through, narrow slits; these data are relevant to diagnostic-and laser-entrance-hole closure in hohlraums. Gold slits of different dimensions were mounted on hohlraum targets heated by the AWE Helen laser and their closure was diagnosed using a streaked imaging system operation at 120eV and 880eV photon energies. Targets without the wall of the hohlraum facing the imaging system enabled emission from the hohlraum and the edges of the slit to be separately identified. The data are compared with post-processed 2-D AWE hydrocode simulations.

GAS HOHLRAUM SIMULATIONS*

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Our current hohlraum designs for the National Ignition Facility require about 1 mg/cc of HeH gas to keep the walls from blowing in. Many Nova experiments with gas hohlraums have shown that gas does retard wall motion. We have simulated gas-filled implosion experiments with integrated calculations, in which a laser source produces x rays in the hohlraum wall, which then implodes a capsule.

The x-ray image of the imploded capsule is usually analyzed by taking the contour of half peak intensity and measuring the ratio of the two axes a/b. If a/b < 1, the image is prolate (sausaged). If a/b > 1, the image is oblate (pancaked). The ratio a/b is a function of where the laser is pointed. Measured x-ray images show a shift of 120 μm in equivalent laser pointing relative to calculations - that is, the measured images are more pancaked than the calculated images. We have investigated several hypotheses that may explain this offset.

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* This work was performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

Results from Implosion Experiments with Gas-Filled Nova Hohlraums

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K. Gifford**, A. A. Hauer , E. L. Lindman , G. R. Magelssen , J. B. Moore ,
M. B. Nelson*, S. M. Pollaine*, L. V. Powers*, L. J. Suter*, R. J. Wallace*,
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In the National Ignition Facility target point design, the hohlraum is filled with a He/H_2 mixture to prevent filling of the hohlraum with ablated wall material which would otherwise prevent the beams from entering the hohlraum at late time. Recent Nova experiments have concentrated on gas-filled hohlraums. One important set of experiments seeks to measure the symmetry of implosions in gas-filled hohlraums as a function of laser pointing and fill gas. Implosion symmetry is diagnosed by measuring the distortion of x-ray images of the imploded fuel region of the capsule. Symmetry scaling with laser pointing for methane-, propane-, and neopentane-filled hohlraums, and hohlraums with windows but no gas, have been obtained and compared with scalings using vacuum hohlraums. It is found that for the same laser pointing, there is more flux on the pole of a capsule relative to the waist for a gas-filled hohlraum or a hohlraum with windows than for a vacuum hohlraum. Capsule performance in methane-filled hohlraums is not significantly degraded from vacuum results. Small reductions in neutron yield are seen in methane-filled hohlraums, but greater reductions are obtained with propane or neopentane. Average neutron emission time ("bang time") is later in gas-filled hohlraums than in vacuum. Areal densities (ρR) show no degradation with gas-fill.

This work was performed under the auspices of the U. S. DoE by the Lawrence Livermore National Laboratory under contract number W-7405-Eng-48 and by the Los Alamos National Laboratory under contract number W-7405-Eng-36.

NIF and NOVA Hohlraum Plasma Conditions Correlated to SBS and SRS Measurements*

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The plasma conditions in NIF and NOVA hohlraums that contain ICF capsules are very complicated. The NIF point design contains 0.8 mg/cm^3 (3% of critical when fully ionized) He-H gas to mitigate hohlraum plasma filling . At peak laser power this plasma develops spatially complex densities near 10% of critical with electron temperatures of 3 to 5 keV. The NOVA symmetry experiments have been fielded with CH_4 (3%), C_3H_8 (7%), and C_5H_{12} (11%). For laser plasma instability measurements more uniform and better characterized plasma conditons with longer scale lengths than in the standard Scale 1 experiments are desired. Therefore special toroidal-shaped hohlraums, that achieve 3 keV electron temperatures, have been designed and fielded on NOVA with C_5H_{12} (11%), C_5D_{12} (11%), CO_2 (6%) at 1 Atm pressure and He-H (3%) at 5 Atms. We anticipate fielding higher density He-H at higher pressures and/or lower temperatures to simulate the 10% of critical density reached in the NIF. To see whether SRS is reduced at higher temperatures, we are designing hohlraums that approach electron temperatures of 5 keV. The plasma conditions in all these different hohlraums will be compared. Spatially, temporally, and spectrally resolved SBS and SRS measurements in the NOVA hohlraums will be compared and correlated with their plasma conditions to determine whether more NIF-relevant experiments can be performed on NOVA.

* Work performed under the auspices of the U.S. DOE under contract no. W7405-ENG-36

UPDATE ON TIME-DEPENDENT MEASUREMENTS AND THEORETICAL COMPARISONS OF RADIATION SYMMETRY WITHIN NOVA HOHLRAUMS

G. R. Magelssen, N. D. Delamater, E. L. Lindman, A. A. Hauer,
M. R. Clover, J. L. Collins, C. W. Cranfill, and W. J. Powers
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The time-dependent pole-to-equator (P2) asymmetry in vacuum hohlraums has recently been measured during the foot of PS22. This was accomplished by replacing the mounting web with a 7 micron diameter carbon stalk. In methane filled hohlraums, a pointing scan for "SYMCAP" capsules with shell thicknesses from 16 to 22 microns has been completed. Detailed comparisons between experimental results and calculations will be presented.

Abstract submitted to the Anomalous Absorption Conference

NONLINEAR EULERIAN HYDRODYNAMICS IN THREE DIMENSIONS*

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Because of computer limitations on space and time, most physics codes rely on one- or two-dimensional hydrodynamics models. In order to accurately simulate three-dimensional laser/plasma interactions in the presence of strong ponderomotive drive, we have developed a fully three-dimensional nonlinear Eulerian hydrodynamics package (B3D) in Cartesian coordinates. B3D uses the method of Leblanc and Christiansen,[1,2] second order accurate monotonic approximations and an upwinding scheme in a finite-difference operator splitting to solve the advection versions of the continuity, momentum and energy equations. In addition to hydrodynamics, B3D includes ponderomotive force.

In this presentation, we develop the algorithms and show several examples from numerical experiments to illustrate the behavior of a plasma driven by a ponderomotive force. Finally, we present results obtained by integrating this hydrodynamics package into our three-dimensional laser filamentation code (F3D).

* Work performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

1. *R. L. Bowers* and *J. R. Wilson*, **Numerical Modeling in Applied Physics and Astrophysics**, Jones and Bartlett, 1991.

2. *D. S. Miller*, Ph.D. Thesis

ORAL SESSION 4

LASER PLASMA INTERACTIONS

Albert Simon, Chair

and

SPECTROSCOPY AND ATOMIC PHYSICS

Jill Dahlburg, Chair

Wednesday, May 31

25th Anomalous Absorption Conference

BEAM STEERING BY FILAMENTATION IN FLOWING PLASMAS *

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We revisit the theory of ponderomotive filamentation in plasma with near sonic transverse flow, where it has been shown that in steady state, filaments grow in a direction tilted downstream to the initial laser direction.[1] One of the two ion waves becomes nearly resonant when the flow is near sonic, so the instability acquires some of the characteristics of near forward SBS. This mechanism has been proposed as contributing to a change in effective beam pointing in gas-filled hohlraum symmetry experiments.[2]

We extend this theory to include a better treatment of ion Landau damping and to consider transient effects. The latter is important even in the absence of deliberate temporal beam smoothing because the speckle pattern of the laser beam can be expected to shift on the transient time scale.

We find that transient effects induce beam steering even in the absence of ion wave damping– an ingredient that was necessary in the steady state analysis.

(1) R. W. Short, R. Bingham and E. A. Williams, Phys. Fluids **25**, 2302 (1982)

(2) H. Rose, presentation at LLNL (1995)

* Work performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

25th Anomalous Absorption Conference

Beam steering induced by transverse plasma flow *

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In gas-filled hohlraum experiments performed at LLNL, there is evidence that the effective laser spot on the hohlraum wall is roughly 150μm closer to the laser entrance hole (LEH) than anticipated. It has been suggested [H. A. Rose, LLNL presentation, 1995] that this may be caused in part by a plasma flow transverse to the laser beam, which then causes the beam to bend in the direction of flow. It has already been shown [R. W. Short, R. Bingham, and E. A. Williams, Phys. Fluids **25**, 2302 (1982)] that when the effect of transverse flow is included in the steady state filamentation dispersion relation, there is roughly a 1.5° bend in the filament. Refraction of the laser beam into the filament would then cause a 25μm deflection in the spot location on the wall.

A series of fluid simulations modelling this effect have been performed using F3D [R. L. Berger, B. F. Lasinski, T. B. Kaiser, E. A. Williams, A. B. Langdon, and B. I. Cohen, Phys. Fluids B **5**, 2243 (1993)]. The beam steering scales linearly with intensity and path length, and also depends strongly on Mach number $M \equiv u/C_s$, where u is the transverse plasma flow. LASNEX simulations of gas-filled hohlraums show that the velocity profile transverse to the laser beam is sheared. This effect has been incorporated into F3D. Preliminary investigations show that the majority of the beam bending occurs near the sonic point in the transverse flow profile. The transient response to a near sonic transverse flow can tilt the beam by up to 6°, causing a 100μm deflection in the spot location toward the LEH on the hohlraum wall. Whole beam effects, including multiple filaments, and three dimensional effects will also be presented.

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

Twenty–Fifth Annual Anomalous Absorption Conference
Aspen, Colorado
27 May-1 June, 1995

Whole Beam Deflection through a Hohlraum Window Plasma

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D. S. Montgomery, R .L. Berger, D. E. Hinkel,
T. D. Shepard, and E. A. Williams

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We have measured the deflection of a Nova laser beam through a plasma created by exploding a hohlraum window (0.65 μm foil of polyimide) with four other Nova beams. The purpose of these measurements is to determine the effect of the window plasma present in gas filled hohlraum symmetry experiments on laser beam steering. Hohlraum symmetry experiments done on Nova, which are discussed at this meeting, indicate that the beams deflect from their expected trajectories before reaching the hohlraum wall. These experiments isolate the effect of the hohlraum window on beam deflection. The 5 Nova beams are 351 nm, impinge on the target at about 50 degrees from the target plane normal, and have about a 2.3 ns pulse shape which is approximately constant for the first 1.3 ns and then increases in intensity by about a factor of 3 for the last 1 ns. This is the same pulse shape used in gas filled hohlraum symmetry experiments. Deflection of one beam is determined by measuring the location at which the beam strikes an f/2 scatter plate placed 2 meters from the target. The measured beam is reduced in aperture to f/8 (all other beams are f/4.3) in order to exaggerate any angular deflection. Measurements of beam deflection are made with a streak camera and a gated optical imager (GOI). The streak camera shows beam deflection along one direction on the scatter plate and the GOI shows images of the two-dimensional light distribution on the plate. We find that without a random phase plate (RPP) the transmitted beam spreads to about f/4 and deflects from 3 to 7 degrees. The deflection is such that it increases the angle between the transmitted beam and the target normal. Increasing beam intensity increases the deflection for intensities above about $2 \times 10^{14}\,\mathrm{W/cm^2}$; below this intensity we see no beam deflection. Addition of a RPP suppresses beam deflection even at the highest irradiances ($1.5 \times 10^{15}\,\mathrm{W/cm^2}$) and reduces the beam spreading to about f/6. We will present the observations and discuss effects which may explain the observations.

*Work performed under the auspicies of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W–7405–ENG–48.

Crossed laser beam interactions in laser fusion plasmas.

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C. E. Capjack
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An indirect drive approach to inertial confinment fusion (ICF) has been investigated in experiments the involving interaction of several laser beams with a large hohlraum plasma. Typical geometries found in these experiments include an overlap of individual laser beams in the plane of the laser entrance hole. Nonlinear interactions between the beams in the overlap region may constitute a serious threat to a carefully planned ICF reactor scheme. We will illustrate this point by showing the wealth of different parametric interactions in the model calculations involving a low frequency plasma response to two crossed Gaussian laser beams. These interactions result in: a strong ion density grating; Bragg diffraction, including second order diffraction on ion acoustic waves; and enhanced forward stimulated Brillouin scattering (SBS) in the directions of the two beams, which leads to rapidly varying in time energy exchange between the beams. These primary effects have been observed in our simulations in addition to previously described SBS instabilities related to the symmetries of the overlap region, like double SBS which corresponds to backward SBS from each beam sharing a common ion acoustic wave or so called scattered light symmetric mode, where a single scattered light wave is common to two crossing pumps and resonant ion acoustic waves. Finally, the complex interaction physics of the overlap region also includes single Gaussian laser beam instabilities like self-focusing, filamentation and SBS [1], which can produce a spreading of the transmitted light and splitting of the laser beam into several beamlets.

We will also discuss the analysis of these processes by means of the fully three dimensional nonparaxial interaction code.

[1] V. Eliseev, W. Rozmus, V. T. Tikhonchuk, and C. Capjack, Phys. Plasmas **2** (5), (1995).

* *On leave from Russian Academy of Sciences, Moscow, Russia.*

25th Annual Anomalous Absorption Conference, Aspen CO, May 27 - June 1 1995

Observation of Energy Transfer Between Frequency Mis-Matched Laser Beams in a Large Scale Plasma*

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We have performed a series of experiments using the Nova laser which investigate the interaction of laser beams with slightly differing frequencies ($\Delta\omega/\omega \leq 2 \times 10^{-3}$) in a NIF-like plasma ($n/n_{cr} = 0.1$, $T_e = 3$ keV, scale length ~ 2mm). The design of a multi-color, multi-beam laser system for indirect drive targets requires understanding these interactions. Energy transfer from a short wavelength beam to a long wavelength beam is expected if the separation frequency of the two beams ($\Delta\omega$) is close to the ion wave resonance (i.e.; $\Delta\omega = |\mathbf{\Delta k}| c_s$) via stimulated Brillouin scattering (SBS). Measurements of the transmitted energy of a low intensity probe beam ($I \leq 1.5 \times 10^{15}$ W/cm^2 peak) intersected by a high intensity pump ($I = 5 \times 10^{15}$ W/cm^2 peak) at an angle of 53° shows a peak amplification of as much as 2.4 over the case with no pump beam. The amplification is observed to be largest when the separation of the beam frequencies is near the ion acoustic resonance with the pumps frequency higher than than the probes. When $\Delta\omega$ is de-tuned by 50% the amplification drops to near unity indicating the importance of the ion resonance. A scan of intensity indicates that the gain is constant (linear) when the probe intensity is less than 14% of the pump. The data will be compared with theoretical predictions for the gain and resonance width[1] including the effects of an inhomogeneous flow profile[2] and any evidence of saturation at high intensity will be discussed.

[1] W. L. Kruer, et. al., at this conference
[2] B. B.Afeyan et. al., at this conference

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*This work was performed under the auspices of the United States Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W7405-ENG-48

Prefer Oral Session

Observation of Threshold, Growth, and Saturation Behavior of Stimulated Brillouin Scattering in Inhomogeneous Plasmas *

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ABSTRACT

Among the numerous experiments to study stimulated Brillouin Scattering (SBS), few experiments have observed thresholds or the onset of saturation. This is particularly true of experiments using laser light of wavelength ≤ 1 μm, which largely appear to produce some sort of saturated regime. We report here results of an experiment in which the noise level, the scaling of the threshold for SBS, and the onset and scaling of the saturation behavior were measured. This provides detailed, quantitative data for comparison with theories.

The experiment was performed at the Trident laser facility at Los Alamos. A plasma was formed by irradiating a 6.7 μm thick, CH target with a 1.3 ns pulse. SBS was driven in this plasma, 300 ps after the preform pulse ended, by another narrowband, 527 nm laser beam that passed through a Random Phase Plate. Absolutely-calibrated measurements of the spectral intensity of the scattered light, combined with LASNEX simulations of the plasma, permit detailed results to be obtained. We observed the noise level when SBS was below threshold, the threshold or the growth rate (depending on plasma density), and the saturation behavior. The implications of these observations for interpretation will be discussed.

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

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Acceleration to 44 MeV of Electrons Trapped in Plasma Waves Generated by Forward Raman Scattering and Wakefield Action

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A 1 μm, 1 ps, 20 TW laser pulse focused at f/4 onto the edge of a hydrogen or helium gas jet ($n_e \sim 3\times10^{18}–2\times10^{19}$ cm^{-3}) generates relativistic electron plasma waves via the forward Raman scattering (FRS) instability. Evidence for FRS is seen in the transmitted laser spectrum which shows multiple sidebands separated by ω_{pe}. This is observed as well in a self-generated second harmonic beam. The sidebands broaden as the electron density is increased. Self-trapped electrons accelerated over a distance of 0.3-1 mm are detected in a *f*60 forward cone with energies up to 44 MeV (this being the limit of the electron spectrometer). This corresponds to an electric field of up to 1 GV cm^{-1}. Single-shot electron spectra, obtained using a fluorescer/film pack, show a tail which is roughly exponential and a yield, calibrated with a silicon detector, of $\sim10^6$ electrons/MeV at 30 MeV. Shots in helium show an even higher electron yield and much flatter electron spectrum indicating that as much as 10^{-4} of the plasma electrons are accelerated. Best results are obtained at electron densities around 8×10^{18} cm-3.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Diffractive Irradiation Patterns Inside the Plasma Corona

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ABSTRACT

We have begun to apply scalar diffraction theory to compute the electromagnetic field distribution inside a spherical plasma irradiated by focused beamlets transmitted through a random phase plate. Due to the assumed spherical symmetry of the target the field can be expanded into spherical harmonics, and only the solution of the Schrödinger-type differential equation in the radial direction is required. This numerical integration is time and memory consuming and can be avoided by using the approximate WKB-Langer formula. We will present some first results for speckle irradiation patterns for plasmas under realistic conditions of experiments performed at LLE. Our results are especially important for those regimes (dense plasmas, near caustics, and near the critical surface) where traditional uniformity calculations (typically performed in the geometrical-optics limit) are expected to become unreliable.

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.

Ionization Induced Refraction In Recombination X-Ray Lasers

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Abstract

We examine ionization induced refraction in regimes relevant to recent and planned recombination x-ray lasing experiments [D. C. Eder et. al, Phys. of Plasmas **5**, 1744 (1994).] We present a model which self consistently evolves the laser radiation as it ionizes a neutral gas. The model allows for multiple ionization levels and for spatial variations in the neutral gas density appropriate for studying gas jets and laser evaporated gases. We calculate the length of highly stripped plasma in H-like Li and Li-like N systems where the conditions are appropriate for recombination. We find that for a given pump power there is always an optimal spot size and focal position with respect to the gas jet which minimizes refraction and maximizes the length for which gain is possible.

Work was performed under the auspices of the U.S. Department of Energy by the Lawerence Livermore National Labratory under contract No. W-7405-ENG-48.

25th Anomalous Absorption Conference, Aspen, Colorado, May 27 - June 1, 1995

Debye screening in multicomponent plasmas

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A general expression of Coulomb logarithms for collisions in a classical plasma is given, for any number of particle species whose masses, charges, densities, temperatures, and mean velocities may be different. It is obtained from a proper averaging of the Balescu-Lenard collision integral. The main result is the Debye length $\lambda_D = 1/k_D$ for the interaction between two species α and β, screened by all particle distributions γ, including themselves.

For a single plasma (the most common case where all mean velocities are equal):

$$k_D^2 = \sum_\gamma 4\pi n_\gamma Z_\gamma^2 e^2 \Big/ \left(T_\gamma + \frac{m_\gamma}{\frac{m_\alpha}{T_\alpha} + \frac{m_\beta}{T_\beta}} \right) .$$

For the slowing down of a test particle α with velocity U by a single plasma (all mean velocities equal to zero):

$$k_D^2 = \sum_{\gamma \neq \alpha} 4\pi n_\gamma Z_\gamma^2 e^2 \Big/ \left(T_\gamma + m_\gamma \frac{U^2 \frac{T_\beta}{m_\beta}}{3\frac{T_\beta}{m_\beta} + U^2} \right) .$$

In the simplest example of an electron-ion plasma, these formulas agree with the usual qualitative screening rules [H. Brysk et al., *Plasma Physics*, **17**, 473 (1975)]:

> « In the test particle formalism, a particle is shielded by ambient particles that move more rapidly than it does and so have time to rearrange to 'dress' it. For interacting distributions, this prescription is to be applied from the point of view of the slower group. »

Plasma interpenetration. When the rule tells about particles that "move rapidly", it is thermal motion which is meant. The opposite effect is expected for directed motion: particle distributions that move too fast don't have time to rearrange to screen an interaction. This is what gives the general formula:

$$k_D^2 = \sum_\gamma 4\pi n_\gamma Z_\gamma^2 e^2 \Big/ \left\{ T_\gamma + m_\gamma \left[\frac{1}{\frac{m_\alpha}{T_\alpha} + \frac{m_\beta}{T_\beta}} + \frac{W^2\left(\frac{T_\alpha}{m_\alpha} + \frac{T_\beta}{m_\beta}\right) + \frac{1}{2}|\mathbf{W} \times \mathbf{U}|^2}{3\left(\frac{T_\alpha}{m_\alpha} + \frac{T_\beta}{m_\beta}\right) + U^2} \right] \right\} ,$$

$$\mathbf{U} = \mathbf{u}_\alpha - \mathbf{u}_\beta \ , \ \mathbf{W} = \frac{\frac{m_\alpha}{T_\alpha}(\mathbf{u}_\alpha - \mathbf{u}_\gamma) + \frac{m_\beta}{T_\beta}(\mathbf{u}_\beta - \mathbf{u}_\gamma)}{\frac{m_\alpha}{T_\alpha} + \frac{m_\beta}{T_\beta}} .$$

NON-LTE IMPLEMENTATION IN AN EULERIAN HYDROCODE*

D. A. Garren[a], M. Klapisch[b], J. H. Gardner[c], D. Colombant[d],
J. P. Dahlburg[c], and M. Busquet[e]

It is well-known that non-LTE effects are important in accurately predicting conversion efficiencies and coronal temperatures in laser-produced plasmas. The ICF group at NRL has incorporated Busquet's non-LTE model [1] into an existing 2-D Eulerian multigroup hydrodynamics code (RAD2D) [2] that uses LTE opacities and equation of state. The current implementation permits both 1-D and 2-D non-LTE simulations in terms of hydrodynamics equations that conserve energy. In addition, NRL's non-LTE hydrocode uses LTE opacity databases that are generated with the STA code [3].

NRL's non-LTE code is based upon Busquet's radiation-dependent ionization model (RADIOM) that he implemented into a 1-D multigroup Lagrangian hydrodynamics code. This non-LTE methodology applies the concept of an ionization temperature T_z that depends upon the electron temperature, number density, and the radiation energy density in each frequency group. The actual calculation of T_z is found from a "generalized Saha equation" in a manner similar to that introduced by Zel'dovich [4]. Non-LTE opacities are then found from an LTE table look-up evaluated at the ionization temperature T_z rather than the electron temperature T_e. Modifications of the non-LTE radiation source function and the equation of state variables from their respective LTE values are also found from T_z and T_e.

NRL's hydrodynamics code is applied to investigate the differences between non-LTE simulations and those found under the assumption of LTE. Computations for both aluminum and gold are performed for various laser profiles and intensities. As expected, non-LTE simulations yield lower conversion efficiencies and higher coronal temperatures than the corresponding LTE calculations.

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

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[1] M. Busquet, *Phys. Fluids B* **5**, 4191 (1993).
[2] J. H. Gardner, S. E. Bodner, and J. P. Dahlburg, *Phys. Fluids B* **3**, 1070 (1991).
[3] A. Bar-Shalom, J. Oreg, and W. H. Goldstein, *J. Quant. Spectr. Radiat. Trans.* **51**, 27 (1994).
[4] Y. B. Zel'dovich and Yu. P. Raizer, *Physics of Shock Waves and High Temperature Hydrodynamic Phenomenas*, edited by W. D. Hayes and R. F. Probstein (Academic, New York, 1967), p. 201.

Non LTE Effects on Radiative Plasma Structures*

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Radiative Plasma Structures (RPS) were previously reporte[1] in simulations of laser produced plasmas with the RAD2D hydrodynamics code[2] using LTE opacity databases generated with the STA code[3]. RPS were obtained in mostly low and moderate Z materials. They correlated with plasma conditions near maxima of radiative power loss - with respect to temperature Te and density r - due to atomic shell structure.

We have now implemented an algorithm[4] giving the bulk of non LTE effects in RAD2D. This Radiation Dependent Ionization Model (RADIOM) uses an effective ionization temperature Tz as the variable for a table lookup in the STA generated opacity database. Tz depends on Te, r, and the local radiation energy density in each photon energy group.

Non LTE effects on planar targets of medium and high Z materials modify the evolution of the plasma, sometimes drastically, and cause the RPS to appear at different times, locations, and laser intensities. RPS are observed to appear in non LTE simulations when similar plasma conditions as in LTE are met, except that Te is now replaced by Tz. RPS occur when a heat front develops near a maximum of radiative loss. The outflowing cold matter gets rapidly heated because of the sudden drop of radiation. This in turns creates a pressure gradient that compresses the cold matter upstream. We are planning experiments to observe RPS, expecting to assess the quality of our opacity database and non LTE algorithm.

*Work supported by the US Department of Energy.
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[1] J. P. Dahlburg, M. Klapisch, J. H. Gardner, C. R. DeVore, A. J. Schmitt and A. Bar-Shalom, in 6th International Workshop on Radiative Properties of Hot Dense Matter, Sarasota, Fla, 1994, edited by R. W. Lee, J. C. Gauthier and W. H. Goldstein, to be published in J. Quant. Spectr. Radiat. Trans. (1995)
[2] J. H. Gardner, S. E. Bodner and J. P. Dahlburg, Phys. Fluids B, 3, 1070 (1991).
[3] A. Bar-Shalom, J. Oreg and W. H. Goldstein, J. Quant. Spectr. Radiat. Trans., 51, 27 (1994).
[4] M. Busquet, Phys. Fluids B, 5, 4191 (1993).

ABSTRACT FOR
25TH ANOMALOUS ABSORPTION CONFERENCE

PRELIMINARY EXTRACTION OF CORE/PUSHER CAPSULE CONDITIONS FROM X-RAY IMAGE AND SPECTROSCOPY DATA FOR HYDRODYNAMICALLY EQUIVALENT PHYSICS (HEP) SHOTS

by

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ABSTRACT

Recent experiments on NOVA have used capsules having pushers doped with mid-Z elements to minimize scale-length and ablative stabilization of Rayleigh-Taylor and Richtmyer-Meshkov instabilities. These capsules are designed to have calculated single-mode growth factors approaching those envisioned for the NIF facility. Both DD gas and pusher have been doped with elements designed to strip to the k shell near maximum compression, allowing a reasonably simple x-ray line spectrum to be measured. I use the post-processor TDG/DCA to extract core temperature, density, and mix structure at peak compression for selected capsule implosions in this and previous experimental series. I find that the core is cooler (by at least 10%), and the pusher hotter (by at least 10%), near peak compression, compared to 1D simulations. Part of the analysis rests on absolutely calibrated x-ray pinole camera images. The data indicate discrepancies in absolute image intensities between theory and experiment.

Two-Dimensional Models of Emission Line Ratios in ICF Target Implosions

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In this paper we report results of detailed spectral postprocessing calculations of indirectly driven ICF implosions. The results of one and two-dimensional Lasnex hydrodynamic simulations are postprocessed using detailed atomic kinetics models to produce simulated spectra. Attention is focussed on line ratios which are used as diagnostics of the fuel temperature as well as the presence of pusher-fuel mix. Our results show significant differences between optically thin, escape probability, and full radiative transfer treatments of the lines. We discuss how the line ratios vary as the imploding capsule becomes distorted due to drive asymmetries. Two different atomic models with different numbers of atomic levels have been used, and we show how this affects the line ratios. We have run some models on the Meiko parallel computer, and show that large speedups for problems with only a few optically thick lines will require better load balancing.

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

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Simulations of Time-Dependent Spectral Signatures of Fuel-Pusher Mixing in Laser-Driven Implosions

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ABSTRACT

In laser-driven implosion experiments on polymer shells, the hydrodynamic instability near the interface between the decelerating shell and the DT fuel core is a crucial limitation on target performance. We consider how the resulting fuel-shell mixing can be observed through its effect on time-resolved spectra of the x-ray emission from additive layers in the shell and from a fuel additive. The effects of Rayleigh-Taylor flow are simulated in real-time in the one-dimensional hydrocode *LILAC* as a transport process where material constituents are redistributed continuously, along with their thermal energy, within a growing mix region whose outer and inner boundaries are taken to be, respectively, the RMS bubble-and-spike amplitudes obtained from a saturable multi-mode model of the Rayleigh-Taylor instability. Spectra are simulated in detail using a non-LTE radiation-transport post-processor upgraded to make full use of the multi-material mix information from the one-dimensional hydrodynamic simulations. Opacity and intensity profiles change as mixing spreads the signature additives over the temperature and density profiles that are also affected by mixing. Relationships among the degree of mixing, the free parameters of the mix model, and changes in the resulting simulated spectra are described.

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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.

ORAL SESSION 5

SHORT PULSE LASER INTERACTIONS

William Kruer, Chair

Thursday, June 1

The generation of high harmonics using a short pulse KrF laser

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The majority of groups investigating high harmonic generation of short pulse lasers have used long wavelength lasers, due to the quadratic scaling of ponderomotive energy with wavelength for a given intensity. It has been reasoned that such lasers should therefore produce the highest energy harmonics. However, short wavelength lasers are known to generate harmonics more efficiently, and it has recently been shown that harmonic generation from a KrF laser can only be explained by invoking the response of ions, rather than neutrals.[1] The response of ions is of import due to their higher ionisation potentials and threshold ponderomotive energies. Long wavelength lasers (800-nm - 1053-nm) do not produce harmonics efficiently from ions. It is therefore timely to investigate whether higher energy harmonics can be produced from short wavelength lasers interacting with ions than from long wavelength lasers interacting with neutrals. We present here data on harmonic generation using the short pulse (350-fsec) KrF laser 'Sprite' at the Central Laser Facility of the Rutherford Appleton Laboratory interacting with helium and neon gas targets. The harmonics produced are, to our knowledge, the highest energy yet observed, and can only be explained by invoking response from singly ionised helium and doubly ionised neon. The relative conversion efficiencies are in excellent agreement with numerical simulations of the single atom response using the single active electron approximation. This work has been funded by the UK Engineering and Physical Sciences Research Council.

[1] Jeffrey L. Krause, Kenneth J. Schafer, and Kenneth C. Kulander, Phys. Rev. Lett. 68, 3535 (1992).

25th Anomalous Absorption Conference, Aspen, Colorado, May 27 - June 1, 1995

Second Harmonic Generation and Extreme broadening of Stimulated Raman Scattered Light from High Intensity Laser Interaction in Underdense Plasmas

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Abstract

Experiments examining nonlinear scattering mechanisms of high intensity (2×10^{18} W/cm^2) laser light in underdense plasmas were performed. Red-shifted second harmonic emission at 45° from the directly backscattered direction was observed from field ionized plasmas having electron densities ranging up to 10^{19} cm^{-3}. This result was due to the doubling of stimulated Raman sidescattered light from the large plasma electron density gradients produced by ponderomotive cavitation. Broad and oscillatory spectra were observed for the forward scattered light. The Raman backscattered spectrum showed an extremely broad, supercontinuum like nature, extending from 450 nm to greater than 1200 nm. Narrow and large amplitude modulations in the spectrum of the backscattered radiation were measured and are attributed to scattering from ion waves.

Abstract for the 25th Anomalous Absorption Conference 1995

Fast Ignitor Plasma Physics Issues*

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We look at a number of plasma physics issues associated with the Fast Ignitor (FI) fusion concept. Analysis of recent experiments relevant to the FI will be presented, as well as the current state of the theory of the important laser-plasma interactions. These interactions include channel creation in underdense plasma, propagation of an intense laser pulse in a channel, hot electron generation and channel stability at the end of the channel. Results of large 2-D simulations, with realistic plasma density profiles, will also be presented.

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

Ponderomotive and Magnetic Effects under Bright Source Laser Illumination*

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We have used the ANTHEM[1] 2-D implicit multi-fluid code to track electron transport and magnetic field generation in foils near the deposition point of a bright source laser. With 6×10^{18} W/cm^2 1.06 μm illumination, deep overdense B-fields of up to 35 MG are calculated[2], provided that the peak foil density is of order 1.3 n_{crit}. These fields oppose the traditional thermoelectric polarity. The B- field derives from the curl of the E-field required to draw return the current up to nearly relativistic speeds in the low density background. The field becomes progressively more intense, and confined to the surface (as predicted by Sudan[3]) as the foil density is increased. For foils at 10 n_{crit} 100 MG fields are seen at the surface. Alternatively, if the ponderomotive force is reduced below a factor of 0.2, the B-fields in the older thermoelectric sense reemerge. At densities exceeding 100 n_{crit}, the calculations show that both the deposited hot electrons, and the return current flow are pinched into a narrow channel below the laser deposition point. When a region out to 3 times the spot radius is examined, we find that the field converts to the traditional polarity at the larger radii. When hot electron emission is suppressed, while the background electrons are still given a "kick" by the ponderomotive forces, 100 MG B-field are still seen neighboring the spot. The polarity of this field reverses, when the beam is made annular, with the highest intensity prevailing at the outer edges.

[1] R. Mason, J. Comp. Phys. **71** 429 (1987).
[2] S. Wilks, et al., PRL **69**, 1383 (1992).
[3] R. Sudan, PRL **70**, 3075 (1993).
*Work supported by the USDOE.

Kinetic Simulations of Intense Ultra-Short-Pulse Laser Light on Thin Targets*

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We investigate the interaction of high-intensity, short-pulse lasers with thin, solid-density targets using kinetic particle-in-cell simulations. The simulations are one-dimensional in space with three velocity components, and electron-ion Coulomb collisions are included. The plasma is initialized as a cold, fully-ionized plasma slab with sharp density jumps from vacuum to solid material. Our nominal case is a 100 nm thick aluminum target, illuminated by 400 nm wavelength light with a 100 fs full-width-half-maximum Gaussian time history.

When the peak laser intensity is $I=10^{18}$ W/cm^2, the fractional absorption is approximately 3% with mean electron energies of about 20 keV. At $I=10^{19}$ W/cm^2, a sizable population of high-energy (>100 keV) electrons appears, and the absorption increases to 7%. In this case, and at higher energies, trains of high-energy electron pulses can be seen in the plasma, separated by half the wavelength of the incident light wave; these electrons interact strongly with the background plasma through excitation of plasma waves. The absorption increases to 12% for $I=10^{20}$ W/cm^2, and at $I=10^{21}$ W/cm^2 it increases to 20%. At the higher intensities, some electrons reach several MeV.

The absorption, once the plasma reaches a few keV, is collisionless, and the mechanism appears to be the proposed by Kruer and Estabrook [1]. This mechanism relies on the pulsed nature of the electromagnetic ponderomotive force. The electrostatic confinement of the energetic electrons, characteristic of a thin target, is crucial to the enhancement of the absorption, as demonstrated by simulations in which the energetic electrons are absorbed at nearby boundaries. The expansion of the ions, although not large, also plays a role in enhancing the absorption.

Following the absorption of energy by the electrons, the ions are accelerated by the ambipolar field. For the 10^{20} W/cm^2 intensity, some ions are accelerated to more than 100 MeV (~0.1*c*). These ions may be useful for bombarding a secondary target.

We will show further results, varying target thickness, pulse length, pulse shape, and laser wavelength.

[1] W.L. Kruer and K. Estabrook, *Phys. Fluids* **28**, 430 (1985)

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

Hydrocode Simulation of Sub-Picosecond Laser Interaction with Solid-Density Matter

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ABSTRACT

The interaction of ultra-short laser pulses with initially cold and solid matter is investigated in order to characterize the regime of the so-called laser-heated solid or 'hot solid'. For this purpose the MULTI hydrocode (R. Ramis et al., Comput. Phys . Commun. 49, 475, 1988) has been modified by replacing Beer's law by an absorption routine which solves Maxwells equations in order to describe the interaction of the laser with a steep plasma profile. In addition, the collision frequency which is needed for the absorption and the electron heat transport has been modified by including high density and degeneracy effects.

Systematic numerical calculations were performed with intensities varying between 10^{12} and $10^{17} W/cm^2$ and pulse durations from $50fs$ up to $10ps$. For aluminum, we elaborate the intensity and the pulse duration scaling of the temperature, the density, the pressures (up to the $100Mbar$ regime) and the x-ray emission. For the case of normally incident laser light, it is found that the laser-heated solid regime with negligible expansion can be accessed with pulse durations being shorter than $1ps \times (I_{15}\lambda_{\mu m}^2)^{-0.3}$ where I_{15} is the intensity in $10^{15} W/cm^2$ and $\lambda_{\mu m}$ the wavelength in μm.

25th Annual Anomalous Absorption Conference
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Laser Absorption, Plasma Evolution, and X-Ray Emission in Solid Targets Heated by Femtosecond Lasers*

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We use the hydrodynamics code LASNEX to simulate the absorption of 100-fs laser pulses on solid density targets. In these simulations, laser absorption occurs by means of inverse bremsstrahlung using a 1D Helmholtz wave equation solved self-consistently with the plasma evolution. During the laser absorption, several processes affect the amount of laser absorption. In the intensity regime from 10^{13} W/cm^2 to 10^{18} W/cm^2, these processes include: (1) laser absorption processes, (2) hydrodynamics, (3) heat conduction, (4) ion-electron equilibration, and (5) separate electron and ion equations of state. We correct for the Gaussian spatial profile of the laser, use a pulse shape derived from autocorrelation measurement, and find excellent agreement with recent LLNL experiments for aluminum targets. We examine briefly questions related to ponderomotive steeping of the density profile, changes in plasma evolution due to laser pulse shape, and time-duration of x-ray emission.

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

25th Annual Anomalous Aborption Conference, Aspen, Colorado, May 27 - June 1, 1995

Two-Dimensional Stimulated Raman Scattering of Short Laser Pulses

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ABSTRACT

Several analyses of the stimulated Raman scattering (SRS) of short laser pulses have been made in recent years.[1-5] Two issues of particular interest are the spatiotemporal evolution of the instability and the angular dependence of the peak daughter-wave amplitudes.

The linearized equations governing the initial evolution of two-dimensional SRS are solved analytically and numerically, in a frame moving with the laser pulse, for initial and boundary conditions that are representative of a laser pulse convecting into fresh plasma. Forward SRS exhibits growth in space and time and is saturated by the damping of the Stokes wave and the convection of the Stokes wave relative to the laser pulse. Backward SRS exhibits only spatial growth because of the rapid convection of both daughter waves relative to the laser pulse. The peak Langmuir amplitude is determined as a function of the scattering angle, the damping rates of the Langmuir and Stokes waves, and the aspect ratio of the laser pulse. In the absence of Landau damping, the peak Langmuir amplitude is a monotonically increasing function of the scattering angle.[3] In the presence of Landau damping, backward SRS is suppressed.[1]

1. C. J. McKinstrie and R. Bingham, Phys. Fluids B **4**, 2627 (1992).
2. T. M. Antonsen, Jr. and P. Mora, Phys. Rev. Lett. **69**, 2204 (1992).
3. T. M. Antonsen, Jr. and P. Mora, Phys. Fluids B **5**, 1440 (1993).
4. W. B. Mori, C. D. Decker, D. E. Hinkel, and T. Katsouleas, Phys. Rev. Lett. **72**, 1482 (1994).
5. C. J. McKinstrie, R. Betti, R. E. Giacone, and T. Kolber, Bull. Am. Phys.Soc. **39**, 1518 (1995).

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.

Time-resolved reflectivity measurements of electron heat conduction and hydrodynamics in an ultra-short pulse plasma

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In ultrashort pulse laser produced plasmas, electron heat transport down steep thermal gradients carries absorbed laser energy away from the plasma and into cold, bulk target regions. Supersonic electron conduction is predicted to be the limiting factor for both the peak and duration of the initial plasma heating.[1] Therefore, a quantitative understanding of electron energy transport rates and heat wave details is important to studying these plasmas as high-energy-density, strongly-coupled matter and to their application as high-brightness x-ray sources. Hydrodynamic expansion, at the sound speed, follows most electron conduction lowering the plasma temperature and density and obscuring the experimental reflection signal. The transition between these two primary plasma energy channels exists on a several picosecond timescale, which can only be probed by femtosecond pulses.

We present pump-probe reflectivity measurements spatially and temporally-resolving plasma reflectivity with a nonintrusive (low-intensity) probe pulse. The reflectivity signal and simulations are used to infer evidence of a transition between rapid heat transport away from the plasma via electron conduction and significant hydrodynamic expansion.

Plasma was created from an SiO_2 (fused quartz) target by the intense ($\sim 10^{16} W/cm^2$), ultra-short (130fs) laser pump pulse.[2] A nonintrusive fraction of the pump beam was used to probe the plasma. Temporal resolution of 130fs (probe pulsewidth-limited) was attained by measuring reflectivity as a function of the time delay between the arrival of the pump and the probe pulse. Spatial resolution of ~3μm was achieved by aperturing magnified images of the reflected and transmitted probe beam at the target interaction region.

The time resolved reflectivity signal indicates a sharp reflectivity increase upon plasma formation, followed by two distinct relaxation times. The initial (~100fs) reflectivity drop is associated with electron conduction to the bulk target, lowering the surface plasma temperature and density. The second reflectivity relaxation appears coincident with expected significant hydrodynamic expansion and has a timescale comparable to this expansion. Simulations integrating beam propagation and the LASNEX hydrodynamic plasma code point to these correlations. The experimental electron conduction signal is not seen at intensities $<10^{16} W/cm^2$ or in impure forms of SiO_2-based materials. In both cases, a smaller temperature gradient reduces the reflectivity signature for electron conduction below reflectivity losses due to hydrodynamic expansion.

[1] R. M. More, , Lawrence Livermore National Laboratory, (1993).

[2] W. E. White, H. Nathel, W. Tulloch, *et al.*, in *American Physical Society: Division of Plasma Physics Annual Meeting* (American Physical Society, Cincinnati, Ohio, 1990).

Dynamics of Femtosecond-Laser-Pulse-Produced Plasmas in Transparent Solids by Electron Thermal Transport

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We present the first direct evidence for a supersonically moving steep ionization front in a solid density hot plasma. The plasma was produced by irradiating a transparent solid target with 100fsec. laser pulses at a peak intensity of $5\times10^{14}W/cm^2$. Time-resolved measurements of reflectivity, transmissivity and frequency shift of a probe light, incident on the rear of the plasma or solid-plasma interface, showed rapid formation of an overdense plasma layer with a long-lived (~15ps) steep gradient that penetrates supersonically into the bulk target.[1] In addition, when compared to the measurements taken with another probe light, incident on the front of the plasma or vacuum-plasma interface, the results show that plasma cooling by hydrodynamic expansion is small, and that cooling by electron thermal conduction into the underlying colder region behind the target surface is more important.[2] Calculations using a simple nonlinear heat wave model, driven by electron thermal transport, show good agreement with the experimental results.

1. B.-T. V. Vu, A. Szoke & O. L. Landen, Phys. Rev. Lett., 72, 3823, (1994).
2. B.-T. V. Vu, O. L. Landen & A. Szoke, to be published in J. Physics of Plasma, Feb., 1995.

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

X-ray spectrum by femtosecond laser-produced plasma from periodically modulated targets

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The generation of ultra-bright and ultra fast x-ray pulses is a challenge in the study of physics of high density and high temperature plasmas. To obtain a high x-ray yield above the keV it is necessary to increase the laser absorption. One way is to take advantage of grating targets to convert the incoming transverse laser radiation into surface plasmon modes. When the phase matching between the diffracted laser light and the surface wave occur the laser light is converted into surface wave. These can be obtain by tuning the angle of the incident beam with respect to the grating target.

We have studied the x-ray emission above one keV from the laser-produced plasma on periodically modulated surface targets. Gratings were irradiated by a 120 fs, 25 mJ Ti:Sapphire laser λ~800nm at intensities 5 10^{16} W/cm^2 The laser contrast was optimised and measured to be 10^{-6}. X-ray spectrum of the He-like and Li-like satellites of silicon were spectrally dispersed by a Von hamos spectrometer and recorded on a cooled CCD array. The spectrum was recorded as a function of incidence angle and laser polarisation. Spectra obtain on flat targets and with longer pulses wen also recorded.

Results show clearly a resonance of the X-ray output with the incidence angle on the grating target. Electron densities are largely above 2 10^{23} cm^{-3}, as inferred from the widths of the K-shell lines. Comparison of spectra for different pulse durations (1ps-100fs) shows a large difference due to the hydrodynamic motion occurring during the longer pulse.

Depending of the plasma scale length the surface wave can be strongly coupled with the electrostatic wave at critical density. The use of two-dimensional particle-in-cell (PIC) simulations shows the importance of wave breaking on the damping of the generated resonance and surface plasma waves.Results from these simulations and detailed analysis of the spectra will be presented at the Conference.

25th Annual Anomalous Absorption Conference, Aspen, CO, 27 May – 1 June 1995

Observation of Relativistic Quiver Effects and Multiphoton Compton Scattering during High-Intensity Laser-Electron Interactions

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ABSTRACT

Laser-electron scattering has been measured during the interaction of a high-intensity laser (~10^{18} W/cm^2) with low-energy electrons ($\gamma \sim 1$). The electrons are born in the focus by field ionization of noble gas atoms. They gain energy due to their quiver motion and initial canonical momentum. In addition, the electrons gain momentum in the $\vec{k}$-direction due to conservation of momentum. The perpendicular and parallel momenta are related by[1]

$$p_z = \frac{p_\perp^2}{2m_0c}. \quad (1)$$

The angle of the ejected electron relative to the wave vector of the laser(θ) depends on the final electron energy γmc^2 as

$$\tan\theta = \sqrt{\frac{2}{\gamma - 1}}. \quad (2)$$

The effect of the ponderomotive gradient is to transform the quiver energy to directed kinetic energy.

The energy and angular distributions of electrons with energies up to 175 keV have been measured. The highest-energy electrons are ejected from the focus with an angle of ~70° from the $\vec{k}$-direction. To match the observed spectra, calculations of the electron trajectory must include relativistic quiver effects.

1. P. B. Corkum, N. H. Burnett, and F. Brunel, in *Atoms in Intense Fields*, edited by M. Gavrila (Academic Press, New York, 1992), p. 109.

Abstract Submitted for an Oral Presentation at the
25^{th} Anomalous Absorption Conference
The Aspen Institute, Aspen, Colorado, 27 May - 1 Jun 1995

Hose–Modulation Instability of Laser Pulses in Plasmas

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Ultrahigh accelerating fields (≥ 10 GV/m) can be generated in the laser wakefield accelerator (LWFA) by propagating a short (≤ 1 ps), high intensity ($\geq 10^{18}$ W/cm^2) laser pulse through a plasma. Diffraction is the most severe constraint on pulse propagation. Diffraction can be prevented by relativistic and/or density channel guiding. Optically guided laser pulses can undergo a combination of self–modulation[1,2] and laser–hose instabilities.[3,4] Strong self–modulation occurs when the pulse power is above the guiding threshold and when the pulse length is long compared to a plasma wavelength, λ_p. This can result in a fully–modulated (at λ_p) laser pulse and a resonantly excited, large amplitude wakefield. Self–modulation can serve as the basis for a LWFA, in which enhanced acceleration (> 100 GeV/m) is achieved.[5,6] A laser–hose instability, or a kinking of the pulse centroid, can result if the pulse centroid has an initial tilt, i.e., a head to tail centroid displacement with respect to the propagation direction. The hose–modulation instability can exist in an initially uniform plasma or in a preformed plasma density channel. Coupled equations for the laser centroid and envelope are derived and solved for a finite–length laser pulse.[4] Significant coupling between the centroid and the envelope, harmonic generation in the envelope, and strong modification of the wakefield can occur. Methods to reduce the growth of the hose instability are demonstrated.

*Supported by ONR and DOE.

[1]P. Sprangle, E. Esarey, J. Krall and G. Joyce, Phys. Rev. Lett. 69, 2200 (1992).
[2]E. Esarey, J. Krall and P. Sprangle, Phys. Rev. Lett. 72, 2887 (1994).
[3]G. Shvets and J. Wurtele, Phys. Rev. Lett. 73, 3540 (1994).
[4]P. Sprangle, J. Krall and E. Esarey, Phys. Rev. Lett. 73, 3544 (1994).
[5]J. Krall, A. Ting, E. Esarey and P. Sprangle, Phys. Rev. E 48, 2157 (1993).
[6]E. Esarey, P. Sprangle, J. Krall, A. Ting and G. Joyce, Phys. Fluids B 5, 2690 (1993).

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