24th Annual

Anomalous Absorption Conference

Asilomar Conference Center
Pacific Grove, CA
June 5-10, 1994

Book of Abstracts

CONF-9406152 Absts.

24th Annual Anomalous Absorption Conference

Asilomar Conference Center, Pacific Grove, CA — June 5-10, 1994

Chairman: Hector Baldis

Program Committee:
Bob Kauffman
Bill Kruer
Bruce Langdon
Dennis Matthews
Scott Wilks

Conference Coordinators:
Laurie J. Pinkerton
Janice E. Stevenson

Conference Schedule

24th **Annual Anomalous Absorption Conference**
June 5-10, 1994, Pacific Grove, CA USA

MONDAY AM — Parametric Instabilities I

8:30 - 8:45 **Welcome and opening comments**

8:45 - 9:00
AO 1 The Study of Parametric Instabilities in Large-Scale-Length Plasmas Produced by Laser Irradiation of Thin-Walled Gas-Balloons
B.J. MacGowan, C.A. Back, R.L. Berger, K.S. Bradley, J.D. Colvin, S.N. Dixit, D.I. Eimerl, K.G. Estabrook, B.H. Failor, M.A. Henesian, W.W. Hsing, D.H. Kalantar, R.L. Kauffman, D.E. Klem, J.A. Koch, W.L. Kruer, J.L. Miller, D.S. Montgomery, J.D. Moody, D.H. Munro, T.J. Murphy, D.M. Pennington, L.V. Powers, T.D. Shepard, G.F. Stone, R.J. Wallace, T.W. Weiland, R.B. Wilcox, S.C. Wilks, E.A. Williams

9:00 - 9:15
AO 2 The Temporal and Three-Dimensional Spatial Evolution of Stimulated Brillouin Scattering Aided and Abetted by Filamentation
R.L. Berger, B.F. Lasinski, B. Afeyan, B.I. Cohen, S.N. Dixit, D.I. Eimerl, K.G. Estabrook, W.W. Hsing, D. Hinkel, T. Kaiser, R.L. Kauffman, W.L. Kruer, A.B. Langdon, D.S. Montgomery, J.D. Moody, D.H. Munro, L.V. Powers, R.E. Turner, S.C. Wilks, E.A. Williams

9:15 - 9:30
AO 3 Saturation Spectra of the Two Plasmon Decay Instability and its 3/2w radiation
D.F. Dubois, D. Russell, H.A. Rose

9:30 - 9:45
AO 4 Two-Dimensional Stimulated Brillouin Scattering
C.J. McKinstrie, R. Betti, R.E. Giacone, T. Kolber, J.S. Li

9:45 - 10:00
AO 5 Experimental Studies of Ion-Acoustic Waves from Linear to Non-Linear Regime
C. Labaune, H.A. Baldis, N. Renard, E. Schifano, A. Michard, S. Baton, W. Seka, R. Barr, B. Bauer, K. Baker, P. Drake, K. Estabrook

10:00 - 10:15
AO 6 Location of Ion-Acoustic Waves Associated with SBS
H.A. Baldis, C. Labaune, E. Schifano, N. Renard, S. Baton, A. Michard, W. Seka, K. Barr, B. Bauer, K. Baker, K. Estabrook

10:15 - 10:30 **COFFEE BREAK**

10:30 - 10:45
AO 7 Laser Hot Spots and the Breakdown of Linear Instability Theory with Application to Stimulated Brillouin Scattering
H.A. Rose, D.F. DuBois

10:45 - 11:00
AO 8 Stimulated Brillouin Backscatter in Plasmas with Light and Heavy Ions
S.C. Wilks, W.L. Kruer, J. Denavit, D.E. Hinkel, E.A. Williams, K. Estabrook, R.L. Berger, A.B. Langdon

11:00 - 11:15

AO 9 Dynamics of Stimulated Brillouin Scattering and Self-Focusing Instability Driven by Gaussian Beams
W. Rozmus, V. Eliseev, V.T. Tikhonchuk, C.E. Capjak

11:15 - 11:30

AO 10 Stimulated Brillouin Scattering at 1 μm in Long-Scale-Length Laser Plasmas
A. Chirokikh, W. Seka, R.E. Bahr, R.S. Craxton, R.W. Short, A. Somon, M.D. Skeldon

11:30 - 11:45

AO 11 Saturation of Stimulated Raman Scattering by Weak Turbulence Cascading
K.L. Baker, K. Estabrook, R.P. Drake, B.B. Afeyan, K.S. Bradley

11:45 - 12:00

AO 12 Theory of Convective Saturation of Langmuir Waves during Ionospheric Modification of a Barium Cloud
M.V. Goldman, D.L. Newman, R.P. Drake, B.B. Afeyan

MONDAY PM — Review Talk

7:30 - 8:30

R 1 The Physics of Radiation Driven ICF Hohlraum and Capsules,
M.D. Rosen

8:30 - 11:00 PM — Mixed Posters

AP 1 Stimulated Brillouin Scattering in Inhomogeneous, Flowing Plasma from Backscattering to Sidescattering
B.B. Afeyan, E.A. Williams

AP 2 Shocked Witness Foam-Ball Diagnostic for Nova Hohlraum Time-Dependent Drive Asymmetry
P.A. Amendt, S.G. Glendinning, B.A. Hammel, R.G. Hay, L.J. Suter

AP 3 Narrowband SBS in a Laser-Produced Plasma with a Controlled Flow Profile
B.S. Bauer, R.P. Drake, K.G. Estabrook, T.D. Shepard, J.F. Camacho, B.B. Afeyan, R.G. Watt, G.E. Busch, S.E. Caldwell, J.A. Cobble, M. Wilke, R.B. Gibson, S.A. Baker

AP 4 Numerical and Theoretical Studies of Stimulated Brillouin Scattering and Self-Focusing Instabilities
V. Eliseev, W. Rozmus, V.T. Tikhonchuk, R. Oppitz, C.E. Capjack

AP 5 Ion Thermal Conductivity and Viscosity for Plasmas with Light and Heavy Ions
E.M. Epperlein, R.W. Short, A. Simon

AP 6 Multi-Beam Excitation of the Raman Instability in Laser Plasmas
P.N. Guzdar, R.H. Lehmberg

AP 7 Studies of Hydrodynamic Motion in Hohlraums
J.H. Gardner, S.E. Bodner

AP 8 Stimulated Brillouin Backscatter of Short-Pulse Lasers
D.E. Hinkel, E.A. Williams, R.L. Berger

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AP 9 Long-Scale-Length Plasmas Created with Low Density Foams
W.W. Hsing, N.E. Elliott, B.H. Failor, P.L. Gobby, P.G. Apen, H.X. Vu, J.M. Wallace, B.P. Wilde, K. Estabrook, D. Kalantar, B. MacGowan, D. Montgomery, T.D. Shepard

AP 10 Effect of 4-Color Beam Smoothing on Filamentation
T.B. Kaiser, B.F. Lasinski, R.L. Berger, A.B. Langdon, E.A. Williams, B.I. Cohen, S.N. Dixit

AP 11 Nova High Growth Factor Implosion Experiments : Experiments and Analysis
C.J. Keane, B.A. Hammel, O.L. Landen, R.C. Cook, T. Dittrich, S. Haan, R. Hay, J.D. Kilkenny, S.H. Langer, R.A. Lerche, W.K. Levedahl, R.L. McEachern, T. Murphy, M.B. Nelson, L.J. Suter, R.J. Wallace

AP 12 Nonlinear Effects on SBS in Multi-Ion-Species Plasmas
W.L. Kruer, S.C. Wilks, D.E. Hinkel, E.A. Williams

~~**AP 13** Beam Smoothing as Implemented in the F3D/SBS Code~~
~~*B. Langdon, R. Berger, S. Dixit, T. Kaiser, B. Lasinski,*~~ *C. Still, E. Williams*

AP 14 SBS and Filamentation in Current and Future Experiments
B.F. Lasinski, R.L. Berger, C.A. Back, B.I. Cohen, S.N. Dixit, K.G. Estabrook, D.E. Hinkel, T.B. Kaiser, R.L. Kauffman, W.L. Kruer, A.B. Langdon, B.J. MacGowan, D.S. Montgomery, L.V. Powers, T.D. Shepard, C.H. Still, R.E. Turner, S.C. Wilks, E.A. Williams

AP 15 Modeling Gold Disks Irradiated by Laser and X-Ray Sources
S.H. Langer, F. Ze

AP 16 Some Aspects of Ignition-Scale Indirect Drive ICF Targets
J.T. Larsen

~~**AP 17**~~ Kinetic Effects in the Wake of a Short Intense Laser Pulse in a Tenuous Plasma
P. Mora, T.M. Antonsen

AP 18 Opacity Measurements in Laser-Produced Strongly Coupled Plasmas
A.N. Mostovych, L.C. Chan, K.J. Kearney

AP 19 Models of the Heating and Motion of Nova Gas Bags
D.H. Munro, D.H. Kalantar

AP 20 Enhanced Low Frequency Density Fluctuations and Resulting 1/2 wo and wo Radiation from the Saturated Two Plasmon Decay Instability
D. Russell, D.F. DuBois, H.A. Rose

AP 21 Development of the Two Plasmon decay Instability in k-space of a Laser Produced Plasma and 3/2 harmonic Generation
J. Meyer, Y. Zhu, R. McKenna

AP 22 Signature of Regular and Chaotic Regimes in Saturated Stimulated Raman Scattering
M.M. Skoric, M. Jovanovic

AP 23 Hydrocode Comparisons of Direct-Drive ICF Pellets
A.J. Schmitt, D. Colombant, J.P. Dahlburg, J.H. Gardner

AP 24 Spherical, Ion Kinetic Implosions Simulations
F. Vidal, J.P. Matte, M. Casanova, O. Larroche

BP 9 Lasnex 2-D Analysis of Nova Gasbag Targets
K. Estabrook, T. Back, D. Berger, T.P. Bernat, S. Dixit, B. Failor, M. Henesian, D. Hinkel, J. Harte, W. Hsing, D. Kalantar, B. Kauffman, D. Klem, B.J. MacGowan, D. Montgomery, J. Moody, D. Munro, L.V. Powers, T.D. Shepard, B. Turner, H. Vu, J. Wallace, P. Wegner, S.C. Wilks, E.A. Williams

BP 10 Electron Kinetic Simulations of Ultra-Short, High Intensity Laser-Solid Interaction
S. Ethier, J.P. Matte, J.C. Kieffer, M. Chaker, O. Peyrusse

BP 11 Two-Dimensional Calculation of Perturbation Growth at an Internal Interface of a Plane Target
D. Galmiche, M. Macé

BP 12 Radiative Transport in Slab Geometries
D.A. Garren, M. Klapisch, J. Gardner, D. Colombant

BP 13 Laser Interaction with Expanding Coronal Plasmas
L.A. Gizzi, D. Giulietti, A. Giulietti, T. Afshar-Rad, V. Biancalana, P. Chessa, C. Danson, E. Schifano, S.M. Viana, O. Willi

BP 14 Experimental Investigation of Thermal Self-Focusing of Counter-Propagating Optical Beams in Plasma
L.S. Ingraham, K.A. Marsh, A. Lal, C. Joshi, C.J. McKinstrie

BP 15 Numerical Simulations of Two-Dimensional Stimulated Brillouin Scattering
T. Kolber, C.J. McKinstrie, R. Bettie, R.E. Giacone

BP 16 Experimental Testing of the Relative Consistency of Two Given E.O.S.
M. Koenig, B. Faral, D. Batani, A. Benuzzi, S. Bossi

BP 17 Plasma Heating from Relativistic Electron Plasma Waves
A. Lal, K. Marsh, C. Clayton, M. Everett, D. Gordon, K. Wharton, C. Joshi

BP 18 Multifluid Simulation of Exploding-Foil Collision Experiments
O. Larroche, O. Peyrusse, J.C. Gauthier, C. Chenais-Popovics, O. Rancu, P. Renaudin

BP 19 Thermal Filamentation of Counterpropagating Light Waves
J.S. Li, C.J. McKinstrie, C. Joshi, K. Marsh

BP 20 Tunable Radiation Generation Using Odd Harmonics from the Critical Surface
N.S. Lucas, W.B. Mori, S.C. Wilks

BP 21 Observation of Filamentary Structures and Whole Beam Self Focussing in the Interaction of 350Fs KrF and 12 ps Raman Shifted Laser Pulses with a Dense Gas Jet Target
A.J. Mackinnon, M.W. Jones, M. Borghesi, S. Viana, O. Willi

BP 22 Experimental Study of SBS and SRS in the Nova Gas-Target Large Plasmas
D.S. Montgomery, C.A. Back, R.L. Berger, K.S. Bradley, J.A. Cobble, S.N. Dixit, D. Eimerl, K.G. Estabrook, B.H. Failor, J.C. Fernandez, M.A. Henesian, W.W. Hsing, D.H. Kalantar, R.L. Kauffman, D.E. Klem, W.L. Kruer, B.F. Lasinski, J.L. Miller, J.D. Moody, D.H. Munro, D.M. Pennington, L.V. Powers, T.D. Shephard, G.F. Stone, R.E. Turner, R.J. Wallace, T.L. Weiland, R.B. Wilcox, S.C. Wilks, E.A. Williams

BP 23 Analysis of SRS and SBS Spectra from Nova Exploding Foil Plasmas
J.D. Moody, H.A. Baldis, D.S. Montgomery, R.L. Berger, K. Estabrook, W.L. Kruer, B. Lasinski, E.A. Williams

BP 24 Enhanced Ion Acoustic Fluctuations in Laser Produced Plasmas
W. Rozmus, V.T. Tikhonchuk, V.Yu. Bychenkov, C.E. Capjak

WEDNESDAY AM — Laser Plasma Physics with Short Pulses

8:30 - 8:45
CO 1 Accurate Measurement of the Short Scalelength Plasma Produced by a Femtosecond Laser
P. Audebert, J.P. Geindre, F. Falliès, A. Rousse, J.C. Gauthier

8:45 - 9:00
CO 2 Comparison of Picosecond Laser-Plasma Physics in Different Microstructured Targets
F. Budnik, G. Kulcs‡r, L. Zhao, R. Majoribanks, P. Herman, D. AlMawlawi, M. Moskovits

9:00 - 9:15
CO 3 Laser Pulse Erosion and Local Pump Depletion at Ultra-High Laser Intensities
C.D. Decker, W.B. Mori, K.C. Tzeng

Hydrodynamic Simulations of Femtosecond Laser-Produced Plasmas
F. Falliès, P. Audebert, J.P. Geindre, A. Rousse, J.C. Gauthier

9:30 - 9:45
CO 5 X-Ray and Electron Sources from Femtosecond Laser-Produced Plasmas
J.C. Gauthier, A. Rousse, P. Audebert, J.P. Geindre, F. Falliès, A. Mysyrowicz, G. Grillon, A. Antonetti

9:45 - 10:00
CO 6 Interaction of a 35TW, 800Fs, 1μm CPA Laser with Dense Gas Jet Targets
A.J. Mackinnon, A. Iwase, O. Willi, B. Walsh

10:00 - 10:15
CO 7 An X-Ray Laser Target for the Petawatt Laser
S. Maxon, S. Dalhed, E. Alley, A. Osterheld, R. London

10:15 - 10:30 **COFFEE BREAK**

10:30 - 10:45
CO 8 Flux Limiter in Picosecond Laser-Plasma Interactions
D.D. Meyerhofer, H. Chen, J.A. Delettrez, E.M. Epperlein, Y. Fisher, B. Soom

10:45 - 11:00
CO 9 Interaction of Femtosecond Laser Pulses with High Pressure Gas Jets
C. Stenz, F. Blasco, F. Amiranoff, V. Malka, E. DeWispelaere, R. Bonadio, P. Audebert, J.P. Geindre, J.C. Gauthier, A. Dos Santos, G. Rey, A. Mysyrowicz, A. Antonetti

11:00 - 11:15
CO 10 Stimulated Raman and Brillouin Backscattering Driven by a 500-Fs Laser Pulse in a Preformed Underdense Plasma
C. Rousseaux, G. Malka, J.L. Miquel, F. Amiranoff, S.D. Baton, Ph. Mounaix

11:15 - 11:30
CO 11 Fokker-Planck Simulations of Short Pulse Laser-Solid Experiments
R.P.J. Town, A.R. Bell, S.J. Rose

11:30 - 11:45

CO 12 Experimental Investigation of the Heat Propagation in Hot Dense Plasmas Produced by the Interaction of a 12 Picosecond Laser Pulse with Solid Targets

S.M. Viana, A. Bell, L.A. Gizzi, A.J. MacKinnon, D. Riley, O. Willi

11:45 - 12:00

CO 13 Bright Picosecond Thermal Continuum X-Rays from Intense Sub-Picosecond Laser-Plasma Interactions

J. Workman, A. Maksimchuk, U. Ellenberger, X. Liu, S. Coe, C.-Y. Chien, D. Umstadter

WEDNESDAY PM — Banquet

7:00 - 10:00 PM **Monterey Bay Aquarium**

THURSDAY AM — Rayleigh Taylor Instability & Hydrodynamics

8:30 - 8:45

DO 1 Imprinting of Laser Nonuniformities with 0.35 and 0.53 mm Drive

S.G. Glendinning, S.V. Weber, S.N. Dixit, M.A. Henesian, J.D. Kilkenny, D.M. Pennington, R.J. Wallace, J.P. Knauer, C.P. Verdon

8:45 - 9:00

DO 2 Bubble-Competition Model for Hydrodynamically Unstable Interfaces

U. Alon, J. Hecht, D. Ofer, D. Mukamel, D. Shvarts

9:00 - 9:15

DO 3 Multiple Cutoff Wave Numbers of the Ablative Rayleigh-Taylor Instability

R. Betti, V. Goncharov, R.L. McCrory, E. Turano, C.P. Verdon

9:15 - 9:30

DO 4 Hydrodynamic Aspects of the Radiative Condensation Instability in Ablating, Laser-Produced Plasmas

J.P. Dahlburg, M. Klapisch, J.H. Gardner, A.J. Schmitt, A. Bar-Shalom

9:30 - 9:45

DO 5 An Interactive Mix Model in LILAC for Linear and Near-Linear Regimes of the Rayleigh-Taylor Instability

J.A. Delettrez

9:45 - 10:00

DO 6 Oblique Shocks and Instabilities in Inertial-Confinement Fusion

A.J. Sierk

10:00 - 10:15

DO 7 A Modal Model for the Nonlinear Evolution of Multimode Rayleigh-Taylor Mixing Zone

D. Ofer, U. Alon, D. Shvarts, C.P. Verdon, R.L. McCrory

10:15 - 10:30 **COFFEE BREAK**

10:30 - 10:45

DO 8 Simulations of Soft X-Ray Generated Plasmas Created to Enhance Thermal Smoothing

R.S. Craxton, M. Dunne, O. Willi, T. Afshar-Rad

Nonlocal Electron Transport in the Presence of High-Intensity Laser Irradiation
E.M. Epperlein, R.W. Short

Smoothing of Laser Irradiation of ICF Targets using Pre-Formed Refracting Atmosphere with Small-Scale Inhomogeneity and Time Dependence
R. Epstei , S. Skupsky, C.P. Verdon

11:15 - 11:30
DO 11 Three Dimensional Simulations of Laser Driven ICF Target Implosions
B.J. Jones, R.P.J. Town, A.R. Bell

11:30 - 11:45
DO 12 Generalized Fluid Equations for Laser-Irradiated Plasmas
R.W. Short, E.M. Epperlein

11:45 - 12:00
DO 13 Three-Dimensional Simulation of the Late Nonlinear Stage of the Rayleigh-Taylor Instability
J. Hecht, D. Ofer, U. Alon, T. Tlusty, D. Shvarts, C.P. Verdon, R.L. McCrory, S.A. Orszag

THURSDAY PM — Review and Panel Discussion

7:30 - 9:00
R 3 Control of Laser Plasma Instabilities in NIF
D. Dubois

9:00 - 11:00 PM — Mixed Posters & Post Deadline Papers

DP 1 Parametric Instabilities Near Daughter Wave Turning Points : Two Generalizations of the Rosenbluth Gain Formula
B.B. Afeyan, M.V. Goldman

DP 2 2-D Calculations of Instability Growth and Mode Coupling in Convergent Geometry with Mesa
J.B. Beck, N.M. Hoffman

DP 3 Heat Flux Driven Ion Acoustic Instability
V.Yu. Bychenkov, J. Myatt, W. Rozmus, V.T. Tikhonchuk

DP 4 k- a PC and Mac code to Analyze SBS, SRS and Filamentation
K. Estabrook, P.E. Young, E.A. Williams, D.S. Montgomery, P.J. Wegner, M.A. Henesian

DP 5 Effect of Self-Generated Magnetic Fields on Suprathermal electron transport
M.E. Glinsky, M. Tabak, R.J. Mason

DP 6 Angular Dependence of Absorption by Plasmas Heated by Picosecond KrF Laser Pulses
P.A. Naik, Y.Y. Tsui, R. Fedosejevs

DP 7 Preliminary Spectroscopic Analysis of Core Temperature, Density, and Mix Structure for High-Growth-Factor (HEP4) Capsule Implosions
G.D. Pollak

DP 8 Design and Analysis of Nova Gas-Filled Hohlraum Experiments
L.V. Powers, C.A. Back, R.L. Berger, D.H. Kalantar, R.L. Kauffman, B.F. Lasinski, D.S. Montgomery, D.H. Munro, T.D. Shepard, G.F. Stone, R.E. Turner, E.A. Williams

→ A 13

DP 9 Faraday Rotation on Brillouin and Raman Scattering
M. Tabak, K. Estabrook

DP 10 Numerical Modeling of Plasmas Heated by Picosecond KrF Laser Pulses
Y.Y. Tsui, R. Fedosejevs, C. Kan, C.E. Capjack, R. Rankin, V.T. Tikhonchuk, W. Rozmus

DP 11 An Analytical and Numerical Investigation of Ion Acoustic Waves in a Two-Ion Plasma
H.X. Vu, J.M. Wallace, B. Bezzerides

DP 12 SBS in Multi-Species Plasmas
E.A. Williams, R.L. Berger

DP 13 Argon/Chlorine Spectroscopy in Plasmas Produced by Laser Irradiation of Thin Walled Gas Filled Balloon Targets
D.E. Klem, C.A. Back, B.H. Failor, W.W. Hsing, D.H. Kalantar, J.A. Koch, B.J. MacGowan, D.S. Montgomery, J.D. Moody, D.H. Munro, T.D. Shepard, G. F.Stone

DP 14 A DC to AC Converter for Light
W.B. Mori, J.M. Dawson, T. Katsouleas, C.H. Lai

DP 15 Diagrammatic Approach to Laser-Plasma Interactions
G. Shvets, J.S. Wurtele

DP 16 Studies of Laser Light Coversion into X-rays
B.N. Basylev, V.V. Gavrilov, A.Yu.Goltsov, I.A. Kargin, N.G. Kovalsky, G.S. Romanov, V.I. Tolkach

FRIDAY AM — Parametric Instabilities II et cætera

1 Leaky Pulsating Filaments : a Paradigm?
F. Vidal, T.W. Johnston

8:45 - 9:00
EO 2 Evolution of Stimulated Raman into Compton Scattering through Wave-Breaking in a Tunnel-Ionized Plasma
M.J. Everett, C.E. Clayton, A. Lai, D. Gordon, W. Mori, C. Joshi

9:00 - 9:15
EO 3 Theory of Ion Acoustic Waves in Equilibrium Plasmas
V.T. Tikhonchuk, V.Yu. Bychenkov, J. Myatt, W. Rozmus

9:15 - 9:30
EO 4 The Search for Ion Plasma Waves
R.P. Drake, B.S. Bauer, K. Estabrook

→ A012

9:30 - 9:45
EO 5 Direct Measurements of Ion Acoustic Decay Instabilities (IADI) in a Hot, Large Scale Plasma Relevant to Laser Fusion
K. Mizuno, R. Bahr, B. Bauer, S. Craxton, J. DeGroot, R. Drake, K. Narihara, W. Seka, B. Sleaford

9:45 - 10:00

EO 6 Spectroscopic Characterization of Laser-Produced High Temperature (3 kev) Plasmas for the Study of Parametric Instabilities

B.H. Failor, P.G. Apen, N.E. Elliott, J.C. Fernandez, P.L. Gobby, R.G. Hockaday, W.W. Hsing, D.H. Kalantar, D.E. Klem, B.J. MacGowan, T.D. Shepard, G.F. Stone

10:00 - 10:15 **COFFEE BREAK**

10:15 - 10:30

EO 7 High-Power Laser Irradiation of Under-Dense Silicon Aerogel and Agar Foam Targets : Time-Resolved Imaging and Spectroscopy

J.A. Koch, C.A. Back, J.D. Bauer, R.C. Cook, L.B. DaSilva, K.G. Estabrook, E.J. Hsieh, D. Kalantar, L. Klein, B.J. MacGowan, R. Managan, J.D. Moody, J.C. Moreno, C. Rosenkilde, R.W. Lee

10:30 - 10:45

EO 8 Stimulated Scattering from Low-Frequency Modes in Laser-Produced Magneto-Plasmas

A. Simon, R.W. Short

10:45 - 11:00

EO 9 Four-color Laser Irradiation System with SSD for Laser-Plasma Interaction Experiments at Nova

D. Eimerl, D. Pennington, R. Wilcox, M. Henesian, T. Weiland, C. Laumann, H. Powell

The study of parametric instabilities in large-scale-length plasmas produced by laser irradiation of thin-walled gas-balloons*

B.J. MacGowan, C.A. Back, R.L. Berger, K.S. Bradley, J.D. Colvin, S.N. Dixit, D.I. Eimerl, K.G. Estabrook, B.H. Failor†, M.A. Henesian, W.W. Hsing†, D.H. Kalantar, R.L. Kauffman, D.E. Klem, J.A. Koch, W.L. Kruer, J.L. Miller, D.S. Montgomery, J.D. Moody, D.H. Munro, T.J. Murphy, D.M. Pennington, L.V. Powers, T.D. Shepard, G.F. Stone, R.J. Wallace, T.W. Weiland, R.B. Wilcox, S.C. Wilks, and E.A. Williams

Lawrence Livermore National Laboratory, University of California, L-447 P.O. Box 808, Livermore, California 94550, U.S.A.
†Los Alamos National Laboratory, University of California, Los Alamos New Mexico 87545, U.S.A.

We have produced and characterized homogeneous, mm-scale plasmas of high-density and temperature. These plasmas allow us to study parametric instabilities in long-scale-length plasmas similar to those expected in the proposed National Ignition Facility (NIF). The plasmas are created by symmetrically irradiating a 3 mm diameter, thin-walled gas balloon containing of order 1 atmosphere of a low-Z gas (e.g. C_5H_{12}, C_5D_{12} or CO_2). These plasmas, produced in an open geometry, are intended to complement those produced within gas-filled hohlraums, which are described elsewhere at this meeting. When the gas is ionized and heated, it becomes a plasma which is homogeneous, of high density (~10^{21} electrons/cm^3) and temperature (~ 2-4 keV), with large density and velocity gradient scale lengths (~2 mm and ~20 mm respectively). Nine of the NOVA beams are used to produce the plasma, the tenth beam is configured as an interaction beam. The SRS and SBS scattered from the plasma was studied as a function of the interaction beam f/number, intensity, beam smoothing and plasma constituents. The high levels (>30%) of SBS, that have been observed in some experiments, were reduced to insignificant levels (<0.3%) with beam smoothing or by modification of ion Landau damping through choice of target material or doping with hydrogen. The interaction beam was smoothed by using combinations of random phase plates, SSD, and four different colors within the f/8 beam, to mimic the NIF laser architecture. The production and characterization of these plasmas together with the observations and interpretation of the SBS and SRS spectra and reflected power will be presented.

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

The Temporal and Three-dimensional Spatial Evolution of Stimulated Brillouin Scattering Aided and Abetted by Filamentation*

R. L. Berger, B.F. Lasinski, B. Afeyan, B. I. Cohen, S.N. Dixit, D.I. Eimerl, K.G. Estabrook, W.W. Hsing†, D. Hinkel, T. Kaiser, R. L. Kauffman, W. L. Kruer, A. B. Langdon, D.S. Montgomery, J.D. Moody, D.H. Munro, L.V. Powers, R. E. Turner, S.C. Wilks, and E.A. Williams #
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We have constructed a three-dimensional code (F3D) to study the interaction of stimulated Brilouin back scattering and filamentation instabilities driven by laser beams that have large but statistically well-understood nonuniformitiy, e.g. at the focal plane of a laser with random phase plates (RPP). In support of experiments at LLNL with the Nova laser (and reported at this conference) in which the electron density is nearly 1/10 critical ($\sim 10^{21}$ cm^{-3}), the electron temperature is $T_e \sim 3$ keV, and nearly constant over 1-2mm, we have studied the behavior of this competition and collaboration between instabilities as a function of laser intensity, laser f-number, ion acoustic damping rate, and plasma size. The effects of laser beam smoothing produced with SSD or 4-colors (this latter scheme will be explained at the meeting) are also examined. Since the length of the hot spots in laser beam focal plane is larger than the filamentation growth length for higher intensities or f-numbers, filamentation is vigorous unless SBS depletes the laser intensity. Use of temporal smoothing surpresses filamentation.

The level of SBS is calculated to increase with f-number even if filaments are not unstable. However, temporal smoothing schemes with modest amounts of bandwidth are also calculated to be effective in controlling the level of SBS. The levels of SBS, given estimated gains from Lasnex and experimentally determined plasma parameters, are calculated to be larger than observed, especially in hydrogen-rich plasmas, which suggests the existence of a powerful nonlinear saturation mechanism(s)

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† Los Alamos National Laboratory

many others (unmemtioned) from LANL and LLNL contributed to the design and execution of the experiment, to the interpretation, and to theoretical concepts.

SATURATION SPECTRA OF THE TWO PLASMON DECAY INSTABILITY AND ITS $3/2\omega_0$ RADIATION*

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A reduced nonlinear model of the two plasmon decay instability has been solved using spectral methods in two dimensions for a homogeneous plasma. The model includes collisional and Landau damping of Langmuir waves, secondary Langmuir decay, ponderomotive density modification, scattering of Langmuir waves on ion acoustic waves and Langmuir collapse. These results are applicable to the recent experiments of Meyer and Zhu(1), which involved a long scale length plasma whose density scale length is large compared to the induced Langmuir turbulence correlation lengths. The spectral distribution of electron density fluctuation, $<|n_e(\underline{k})|^2>$, can be compared to the experimental Thomson scatter spectra. The spectrum is enriched beyond the linearly unstable modes and contains modes due to secondary Langmuir decay and collapse, depending on the local background density. The $3/2\omega_0$ light can couple directly and locally to these nonlinearly excited modes. The angular dependence and power spectra of the computed $3/2\omega_0$ light compare well with observations. Agreement between theory and experiment is obtained by assuming a slowly varying (parabolic) density profile in which the spectra from various densities add incoherently.

(1) J. Meyer and Y. Zhu, Phys. Rev. Lett. 71, 2915 (1993)

*An oral presentation for the 24th Annual Anomalous Absorption Conference, Asilomar Conference Center, Pacific Grove, CA, June 5-10, 1994

Research supported by the U.S. D.O.E.

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

TWO-DIMENSIONAL STIMULATED BRILLOUIN SCATTERING

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The evolution of the stimulated Brillouin scattering (SBS) instability, in time and two spatial dimensions, is studied analytically and numerically. The inhomogeneities of a typical inertial confinement fusion plasma complicate the analysis of SBS considerably. However, as the main effect of these inhomogeneities is to limit the region over which SBS occurs, the interaction region can be modeled as a homogeneous slab whose dimensions are chosen with the true plasma inhomogeneities in mind. This simplification facilitates the study of two-dimensional effects, about which little is known.

An exact solution of the linearized equations governing SBS in a homogeneous plasma[1] shows that this two-dimensional instability usually saturates because of the convection of the ion-acoustic wave, regardless of whether the associated one-dimensional interaction is convectively or absolutely unstable. The steady-state intensity profile of the Stokes light wave is often highly two-dimensional, and the spatially averaged Stokes output is often much less than that predicted by the associated one-dimensional model.

1. C. J. McKinstrie, R. Betti, R. E. Giacone, T. Kolber, and J. S. Li, submitted to Phys. Rev. Lett.

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

Prefer Oral Presentation before T. Kolber's Poster Presentation

24^{th} **Anomalous Absorption Conference**
Monterey CA, 6-10 June 1994

Experimental studies of ion-acoustic waves from linear to non-linear regime

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W. Seka, R. Barr *(Laboratory for Laser Energetics, Rochester, USA)*
B. Bauer, K. Baker, P. Drake *(Plasma Physics Research Institute, Livermore, USA)*
K. Estabrook *(Lawrence Livermore National Laboratory, USA)*

We have measured time-resolved spectra and wave-numbers of ion-acoustic waves by using Thomson scattering in a multiple beam experiment. These waves are excited by the interaction between a 1.053µm beam and a preformed plasma. The geometry of the diagnostic was designed to collect the scattered light from ion-acoustic waves associated with Stimulated Brillouin Backscattering.

The plasma was created and heated by three 0.53µm beams focused through Random Phase Plates on mass-limited targets. It was characterized using time-resolved Raman spectra from the heating beam and thermal Thomson scattering from a 0.35µm probe beam. The timing between the different beams was chosen as to have a maximum electron density of less than the quarter-critical density. The Raman spectra showed that the top of the density profile decreased from 16% to 8% of critical density during the interaction pulse. The temperature of the preformed plasma was around 0.5 keV before interaction. Hydrodynamics simulations indicate that some heating occurs due to the interaction beam.

The Thomson scattering ion-acoustic waves spectra show a strong modification when increasing the interaction laser intensity from 10^{13} to 10^{14} W/cm^2. At low laser intensities, the Thomson scattered light shows a frequency spectrum and a wave-number spectrum with values as expected from an ion-acoustic wave excited by SBS. At intensities higher than 2×10^{13} W/cm^2, a new, intense broad component is observed which is red-shifted by a few times the ion-acoustic wave frequency and with a wide wave-number spectra. The ion-acoustic waves observed at high intensities do not fall within the normal dispersion equation, and can provide informations on the non linear processes taking place.

24th Anomalous Absorption Conference
Monterey CA, 6-10 June 1994

Location of ion-acoustic waves associated with SBS

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K. Estabrook *(Lawrence Livermore National Laboratory, USA)*

The location and temporal evolution of ion acoustic waves associated with stimulated Brillouin scattering (SBS) have been studied with the aid of Thomson scattering (TS). The experimental configuration is the same as in the previous paper, where a preformed plasma was produced by exploding a thin CH disk target by using 2ω light, followed by an interaction beam at 1ω and a TS probe at 3ω. An image of the plasma along the direction of the interaction beam was formed at the entrance of a streak camera, thus permitting to obtain space and time resolved information on the location of the ion acoustic waves.

The combination of space resolved TS and backscattered spectra of SBS has permitted to confirm the Doppler nature of the shifts observed on the backscattered light, using numerical simulations to infer the flow velocities. At low pump intensities ($8x10^{12}$ W/cm^2) the SBS spectral shift is in agreement with the expected ion acoustic shift for the plasma conditions of the experiment. At this pump intensity the summit of the parabolic electron density profile is the most favorable location for the instability to grow. At higher pump intensities the spectrum becomes blue and the localization of growth shifts away from the centre. The change in location of SBS at higher laser intensities ($1x10^{14}$ W/cm^2) indicates the need to invoke more than linear processes in order to account for the development of the instability.

Laser Hot Spots and the Breakdown of Linear Instability Theory With Application to Stimulated Brillouin Scattering*

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Convective instabilities in the strongly damped regime are shown to exhibit essential nonlinear behavior due to random phase plate (RPP) induced laser hot spots when the average laser intensity, $\langle I \rangle$, approaches a critical threshold value, I_c. The onset of this nonlinear regime is mathematically signaled by the divergence of the average convective amplification, $\langle A \rangle$ as $\langle I \rangle \rightarrow I_c$. An independent hot spot model of random phase plate (RPP) optics predicts that $\langle A \rangle \sim 1/(I_c - \langle I \rangle)^2$. This is a valid model if the instability interaction length, L_{int} is not large compared to a hot spot length. Alternatively, at fixed $\langle I \rangle$, there is a critical value of L_{int} at which $\langle A \rangle$ diverges. For interaction lengths not small compared to a speckle length, $I_c \sim \sqrt{\nu_i}/F$, where ν_i is the dimensionless acoustic damping coefficient and F is the optic f/#.

Physically, there is no divergence[1] but the onset of intrinsically nonlinear SBS behavior. In principle, if the average laser intensity could be finely controlled, and the SBS source were very small so that nonlinear effects are suppressed as $\langle I \rangle \rightarrow I_c$, then in this limit large fluctuations would be observed in the SBS reflectivity because fluctuations in the plasma density along the ray paths of the RPP beamlets will change the relative beamlet-beamlet phase differences, which is equivalent to sampling different members of the mathematical RPP ensemble.

A saturated hot spot model of nonlinear SBS predicts a rapid turn on and saturation of SBS reflectivity with laser intensity and optic f-number.

*Research supported by USDOE

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[1]In the strictly linear regime the limit of an infinite number of RPP elements must be taken to obtain divergence. Very large amplification fluctuations are observed, however, for the order of 10^3 elements.

STIMULATED BRILLOUIN BACKSCATTER IN PLASMAS WITH LIGHT AND HEAVY IONS*

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A particle ion, fluid electron simulation code is used to investigate Stimulated Brillouin Backscattering of laser light when more than one species of ions is present. Recent mixed species experiments using the NOVA laser have shown relatively high levels of SBS from CO_2 plasmas with $3\omega_0$ light pumps at intensities of 1-4 x 10^{15} W/cm^2. When a hydrogen containing gas (propane) is mixed with the CO_2, in a ratio of about 30% H to 70% CO_2 for example, a dramatic decrease in the SBS reflectivity is observed. Simulation results will be presented that agree with the general trends seen in these experiments. These simulation results allow us to study saturation mechanisms that may be present in the experiments. In particular, collisionless nonlinear saturation mechanisms are well modeled with this ion particle code. For example, the effect of a self-consistently evolved non-Maxwellian ion distribution (for the light ions) on the ion wave amplitude can be observed in detail. We also discuss linear and nonlinear mechanisms for the dependence of SBS on plasma composition, as well as the role collisions play in preserving a Maxwelian ion distribution.

*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore

Dynamics of Stimulated Brillouin Scattering and Self-Focusing Instability Driven by Gaussian Beams

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We have modified our 2D model of laser driven ion wave scattering instabilities [1] to account for a proper 3D Gaussian geometry of the interacting laser beam. We do not assume a paraxial optics approximation and our studies are relevant to interaction processes in a single laser hot spot. They emphasize plasma channel formation, and the interaction between stimulated Brillouin scattering (SBS) and filamentation or self-focusing instabilites.

For the case of a homogeneous background plasma, laser pump induced density inhomogenities play an important role in saturation of SBS. In such plasmas, the stationary SBS gain always predicts the dominance of scattering over self-focusing [2]. However, for a focusing optics f-number <10, and during initial temporal evolution of SBS, fast developing self-focusing can effectively compete with backward scattering, even in the high SBS gain regime. This results in intense hot spots and corresponding density modifications which scatter the laser light in the forward direction. The angular width of this scattered light violates paraxial optics approximation.

[1] M. R. Amin, C. E. Capjack, P. Frycz, W. Rozmus, and V. T. Tikhonchuk, Phys. Rev. Lett. **71**, 81 (1993); Phys. Fluids B **5**, 3748 (1993).
[2] H. A. Rose, D. F. DuBois, *Laser Hot Spots and the Breakdown of Linear Instability Theory with Application to SBS*, Phys. Rev. Lett., 1994.

* *On leave from General Physics Institute, Russian Academy of Sciences, Moscow 117924, Russia.*
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24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

STIMULATED BRILLOUIN SCATTERING AT 1 μm IN LONG-SCALE-LENGTH LASER PLASMAS

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Using long-scale-length plasmas generated by multiple-beam irradiation of mass-limited flat targets, we have investigated stimulated Brillouin backscattering at λ_L = 1.054 μm. We have observed 3% to 6% time-integrated, backscattered SBS light. The time-resolved SBS spectra show predominantly blue-shifted signals, which we interpret as originating from the near side of the expanding thin-foil targets. The spectra also include some fine structures whose wavelengths shift toward the blue with time.

We have modeled these time-resolved spectra using standard SBS theory with input provided by two-dimensional hydrodynamic simulations using the Eulerian code *SAGE*. The intensities used for these simulations were obtained from the spatially averaged speckle pattern of the distributed phase plates in accord with the theory developed by B. Ya. Zel'dovich for SBS scattering in nonlinear optics. This theory appears more appropriate than the more standard approach of treating SBS in individual speckles.

The model predictions agree rather well in overall time-resolved spectral shapes and the magnitudes of the time-integrated SBS backscattered signal. The observed fine structure is not observed in these model calculations.

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

Prefer Oral Presentation

Saturation of Stimulated Raman Scattering by weak turbulence cascading.*

K.L. Baker[1,2,3], K. Estabrook[3], R.P. Drake[2,3], and B.B. Afeyan[2,3]
University of California at Davis[1], Plasma Physics Research Institute[2], and the Lawrence Livermore National Laboratory[3].
K.S. Bradley
Los Alamos National Laboratory

The effect of daughter wave cascading on the saturation of Stimulated Raman Scattering is examined. In particular, the amplitude of the daughter electron plasma wave is calculated such that it can in turn become the pump driving a secondary decay process. The reflectivity level necessary to produce an electron plasma wave with the required amplitude is then calculated. The secondary process can then be viewed as an additional damping mechanism on the primary process providing a means for its saturation.

*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.

THEORY OF CONVECTIVE SATURATION OF LANGMUIR WAVES DURING IONOSPHERIC MODIFICATION OF A BARIUM CLOUD.

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University of Colorado at Boulder

R.P. Drake and B.B. Afeyan

Lawrence Livermore National Laboratories

In recent experiments by Djuth, et al[1], a parametric electron-ion decay instability was excited by an ordinary-wave HF pump during an ionospheric chemical release from a rocket over Arecibo, PR, which created an artifical "Barium ionosphere," with peak plasma frequency above the pump frequency. At least one notable feature make this experiment relevant to the laser-plasma community. An initialy steep density gradient was produced in the ionized Barium — scaling more like the gradients in laser-produced plasmas than in the ambient ionosphere. Near the critical point, the pump electric field is approximately parallel to the weak geomagnetic field , as is the flow. The simplest geometry results when the measured density gradient is also assumed to lie along the magnetic axis.

Simultaneous incoherent scattering measurements reveal a strong initial asymmetry in the amplitudes of almost vertically upgoing versus downgoing measured plasma waves. The measured wave amplitudes eventually equalized, as the density gradient slowly relaxed.

We have attempted to explain this asymmetry in terms of linear convective saturation of parametrically unstable plasma waves originating from a range of altitudes. The relevant unstable waves at each altitude are those whose wavevectors evolve into that of the measured plasma wave after propagation, according to geometric optics. The measured downgoing wave receives contributions from downgoing waves amplified as they descend from above, as well as from upgoing waves which are amplified both before and after reflection. The measured upgoing wave, on the other hand, can only receive contributions from a range of lower altitudes determined by Landau damping. Hence, the measured downgoing wave is expected to be larger than the upgoing wave.

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[1] F.T. Djuth, M.P. Sulzer, J.H. Elder, and K.M. Groves, *The CRRES AA-2 Release; HF Wave-Plasma Interactions in a Dense BA+ Cloud,* submitted to Journal of Geophysical Research, December, 1993.

Review Talk 1

— preheat above pure Fermi degen. for stability.

The Physics of Radiation Driven ICF Hohlraum and Capsules

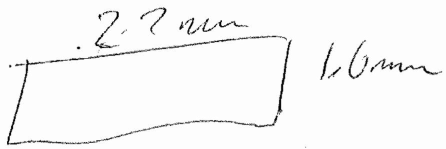
Electrons have most of the energy, + Radiation does most of the flux.

Rosseland MFP.

M.D. Rosen

$C_v \sim T^{1/2}$ from $Z^2 \sim T$ for ionization

$\sim T^{-3/2}$



Hohlraums

get

stabilization.

$\dot{m} = I / C_s^2$

hydro eff.

$L_{map} = \frac{P}{\dot{m}} \ln(x)$

$= C_s \ln(x)$

Poster Session 1

Stimulated Brillouin Scattering in Inhomogeneous, Flowing Plasma From Backscattering to Sidescattering †

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Lawrence Livermore National Laboratory

Stimulated Brillouin Scattering (SBS) in an inhomogeneous plasma but in the absence of an inhomogeneous flow profile is a convective instability with a gain coefficient that has recently been calculated from back to sidescattering by Afeyan and Goldman[1]. In the presence of a flow profile gradient, Stimulated Brillouin Sidescattering (SBSS) may become an absolute instability with a temporal growth rate calculated previously by Afeyan, Estabrook, and Williams[2]. It is our aim to show how these two limits are bridged by calculating convective amplification coefficients in inhomogeneous plasmas with nonunifrom flow and studying the transition to bound state solutions as the scattered light wave approaches its turning point.

We do this with approximate analytical methods, such as WKB in k-space, and compare with initial value calculations using the computer code SBS SOFTSTEP. Here the slow temporal envelope parabolic partial differential equations describing SBS are solved using a split operator, FFT scheme. The LRW approximation[3], which is presumably valid at least in the strong ion wave damping regime is also implemented analytically and numerically and the results compared to the full ion-wave description found in SBS SOFTSTEP.

[1]Afeyan, B. B., and M. V. Goldman, Parametric instabilities near daughter wave turning points: Two generalizations of the Rosenbluth gain formula, Anomalous Absorption, 1994

[2]Afeyan, B. B., K. Estabrook, and E. A. Williams, Stimulated Brillouin Sidescattering in Inhomogeneous Flowing Plasmas from Weak to Strong Coupling, Anomalous Absorption, 1993

[3]Liu, C. S., M. N. Rosenbluth, and R. B. White, Raman and Brillouin scattering of electromagnetic waves in inhomogeneous plasmas, Physics of Fluids, 17, 1211 (1974)

†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.

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 hohlraums enables direct imaging of the indirectly-driven shock trajectory versus time. An immediate application of the technique is a new method for measuring drive temperatures in NOVA hohlraums. Measured drive asymmetries are exaggerated due to an increased shock speed in low density foam balls. From the backligher-imaged distortion of the radially converging shock, the time-dependent flux asymmetry near the center of the hohlraum can be inferred. Results from a 3:1 peak-to-foot contrast ratio pulse shape (ps22) are presented and analyzed to demonstrate the viability of the method. Work is continuing on a larger contrast ratio (10:1) pulse shape (ps23) where time-dependent symmetry swings are enhanced due to increased laser spot motion. The current goal is to identify the crossover point in time where the flux on capsule changes from waist-high (sausaging) to pole-high (pancaking).

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

Narrowband SBS in a Laser-Produced Plasma with a Controlled Flow Profile†

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R. G. Watt, G. E. Busch, S. E. Caldwell,
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Los Alamos National Laboratory

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

A novel long-scalelength (L = 1 mm) plasma with a controlled flow profile is produced by an intensity tailored line-focus of a laser (400 J, 4 ns, λ_0 = 5265 Å) on a solid copper target. The plasma flow lines are observed with gated 60-ps x-ray images of the expanding plasma using embedded beryllium microdots. The observed flow field compares closely with that predicted by LASNEX plasma hydrody-namical computer modeling of the experiment. The spatial distri-bution of laser intensity is adjusted to yield plasma flow predom-inantly perpendicular to the target surface. A laser probe beam (10 J, 200 ps, λ_0 = 5265 Å, $f/20$) is injected into the plasma to drive SBS. This yields very narrowband ($\Delta\lambda \approx 1$ Å) SBS, slightly Doppler-shifted ($u \ll c_s$) to the red, when the probe laser is sent parallel to the target surface. When the probe laser is pointed 10° from par-allel, toward the target, scattering occurs from plasma layers with a wide range of fluid flow velocities ($\Delta u > c_s$), producing broadband ($\Delta\lambda \approx 11$ Å) SBS. The experimental configuration is well-suited for the study of the basic properties of SBS, such as its dependence on the plasma flow profile, the plasma density, the plasma ionic composition, and the $f/\#$ of the laser beam.

†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.

Post Deadline Papers (Thursday PM)

Observation of Spectrally Modulated Stimulated Raman Backscatter
C.A. Coverdale, C.B. Darrow, M.D. Perry

Relativistic Two-Plasmon Decay of Laser Radiation Near Critical Layer
C.S. Liu, V.K. Tripathi

Time-Dependent Symmetry Measurements in Lined Hohlraums Using the Symmetry Capsule Technique
G.R. Magelssen, D.B. Harris, A.A. Hauer, N.D. Delamater

Mass Resolved Time of Flight Observations of Ions Produced by 140 fS Laser Pulses on Solid and Buried Layer Targets
G. Guethlein, D. Price, J. Bonlie, B. Young, R. Shepherd, R. Stewart

Modeling of Laser Filamentation in Janus Experiments
J.H. Hammer, S.W. Wilks, W.L. Kruer, P. E. Young

An Analytical Slab Model for Rayleigh-Taylor Instability with Heat Conduction
A. Estevez

Monday, June 6, 1994

Oral Session 1

Parametric Instabilities I

Numerical and Theoretical Studies of Stimulated Brillouin Scattering and Self-Focusing Instabilites

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We have conducted systematic studies of stimulated Brillouin scattering (SBS) by using multidimensional wave interaction codes [1,2] and several simplified theoretical and numerical models. The instability is produced by Gaussian laser pump in plasmas that are several Rayleigh lengths long. The evolution of the self-focusing instability (SFI) and the reflectivity of SBS are characterized in terms of the stationary SBS gain, SFI critical power and f-number of the optics.

The formation of a plasma density channel by the focused laser beam confines the backscattered SBS light to an angular width which corresponds to the pump f-number. A density inhomogeneity along laser axis creates mismatch in SBS resonance conditions which can saturate instability. We have constructed a simple 1D model reproducing this effect, which relies on the time dependent density modifications. The dynamics of channel formation and/or SFI [2] results in the characterstic overshooting of the SBS reflecitvity during initial evolution. Backscattered SBS grows in the region outside the main laser focus, in fact the gain length extends beyond Rayleigh length towards the laser. This separation between regions of SBS growth and laser field enhancement is further increased by SFI. Far field calculations show wide angle scattering in the forward direction that is caused by SFI.

Laser produced plasma density channels justify 1D studies of backscattered SBS which have been conducted by using nonlinear inhomogeneous model of ion waves based on the Korteweg-de Vries equation. We will also describe results of several simulations conducted using parameters found in short laser pulse interaction experiments.

[1] M. R. Amin, C. E. Capjack, P. Frycz, W. Rozmus, and V. T. Tikhonchuk, Phys. Rev. Lett. **71**, 81 (1993); Phys. Fluids B **5**, 3748 (1993).

[2] Talk by W. Rozmus et al. at this Conference, *Dynamics of SBS and Self-Focusing Instability Driven by Gaussian Beams*

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24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

ION THERMAL CONDUCTIVITY AND VISCOSITY FOR PLASMAS WITH LIGHT AND HEAVY IONS

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The ion thermal conductivity and viscosity are calculated for a mixture of light and heavy ions, in an unmagnetized plasma. Comparison with classical fluid theory results based on an average-ion model of a CH plasma shows a factor of 60 enhancement in the thermal diffusion rate and a factor of 5 enhancement in the viscous damping rate. The corresponding increase in the collisional damping rate of an ion-acoustic wave is predicted to be seventeen-fold for $T_e \approx T_i$.

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

Prefer Poster Presentation

MULTI-BEAM EXCITATION OF THE RAMAN INSTABILITY IN LASER PLASMAS*

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

The NIKE laser facility, now being completed at the Naval Research Laboratory has a forty-eight beam lens array which focusses the laser light on target. Since each beam has a finite angle with every other beam the spectrum of the scattered Raman instability can be significantly different compared to a single beam case depending on the intensity in each beam and the laser wavelength. In fact in this case the Raman problem is al least 2D. We will report on the study of 2D and 3D Raman instability in the presence of such a multi-beam pump. We have derived a simple analytical criterion involving the angle between the beams, the intensity in each beam(assumed to be the same for all the beams) and the wavelength of the laser incident laser light for which each of the beams act independently. The implication of these results to experiments on the NIKE system will be discussed.

*Work Supported by the PPD, NRL Contract N00014-90-K-2010

Studies of Hydrodynamic Motion in Hohlraums

John H. Gardner

LCP&FD, Naval Research Laboratory, Washington, DC

and Stephen E. Bodner

Laser Plasma Branch, Plasma Physics Division
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We have been using a simple one dimensional cylindrical geometry to study the fundamental nature of the hydrodynamic wall motion in a hohlraum. We have studied various configurations in a attempt to minimize the time dependent asymmetry.

Work supported by USDOE and ONR.

***Stimulated Brillouin Backscatter of Short-Pulse Lasers**

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The interaction of a short-pulse laser with plasma, where the pulse length is short compared to the plasma length and the Rayleigh length, drives stimulated Brillouin backscatter (SBS) in a qualitatively different manner than when the pulse length is long compared to the plasma length. In a reference frame moving at the group velocity of the laser pulse, the front of the pulse encounters a constant level of scattered light wave, with which the pulse interacts to ponderomotively drive density fluctuations. The scattered light wave is amplified as it moves backward through the pulse, and as it exits the back side of the pulse it free streams toward the detector. In the weak coupling limit, where the growth rate is small compared to the ion acoustic wave frequency in the lab frame, the set of coupled mode equations describing SBS has an exact solution in terms of an infinite sum over modified Bessel functions. The qualitative features of the weakly coupled solution are best addressed by examining the growth rate of the wave amplitudes. For times $t < L/(2c)$, where L is the pulse length and c is the speed of light, the wave amplitudes grow at a rate γ_0, which is the coupling strength of the problem, $\gamma_0 \equiv k_0 v_0 \omega_{pi}/\sqrt{\omega_0 \omega_a}$, where k_0 is the vacuum wavenumber, v_0 is the quiver velocity, ω_{pi} is the ion plasma frequency, ω_0 is the laser frequency, and ω_a is the ion acoustic wave frequency. During the time interval $L/(2c) < t < L/c$ the growth rate drops to zero, and for times $t > L/c$ the growth rate remains at zero. Similar characteristics of the instability are found in the strong coupling limit, where the growth rate is on the order of or larger than the ion acoustic wave frequency. In this limit, for times $t < L/(2c)$ the wave amplitudes grow at a rate $\gamma_0^{2/3}\omega_a^{1/3}$; the growth rate then drops to zero during the time interval $L/(2c) < t < L/c$, and remains zero for all subsequent times. Power spectrum calculations for the two regimes, where the experiment runs for times short and long compared to two light wave transit times will be discussed and presented.

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LONG SCALE-LENGTH PLASMAS CREATED WITH LOW DENSITY FOAMS*

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The creation of long scale length plasmas is presently of intense interest to study laser-plasma interactions in regimes predicted for the National Ignition Facility. We have produced and characterized plasmas irradiated on NOVA two-beam and ten-beam facilities using low density TPX $(CH_2)_n$ foams (3 -5 mg/cc). These plasmas have electron densities ~ 1021 cm-3 and a measured electron temperature of 2-5 keV. The foams were 2 mm long and 1-2 mm diameter. Line ratios were measured using streaked and gated crystal spectrometers with Ar, Ti and Cr dopants uniformly dispersed into the TPX. Spatial uniformity was measured with gated x-ray pinhole cameras. Propagation velocities were measured with a streaked pinhole camera. Time-resolved SBS and SRS spectra were also measured. Results and comparisons with calculations will be presented.

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Abstract submitted to the 24th Annual Anomalous Absorption Conference, Pacific Grove, CA, June 5-10, 1994.

Effect of 4-Color Beam Smoothing on Filamentation*

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We have used our 3D fluid simulation code F3D[1] to continue our study of the effect of 4-color beam smoothing on filamentation. In the 4-color scheme a laser beam of intensity I_0 is split into four separate beams with equally-spaced frequencies $\omega_1 < \omega_2 < \omega_3 < \omega_4$, all having a common focus and intensity $I_0/4$. When used in conjunction with RPP this induces a time variation in the intensity speckle pattern that is intended to reduce filamentation growth rates in a manner similar to the beneficial effects of smoothing by spectral dispersion (SSD). Because of the regularity of the 4-color frequency spectrum the (x, y)-dependent incident intensity recurs exactly after a time $t_{rec} \equiv 2\pi/\Delta\omega_{sep}$, where $\Delta\omega_{sep}$ is the frequency separation between any two adjacent colors. We observe that this recurrence persists throughout the plasma to the exit plane, even at densities of 0.1 critical. The time-averaged intensity saturates, and the spatially-averaged intensity in a speckle varies, however, on the timescale $2\pi/(\omega_4 - \omega_1) = t_{rec}/3$. It is the latter bandwidth that we observe to be the relevant one for stabilization of filamentation, the criterion for which is, roughly, $\omega_4 - \omega_1 > (\omega_0/8)(n_e/n_c)(v_{osc}/v_e)^2$. The effect of adding SSD bandwidth to each 4-color frequency is currently under investigation.

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

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NOVA HIGH GROWTH FACTOR IMPLOSION EXPERIMENTS: EXPERIMENTS AND ANALYSIS

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Of primary concern in current and next generation inertial confinement fusion (ICF) implosion experiments is Rayleigh-Taylor (RT) instability of the pusher-fuel interface occurring upon acceleration and deceleration of the pusher. This results in the mixing of hot fuel with cold pusher material. We report on experiments and modeling whose aim is to quantify this effect and thus assess current capabilities of modeling mix in convergent geometry. This is important for next generation ICF facilities where accurate modeling of pusher/fuel mix is an essential component of implosion target design.

In these experiments the variation in neutron and x-ray emission is studied for high growth factor capsules (~200-400) as a function of *controlled* outside surface perturbation. Previous experiments of this type ("HEP3") have been carried out with lower growth factor (~5-10) capsules. In the current work both 1-ns square and 2.2-ns long shaped laser pulses were used to indirectly drive plastic capsules filled with a 50 atm, 50/50 mix of D and H. The capsule ID was 440-μm and the wall thickness was varied between 35-μm and 45-μm. The ablator was doped with 1.8% Br. The preheat shielding arising from the Br is primarily responsible for increasing the RT growth of these targets over that seen in HEP3. The outer surface perturbations were created using a novel laser ablation technique and consisted of 200 randomly placed, laser ablated pits. The RMS surface roughness was varied between 0.15-μm and 2-μm by varying the pit depth from 0.28-μm to 4-μm. Ar (0.05% atomic) and Ti (0.07% atomic) were doped into the fuel region and the innermost region of the capsule wall adjacent to the fuel, respectively. The variation in the ratio of Ar Ly-β/Ti He-α was used as a diagnostic of mix.

In these experiments a factor of 15 yield degradation was seen over the range of surface perturbations studied. This is the first evidence for high growth factors in controlled implosion instability experiments. Variations in Ar and Ti emission with surface roughness were also in qualitative agreement with expectation. Evidence for laser light reflected off the hohlraum wall striking the capsule was also seen; this is under investigation. These and other results, along with comparisons to detailed modeling, will be presented.

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Abstract for 24th Annual Anomalous Absorption Conference
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Nonlinear Effects on SBS in Multi-ion-species Plasmas

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A number of nonlinear effects relevant to current experiments on SBS in large, multi-species plasmas are discussed. Strong trapping calculations, including the effects of ion temperature, are extended to include ions with different charge-to-mass ratios. It is shown that strong ion trapping occurs at a lower amplitude in a mixture of C and H plasma than in either a pure H or a pure C plasma. Distortions of the ion distribution function associated with this trapping significantly change the wave-particle damping from linear Landau damping on the original distribution to something determined nonlinearly. Relevant effects then include a frequency decrease (say, due to trapped ions) which lowers the phase velocity into neighboring distribution with "fresh" slope as well as diffusion and transport of fast ions out of the region of large reflectivity, which allows the plateau region to develop a slope. These considerations underscore the need to delineate regimes of validity for coupled-mode models of SBS which rely on linear Landau damping. An additional benefit of the use of SSD or 4-colors is also suggested. The Speckle motion impedes distortions of the ion distribution function. Finally a simple nonlinear coupled-mode model is proposed and solved analytically.

(1) B. MacGowan et al., 24th Anomalous Absorption Meeting, 1994

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Abstract submitted to the 24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5-10 June 1994.

Beam smoothing as implemented in the F3D/SBS code†

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The F3D filamentation + stimulated Brillouin back-scattering code includes modeling of several beam smoothing methods that are available in the NOVA facility and that may be feasible in the proposed National Ignition Facility (NIF). Results of this code and recent NOVA experiments are reported in other talks.

Implementation of beam smoothing corresponds to components of a simple cartoon of a laser beam line. There is an oscillator, to which we may add sinusoidal frequency modulation (FM) or or cross-phase modulation (XPM). A smoothing by spectral dispersion (SSD) grating is implemented as a time delay that varies linearly across the grating and therefore across the final focus lens. Implementation in the time, rather than frequency, domain makes the grating coding independent of the bandwidth mechanism. The only grating parameter needed is the range of time skew, typically 300-400 ps for NOVA with FM bandwidth. (To really get SSD, you also need bandwidth.) When we model four-color NOVA, a frequency shift is applied to each quadrant of the beam. FM or XPM, if present, are the same on the four quadrants. Also there are 4 SSD gratings arranged in a wedge, instead of one grating. There is an amplifying chain with some magnification; this doesn't appear in the coding here. There is a frequency multiplier, and a lens with some f number. There is a random phase plate (RPP) in nearly all applications. The details differ between one-color and four-color.

There is no interaction between the beam line components except that the four-color option in NOVA affects the SSD grating (if any) and the RPP, in the code. Parameter choices for each component are independent and can be used in many combinations, although some combinations won't make sense and some aren't an option experimentally.

Limitations on the size of the computational simulation region limit the number of RPP elements that can be modeled for a given f-number. The time duration of the simulation is a small fraction of the FM period, however NOVA SSD parameters result in the full range of FM bandwidth being represented across the lens and in the simulations.

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Abstract

SBS AND FILAMENTATION IN CURRENT AND FUTURE EXPERIMENTS.*

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We have been using our 3-D SBS/filamentation code to study the effect of beam smoothing techniques on these instabilities in present and future experiments. We compare f/4 and f/8 optics for these 3ω, 2×10^{15} W/cm^2 irradiations of plasmas at 0.1 n_c and 3 keV electron temperature. The dependence on the incident laser intensity is discussed. We also consider variation in the ion acoustic damping rate. Our simulation scaling results guide our interpretation of current NOVA experiments.

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MODELING GOLD DISKS IRRADIATED BY LASER AND X-RAY SOURCES*

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Frederic Ze
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The efficiency with which gold disks convert laser energy into x-rays has been studied for many years. In this paper we consider the x-ray emission from a gold disk that is simultaneously illuminated by both a laser and a flux of x-rays. The experimental data consists of x-ray images obtained by the Soft X-ray Framing Camera (SXRFC). The SXRFC takes four images in each of three channels during a single shot on the NOVA laser. In these experiments, a single image shows both a gold disk mounted on the outside of a hohlraum and a laser spot on the inside of the hohlraum. The experiment is modeled using 2D planar disks in LASNEX. LASNEX cannot model a round spot inside a hohlraum (that would require a 3D code), so we have chosen to use an externally applied x-ray source and model the geometry of an azimuthally symmetric laser spot. The x-ray flux is quite uniform across the wall of the hohlraum, so this is a reasonable approximation.

Comparisons of the models to images of gold disks obtained with the Soft X-ray Framing Camera show good general agreement. Some of the differences between the models and the experiments are due to assuming azimuthal symmetry and ignoring small spatial scale laser intensity fluctuations in the models. Another complication is that to obtain good contrast between the laser spot and the hohlraum wall in the SXRFC images we have used a higher laser intensity than is used in capsule shots. We discuss plans for future improvements in the modeling and experimental changes that could simplify the modeling and reduce experimental uncertainties.

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Kinetic effects in the wake of a short intense laser pulse in a tenuous plasma

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Channeling of intense optical fields is an important challenge, with possible applications in the context of laser plasma accelerators or X-rays lasers. It has been shown in recent papers that self-channeled pulses are subject to severe instabilities of the Raman type which modulate the laser pulse and erode its tail [1-5]. The simulations of Refs. 1-4 were based on laser-plasma fluid models corresponding to a cold plasma, which prevents from treating situations where the plasma oscillations reach the wavebreaking limit. In addition the models contain a mathematical singularity at zero plasma electron density which prevents its use when the electrons are totally expelled from the axis of the laser propagation (electron cavitation). Such features are strong limitations of the fluid models in the high intensity regime.

In this paper, we present a particle model which describe the plasma behavior under the action of an ultrahigh intensity (of the order of 10^{18} W/cm^2 or more), short laser pulse (1 psec or less). The model is fully nonlinear, relativistic, two-dimensional. It uses the quasistatic approximation, which assumes that the electron transit time through the laser pulse is short compared to the laser pulse duration. The code offers the possibility to study the propagation of high intensity laser light, with total electron cavitation in the laser channel and electron jet formation. Thus we are able to observe the self-channeled propagation of beams with power exceeding the critical power P_c for relativistic self-focussing [$P_c = 16.2\ (\omega_0/\omega_p)^2\ 10^9$ W] by a factor of the order of 2 or more, on distances very large compared to the Rayleigh length (more than 50), which is the natural diffraction length. On the other hand, behind the laser pulse, the electrons come back to the center of the channel under the action of the radial restoring force due to the ambipolar field and this results in a strong heating of the electron component in the wake of the pulse with formation of a high velocity electron component which propagates at an angle with respect to the laser light propagation axis.

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Opacity Measurements in Laser-Produced Strongly Coupled Plasmas*

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In past experiments,[1] we have demonstrated techniques by which strongly coupled plasmas with $n_e \sim 10^{20} cm^{-3}$, $T_e \sim 2$-6eV, and coupling parameter $\Gamma \sim .1-1.5$ are produced by laser ionization and heating of a dense Al vapor. The dense vapor is generated by laser vaporization of thin metal films from glass substrates. The vapor flows through a slit to form a thin ($\Delta x \cong 100$ μm) slab of metallic vapor. After the vapor slab has reached the appropriate expansion length and the desired density a second laser is used to heat and ionize it. The heating occurs over a time of 5-10 ns and produces a fully ionized optically-transparent plasma with an average ionization of Z ~ 1-3. These plasmas are produced under well controlled conditions and because they are optically transparent they can be accurately diagnosed by optical techniques. These plasmas are well suited for optical studies of strongly coupled plasmas and could have significant impact on our understanding of plasma transport properties in astrophysical plasmas, inertial confinement fusion plasmas, and other high density plasmas such as the ones found in electromagnetic railgun launchers.

Recent measurements of the plasma opacity, at 0.351μm, 0.527μm, and 1.054μm in Aluminum will be presented along with comparisons to theoretical opacity calculations for dense plasmas.

* Supported by the Office of Naval Research

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Models of the heating and motion of Nova Gas Bags

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We study laser propagation through 2 mm of tenth critical plasma. The Nova laser heats balloons filled with neopentane gas to more than 3 keV. Inverse bremsstrahlung heating leads to hydrodynamic motion which is complicated by the three dimensional illumination geometry and non-uniformity of the heating beams. Our computer models are limited to two dimensions, but simulations with cylindrical symmetry about a laser beam axis can be post-processed using three dimensional ray tracing for comparison with experimental X-ray images. We have both gated and streaked images of gas bags. Tightly focussed heater beams blow low density channels through a gas bag, which are visible in the gated X-ray images. Images of gas bags heated by defocussed beams are more uniform. Models also show an imploding blast wave launched when the balloon skin pops. Blast waves are visible in some of the images of actual targets.

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ENHANCED LOW FREQUENCY DENSITY FLUCTUATIONS AND RESULTING 1/2 ω_0 and ω_0 RADIATION FROM THE SATURATED TWO PLASMON DECAY INSTABILITY*

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The reduced nonlinear model of the two plasmon decay instability, discussed in an oral presentation at this meeting, predicts that high levels of low frequency density fluctuations will be excited in the nonlinear saturated state. These fluctuations are excited with small wave vectors by ponderomotive beats of Langmuir waves with nearby wave vectors and at larger wave vectors by secondary Langmuir decay and by Langmuir collapse. We find greatly enhanced levels (over thermal) of Thomson Brillouin scattering (TSB) from these fluctuations, which can act as a local seed for stimulated Brillouin scattering. It can also act as a seed for backward SBS at lower densities ($n < 0.25\ n_c$) provided the doppler detuning due to different flow velocities is not too great. We compute the angular distribution and power spectra of the ω_0 and 1/2 ω_0 radiation. The dominant current contributing to the total 1/2 ω_0 radiation is found to be the Thomson conversion of Langmuir waves into light on the low frequency density fluctuations, not the Raman down scattering of the laser. The linear coupling of TPD and SRS at $n \simeq 0.25\ n_c$ to form a hybrid instability is taken into account in these homogeneous simulations. The nonlinear coupling of TPD and SRS at lower densities appears to be a compelling area for further study.

*A poster to be presented the 24th Annual Anomalous Absorption Conference, Asilomar Conference Center, Pacific Grove, CA, June 5-10, 1994

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Development of the two plasmon decay instability in k-space of a laser produced plasma and (3/2)-harmonic generation

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We continued our investigation of the two plasmon decay instability in a near uniform CO_2-laser produced plasma using Thomson scattering of ruby laser radiation as a probe. In an extensive survey the whole k-space spectrum of unstable plasma waves is studied. Initially the instability is seen to grow as decay pair of plasma waves at wave vectors expected by linear theory. However, measured growth rates are an order of magnitude smaller than theoretically calculated for the present inferred axial scale lengths and may be limited by convection out of the radial pump beam profile (50 μm 1/e intensity radius). During saturation unstable plasma wave activity spreads over wide regions in k-space with various intensity maxima which cannot be combined into matching decay wave pairs. Comparing the saturated plasma wave vector distribution and the angular variation of (3/2) ω_0 intensity confirms the mechanism in which this radiation is generated by Thomson scattering of pump photons off saturated two plasmon decay waves. The presented measurements provide a test bed for numerical Langmuir turbulence simulations of the two plasmon decay instability (see D.F. DuBois et al., this section).

SIGNATURES OF REGULAR AND CHAOTIC REGIMES IN SATURATED STIMULATED RAMAN SCATTERING

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In recent years, a solid evidence has emerged that stimulated Raman scattering (SRS) often becomes absolute into laser fusion plasmas; that has brought the problem of nonlinear saturation in a focus of many SRS studies[1]. Different physical mechanisms[2] have been proposed, resulting in models of varying complexity that point to a nonlinear physics of the electron plasma wave (EPW) as a decisive factor which determines the nature of saturated SRS states. Moreover, an inherent feature of strongly nonlinear SRS to transit from regular (coherent) to chaotic (turbulent) dynamics has been anticipated[1,3].

In this contribution, temporal, spatial and spectral signatures of saturated SRS regimes are studied in typical laser fusion conditions. In our model, plasma is assumed finite, uniform and moderately collisional. The set of three weakly-coupled equations, accounting for: the pump depletion, collisional damping and nonlinear detuning of EPW, is solved numerically in space-time with nonzero source boundary conditions[3]. Above certain threshold, through a variation of laser and plasma parameters; in particular, by increasing (lowering) the pump strength (damping rate), the system is driven toward a chaotic state[1,3].

A systematic route, generic to our model[3], via: steady-state, periodic and quasi-periodic regime with an intermittent transition to an extensive spatio-temporal chaos[4] is revealed. A similar type of temporal intermittency, in which periodic or quasi-periodic oscillations are interrupted by chaotic bursts, has been observed at the onset of fluid turbulence in several viscous flows in bounded geometries[4].

We investigate signatures of nonlinear saturated regimes in our model of SRS, for typical laser fusion conditions, by applying: space-time plots, phase diagrams, power and correlation spectra. Distinctive, strongly nonlinear features, such as: spiky-burstlike reflectivity, spectral broadening and incoherent (irreproducible) dynamics are observed, which are qualitatively consistent with more complex, Zakharov-type models. Relation to more recent spectral data on EPWs driven by SRS, based on ω- and k- resolved measurements, is outlined[2].

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Hydrocode Comparisons of Direct-Drive ICF Pellets*

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Abstract

We have constructed two versions of a 1-D hydrocode for calculating the performance of laser-driven direct-drive pellets. One is based on the standard Lagrangian hydrodynamic formulation[1], while the other is based on a flux-corrected transport (FCT) algorithm[2] that allows more flexibility in gridding. Aside from the different hydro algorithms, the two codes share the same radiation transport (STA-based LTE opacities), thermal conduction, laser deposition, thermonuclear burn and alpha transport routines, which will also be described.

We have benchmarked these codes on ICF related benchmarks, and have used them to design high-gain laser ICF pellets. Comparisons of the results from these two codes are used to identify problem areas and limitations in each of the hydro algorithms. Compared to the FCT algorithm, the Lagrangian version appears to be less sensitive to changes in input parameters and exhibits "smoother" solutions, but experiences problems due to suboptimal grid behavior particularly in the ablator.

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SPHERICAL, ION KINETIC IMPLOSIONS SIMULATIONS.

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Our ion kinetic code, which previously was used to simulate planar shock waves [1,2], has been converted to sherical geometry. The anisotropy of the ion velocity distribution is fully described. We have performed simulations of the implosion of DT gas filled glass microballoons. The movement of the ablator was modelled by a simple fluid model, adjusted to reproduce the results of more eleaborate Lagrangian hydrocodes. All kinetic simulations were compared to fluid calculations. Two different boundary conditions were used for the DT-ablator interface: a) perfect reflection; b) fixed temperature (incoming ions are absorbed and re-emitted as a thermal distribution at the ablator's temperature). The latter cools the fuel considerably. Very strong deformations of the ionic distribution function are seen. The neutron yield is computed by performing appropriate integrations over the velocity distribution functions.

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Tuesday, June 7, 1994

Oral Session 2

Hohlraum Physics

24th Annual Anomalous Absorption Conference
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Design and Modeling of Ignition Targets for the National Ignition Facility*

Steven W. Haan and Steven M. Pollaine

ABSTRACT

We have designed several targets that give yields of 1-30 MJ when indirectly driven by 0.9-2 MJ of 0.3 μm laser light. We describe the targets, the modeling that was used to design them, and the modeling we have done to set specifications for the laser system in the proposed National Ignition Facility. Capsules with beryllium or CH ablators are enclosed in gold hohlraums. All of our designs include a cryogenic fuel layer; we will explain why it is very difficult to achieve ignition at this scale with a noncryogenic capsule. It is necessary to use multiple bands of illumination in the hohlraum to achieve sufficiently uniform x-ray irradiation, and to use a low-Z gas fill in the hohlraum to reduce gold filling.

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LLNL NIF HOHLRAUM DESIGN*

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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 a laser source produces x-rays in the hohlraum wall, which then drive a capsule that subsequently ignites and burns. Our principal objective is providing a symmetric radiation flux that drives the capsule, while avoiding any hydrodynamic coupling to the capsule. Blowoff of the gold wall is reduced by either a CH liner, He gas fill, or both. We found that without He, the CH liner stagnates on axis and produces a jet that disrupts the capsule.

We achieve adequate flux symmetry by dividing the laser beams into two sets of rings per side. By varying the relative power balance in the two rings, we dynamically eliminate the second Legendre moment of the flux asymmetry. Odd order moments are zero by virtue of left-right symmetry. The fourth Legendre moment is controlled in a time-average way by varying the hohlraum aspect ratio. Higher order moments are smoothed by the radiation transport from the walls to the capsule.

The biggest calculational problem was spurious numerical noise in the photon drive, which is further amplified by hydrodynamic instabilities in the capsule. We present several techniques that smooth the numerical perturbations.

Our best calculation to date uses 1 mg/cc of He and no CH liner, with the capsule producing 9 MJ of fusion yield.

* 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.

Indirectly Driven Beryllium Capsules for Ignition

by

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DT filled capsules with beryllium ablators may be a viable alternative to those using plastic in indirectly driven implosions. We are exploring a number of beryllium capsule designs with peak drive temperatures from 200 to 300 eV. We will show the results of integrated, two dimensional calculations of the hohlraum and capsule, driven near 300eV, and one dimensional calculations at lower temperatures.

In both beryllium and plastic ablators a dopant is used to increase the opacity and decrease the shell thickness, shortening the overall radiation drive pulse length. For a standard National Ignition Facility (NIF)design, bromine is added to the plastic. A beryllium ablator can use copper to achieve the same objective. Copper dopant concentrations vary from 0.9 atom% at 300 eV, to 0.4% at 250eV, and 0% at 200 eV.

A comparison of the performance of a capsule with a bromine-doped plastic ablator and one with copper-doped beryllium with the same DT ice and gas and placed in the same hohlraum shows the beryllium capsule absorbing about 25% more energy.

This work is supported by the USDOE under contracts W-7405-ENG-36 and W-7405-ENG-48

NONLINEAR MULTIMODE CALCULATIONS OF ICF CAPSULE STABILITY *

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We are investigating the fluid stability of imploding ICF capsules by explicitly following the evolution of multiple interacting perturbation modes far into their nonlinear regimes. The modes are initiated by interface displacements in the capsule, having finite amplitudes and a spectrum that approximates realistic surface-roughness spectra for the inner and outer surfaces of capsule shells. Typically 8 to 12 modes (with mode numbers l ranging from 4 to 48) are imposed on inner (ice) and outer (ablator) surfaces simultaneously. The mesh is initially perturbed according to incompressible spherical eigenmodes of the Rayleigh-Taylor instability; thus the contribution of mode l to the total initial mesh perturbation varies as a Legendre function $P_l(\theta)$ in angle θ and as a sum of terms in r^l and r^{-l-1} in radius r. A 90-degree sector is calculated, permitting all even modes to be represented with the correct reflective boundary condition. The code used is a 2D Lagrangian nonlinear radiation-hydrodynamics code. We have used this technique to calculate performance of a NIF capsule as a function of increasing initial RMS surface roughness σ on the outer surface of the capsule. We find a "cliff" at a critical value of σ such that the yield of the capsule decreases abruptly for σ greater than the critical value. We are attempting to validate this technique by comparing results to theory, calculations with Eulerian codes, and experimental data from HEP capsule implosions at the Nova laser. Preliminary nonlinear single-mode calculations of spectroscopically-traced Nova HEP implosions show that higher amplitudes of initial surface perturbation, for modes $l = 10$ to $l = 40$, lead to stronger calculated emission from the capsule shell's tracer (typically chlorine), compared to the emission from the capsule fuel's tracer (typically argon). This is in qualitative agreement with the data, and demonstrates that it is not necessary to hypothesize intimate atomic-scale mixing of shell and fuel to account for enhanced shell tracer emission. Shortcomings of this technique include: two-dimensionality, finite mesh resolution, Lagrangian mesh problems and rezoning, and the sparse approximation to the surface roughness spectrum. Strengths include explicit treatment of nonlinearity, multimode interactions, and the simultaneous perturbation of outer and inner surfaces.

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Use of Thin Wall Imaging in the Diagnosis of Laser Heated Hohlraums.* L.J. Suter, F. Ze, R.L. Kauffman, A.R. Thiessen, R.H. Price, V.C. Rupert, V.W. Slivinsky, C. Wang, Lawrence Livermore National Laboratory— High-Z hohlraums can be made thick enough to contain thermal radiation, yet thin enough to let out xrays >~6keV which are produced by hot, relatively dense blow-off plasma. We have been using various types of these "thin wall hohlraums" to observe the physical location of the hot, dense plasma in hohlraums produced by our last three ICF laser systems; Shiva, Novette and Nova. Processes which create hot, dense blow-off which we can see include laser deposition, plasma stagnation and heating of blow-off at the laser entrance hole (LEH), where the intensity is greatest. Thus, this technique has allowed us to come to some empirical understanding of laser transport/ deposition, plasma stagnation and plasma at the LEH of hohlraums heated by various lasers. In particular, these experiments provided the first information which made us realize that axial stagnation is overestimated in our hydrocodes and that colliding plasmas in laser heated hohlraums often may be more correctly viewed as interpenetrating. In this paper we discuss the technique, its limited dynamic range as a measure of laser intensity, the conversion of film density to relative exposure and show examples of what it has taught us over the years.

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

Oral Session Preferred

Larry Suter

24th Annual Anomalous Absorption Conference
June 5-10, 1994
Pacific Grove, CA

NOVA SBS EXPERIMENTS USING LARGE GAS-FILLED HOHLRAUMS*

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We present an overview of Brillouin scattering measurements obtained from cylindrical (2.5 mm long, 2.5 mm diameter), gas-filled hohlraums. The targets contained 1 atmosphere of neopentane gas (C_5H_{12}) plus 1% Ar and Cl for spectroscopic tracers. This produces an electron density of about 0.1 n_c for the 350 nm laser light. Thin CH foils coated with Ti and Cr, or Cl and K, were also used to obtain spectroscopically inferred electron temperatures. Laser propagation times through the gas to the gold walls were measured by streaking the x-ray emission from Ar, Cl, and Au; these compared favorably with calculations. Back-scattered light was collected over the full aperture of one of Nova's beams for a variety of beam smoothing conditions, ranging from unsmoothed beams, to the use of a phase plate, to adding bandwidth and SSD. As expected, increased smoothing resulted in less SBS. SBS was also measured from this beam when an f/8 focus lens was used and the laser configured to provide 4 closely spaced frequencies. The damping of the ion acoustic wave due to hydrogen ions was investigated by substituting deuterated neopentane for some shots. The data show that while large levels of SBS can be generated under some conditions, the instability is reduced to low levels for conditions similar to those calculated for proposed NIF targets.

*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.

Request oral talk

ANOMALOUS ABSORPTION '94, DRAFT 4/5/94

PLASMA-INSTABILITY MEASUREMENTS IN HOHLRAUMS*

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The Laser-Matter-Interaction group at Los Alamos is studying a key issue in indirect-drive laser fusion, namely, the role of plasma instabilities in scattering laser light inside the hohlraum. Laser reflectivity due to Stimulated Brillouin Scattering (SBS) has been studied at the NOVA laser in different hohlraum-plasma configurations, some of which approach electron temperatures (T_e), electron densities (n_e) and scale-lengths expected in ignition hohlraums, *i.e.*, 3–5 keV, $\approx 10^{21}$ cm^{-3} and 2 mm. These conditions have been obtained in gold hohlraums (shaped like a cylinder with rounded corners) which are filled with 1 atm of gas. The gas is contained by silicon-nitride windows, 0.3 μm in thickness, 2 mm $\times$ 2 mm in size, covering the two round laser-entrance holes, 1.6 mm in diameter. Three gas species have been used, namely, C_5H_{12}, C_5D_{12}, and CO_2. Open CH-foam targets with similar plasma conditions have also been studied. Characterization data from these plasmas are presented, particularly T_e from newly-developed spatially-resolved, time-gated X-ray spectrometers. These plasmas were studied with f/4 probe and heater beams. Laser propagation speeds through the hohlraum gas fill of about $\approx$ 4 mm/ns have been measured.

As expected, SBS increases with laser intensity and pulse duration (which usually increases the plasma scale-length). However, SBS reflectivity also varies in different configurations depending on other factors such as ion species and temperature (which can change the Landau damping of the daughter ion wave), and apparently light scattered by non-SBS processes which can be amplified by SBS. For example, in gas-filled hohlraums with C_5D_{12} and CO_2, which have the lowest damping in these conditions, the laser reflectivity is in the 0.5–2% range for probe-beam intensities below 2.5×10^{15} W/cm^2. Above this intensity, the reflectivity rapidly increases to as much as 7% for C_5D_{12} and 30% for CO_2 when the intensity reaches 3×10^{15} W/cm^2. In C_5H_{12}, the reflectivity remains below 1.5% for all intensities. Similar experiments in higher f/# are beginning. In smaller, cylindrical, empty, gold hohlraums, the SBS reflectivity of an f/4 beam increases monotonically when either the laser intensity or the pulse duration increase independently.

*This work supported by the US DOE.

Tina 7

Isoelectronic Spectroscopy Measurements of Gas-Filled Hohlraums*

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X-ray spectroscopic diagnostics of high temperature underdense plasmas have been developed to measure the electron temperature inside of hohlraum targets. The diagnostic technique uses the line intensity ratios of the *K*-shell emission from two different tracer elements that have similar atomic numbers.† In this work, the x-ra diagnostics have been designed and tested for a 1 to 4 keV electron temperature regime.

The plasmas in these experiments are useful for plasma physics studies because the scale length can be made long to permit comparisons between experiments and idealized calculations of the growth of plasma processes. Further, these plasmas are of importance in larger scale experiments that will be pursued for the next generation of ICF experiments. Therefore, the importance of the present work lies in our ability to provide spectroscopic verification of the plasma conditions.

The present experiments were developed for the hohlraum environment, while other similar experiments have been performed on large gas-filled bags. The hohlraum is a challenging target because it produces a confined plasma in which an intense radiation field is created. These targets are Au hohlraums 2.5 mm long and 2.5 mm in diameter filled with neopentane (C_5H_{12}) doped with 1% Ar and 1% Cl. In addition, the tracer material is deposited on an 800 Å thick CH substrate which is free-standing inside of the hohlraum. The plasma regions heated directly by the laser and those heated by electron conduction have been diagnosed with tracer combinations of Ti and Cr or K and Cl. In the analysis, comparisons to calculations will be presented to assess the impact of steady-state versus time-dependent plasma models. We also explore the impact of the radiation field on the x-ray spectroscopy.

*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.

† Marjoribanks, et al. Phys. Rev. A **46**, 1747 (1992)

ISOELECTRONIC X-RAY SPECTRAL TECHNIQUÉS FOR T_e MEASUREMENT IN OPEN- AND CLOSED-GEOMETRY LONG-SCALE-LENGTH LASER PLASMAS*

TOVM

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We have successfully employed isoelectronic line ratios to measure the electron temperature in gas-filled hohlraums and gas bags shot with the Nova laser. Isoelectronic line ratios are well suited to this measurement because they are relatively insensitive to radiation field effects (in hohlraums), opacity, transients, and variations in electron density compared to conventional line ratios. Gaseous impurity dopants consisting of Ar and Cl were introduced at partial pressures of 1 percent each, while solid dopants of K plus Cl and/or Ti plus Cr were introduced as surface coatings on thin carbon fibers and films suspended in the interior of the targets.

The targets were designed using the Lasnex hydrodynamics code to produce plasma parameters $T_e \sim 3$ KeV and $N_e \sim 1 \times 10^{21}\ \mathrm{cm}^{-3}$ over a scale length of ~ 2 mm. The properties of isoelectronic line ratios were surveyed for the expected temperature and density ranges using a collisional-radiative atomic kinetics code (Fly) leading to the chosen atomic numbers for the impurity dopants. To analyze experimental data, multipliers were applied to spatially-averaged prototype T_e and N_e time histories taken from the Lasnex design calculations. These histories were then used in Fly calculations to produce families of line-ratio histories at different temperatures. Experimental electron temperature was then deduced by interpolation. The effects of spatial non-uniformities and velocity gradients on the impurity spectra and the perturbations caused by the fibers and films were studied by post-processing Lasnex calculations using a 2-dimensional, time-dependent, collisional-radiative kinetics/line transfer code (DSP). The impurities were found not to significantly perturb the temperature measurement, although significant velocity gradients were introduced. Reasonable agreement was found between predicted and measured temperatures.

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Laser propagation and heating in gas-filled targets on Nova*

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Gas-filled targets containing 1 atmosphere of neopentane (3 mg/cm^3 of C_5H_{12}) have been irradiated with ten Nova laser beams in order to create a large uniform plasma with electron density 0.1 n_c. Thin-walled gas bags and gas-filled hohlraums have been irradiated at up to 4×10^{15} W/cm^2. Streaked and gated x-ray imaging diagnostics are used to measure the propagation of a 3ω laser beam into the gas and the uniformity of the large plasma that is created.

The gas bag targets were irradiated with both large and small beam spots. Using tightly focused beams, low density regions are visible due to shock waves generated by the incident laser beams. With large defocused laser spots, the plasma is uniformly heated, resulting in a density plateau that blows down with the propagation of a rarefaction wave into the plasma.

The gas-filled hohlraums were irradiated using tightly focused beams. Propagation of the beams into the gas is measured from the time the laser reaches the inner gold wall of the hohlraum. Plasma heating and uniformity are obtained from end-on imaging diagnostics.

Results from the laser propagation and plasma uniformity will be presented for gas bag and gas-filled hohlraum targets.

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25th Annual Anomalous Absorption Conference
Asilomar, Pacific Grove, CA, June 5-10, 1994

Indirect-Drive Rayleigh-Taylor Experiments on Nova*

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Rayleigh-Taylor (RT) experiments have been conducted with planar CH(Br) foils accelerated by x-ray ablation. The 2D surface perturbations investigated consisted of single-mode, 2-mode, and 8-mode sinusoids. The 3D perturbations investigated corresponded to smooth versus rough surface finish. The perturbation evolution begins during the shock transit phase, when long-wavelength modes show gradual growth and short-wavelength modes show a perturbation phase reversal due to a Richtmyer-Meshkov-like instability. After shock breakout, the compressed foils accelerate as a unit and further perturbation growth is due to the Rayleigh-Taylor instability. Detailed comparisons with simulations indicate that in the linear Rayleigh-Taylor regime the 2D single-mode perturbations grow exponentially in time. In the nonlinear regime the growth slows and the perturbation shape changes from sinusoidal to "bubble and spike" with the appearance of higher Fourier harmonics. In the multimode perturbations, the individual modes grow independently in the linear regime, but become coupled in the nonlinear regime. In addition to the higher harmonics of the individual modes, coupling leads to the appearance of $k_i \pm k_j$ "beat" modes. This results in a redistribution of the perturbation into a broader Fourier spectrum causing a change of shape: bubbles become broader and spikes narrower. The overall size of the perturbation is not significantly altered, in agreement with simulations and multimode theory. The 3D experiments compare the growth from a rough, $\sigma_{rms} \approx 2$ µm surface to that from a smooth, $\sigma_{rms} \approx 100$ Å surface. The rough surface yields prominent ~120 µm diameter "hexagonal" bubbles and spike sheets late in time, whereas the smooth surface shows much less contrast. Close examination of the smooth foil data late in time, however, shows faint features of similar ~120 µm diameter.

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RICHTMYER-MESHKOV EXPERIMENTS ON THE NOVA LASER*

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We investigate the Richtmyer-Meshkov instability using the Nova laser to indirectly drive and compress planar targets consisting of a high density Be ablator and a low density tamper (~0.12 g/cc foam or ~ 1 g/cc plastic). The radiation drive is varied using different scale nickel coated hohlraums. The targets are diagnosed with 1D streaked and 2D gated radiographs in the face-on and side-on orientation. The shock velocities and compression agree with 1D hydrodynamic simulations using the measured xray drive. The growth, saturation, and phase of imposed single wavelength interfacial perturbations are compared with linear theory and 2D hydrodynamic simulations for a variety of wavelengths, initial amplitudes, shock and interface speeds, compressions, and density ratios. The linear growth is consistent with linear theory until the mode saturates at an amplitude ~ 30% of the wavelength. Initial experiments with multimode and random perturbations at the interface will also be described.

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Review Talk 2

Recent Developments in Short-Pulse High-Intensity Laser-Plasma Interactions

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The advent of intense short-pulse lasers has led to new applications for laser-plasma physics, such as laser-plasma accelerators, optical-field-ionized x-ray lasers, and the fast ignitor fusion concept. Furthermore, it has provided the impetus for experimental, theoretical, and computational studies of some fundamental laser-plasma interaction subjects.

These lasers have pulse lengths less than an ion plasma period. This enables for the first time the experimental study of laser-plasma interactions which occur on electron time scales, such as Raman Scattering, without the complication of ion dynamics. In addition, the pulse lengths are much shorter than the Rayleigh length and the plasma size. This requires the development of spatial-temporal theoretical description of the relevant instabilities. It also permits for the first time the modeling of laser-plasma experiments one-to-one in 2-D using PIC simulations. Last, the intensity of these lasers is large enough that the quiver momentum of an electron can be substantially larger than m_0c. This permits the study of ultra-relativistic laser-plasma phenomena. In this talk we will review some of the most recent work. We will emphasize underdense phenomena, such as Raman Backscatter, Raman Forward Scatter, relativistic self-focusing, ponderomotive electron blow-out, laser hosing, laser sausaging, laser channeling, cascade focusing, upshifting from ionization fronts, and wakefield generation.

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Poster Session 2

Nd-laser beatwave acceleration experiments

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We have shown previously[1] that the beating between two Nd-Yag (λ=1.064 μm) and Nd-Ylf (λ=1.053 μm) laser beams focused in deuterium generates intense plasma waves. These waves reach electric fields on the order of 1 GV/m before they couple with ion density perturbations.

We now study the acceleration of an external electron beam (E= 3 MeV) in these relativistic plasma waves. We describe the experimental set-up including the injection and the detection of the electrons and present the first results of these experiments.

1. F. Amiranoff et al ; Phys. Rev. Lett, 68, 3710 (1992)
   F. Moulin et al ; to be published in Plasma Physics (May 1994)

Modulational and Raman instabilities in the relativistic regime

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A large amplitude electromagnetic wave propagating in a plasma is known to be subject to severe modulational and Raman instabilities [1-2]. The works of Refs [1-2] were devoted to the weakly relativistic limit and applied mainly to an underdense plasma. We extend these works to include the fully relativistic limit for a circularly polarized light. We also calculate the characteristics of the instabilities in the case where the plasma is classically overdense, with $1 < (\omega_p/\omega_0)^2 < \gamma$, where ω_p is the plasma frequency, ω_0 is the laser frequency, and γ is the relativistic factor of an electron in the laser field.

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Abstract prepared for submittal to
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Conference, June 5-10, 1994, Monterey, CA

Evidence of Collisionality Saturation in Low Temperature Picosecond Laser Plasmas*, O.L. Landen, W.E. Alley and Y.T. Lee, LLNL, Livermore, CA 94550. The evolution in density and collisionality profiles for low temperature (< 10 eV) picosecond laser-plasmas expanding from a solid gold target has been inferred from detailed scans of the angle-dependent specular reflectivity of P- and S-polarized non-invasive probe picosecond pulses. The reflectivity data has been fit by rapid computerized solutions to the Helmholz wave equations[1-4] using multiple-parameter analytic expressions for the density and collisionality profiles that are inserted into the Drude model for the plasma dielectric function. We demonstrate that density scale-lengths as short as 1 nm and with 10% accuracy above 10 nm can be inferred from the data, and that deviations from a simple linear dependence of collisionality with ion density n_i is needed to explain the data. The best fit collisionality profiles follow an $n_i^{1/3}$ scaling at early delays (< 5 ps), consistent with simple arguments (e.g. Ref. 5) and published conductivity calculations[6] for strongly-coupled plasmas. At later delays corresponding to lower temperatures, a collisionality scaling independent of density or even following $n_i^{-0.2}$ fits best, which can be explained by simple analytic arguments including both non-ideality and partial Fermi degeneracy. The density and collisionality profiles are also compared with fine-mesh 1-D hydrodynamic simulations[7] incorporating a wave-solver and low temperature and solid-state conductivity models[6].
*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.

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[3]J.C. Kieffer *et. al.* Phys. Rev. Lett. **62**, 760 (1989).

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[6]Y.T. Lee and R.M. More, Phys. Fluids B **2**, 1395 (1990).

[7]O.L. Landen and W.E. Alley, Phys. Rev. A **46**, 5089 (1992).

Two Dimensional Numerical Simulations of the Spherical Pinch as a Neutron Generator

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Abstract

The fluid dynamics and high-temperature hydrodynamics of the spherical pinch can be briefly described as an explosion within an implosion[1]. In the resistive type spherical pinch, the implosion shock waves are generated by a discrete number of electrodes positioned symmetrically on the internal surface of a sphere. A 2-D hydrodynamic code based on an FCT algorithm has been developed to simulate the phenomena of the resistive spherical pinch. We present numerical simulations in terms of density, pressure, temperature, confinement time, total accumulated number of neutrons, and time resolved neutron flux from reactions in a deuterium-tritium mixture. The importance of symmetry of electrode positioning is discussed. The study presented here lays the groundwork for our forthcoming systematic stability study of the spherical pinch.

[1]H. Chen, J. Chen, B. Hilko, E. Panarella (1994) "Numerical Comparison between ICF and ICF-Spherical Pinch" *Journal of Fusion Energy*, Submitted.

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Interdiffusion of Ions in Plasmas

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If there are several kinds of ions in a plasma, the usual hydrodynamical equations must be supplemented by a set of equations for the evolution of concentrations. Closing the system of equations requires transport equations that give "diffusion velocities", or "mass fluxes", in addition to the usual heat fluxes, as linear functions of the gradients of concentrations, temperatures, and pressure.

Calculating the transport coefficients requires in general the solution of a set of coupled linearized Fokker-Planck equations. At the same level of approximation as used by Braginskii (three Sonine polynomials), it amounts to inverting a $3N \times 3N$ matrix (N is the number of species), which is quite feasible in line in the hydro code. To check the accuracy of this approximation, and to get more insight into the form of the transport equations, the Fokker-Planck perturbation equations have been solved numerically in two particular cases: two kinds of ions with very different masses, and N ion species with equal masses.

The concentration equations are mainly diffusion ones, but "thermo-diffusion" terms also may be important. Numbers show that ion interdiffusion, being proportional to $T_i^{5/2}$, goes from negligible at 10 eV to important at 1 keV in laser produced plasmas: no sharp interface between materials can survive for more than picoseconds at 1 keV. However, the pure coulombic effects calculated here slow down if turbulence is established.

Perturbation growth in initially-perturbed laser-irradiated foils before the first-shock breakout

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Perturbation growth in laser-driven imploding shells is a critical issue of laser fusion. In this paper, we report an experimental study on perturbation growth in the initial stage of laser-driven foil acceleration, that is, in the period of the first-shock propagation. The perturbation growth in this period gives initial conditions of the Rayleigh-Taylor instability in the following acceleration phase. The experimental conditions and results are described below.

Target: As targets, we used polystyrene foils whose thickness ranged from 40 to 80 μm. The foils had sinusoidal perturbation on the laser-irradiated surface, whose wavelengths were 60 and 100 μm and whose amplitude ranged from 0.3 to 6 μm.

Laser: We used a spectrally-dispersed partially-coherent laser produced by the fiber-smoothing technique, with a random-phase plate. The laser wavelength was 0.53 μm, and the laser intensity was 4×10^{13} W/cm^2. The pulse duration was 2.3 ns (FWHM), and the waveform was a flat-top pulse whose rise time and decay time were both 0.1 ns.

Diagnostics: The laser-irradiated targets were diagnosed with three methods: face-on x-ray backlighting, edge-on x-ray backlighting, and optical measurement of the shock-front arrival at the rear surface.

Results:

(1) With face-on x-ray backlighting, significant growth of the areal-density perturbation was observed.

(2) With edge-on x-ray backlighting, no perturbation growth at the laser-irradiated surface was observed.

(3) With optical measurement of the shock front, the rippled shock front and its phase inversion were observed.

From the above experimental results, it is concluded that the major mechanism of the areal-density-perturbation growth before the first-shock breakout is not Richtmyer-Meshkov instability at the laser-irradiated surface but the rippled-shock-front propagation accompanied with phase inversion.

Anomalous Absorption Conference, June, 1994
Monterey, CA
Lasnex 2-D Analysis of Nova Gasbag Targets*

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We simulate the Nova 10 beam gasbag target with the random phase plate probe along the centerline of the cylindrically symmetric Lasnex model. The experiment has a dark ring around the probe beam since the probe has a much smaller radius than the heater beams. We simulate the dark ring by no intensity between the probe with FWHM $\sim$ .022 cm to an outer radius of .09 cm. The heater beams have fairly uniform intensity around the rest of the target. We include the polyimide skin of .4μm thick. A shock forms on the heater sides with some ion heating, but little shock or ion heating occurs near the probe due to radial divergence.

T_e becomes fairly uniform by .5 ns by electron transport and the heater beams opposite the probe in spite of the dark ring. Runs with electron transport flux limiter =.1 and .03 both showed T_e uniformity.

The center T_i/T_e increases for both reasons of T_e dropping and T_i increasing from electron-ion collisions, but the damping decreases because of the peculiarity of ion Landau damping with slow and fast (proton) species (see E.A.Williams' talk).

Velocity and density gradients increase with time, but the Rosenbluth gain is much larger than the homogeneous gain in a speckle length.

Nishikawa and Liu, Adv.Plasma Phys. Vol. 6, eq. III-29 show the homogeneous gain is $\sim$ 4 in a speckle length of 52 microns with ion Landau damping of .1 and with the average intensity. A calculation of gain with a probability distribution of intensity may partly account for the observed scattering (see Harvey Rose's talk). E.g., for a random phase plate, a probability distribution of exp(-I/<I>) fits Paul Wegner's measured data. For I/<I>=4, exp(-I/<I>)=.02 so if we estimate that $\sim$ half of the light with gain $\gtrsim$ 16 is scattered, we roughly fit the data. Other factors affecting scattering will be discussed.

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

24th Annual Anomalous Absorption Conference
Asilomar Conference Center, Pacific Grove, CA June 5-10, 1994

ELECTRON KINETIC SIMULATIONS OF ULTRA-SHORT, HIGH INTENSITY LASER-SOLID INTERACTION

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Simulations of ultra-short (300 fs), high contrast, high intensity (>5×10^{16} W/cm^2) laser-target interaction were performed with our electron kinetic code "FPI" [1]. The laser wavelength was 0.53 μm, and the target was aluminum. Absorption occurs at a density near 10^{23} cm^{-3}, far above critical, but below solid density. However, not only is solid density material heated by thermal conduction, but also compressed material, at nearly twice the solid density, reaches a temperature of approximately 200 eV, enough to create significant populations of Li-like, and even He-like ions. Furthermore, non-local transport effects imply that an important population of electrons of sufficient energy (>1.5 keV) reach this region, and can excite K-shell electrons there. Thus, this regime offers the opportunity to observe K-shell spectra at above solid density.

[1] J.P. Matte et al., Phys. Rev. Lett. 49, 1936 (1982); 53, 1461 (1984); 72, 1208 (1994).

Two-dimensional calculation of perturbation growth at an internal interface of a plane target

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Mix at an internal interface has been evidenced in laser planar driven layered foils experiments conducted on Octal laser system at CEL-V [1]. In support of these experiments, simulation of an accelerated Al/Au flat target has been performed with a 2D multifluid Coupled Eulerian-Lagrangian code.
A perturbation is located at the aluminium/gold interface; it's initial spectrum includes 20 wavelengths (from 1μm to 20μm). Mix development is ruled successively by Richtmyer-Meshkov (R-M) instability and by Rayleigh-Taylor (R-T) instability. In spite of flow compressibility, mode development obeys classical R-M and R-T linear growth rates as long as mode coupling is not active. Fourier analysis of the pertubed interface put in evidence the spectrum enlargement with time, as the dominating mode slips towards small modes. We obtain quantitative informations about instability-induced mixing such as the fluctuating part of the kinetic energy FKE, the lost potential energy LPE,... Detailed analysis of the R-M phasis is on progress.

[1] P.A. Holstein et al. Nuclear Fusion, **32**, 670 (1992)

RADIATIVE TRANSPORT IN SLAB GEOMETRIES*

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The problem of solving the radiative transfer equations is examined for slab geometries having Raleigh-Taylor undulations in the temperature and density profiles. We develop a modification of the variable Eddington approximation in which the variable Eddington factor is evaluated using a particular *ad hoc* radiation intensity profile. This model requires less computation than full radiative transport but is more accurate than the standard diffusion approximation. In particular, our model agrees with known results corresponding to the limiting cases in which the radiation intensity is nearly isotropic, the limit of all photons streaming in one direction, and the limit in which the photon mean free path greatly exceeds the slab thickness. We compare our model with traditional treatments of radiative transfer.

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24th Annual Anomalous Absorption Conference
Asilomar Conference Center, Pacific Grove, CA (USA) June 5-10, 1994

LASER INTERACTION WITH EXPANDING CORONAL PLASMAS

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Uniform deposition of laser energy onto a pellet surrounded by an underdense coronal plasma is a key issue in the direct-drive scheme of Inertial Confinement Fusion. The onset of laser induced plasma instabilities though, can seriously affect the laser-plasma coupling leading to detrimental effects such as reduction of absorption and enhancement of density and/or intensity non-uniformities. To study the physics involved, two conditions must be primarily fulfilled. The underdense test plasmas typically used in interaction experiments must be fully characterised and the interacting laser beam must be controlled in terms of spatial and temporal coherence in order to study the dynamics of these instabilities.

Recent experimental results will be presented and discussed, including a careful characterisation of preformed plasmas and measurements of interaction effects with a 600 ps laser pulse. The far field intensity distribution of the laser beam was either modulated or smoothed with various smoothing techniques. X-ray emission, second harmonic generation and back-scattering by stimulated ion-acoustic waves have been studied. Information has been obtained on the local evolution of plasma conditions.

EXPERIMENTAL TESTING OF THE RELATIVE CONSISTENCY OF TWO GIVEN E.O.S.

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D. BATANI, A. BENUZZI, S. BOSSI (Université de Milan, ITALIE)

High pressures laser shock waves are used for testing in a simple way the mutual coherence of two given EOS. The technique we used is derived from the mismatch impedance one [1], and needs structured step-targets. In order to obtain a laser focal spot uniform on a relatively large distance (≈ 200 μm diameter), we used a new optical smoothing technique, using random Fresnel phase zone plates (PZP)[2]. The targets are made of a basis of material A (aluminium) on which are made two steps of known height, one of the same material A, the other of material B (gold). The rear of the target is imaged on the slit of an optical streak camera. The time of the breakthrough of the laser induced shock is measured at the bottom of the steps and at the top of each one. The velocities of the shocks induced in each material are then experimentally measured, and the shock pressures are deduced, using the given EOS. Since the pressures in the two materials are not independent, but related by the impedance matching equations, the experimental pressures must agree if the two given EOS are mutually coherent.

[1] Ya. B. ZEL'DOVICH and Yu. P. RAIZER, Physics of Shock Waves and High Temperature Hydodynamic Phenomena (Academic, New York and London, 1966)
[2] R. M. STEVENSON et al. , RAL Annual Report, p. 125 (1993)

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Abstract for the 24th Annual Anomalous Absorption Conference
June 6-10, 1994
Pacific Grove, California

Poster Presentation

Plasma Heating from Relativistic Electron Plasma Waves

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Recent experiments at UCLA have studied the generation of large amplitude relativistic plasma waves produced by two collinear lasers. Several diagnostics (electron acceleration, Thomson scattering, etc.) in these experiments have indicated that plasma waves with an amplitude n_1/n_o = 30% are being excited. Since these waves experience almost no Landau damping, plasma heating by these waves has often been considered unimportant. Electrons in these waves, however, can have quiver velocities of $v_{osc}/c \approx 0.3$, and this energy can eventually be coupled into the plasma. This heating has been studied by monitoring the x-ray emission from the plasma (due to bremsstrahlung) with an x-ray CCD camera. Experimental results show that when a large amplitude plasma beat wave is excited, the plasma is heated to 2-3 keV. When the the density is tuned away from the resonant density, or the laser is operated on a single frequency, the x-ray flux and the temperature are much lower ($T \approx 100$ eV). Results are presented from both hydrogen and argon plasmas, and from linear and circular polarization of the laser. Future plans include using a pinhole or a ring aperture to produce an x-ray image of the beat-excited plasma.

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24th Anomalous Absorption Conference 1994

Multifluid simulation of exploding-foil collision experiments

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A multispecies Eulerian one-dimensional fluid code is described, which allows interpenetrating flows to be simulated in the frame of the quasineutral hypothesis (short Debye length approximation). The convection of the mass, momentum and energy densities for each ionic species is computed using the standard FCT modules of Boris[1] with some improvements for dealing with plasma-vacuum interfaces. Electronic transport, including all terms relevant to the multifluid case, is treated in the frame of a generalized Spitzer formalism[2], leading to effects usually not taken into account in hydrocodes, such as ion-ion frictions mediated by the electrons. This code thus provides a more complete and consistent treatment of transport in the case of interpenetrating fluids than, e. g., the code of Rambo and Denavit[3]. The multifluid code takes standard hydrodynamic simulations of single exploding foils from the code FILM as input and its output is then post-processed by the atomic physics package TRANSPEC[4], yielding reconstructed spectra to be compared with the experimental results.

Typical simulation results in the case of colliding laser-accelerated aluminum foils are shown. These experiments were conducted using two beams of the LULI laser at 2ω with random phase plates, symmetrically impinging onto two Al foils of .8 μm thickness, yielding a gaussian pulse of 600 ps FWHM and 3×10^{13} W/cm^2 maximum irradiance. This set of parameters was chosen so that the foils would become fully ablated at collision time. Plasma diagnostics include pinhole imaging of the collision region, time-resolved monochromatic imaging at 6.64 Å using toroidally bent quartz crystals, low resolution time-resolved and high resolution time-integrated spectroscopy of the exploding-foil plasmas and of the collision region. Preliminary experimental results give an estimate of the electron density and temperature in the collision region. Qualitative agreement is found between the measured spatial extension of the emission zones of various heliumlike and hydrogenlike lines with the multifluid code results post-processed by TRANSPEC.

[1] J. P. Boris, "Flux-corrected transport modules for solving generalized continuity equations", NRL Memorandum Report N° 3237 (1976).

[2] from: F. L. Hinton, "Collisional transport in plasma", in "Handbook of Plasma Physics" Vol. 1, A. A. Galeev and R. N. Sudan eds (North Holland, Amsterdam 1983) p. 147.

[3] P. W. Rambo, J. Denavit, J. Comput. Phys. **98**, 317 (1992).

[4] O. Peyrusse, Phys. Fluids B **4**, 2007 (1992).

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

THERMAL FILAMENTATION OF COUNTERPROPAGATING LIGHT WAVES

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The interaction geometry of two counterpropagating light waves occurs in basic plasma physics experiments and in burn-through experiments in inertial confinement fusion. Although the transverse modulational instability due to the ponderomotive nonlinearity has been well studied,[1] the thermal nonlinearity dominates the ponderomotive nonlinearity for parameters typical of recent experiments at UCLA[2] and lowers the instability threshold dramatically.

Detail analyses of thermal filamentation and the resonant ion-acoustic response associated with pump waves of unequal intensity are given. The experimental signatures of this instability are described, and the results of current experiments are discussed. The possibility of using these instability signatures to test the nonclassical heat transport theory[3] is also discussed briefly.

1. G. G. Luther and C. J. McKinstrie, J. Opt. Soc. Am. B **7**, 1125 (1990); C. J. McKinstrie and M. V. Goldman, J. Opt. Soc. Am. B **9**, 1778 (1992).
2. Y. Kitagawa, R. L. Savage, Jr., and C. Joshi, Phys. Rev. Lett. **62**, 151 (1989); A. Lal and C. Joshi, J. Opt. Soc. Am. B **8**, 2148 (1991).
3. E. M. Epperlein, Phys. Rev. Lett. **65**, 2145 (1990).

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Prefer Poster Presentation Next to UCLA Poster Presentation

Abstract for the 24th Annual Anomalous Absorption Conference
June 5-10, 1994
Pacific Grove, CA
Poster Presentation

Tunable Radiation Generation Using Odd Harmonics from the Critical Surface[1]

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The generation of odd harmonics from the interaction of an intense electromagnetic wave with an overdense plasma is investigated. This interaction could lead to a novel tunable radiation source in the ultraviolet to soft x-ray wavelengths. The harmonics result from relativistic mass effects and $\vec{v} \times \vec{B}$ density bunching within a skin depth of the critical surface. In PIC simulations, the power reflected into the third harmonic agrees reasonably well with theoretical expressions obtained from a perturbative analysis. The power efficiency into higher order harmonics and the scaling of the density, and incident intensity are obtained from the simulations. Conversion efficiencies as high as 10^{-4} have been obtained into the 15th harmonic.

1 Work supported by DOE Grant Nos. DE FG03-91ER12114 and DE FG03-92ER40727, and LLNL Tasks #20 and 32

Observation of filamentary structures and whole beam self focussing in the interaction of 350fs KrF and 12ps Raman shifted laser pulses with a dense gas jet target.

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Whole beam self focussing and filamentary structures were observed when high intensity ultraviolet laser pulses of durations of 350fs or 12ps, were focussed into a Neon gas jet The 350fs interaction produced filamentary structures that showed an abrupt threshold with both incident intensity and target density , and were evident when the intensity-density product was greater than 1×10^{35} W/cm^2 atoms/cc. The interaction of the 12ps, 268nm laser pulse with the gas jet was similar to the 350fs one at moderate density - intensity products with the production of strong filamentary structures. At higher target density - intensity products, the outer edges of the continued to produce the filamentary structures but the centre of the beam was found to self focus down to a diffraction limited filament. Comparisons with analytic estimates and 2D PIC simulations suggest that the dominant filamentary and self focussing mechanism in both of these experiments was due to ponderomotive ejection of electrons from hot spots initially present on the laser focal profile. These measurements have important implications for X-ray laser, plasma accelerator and harmonic generation schemes which require a uniform laser- plasma interaction when the intensity -density product can approach or exceed 1×10^{35} W/cm^2 atoms/cc.

"Experimental study of SBS and SRS in the Nova gas-target large plasmas"

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Long scale length, high temperature plasmas (~ 2 mm, 2 - 4 keV) have been produced in both open geometry and hohlraum geometry targets. These plasmas have similar conditions to those expected in the underdense plasma region of ignition-scale ICF hohlraum targets. A high intensity 351 nm interaction beam was used to study the scaling of SBS and SRS with laser intensity, f-number, beam smoothing, and varying plasma conditions. SBS reflectivity as high as 30% has been observed, with SRS levels of ~ 1% or less. Several interesting trends are present in the data including anti-correlation of SBS and SRS reflectivity, SBS scaling with plasma species, and changes in the SBS spectra with laser intensity and SBS reflectivity. A comparison of the data from the open geometry and two hohlraum geometry targets will be made, with an emphasis on similarity of trends in the data from all three targets.

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Twenty-Fourth Annual Anomalous Absorption Conference
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Analysis of SRS and SBS spectra from Nova Exploding Foil Plasmas*

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SRS and SBS spectra from Nova exploding foils show interesting and complex structure such as 1) broadband temporal bursts together with slowly time varying features in the SRS spectra, 2) strong SRS emission in the wavelength region 1.1 to 1.2 λ_0, 3) temporal evolution of the SRS Landau cutoff, 4) presence of $\omega_0/2$ emission, 5) bursty and smooth temporal evolution of SBS spectra, and 6) correlation of SRS and SBS emission. One interpretation suggested by the nature of these spectra is that the SRS and SBS instabilities occur with as well as without hot spot self-focusing. These spectra also provide information about electron temperature, electron density, and plasma flow speed in the instability region, and in some cases instability thresholds. Similar SBS backscatter levels in CH and Ti plasmas indicate that the SBS instability is limited by velocity gradients. These plasmas are produced by preheating either a CH or Ti foil with 2300 J of 351 nm laser light in a 1 ns square pulse. The plasma instabilities are driven with a 1 ns square pulse of 527 nm laser light with a range of intensities and energies. In addition, both random phase plate (RPP) and temporal smoothing by spectral dispersion (SSD) are applied to the interaction beam. We will present the detailed structure of the spectral measurements and discuss the relative roles of velocity gradients, density gradients, Landau damping, and filamentation on the instabilities as suggested by the measurements.

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Enhanced Ion Acoustic Fluctuations in Laser Produced Plasmas

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The nonuniform laser heating of a plasma has been identified as contributing to a source of enhanced ion acoustic fluctuations that occur during the initial phase of the laser plasma interaction process. The resulting temperature gradient creates a heat flux which is responsible for the excitation of unstable ion waves which propagate predominantly in a plane perpendicular to the laser beam axis. We have used the results of weak turbulence theory to estimate the stationary level and the angular distribution of these fluctuations. These are shown to have a dramatic effect on the Brillouin scattering reflectivity. The importance of this ion wave enhancement mechanism for the short (10 ps) laser pulse interaction experiments is discussed.

* *On leave from P. N. Lebedev Physics Institute, Russian Academy of Sciences, Moscow 117924, Russia.*

Wednesday, June 8, 1994

Oral Session 3

Laser Plasma Physics with Short Pulses

24th Anomalous Absorption Conference 1994

Accurate measurement of the short Scalelength plasma produced by a femtosecond laser

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A key issue in the field of laser-matter interaction using very intense femtosecond

dense hot plasmas. For instance, in the case of the interaction with metallic targets, it is important to obtain a time- and space-resolved picture of the critical density layer of very small gradient scale length $L/\lambda<0.1$. This determines the region where most of the energy transfer takes place.

We describe a method which allows to measure the location of the critical density front in a laser-produced plasma with greatly improved space resolution while retaining the time resolution. Our method is quite general and can be applied to other situations involving weak but fast phase shifts, such as in the characterization of laser-induced plasma in low density gases, or in the study of free carrier generation in solids occuring on a subpicosecond timescale.

In the experiments, the target is irradiated with an intense femtosecond optical pump pulse and is simultaneously probed with two successive identical femtosecond probe pulses separated in time by an external Michelson interferometer. It is well known that the power spectrum of a double pulse sequence is modulated with a fringe period inversely proportional to the pulse separation. Any phase shift due the change of propagation conditions induced by the pump pulse which occurs between the two pulses can be therefore detected directly in the reflected or transmitted spectrum of the two probe pulses as a fringe displacement

Two different regimes can be implemented. In the first regime, the plasma-inducing strong pump pulse lies between both probe pulses. This type regime is well adapted to the absolute measurement of the location of the reflective plasma layer at a given delay. In the second regime the pump pulse precedes both probe pulses. This regime yields, with high accuracy, the relative location of the critical layer at two different times and is therefore well suited for the precise measurement of the plasma axial expansion velocity.

We have measured the dephasing of the second probe pulse due to the plasma expansion over a wide range of laser flux up to 10^{16} W/cm^2 on different targets. The results are interpreted by performing extensive numerical simulations of the experiment. We use the hydrocode FILM to calculate the evolution of a laser generated dense plasma with short scalelength gradients. The effects of beam propagation through the subcritical region and the transition from the Fresnel reflective regime of a metal to the resonant absorption in a short scale-length plasma gradient are computed with an electromagnetic solver. From an analysis of the results it is possible to extract a precise dynamical determination of the plasma density gradient of the laser-produced hot plasma.

Comparison of Picosecond Laser-Plasma Physics in Different Microstructured Targets

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&
THE ONTARIO LASER AND LIGHTWAVE RESEARCH CENTRE

Applications are developing for laser-produced plasmas as marvellous soft x-ray sources for lithography and microscopy,[1] and prospectively as sources with sufficiently high peak power to pump soft x-ray and XUV lasers.[2] An important part of the success of these applications, and particularly for soft x-ray laser development, is the improvement of x-ray conversion efficiency in laser plasmas. Falcone and co-workers have introduced the use of microstructured materials, both lithographically produced and evaporation-deposited 'smoke' targets, as subpicosecond laser-plasma targets, and have shown that such targets produce conversion efficiencies an order of magnitude greater than that found for flat or polished targets.[3]

We describe early results of our investigations of the laser-plasmas produced in such targets: efforts to measure the isoelectronic-line-ratio temperature in 'smoke' targets; and a comparison of one-dimensional structures, such as lithographically ruled targets, and three-dimensional structures, such as the quasi-fractal 'smoke' targets, to a new type of structured target which has a more nearly two-dimensional, rod-like structure. These new velvet-like targets are electrochemically produced, cheaply and in substantial areas, and can be prepared using a number of different metallic elements.[4] With structural regularity and small-scale expansion divergence of these targets intermediate to the lithographically produced targets and quasi-fractal 'smoke' targets we hope to produce a more analytic description of absorption and plasma hydrodynamics.

These experiments were conducted using the Toronto CPA system, $\lambda = 1\ \mu m/0.53\mu m$, producing pulses ranging from 1 ps, 10^{17} W cm^{-2} to 600 ps, 10^{14} W cm^{-2}.

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Abstract for the 24th Annual Anomalous Absorption Conference
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Oral Presentation

Laser Pulse Erosion and Local Pump Depletion at Ultra-High Laser Intensities[1]

C.D. Decker, W.B. Mori, and K.C. Tzeng, UCLA

We examine theoretically and computationally the erosion of short-pulse high-intensity, $I\lambda^2 > 10^{19}(W/cm^2)\mu m^2$, lasers propagating in plasmas. The pulse erosion is significantly different than the self-modulation from Raman forward scatter which occurs at lower intensities. We derive a local pump depletion equation and show that it predicts the gradual erosion of the laser pulse. This phenomenon is observed in 1-D PIC simulations. Results from 2-D PIC simulations will also be presented which show the additional effects of plasma blow-out and refraction.

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24th Anomalous Absorption Conference 1994

Hydrodynamic simulations of femtosecond laser-produced plasmas

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In recent years, the technology of short pulse laser generation has progressed to the point that optical pulses of 100 fs in duration are routinely produced. Such pulses can be amplified to energies of a few tens of mJ corresponding to focussed intensities exceeding 10^{18} W /cm^2

To model the interaction of this high laser intensity with solid targets, we have used the 1D code FILM in which laser absorption was calculated by solving the Helmoltz equations for *p* and *s* polarization at various incidence angles. For *p*- polarized light the collision frequency was adjusted so that the field in the critical region of the plasma was never higher than the maximum field allowed by the wave breaking limit. The results of the hydrocode were compared with the EUTERPE 1 D 1/2 relativistic particle-in-cell code.

At high intensities, the photon momentum cannot be neglected and must be taken into account in the equations of the plasma hydrodynamics. For steep density gradients, the field penetrates in the dense part of the plasma where the collision frequency is high. For longer density gradients in *p*-polarized light the damping term, which simulates wave breaking, dominates. In both cases we cannot use the collisionless formula $F_p = \varepsilon_0/2\ n_e/n_c\ \mathrm{grad}(E^2)$ for the ponderomotive force because the integral of the force is not equal to the photon momentum: $0.5\ \varepsilon_0\ (1+R)\ \cos^2\theta\ E_0^2$ where R, θ, E_0 are the reflectivity, the angle of incidence and the incident electric field, respectively. We must calculate the ponderomotive force taking into account the dissipation. Electron density and temperature profiles will be presented with and without ponderomotrice force for different laser conditions.

From the plasma electron density and temperature profile given by the code and using the electromagnetic model, we have calculated the absorption and the phase of a specularly reflected probe beam at different angles of incidence. In order to interpret the pump/probe experiment, we have pointed out the different effects which contribute to the phase modification : motional Doppler, propagation through the plasma and phase jump at the reflection point.

The comparison between the results of these computations and pump/probe experiments done at LOA show the transition from the Fresnel reflective regime of a metal to the resonant absorption in a short scale-length plasma gradient. From these analysis it is possible to extract a precise dynamical determination of the plasma density gradient of the laser-produced hot plasma.

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X-ray and Electron Sources from Femtosecond Laser-Produced Plasmas

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Low hydrodynamic expansion plasmas are produced when an intense ultra-short laser pulse (100 fs, 10^{16-17} W/cm^2) is focused on solid targets [1-5]. Laser energy absorbed within the laser skin depth gives rise to a thermal plasma of several hundred eV temperature, close to solid density. Behind the thermal plasma, fast electrons resulting from the specific interaction of the incident laser light through a very steep density gradient eject inner shell electrons of the target plasma. This produces fluorescence line radiation as the inner shell vacancy is filled from outer shells.

It was found recently that the use of a corrugated or a rough target surface increases the total laser absorption [6]. In the present experiment, we control the roughness of the target surface by varying the amplified spontaneous emission (ASE) prepulse energy level [7]. A full width at half maximum (FWHM) 100 fs, 1.5 mJ, $3.x10^{16}$ W/cm^2 laser pulse is provided by a 10 Hz colliding-pulse mode-locked oscillator followed by a series of dye amplifiers. Maximum x-ray conversion is reached for an ASE fluence of 0.7 J/cm^2.

Time-integrated spectroscopy of bi-layered Al/Si targets has been made. Results were analyzed with the help of a Monte Carlo (MC) simulation of Kα fluorescence emission and electron energy deposition. An absolute calibration of the overall efficiency of our Kα x-ray diagnostic system, including the MC code predictions and the spectrograph and film detector, was obtained by using a monoenergetic electron beam as a Kα generator. The distribution of fast electrons was measured to be maxwellian with an electron "temperature" of 8.5 keV. The conversion efficiency of incident laser energy into hot electron energy was found to be 12±5 %.

The measured Kα x-ray intensity is about $5.x10^{12}$ W/cm^2. Assuming that the duration of the hot electron pulse is no longer than the visible laser pulse, the hot electron current density is about $2.5x10^5$ MA/cm^2. This ultrafast incoherent x-ray flash can have interesting applications in the study of conformation change kinetics of biological molecules or in photo-ionized x-ray laser schemes.

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Interaction of a 35 TW,800fs, 1μm CPA laser pulse with dense gas jet targets.

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The interaction of a 800fs, 1μm, CPA laser pulse with a high density gas jet target at powers exceeding 35TW and at relativistic intensities has been studied using time resolved shadowgraphy, Moire Deflectometry and interferometery techniques. Some of the highly non-linear features that were observed included whole beam self focusing, filamentation, and strong evidence for the production of relativistic plasma waves. In Nitrogen the onset of whole beam self focussing occurred at intensity-density products above 1×10^{34} W/cm^2 atoms/cc. When the laser intensity was increased to strongly relativistic levels, a strong central feature was observed to focus to a diffraction limited filament , while the outer edges of the beam broke up into numerous defocussing filamentary structures. When the laser power was very high, density fluctuations were observed that were consistent with the excitation of a large amplitude electron plasma wave. This paper will report on these observations and comparisons will be made with existing analytical theories and 1-D simulations.

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FLUX LIMITER IN PICOSECOND LASER-PLASMA INTERACTIONS

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The penetration of the thermal heat front in picosecond laser-plasma interactions has been studied using multilayer targets. A high-intensity-contrast, 1-ps, 1-µm laser pulse is incident on bulk Si targets coated with varying thicknesses of Al. Both spectroscopic and charge-collector measurements are used to study the thermal conductivity. The spectroscopic observation of Si He-α emission from the target indicates that the solid-density plasma has reached temperatures in excess of 100 eV. The thermal penetration is compared with Fokker-Planck and hydrodynamic simulations. We find that a flux limiter significantly in excess of the 0.03-0.1 typically required for long-pulse, laser-plasma interactions is necessary to explain the experimental observations.

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Prefer Oral Presentation

INTERACTION OF FEMTOSECOND LASER PULSES WITH HIGH PRESSURE GAS JETS .

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The propagation of an intense and ultrashort laser pulse in a high pressure (> 1 bar) gas-filled chamber is strongly modified because of the fast ionization induced by the intense optical field[1]. The laser intensity at focus can by reduced by an order of magnitude from its vacuum value.

We report on experiments where 80 femtoseconds, 620 nm wavelength , 2-3 mJ laser pulses are focused into a high density gas target .We compare the propagation of the laser pulse and the induced gas ionization in a gas-filled chamber or in a pulsed gas jet for laser intensities ranging from 2 to 4 10^{16} W/cm^2. Helium and Argon have been used. Pulsed supersonic gas jets are produced in vacuum by means of a fast - operating valve and a Laval nozzle. A neutral density of 2 10^{19} atoms cm^{-3} is obtained in a 2 mm radius cylindrical gas target.

Laser beam propagation and gas ionization are investigated by shadowgraphy and Moiré interferometry using a 70 fs , 570 nm wawelength laser probe beam. Spectral blue-shifting[2] of the transmitted laser pulse spectrum indicates both broadening and blue shift due to the time and space varying gas ionization.

It is shown that self-defocusing effects observed in Argon filled chamber, much more important as observed in the case of helium, can be significantly reduced by using a pulsed Argon gas jet. This is also well correlated to our observation of strong X-ray emission in gas-jet experiments[3].

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EXPERIMENTAL INVESTIGATION OF THE HEAT PROPAGATION IN HOT DENSE PLASMAS PRODUCED BY THE INTERACTION OF A 12 PICOSECOND LASER PULSE WITH SOLID TARGETS

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The results of an experiment in which a high-power, high-contrast KrF gas laser has been used to irradiate solid targets at intensities above 10^{17} W/cm^2 are presented. The propagation of the heat front was investigated by using multilayered targets. The burn through times were obtained by measuring the time delay between the X-ray emission from aluminium and silicon layers separated by a plastic layer of various thicknesses. The experimental data showed strong inhibition of the heat flux as the focal spot size decreased and the laser energy was kept constant. Although a reasonable agreement with a 1D hydrocode simulation was obtained for focal spots larger than 20 microns, increasing discrepancies were found for smaller focal spot sizes. Lateral transport, non-linear absorption, hot-electron preheat and generation of magnetic fields were considered as possible causes of the observed reduction in the heat flux. The effect of large self-generated magnetic fields on the heat flux was studied with a 2D MHD code for three different conditions. Simulations were carried out either with the magnetic field term neglected or for two different types of diffusion across the field, namely classical (inhibited by $(\omega\tau)^{-2}$) and Bohm (inhibited by $(\omega\tau)^{-1}$) diffusion. It was concluded from the simulations that the effect of the magnetic field becomes increasingly important for focal spot sizes smaller than 20 microns. Both the experimental data and the simulations are discussed.

BANQUET

Monterey Bay Aquarium

7 - 10 pm

Thursday, June 9, 1994

Oral Session 4

Rayleigh Taylor Instability & Hydrodynamics

Imprinting of Laser Nonuniformities with 0.35 and 0.53 μm Drive

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We have performed a series of experiments on modulations seeded by drive modulations in planar foils on the Nova laser at LLNL. For these experiments, samples (flat polyethylene foils 20 μm thick and 700 μm in diameter) were driven with $\sim 10^{14}$ W/cm^2 of laser light for 3 ns. We have used a narrowband laser beam of either 0.35 or 0.53 μm ("blue" or "green") wavelength, smoothed with a random phase plate. The targets are radiographed during acceleration using a multiple frame gated x-ray pinhole camera (gate time ~100 ps). This produced a series of two-dimensional images, from which we inferred modulations in optical depth. We saw an enhanced imprint with the blue drive laser compared with green, in agreement with a cloudy day model.

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BUBBLE-COMPETITION MODEL FOR HYDRODYNAMICALLY UNSTABLE INTERFACES

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The front evolution of Rayleigh-Taylor unstable interface is commonly described as a nonlinear bubble-competition process. A statistical model, based on the Sharp-Wheeler model,[1] which incorporates the basic feature of single-bubble rise and two-bubble competition based on an extended Layzer potential flow model, for $A \simeq 1$ and incompressible fluids has been developed.[2] Results obtained using the model have been found to be in good agreement with full 2-D numerical simulations for the Rayleigh-Taylor as well as the Richtmyer-Meshkov (RM) instabilities. The model offers a unified treatment of both instabilities and predicts a new novel scaling behavior for the RM bubble-front evolution.

For 3-D geometry it will be shown that the more-spherical a bubble is the faster it grows.[3] Therefore, elongated modes tend to become spherical and the front evolution will be dominated by the spherical-bubble competition.

Another description of the front evolution is a model based on a modal analysis.[4] This modal model also results in good agreement with the simulations. The correspondence between the model and bubble descriptions will be presented. It will be shown that even though the dominant long wavelength modes are not in a highly nonlinear stage of their evolution, the integrated effect of all modes presented in the spectrum causes the interface to have well-developed bubbles, competing with each other.

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4. D. Ofer, D. Shvarts, C. P. Verdon, and R. L. McCrory, "A Modal Model for the Nonlinear Evolution of Multimode Rayleigh-Taylor Instability" (to be published and this proceeding).

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Prefer Oral Presentation

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MULTIPLE CUTOFF WAVE NUMBERS OF THE ABLATIVE RAYLEIGH-TAYLOR INSTABILITY

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The cutoff wave number of the ablative Rayleigh-Taylor instability is calculated using an incompressible model. It is found that the cutoff can be characterized by the parameter $\Sigma \equiv V_a/\sqrt{gL}$, where V_a is the ablation velocity, g is the acceleration, and $L = \rho(d\rho/dx)^{-1}$ is the density-gradient scale length. If $\Sigma >> 1$, the cutoff occurs at long wavelengths $k_c L << 1$, while if $\Sigma << 1$, it occurs at short wavelengths $k_c L >> 1$. The case $\Sigma < 1$ is of interest for ICF capsule implosions, and the cutoff wave number is calculated using the physical optics approximation of the WKB theory. It is found that for a single value of the wave number, multiple modes with different eigenfunctions and growth rates can occur. In the γ, k plane the unstable spectrum is characterized by multiple branches with different cutoff wave numbers and eigenfunctions with different numbers of zeros. The theory also provides a formula for the cutoff wave number valid for inertial-confinement fusion (ICF) targets with rather steep density gradients or large ablation velocity ($\Sigma \lesssim 1$). It is also shown that, for modes near the cutoff, the peak of the eigenfunction moves away from the ablation front, and it is convected downstream. Comparison with other theories and with numerical results will be presented.

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

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Hydrodynamic Aspects of the Radiative Condensation Instability in Ablating, Laser-Produced Plasmas

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Radiative condensation instabilities are a subject of much investigation in both astrophysical[1] and tokamak[2] plasmas. The criteria for instability are also present in ablating, laser-produced plasmas. When we use sufficiently-resolved STA[3] opacities in our RAD2D code, we observe the instability as a well-identified, robust phenomenon. The instability is predicted to occur over a range of low to moderate Z target materials and incident laser temporal pulse shapes and intensities.[4] For certain classes of parameters specified by ablator material and laser pulse shapes, the instability can substantially affect bulk target properties. In other dopant and pulse shape regimes the developed instability remains confined to plasmas at mass densities below quarter critical for multinanosecond timescales and is sufficiently insensitive to local variations in laser intensity that it should be straightforward to design an experiment to detect it with NIKE. Such an experiment will be of use in validating hydrocodes and opacity models in ICF-relevant regimes.

Work supported by USDOE and ONR.

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AN INTERACTIVE MIX MODEL IN *LILAC* FOR LINEAR AND NEAR-LINEAR REGIMES OF THE RAYLEIGH-TAYLOR INSTABILITY

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An interactive modeling of the linear and near-linear regimes 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. The mix model need only describe the linear and near-linear regimes in both cases: the multimode analysis of the burnthrough experiment indicated that only a few of the modes become nonlinear, and target high performance requires that the RT instability remains in the linear regime. We present a model based on a multimode treatment of the RT instability in which the energy equation in the Lagrangian hydrodynamic code *LILAC* is transformed into the frame of the Legendre modes that describe the evolution of the RT instability. This permits a more accurate description of the heat conduction between regions of material that are brought in close proximity by the instability. It also takes into account the increased surface area that results from the instability. The model and its assumptions are described, and the results of simulations of recent burnthrough experiments are discussed.

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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.

Prefer Oral Presentation

Oblique Shocks and Instabilities in Inertial-Confinement Fusion

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Abstract

I consider the production of shear layers and subsequent Kelvin-Helmholtz instabilities caused by the interaction of oblique shock waves with density inhomogeneities. I present some clarification and correction of analytical results contained in the Jason report "Shock Obliquity and Stability in Inertial Confinement Fusion", JSR-91-325 by Diamond, *et al.* I present 2-D numerical simulations of oblique shocks interacting with density steps appropriate to ICF conditions, and compare the relative importance of Kelvin-Helmholtz and Richtmeyer-Meshkov instability growth at material interfaces after the passage of an oblique shock wave.

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A MODAL MODEL FOR THE NONLINEAR EVOLUTION OF MULTIMODE RAYLEIGH-TAYLOR MIXING ZONE

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Haan's mode saturation[1] and weekly nonlinear mode-coupling[2] models have been extended to treat the following phenomena:[3]

(a) Highly nonlinear mode coupling.
(b) Saturation of narrow and nonuniform bands of wavelengths.
(c) Density gradient effects.[4]

The model has been compared against full numerical simulation for various classes of initial conditions (uniform initial spectrum; wide and narrow bands; two bands). The results are in good agreement with the full simulations spectra even for the late nonlinear stages of the evolution.

Model results of the classical Rayleigh-Taylor instability, for cases where either the initial perturbations or mode coupling dominate the evolution of the mixing zone, will be presented. Potential application to situations relevant to ICF, will be discussed.

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Prefer Oral Presentation

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

SIMULATIONS OF SOFT X-RAY GENERATED PLASMAS CREATED TO ENHANCE THERMAL SMOOTHING

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The two-dimensional hydrodynamics code *SAGE* has been used to simulate experiments at the Rutherford-Appleton Laboratory in which copper wire targets are irradiated with low intensity soft x rays prior to irradiation with a main 1-μm or 0.5-μm laser beam. The purpose of the soft x-ray preheat is to produce a very uniform initial plasma. The plasmas are diagnosed using a 70-Å XUV probe. Both streaked and gated (~100 ps) images of the transmitted probe intensity are obtained and analyzed. It is of interest to characterize the hydrodynamics of these plasmas in order to assess their potential as a means of enhancing thermal smoothing and, in particular, mitigating the "start-up" problem.

In earlier work[1] density profiles on the front of the wire, obtained via Abel inversion from 351-nm optical probing, were shown to agree very well with simulations. This work has been extended to examine also the evolution of the plasma profile on the rear of the target and seek information about lateral energy transport. Additionally, quantitative comparisons are made with the XUV images, which have been obtained for 10-μm-diameter wires irradiated at 1054 nm and for 25-μm wires irradiated at 527 nm. Both simulations and experiment are consistent with an initial expansion of the plasma due to the soft x rays, ablation of this plasma from the front of the target by the main laser, and flow of plasma to the rear of the target.

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Prefer Oral Presentation

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

NONLOCAL ELECTRON TRANSPORT IN THE PRESENCE OF HIGH-INTENSITY LASER IRRADIATION

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We investigate electron transport in a plasma heated by spatially modulated laser irradiation. When the heating rate is greater than the electron-electron collision rate, the thermal conductivity is reduced by a factor of 3 to 4 from the Spitzer-Härm value for $k\lambda_e < 0.01$ and is less affected by nonlocal heat-transport effects for $k\lambda_e >> 1$, where λ_e is the electron mean free path and k is the perturbation wave number. Implications for thermal filamentation will be discussed.

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

Prefer Oral Presentation

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

SMOOTHING OF LASER IRRADIATION OF ICF TARGETS USING PRE-FORMED REFRACTING ATMOSPHERES WITH SMALL-SCALE INHOMOGENEITY AND TIME DEPENDENCE

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Small deflections of the laser irradiation of an ICF target by density fluctuations in a refracting atmosphere are examined as a means to reduce the irradiation nonuniformities that are dominated by static laser speckle. A suitable atmosphere can be created by exploding a thin, outer shell with a prepulse. Density fluctuations can be seeded initially during the fabrication of the shell, or they can be driven with the small-scale nonuniformity of the laser prepulse. The free propagation distance separating the shell from the main target allows small angular displacements to result in appreciable spatial displacements of the incident rays at the target surface. This can shorten the spatial scale of the speckle so that it is more easily smoothed by other means. As the density fluctuations evolve in time, changes in the ray deflection cause the speckle to evolve, which results in a temporal smoothing effect. Additional temporal smoothing occurs as ablated plasma accumulates in the atmosphere and advances the phase of the incident light waves. Our analysis is based on statistical modeling of density fluctuations, 1-D hydrocode modeling of the formation of suitable atmospheres, 2-D hydrocode simulations of the behavior of density fluctuations in time, and 3-D wave calculations of specific cases.

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

~~Prefer Oral Presentation~~

Three Dimensional Simulations of Laser Driven ICF Target Implosions.

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ABSTRACT

An understanding of relevant hydrodynamic instabilities is crucial to the success of ICF. Most of the work performed, however, has been concerned with ablation surface instabilities during the acceleration phase. We have previously presented results of Rayleigh-Taylor evolution in the deceleration phase using PLATO, our 3 dimensional spherical implosion hydrocode.

We have produced an upgraded version of PLATO with the addition of extra relevant physical phenomena. The code now has an electron thermal conduction model, a laser energy deposition model, a multiple material capability and a sliding mesh.

We are now able to model ICF implosions from the start of the acceleration phase through to stagnation in 3 dimensional spherical geometry with a perturbed laser and/or shell. New results will be presented from this version of the code with our main regions of interest being:

- Rayleigh-Taylor growth rates in the acceleration and deceleration phases.
- Feed through of perturbations from the outer to the inner surface of the shell.
- Inner surface perturbation geometries around maximum compression.
- Oscillations of the inside shell surface during the acceleration phase.

24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

GENERALIZED FLUID EQUATIONS FOR LASER-IRRADIATED PLASMAS

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Generalized fluid models[1,2] are useful for incorporating kinetic effects such as Landau damping and nonlocal thermal transport into fluid simulations of plasmas. This is especially true for studies of laser-plasma interactions, where the hydrodynamics can often be treated linearly. Such models involve choosing the closure coefficients, such as the ratio of specific heats and the thermal conductivity, in such a way as to approximate closely the exact kinetic response.

Time-dependent laser-plasma interactions, such as filamentation and self-focusing, involve two heat sources: inverse bremsstrahlung (IB) and PdV work. PdV work adds energy to the electrons in proportion to their initial energy, tending to maintain a local Maxwellian, while IB heating adds energy primarily to the slowest, most collisional electrons. Heat flux is carried chiefly by the faster electrons ($\sim 3.7\ v_t$); consequently heat arising from IB is transported more slowly than heat arising from PdV work. For short-wavelength perturbations there can be an order of magnitude difference in the appropriate thermal conductivities.

We show that this effect can be accurately modeled using a generalized fluid model with two energy equations, one each for the PdV and IB heat, with appropriate conductivities in each. By comparison with Fokker-Planck simulations we show that this model reproduces the correct response to IB heating from intensity variations over the full range of collisionality, as well as Landau damping in the collisionless limit.

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Prefer Oral Presentation

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24th Annual Anomalous Absorption Conference, Pacific Grove, CA, 5–10 June 1994

THREE-DIMENSIONAL SIMULATION OF THE LATE NONLINEAR STAGE OF THE RAYLEIGH-TAYLOR INSTABILITY

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The growth of the Rayleigh-Taylor instability in 3-D is calculated using a 3-D multimaterial arbitrary Lagrangian Eulerian hydrocode[1] as well as a 3-D Layzer-type potential flow model.[2]

The growth of a single mode in 3-D has been analyzed and shown to reach the same terminal velocity, independent of the initial aspect ratio of the perturbation. However the time that it takes to reach that terminal bubble velocity does depend on the initial shape and is longer as the aspect ratio is increased. This results in reduced penetration of the bubble for larger-aspect-ratio perturbation.[3]

Simulations, similar to that presented in Ref. 4, of the late deceleration stage of ICF spherical targets will be shown. The effect of the initial imposed perturbation and symmetry on the final compressed core shapes will be discussed. It will be shown that these shapes are not specifically the result of the spherical geometry and can be obtained in planar geometry using the same imposed initial perturbation, symmetry, and Atwood number.[1]

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D. Ofer, U. Alon, and T. Tlusty would like to thank the Laboratory for Laser Energetics for its hospitality during their visit. This work was partially supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Prefer Oral Presentation

Review Talk 3

Control of Laser Plasma Instabilities in NIF

D. Dubois

Poster Session 4

Parametric Instabilities Near Daughter Wave Turning Points: Two Generalizations of the Rosenbluth Gain Formula †

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University of Colorado at Boulder

We calculate the gain coefficient of a convective instability in an inhomogeneous plasma when the turning point of at least one of the daughter wave is reached. It is a generalization of the well known Rosenbluth gain formula[1] in two respects. First, we consider the case where the pump wave has a finite k-vector, in which case, only the high frequency daughter wave will be near its turning point. This is the case for Stimulated Brillouin Scattering (SBS) away from the critical density, for example. It may be called the SBS-like limit. Second, we treat the vanishing pump k-vector case, where both daughter waves are near their turning points. This is the case for the Plasmon-Phonon Decay instability (PPD), also known as the parametric decay instability, which occurs near the critical surface. This is the PPD-like limit of the gain. In either case, new scaling exponents and new coefficients are found which extend the range of problems for which convective gain coefficients are now known.

An earlier attempt by Perkins and Flick[2] to treat this problem did not result in complete answers as it relied, among other things, on ordering assumptions on the ion-wave damping which prevented the zero-damping limit to be extracted. Here, an integral representation for the solution will be given which allows all these limits to be derived from a single formulation of the problem. Extensions to cases where both daughter waves introduce inhomogeneity is considered separately[3].

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[2]Perkins, F. W., and J. Flick, Phys. Fluids 14, 2012 (1971) (1974)

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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.

2-D CALCULATIONS OF INSTABILITY GROWTH AND MODE COUPLING IN CONVERGENT GEOMETRY WITH MESA*

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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 growth at this stage is nearly like the classical Rayleigh-Taylor instability. In order to study the effects of convergent geometry and mode coupling upon this type of fluid instability, calculations have been performed in planar and cylindrical geometries. In cylindrical geometry, computational runs have been performed separately with a radial gravity and with an initial velocity. In all runs, the instability modes have been continued out into the non-linear regimes. The convergent geometry has an immediate effect upon the instability due to the fact that the wavelength is directly proportional to the radius. We have also noticed that the convergent geometry causes the mushroom caps' (or "hammer-heads") width to be increased over that predicted in planar geometry. Mode coupling has been found to have the following effects: 1) formation of side-bands due to mode addition, 2) packing of the mushroom caps due to the "nesting" of the high mode by the distortion of the low mode, and 3) convection of the high mode by the low mode. In the last two cases, we have found that convergent geometry enhances these effects primarily because of the wavelength dependence upon radius. The formation of a self-similar turbulent mixing layer has also been studied with the results showing that the growth of the mixing layer is enhanced at larger radii while being damped at smaller radii, when compared to planar geometry.

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

Heat Flux Driven Ion Acoustic Instability

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The kinetic theory of ion acoustic waves (IAW) [1] has been generalized to the case of IAW instability driven by an externally applied temperature gradient. The background electron distribution function supports a finite heat flux and the return current of cold electrons, which drives the instability. We have derived threshold conditions and linear growth rate of IAW in the presence of particle collisions, including e-e collisions. Our new results show two regimes of strong growth: (1) well known collisionless limit of large wavenumbers ($k\lambda_{ei} \gg 1$) [2], and (2) collisional regime ($10 > k\lambda_{ei} > 1$) of long wavelength IAW. The separation between these two regions is due to the effect of i-i collisions [3].

This instability can contribute to the enhanced levels of ion acoustic fluctuations, anomalous transport effects, and jet formations in regions of strong plasma heating.

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Anomalous Absorption Conference, June, 1994, Monterey, CA

k - a PC and Mac code to analyze SBS, SRS and filamentation*

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k solves the dispersion relations for SBS and SRS using table lookups for the Landau damping of the ion acoustic and electron plasma waves. The user enters T_e, T_i, n_e, angle scattered, intensity, wavelength, m_i/m_p, z, f/#, velocity, density, and intensity markers for gradients to print homogeneous and gradient gains, collisional and Landau damping thresholds for convective and absolute instabilities. k tells if the experiment is in the strong, weak coupling or thermal regimes. k prints the frequency shifts, bandwidth and inverse bremsstrahlung (IB) absorption lengths of the scattered light. It tells the growth rates in time and space. k tells the damping times and lengths of the ion acoustic waves or electron plasma waves. It estimates the $\delta n/n$. k gives the hot/cold equilibration lengths and times. k estimates the time for the ions to heat to saturate SBS. k does not calculate collisional damping for SBS but prints $k_{\text{ion}}\lambda_{\text{Debye}}$ and warns when the user is in that regime. The user can specify a random phase plate or measured Nova beam characteristics and k will estimate the fraction scattered from that intensity distribution.[1,2] k gives J.P.Matte's estimate for the power of v for the electron distribution and thus some idea of how non-Maxwellian[3] the electrons are.

The user can enter the observed Raman spectra, and k will print out the possible combinations of T_e and n_e that will radiate that spectra with the $k_{\text{epw}}\lambda_{\text{Debye}}$, electron Landau damping, collisional damping, bandwidth, homogeneous gain, IB absorption of the input and scattered light, convective and absolute thresholds.

k describes filamentation from three theories[4,5,6]. The user enters the initial filament width or lets the code figure the fastest growing mode. k tells the user if the filament is diffraction limited and gives self focus lengths and times. k prints if the filament is limited by speckle lengths.

k gives collision and equilibration times and mean free paths for ion-ions, electron-ion, ion-electron and electron-electron with inverse bremsstrahlung absorption lengths where applicable.

k gives table look up dampings for Maxwellian electron plasma waves and ion acoustic waves from Fried-Conte solutions.

Disks will be available for unlimited distribution. The executable code plus listing with references will be on the disks.

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

Angular Dependence of Absorption by Plasmas Heated by Picosecond KrF Laser Pulses

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Experiments using a 1 ps KrF laser pulse focused to an intensity of 10^{11} to 10^{14} W/cm^2 are being carried out. Angular dependence of the absorption (specular, diffused and backreflection) in this intensity range on solid targets is being studied for both s and p polarized radiation, using an Ulbricht sphere and backscattering diagnostics. Background plasma conditions are monitored by using Faraday cup ion measurements, x-ray emission measurements and specularly reflected Doppler shift measurements. The results of these experiments and our current understanding of the processes involved, will be presented.

ABSTRACT FOR
ANAMOLOUS ABSORPTION CONFERENCE

PRELIMINARY SPECTROSCOPIC ANALYSIS OF CORE TEMPERATURE, DENSITY, AND MIX STRUCTURE FOR HIGH-GROWTH-FACTOR (HEP4) CAPSULE IMPLOSIONS

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 experimental series.

(POSTER SESSION PREFERRED)

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Design and Analysis of Nova Gas-Filled Hohlraum Experiments*

L.V. Powers, C.A. Back, R.L. Berger, D.H. Kalantar, R.L. Kauffman,
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G.F. Stone, R.E. Turner and E.A. Williams

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Low-Z gas fills may prove desirable in NIF hohlraum targets as a means of controlling time-dependent symmetry variations. In current NIF designs, the underdense plasma has larger density and velocity scale lengths than standard Nova hohlraums, and hence may be more susceptible to parametric instabilities. We are producing relevant underdense plasma conditions in 2.5X2.5 mm cylindrical, gas-filled hohlraums with Nova and studying laser interactions in these large plasmas[1].

We discuss design considerations for creating large scale length plasmas on Nova and present calculations of the plasma conditions in these Nova gas-filled hohlraum experiments. Beam propagation and heating inferred from spatially- and temporally- resolved x-ray spectra compare favorably with design calculations. SBS and SRS levels and spectra have been measured in these targets for various 3ω probe beam intensities, focussing geometries, beam smoothing configurations, and fill gases. The features and scaling of the observed scattering are consistent with predictions based on the calculated plasma evolution.

[1] *R.E. Turner et al, 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.

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Anomalous Absorption Conference, June, 1994, Monterey, CA

Faraday Rotation on Brillouin and Raman Scattering

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The growth rate of Brillouin and Raman scattering is proportional to the cosine of the angle between the pump and scattered light (weak coupling limit).[1] A magnetic field with a component in the direction of the light wave propagation will rotate the polarization according to:[2]

$$\phi = \frac{e^3}{2\pi m^2 c^2 f^2} \int n_e \mathbf{B} \bullet dz =$$

$$\frac{2.35 \times 10^4}{f^2} \int n_e \mathbf{B} \bullet dz$$

which for 1 MG, n_e=10^{21}, and dz=.1 cm $\sim$ 2.4 radians. Backscattered light propagating back through the magnetic field will have its polarization rotated the other way. The growth rate dependence with the cosine varies if the Brillouin is strongly coupled,[1] and the spatial growth rate dependence varies with the growth rate depending on whether the damping is large or small,[3] but qualitatively, magnetic fields may be another factor which reduces Raman and Brillouin.

The same phenomenon occurs if light is reflected from critical density through a magnetic field to cause absolute Brillouin.[4,5].

We don't expect Faraday rotation to have a large effect on Raman and Brillouin, but it is interesting.

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[4]I.M.Begg and R.A.Carins, *J.Phys.D : Appl.Phys.* **9** 2341 (1976).
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Numerical Modeling of Plasmas Heated by Picosecond KrF Laser Pulses

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Hydrodynamic simulations of plasmas heated by picosecond KrF laser pulses are carried out using a 1-D code including a wave solver for various angles of incidence and polarizations. These calculations include time dependent ionization, pondermotive forces, Cauble and Rozmus' two temperature electrical conductivity model and the University of Alberta equation of state model. Comparisons will be made to different existing equation of state models and different electrical conductivity models. The calculated results will be compared with experimental data.

An analytical and numerical investigation of ion acoustic waves in a two-ion plasma

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The ion acoustic dispersion relation for a plasma containing two distinct ion species is investigated over a wide range of plasma conditions. An approximate general analytic solution to the dispersion relation has been found and is shown, by comparison to accurate numerical solutions of the individual modes, to be remarkably precise. This solution provides for the first time a systematic account of the totality of ion acoustic modes of the two-ion system.

Our analysis shows that ion acoustic modes with well-defined temporal oscillations (the amplitude of the wave does not decay on a time scale shorter than one cycle of oscillation) consist of two types of modes: (a) weakly damped modes for which $|\Im(\omega)/\Re(\omega)| \ll 1$, and (b) an infinity of critically damped modes for which $\Im(\omega)/\Re(\omega) \simeq -1$.

Our study shows that a plasma consisting of two distinct ion species exhibits at least one, and at most two, weakly damped modes for which $|\Im(\omega)/\Re(\omega)| \ll 1$. Exactly one weakly damped mode exists when only one of the following conditions is satisfied: (a) $(v_S/v_F)^2\Theta_S + \Theta_F \ll 1$, and (b) $1 < \Theta_S/(1+\Theta_F) < v_F^2/v_S^2$, where:

$$\Theta_{S,F} \equiv \frac{1}{1+k^2\lambda_{De}^2}\frac{Z_{S,F}^2 n_{S,F} T_e}{n_e T_{S,F}}.$$

Here, λ_{De} is the Debye length, n_e the electron density, $Z_{S,F}$ the ionzation states of the fast and slow ion species, T_e the electron temperatures, $T_{S,F}$ the ion temperatures, $v_{S,F}$ the ion thermal speeds, and k the wave number of the ion acoustic modes under consideration. When both conditions are satisfied simultaneously, the plasma will exhibit two coexisting weakly damped modes. Given a set of plasma parameters, our analytical close-form solutions will correctly predict the number of weakly damped modes as well as their locations in the complex-ω plane.

Our study also shows that it is possible to maximize the ion acoustic damping in a two-ion plasma by judicious choice of the relative ion concentrations. This will have the effect of reducing stimulated Brillouin backscatter by increasing the threshold laser intensity for the process.

Abstract

SBS IN MULTI-SPECIES PLASMAS

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Plasmas, such as CH, containing a mixture of heavy and light ion species support ion acoustic modes that are qualitatively different from those in single species plasmas. The light species provides additional Landau damping and a new inter-species mode is supported.

We examine the consequent effects on the theory of Stimulated Brillouin scattering.

* 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.

Poster preferred.

DIAGRAMMATIC APPROACH TO LASER-PLASMA INTERACTIONS, G. Shvets and J. S. Wurtele, *Department of Physics, MIT.* A novel diagrammatic technique for analyzing the nonlinear interaction of intense laser pulses with underdense plasmas is developed. We construct a classical field theory which models the laser-plasma interaction as a charged relativistic fluid coupled to electromagnetic fields. Proper renormalization of the electron and photon masses allows for calculations to arbitrary order in the natural smallness parameter of the problem, the ratio of the plasma to laser frequencies. By assuming stationary ions and adopting a special gauge, electromagnetic waves on a cold relativistic moving plasma (i.e., an electron beam) are separated into "photons" and "plasmons". Unlike the previous treatments, important nonlinear effects such as harmonic generation, parametric instabilities and nonlinear phase velocity correction are calculated without making a weakly relativistic assumption. For the first time the rate of 2nd harmonic generation in homogeneous plasma by spatially nonuniform laser pulse is derived. Extensions to thermal and inhomogenious plasmas are discussed and a new numerical approach to laser-plasma interactions, "particle simulations without particles", is suggested.

Studies of Laser Light Conversion into X-Rays in Thin Foil Targets.

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Experiments and numerical simulations were accomplished to investigate the X-ray emission of a plasma generated by laser irradiation of thin foil targets. The possibilities to control the X-ray conversion efficiency by proper adjustment of initial conditions were studied. The experiments were carried out in planar geometry on the "Mishen" facility. The main attention was paid to yield measurements and the spectral-temporal analysis of X-ray emission in the 10...100 A range at laser intensity of about 5*10E13 W/cm2.

Thin (0.025...0.8 micrometer) Cu and Pb layers 0.3...3 mm in diameter coated onto plastic substrata were irradiated. Plasma soft X-ray spectra with temporal resolution, X-ray angular isotropy, and conversion efficiency were measured. Multichannel X-ray calorimeter system and X-ray streak camera matched with transmission grating turned out the most efficient diagnostic tools in these experiments.

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 code was 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.

Comparative analysis of experimental and numerical data supports the concept of "re-emission zone" formation in supercritical density region of a plasma corona. It was shown that the proper choice of initial target parameters allowed one to control the overall yield and spectral intensities of laser-plasma X-rays.

Friday, June 10, 1994

Oral Session 5

Parametric Instabilities II

Abstract for the 24th Anomalous Absorption Conference
June 5-10 1994, Asilomar CA

Leaky Pulsating Filaments: A Paradigm?

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NonLinear Schrödinger Equation (NLSE) circularly symmetric filaments with "saturating" nonlinearities (i.e. ones where the nonlinearity is not infinite even if the field becomes indefinitely large) have often been discussed with an 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). Such integrals are indeed conserved, but the integrals extend over all space, rather than being localized to the filament. Hence one must careful not to assert that the conservation of these spatially (i.e. radially) integrated quantities necessarily implies the conservation of the same objects but limited to the filament. In fact, many simulations, such as in the classic paper of Zakharov et al. [1], have observed gradually decreasing oscillations (around what appears to be an asymptotic limit) in the central magnitude of the field variable, but it had not been 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. Most initial states with negative values for the Hamiltonian lead to such pulsating focusing, typically with an initial burst of outward radiation, followed by a much slower leak rate from the pulsating focused state. Creating a steady well-confined filament seems to be difficult to do, and such a state is likely to be approached via pulsating filaments with slow leaks which would seem to be a paradigm more applicable than that of a stable filament. Leak rates, mechanisms and related topics will be discussed, including the relation with the work presented by Chen and Sudan[2].

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Abstract for the 24th Annual Anomalous Absorption Conference
June 6-10, 1994
Pacific Grove, California

Oral Presentation

Evolution of Stimulated Raman into Compton Scattering through Wave-Breaking in a Tunnel-Ionized Plasma

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When an intense laser beam interacts with a gas, the formation through tunneling ionization and evolution of a plasma is a dynamic process. For intensities necessary for tunneling ionization, the laser is above threshold for the stimulated Raman and Brillouin instabilities. However, Brillouin grows slowly compared to the ionization time scales while the Raman is inhibited by the ionization process itself. Once the ionization process is over, the stimulated Raman scattering instability (SRS) grows and then wave-breaks rapidly, even in a low density plasma. Raman, rather than Compton, grows initially because the longitudinal temperature is cold (<10 eV) even though the transverse temperature of the tunnel ionized plasma is relatively high (50 eV). When the SRS heats the plasma through wave-breaking, the instability evolves into the Compton regime. The SRS instability occurs near w_p while the Compton spectrum is broad, out to 3 w_p, with an ω-k spectrum determined by the laser rather than the plasma dispersion relation.

Using Thomson scattering, we have experimentally measured the temporal evolution of the frequency spectrum of the electron plasma waves from Raman into Compton in a tunnel ionized plasma (4.7×10^{15} cm^{-3}) formed by a 10.6 μm CO_2 laser with a peak v_{osc}/c of 0.2. We have also ω-k resolved the Thomson scattered spectrum for the first time, showing the characteristic slope (dω/dk) of the Compton spectrum on the negative speed of light line. These experiments have been simulated using PIC codes and excellent agreement has been found in both the ω-k spectrum and time evolution of the waves.

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Theory of Ion Acoustic Waves in Equilibrium Plasmas

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We have developed an analytical theory of ion acoustic wave (IAW) dispersion and damping in the entire range of plasma collisionality. Our theory includes proper limiting behaviors in collisional and collisionless regimes. It also describes IAW in intermediate regions where the ion acoustic frequency is comparable to the i-i collision frequency and the ion acoustic wavelength is comparable to the e-i mean free path.

The ion response to acoustic disturbances has been described in terms of generalized fluid equations [1]. They include frequency dependent ion viscosity and frequency dependent ion thermal conductivity. A closure to fluid equations in collisional and weakly collisional regimes has been derived from the generalized 21-moments Grad approximation. Results for IAW damping and dispersion compare very well with the results of Fokker-Planck simulations [2]. We have also generalized this theory to plasmas with two species of ions.

Description of the electron response is based on the analytical solution to the linearized kinetic equation, which includes e-e collisions. We have found deviations from collisionless electron Landau damping as soon as $k\lambda_{ei} \approx Z^{2/3}$ ($Z \gg 1$). They are due to e-e collisions and they lead to $\gamma_e \propto k^{4/7}$ dependence of the IAW damping. Similarly electron thermal conductivity exhibits nonlocal behavior ($\kappa_e \propto k^{-4/7}$) in a wide range of wavenumbers $k\lambda_{ei} > 1$. In the collisional regime of long wavelength $k\lambda_{ei} \ll 1$ our theory shows deviations from the hydrodynamical limit at $k\lambda_{ei} \sim 1/16\sqrt{Z}$. Analytical results fit well data from kinetic simulations [3].

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The Search for Ion Plasma Waves*

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ABSTRACT

Electrostatic ion waves in plasmas have an ion-acoustic-wave regime, in which the dominant restoring force is due to the pressure gradient and the wave frequency is proportional to wavenumber, and an ion-plasma-wave regime, in which the dominant restoring force is due to charge displacement and the wave frequency is determined by the density. Despite the identification of ion plasma waves[1] in 1929, the development of kinetic theory[2] for them in 1961, and an extensive series of laboratory experiments through about 1970, ion plasma waves have not been clearly observed and their dispersion properties remain unverified. This is not surprising as such waves are strongly Landau-damped in typical, low-density and low-Z laboratory plasmas. However, ion plasma waves are in theory very-weakly-damped in plasmas in which $ZT_e/T_i >> 5$, and are the least-damped ion waves when $ZT_e/T_i \sim 50$. Such conditions are obtainable in laser plasmas.

In this presentation we will discuss ion plasma waves, implications of their resonant nature in some laser plasmas, scattering from them, and schemes for observing them. The development of an experimental geometry that may permit us to observe ion plasma waves, using the Trident laser facility at Los Alamos, are discussed in the poster by B.S. Bauer *et al.*

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Direct Measurements of Ion Acoustic Decay Instabilities (IADI) in a Hot, Large Scale Plasma relevant to Laser Fusion

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We have developed a multi-channel UV Collective Thomson Scattering (CTS) system for plasmas produced by short wavelength lasers. The CTS diagnostic allows us to make significant improvement in the understanding of plasma wave instabilities. We present two original results: (1) the first direct observation of the IADI in a laser produced high density plasma, and (2) the first study of the IADI in a plasma that approaches laser-fusion conditions, in a sense of having a large scale length (~mm), hot (~ keV) plasma. Previously, the IADI was studied by measuring the second harmonic (SH) emission. The SH emissions are produced by the product of two unknown electron plasma waves, integrated in a complicated way over wave number, propagation angle, and plasma density. Previously, many authors studied the IADI. All previous studies including ours[1], were performed in a relatively small scale plasma partially because a large laser energy is required to produce a large scale, hot plasma.

The IADI is potentially important for a hot , large scale plasma relevant to laser fusion. The IADI was easily excited , and the threshold laser intensity was low in a hot, large scale plasma. The spectral density functions of the plasma waves were measured by the CTS. We have also shown that the CTS signal from the IADI can be a good tool for measuring a local electron temperature without averaging over the plasma density.

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Spectroscopic characterization of laser-produced high temperature (3 kev) plasmas for the study of parametric instabilities*

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We have produced mm-scale plasmas of high-density ($n_e \approx 10^{21}$ cm^{-3}) and temperature ($T_e \approx$ 2-5 keV) by irradiating thin-walled gas balloons, low density foams, and gas-filled hohlraums. The goal is to produce long-scale-length plasmas similar to those expected in the proposed National Ignition Facility (NIF), and use them to study parametric instabilities, primarily stimulated Brillouin scattering (SBS). The 2-3 mm diameter targets both start out with an electron density of ~10^{21} cm^{-3} at room temperature and are rapidly heated, in ~500 psec, by the NOVA laser to electron temperatures in the 2-5 keV range. This electron heating is measured from the line ratios of various high Z dopants. Isoelectronic line ratios for Ti and Cr have been obtained for both the balloons and foams. In the case of the thin-walled gas balloons, which contain of order 1 atmosphere low-Z gas (e.g. C_5H_{12}, C_5D_{12} or CO_2), a carbon fiber coated with cosputtered Ti and Cr is mounted inside. In contrast, the foams, nominally ~3 mg/cc CH_2, are uniformly doped with Ti and Cr. The balloon and foam plasmas are uniformly illuminated by the laser, as opposed to the gas-filled hohlraums described elsewhere at this meeting.

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High-power laser irradiation of under-dense silicon aerogel and agar foam targets: time-resolved imaging and spectroscopy*

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We present the results of recent experiments performed at the Nova Laser Facility at Lawrence Livermore National Laboratory in which a high-power (4×10^{14} - 1.5×10^{16} W/cm^2), 1 ns, $\lambda = 0.527$ µm laser pulse was used to irradiate low density silicon aerogel (SiO_2, 8 mg/cm^3) and agar foam (CH_2O, 4 - 9 mg /cm^3) targets of millimeter dimensions. The laser/under-dense solid interaction and the resulting energy transport through the material was monitored with several time-resolved and gated diagnostics, including x-ray imagers and an x-ray spectrograph. These experiments represent the first systematic time-resolved investigation of the interaction between a high-power laser and a sub-critical solid target material. The x-ray emission front trajectory data is in quantitative and qualitative disagreement with detailed laser/plasma interaction and hydrodynamics simulations, which predict a much more rapid heating of the cold material than is observed. The data suggests that this discrepancy is not explainable by target inhomogeneities.

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Four-color Laser Irradiation System with SSD for Laser-Plasma Interaction Experiments at LLNL* David Eimerl, Dee Pennington, Russ Wilcox, Mark Henesian, Tim Weiland, Curt Laumann, Howard Powell, *Lawrence Livermore National Laboratory, L-493, P.O.Box 5508, Livermore, California 94550, U.S.A.* We describe in detail the advanced beam smoothing laser configuration used to conduct laser-plasma interaction experiments with four colors and varying amounts of SSD. The Nova master oscillator was modified to generate in one beam line a relatively even equally spaced spectrum of lines. The spectrum is generated by self-phase modulation in a polarization-preserving optical fiber into which two short pulses are injected whose frequencies are separated by a few cm^{-1}. An FM modulator is added to the beam line for SSD. Gain narrowing in the laser amplifiers is a significant spectral modifier, as is the wavelength dependence of the transmission of passive optical elements such as multi-order waveplates. At the input to the disc amplifier section of that beam line, an array of gratings and optical filters is used in conjunction with a spatial filter to permit a different frequency to pass in each of the four quadrants of the beam aperture. Each quadrant then has a unique single frequency. The KDP crystals for frequency tripling are mounted in an array with novel mechanical elements that permit independent adjustment of the KDP orientation in each quadrant, while maintaining tight orientation tolerances with respect to the beam direction. Finally, new 3ω diagnostics were deployed to measure the energy and temporal pulse shape in each quadrant. The performance of this advanced beam smoothing configuration will be described in detail.

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