Epstein

15th Annual

ANOMALOUS ABSORPTION CONFERENCE

UBC

Plasma Physics Group

15th Annual

ANOMALOUS ABSORPTION CONFERENCE

June 23–28, 1985

The Banff Centre, Banff, Alberta

organized by

Plasma Physics Group
The University of British Columbia
Vancouver, British Columbia, Canada

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ACKNOWLEDGEMENT

We wish to express our special thanks to
Dr. Allan Offenberger, University of Alberta,
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15th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

Banff, 23-28 June, 1985

Sunday

	2:00p.m.	Registration	
	8:00p.m.	Reception	

Monday

A	8:30a.m.	Oral	Beat Waves, SBS Chairman : L.M. Goldman (LLE)
B	7:00p.m.	Review	Beat Waves : F.F. Chen (UCLA) Chairman : T.J.M. Boyd (UCNW)
C	8:30p.m.	Oral	X-Rays Chairman : M. G. Haines (IC)

Tuesday

D	8:30a.m.	Oral	SRS, $2\omega_p$ Chairman : A. Simon (LLE)
E	7:00p.m.	Review	Parametric Instabilities : W. Kruer (LLNL) Chairman : H. Baldis (NRC)
F	8:30p.m.	Poster	Parametric Instabilities, X-Rays

Wednesday

G	8:30a.m.	Oral	Hydrodynamics Chairman : R.G. Evans (RAL)
H	7:00p.m.	Review	Hydrodynamics : R.G. Evans (RAL) Chairman : B. Ripin (NRL)
I	8:30p.m.		Hydrodynamics, Transport

Thursday

J	8:30a.m.	Oral	Transport Chairman : F. Mayer (KMSF)
	5:00p.m.	Cocktails	
	6:00p.m.	Barbecue	
K	7:30p.m.	Review	Transport : D. Forslund (LANL) Chairman : T.W. Johnston (INRS)
L	9:00p.m.	Discussion	Next year's meeting : J. Meyer (UBC) Post deadline papers

Friday

M	8:30a.m.	Oral	Instabilities, Magnetic Fields, Waves Chairman : A.A. Offenberger (U of A)

Monday

A. BEAT WAVES, SBS (Oral) - Chairman : L.M. Goldman, LLE

a.m.

8:30 Introductory Remarks, J. Meyer (UBC)

8:45 A1 C.E. Clayton, C. Joshi, C. Darrow, D. Umstadter, F.F. Chen (UCLA)
Colinear Beat-Excitation of Relativistic Plasma Waves

9:00 A2 C. Darrow, D. Umstadter, C. Clayton and C. Joshi (UCLA)
Controlled Studies of Wave-Wave Coupling Processes in Beat-wave Laser Driven Plasma

9:15 A3 R. Bingham, R.A. Cairns, R.G. Evans (RAL)
Saturation of Large-Amplitude Plasma Waves

9:30 A4 W.B. Mori, C. Joshi, J.M. Dawson (UCLA), D.W. Forslund, J.M. Kindel (LANL)
Self-focussing and Filamentation of Intense Laser Light

9:45 A5 R.L. Berger (KMSF)
Absolute and Convective Parametric Instability in Homogeneous Plasma Bounded in Two Dimensions

10:00 Coffee Break

10:30 A6 C.H. Aldrich, B. Bezzerides, D.F. DuBois, H.A. Rose (LANL)
Caviton Collapse of SRS by SBS

10:45 A7 G.R. Mitchell (IREQ), T.W. Johnston (INRS)
Brillouin-Like Scattering from Ion Sound Waves Near Critical Density

11:00 A8 J.E. Bernard and J. Meyer
The Temporal Growth Rate and Saturation Behaviour of Stimulated Brillouin Scattering in a CO_2 Laser-Produced Plasma

11:15 A9 K. Swartz, R.W. Short, A. Simon (LLE)
The Effect of Multiple Beams on Parametric Instabilities.

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B. BEAT WAVES (Review) - Chairman : T.J.M. Boyd (UCNW)

p.m.

7:00 F.F. Chen (UCLA)
Invited review followed by general discussion

C. X-RAYS (Oral) - Chairman : M.G. Haines (IC)

p.m.

8:30 C1 A. Simon, R.W. Short, W. Seka, L.M. Goldman (LLE)
Enhanced Thomson Scattering Theory Applied to Eight Experiments

8:45 C2 E.K. Stover, W.C. Mead (LANL), R.L. Kauffman, R.E. Turner, B.F. Lasinski, J. Smith (LLNL)
Analysis of the X-Ray Emission from 0.26μm Novette Irradiated Planar Gold Targets

9:00 C3 B.F. Lasinski, R.L. Kauffman, R.E. Turner, R.P. Drake, A. Friedman, E.A. Williams. W.L. Kruer (LLNL), W.C. Mead and E. Stover (LANL)
Gold Disk Irradiations at 2ω, 3ω, 4ω

9:15 C4 P. Alaterre, H. Pépin (INRS), R. Fabbro, B. Faral (PMI) F. Cottet, J.P. Romain (ENSMA)
Theoretical and Experimental Study of X-Ray Conversion Efficiency in 0.26μm Laser Irradiated Targets

9:30 C5 B. Bezzerides, D.F. DuBois, H. Rose, D.A. Russell (LANL)
Langmuir Collapse in Laser-Plasma Interactions

9:45 C6 D. Mostacci, J-P. Dinguirard, R. Morse (U of Arizona)
X-Ray Emission from Laser-Heated Spherical Targets

Tuesday

D. SRS, $2\omega_p$ (Oral) - Chairman : A. Simon (LLE)

a.m.

8:30 D1 A.B. Langdon, W.L. Kruer, B.F. Lasinski (LLNL)
ZOHAR Simulations of Raman Sidescattering and Two-Plasmon Decay

8:45 D2 D.M. Villeneuve and H.A. Baldis (NRC)
Mode Coupling from Plasma Waves to Ion Waves in Two-Plasmon Decay

9:00 D3 J.M. Kindel, D.W. Forslund (LANL), W.B. Mori, C. Joshi, J.M. Dawson (UCLA)
Computer Simulations on Two Plasmon Decay

9:15 D4 L.V. Powers (KMSF)
Absolutely Unstable Two-Plasmon Decay in Two Dimensions

9:30 D5 W. Seka, L.M. Goldman, A. Simon, F.J. Marshall, M.C. Richardson, R. Bahr (LLE)
Raman Scattering in Laser-Produced Plasmas

9:45 D6 H.C. Barr, T.J.M. Boyd, G.A. Coutts (UCNW)
Stimulated Raman Scattering from a Plasma in the Presence of Filamentation

10:00 Coffee Break

10:30 D7 J.A. Tarvin, G.E. Busch, E.F. Gabl, R.J. Schroeder, C.L. Shepard (KMSF)
Threshold Conditions for Raman Scattering in Exploding Foils

10:45 D8 C.J. McKinstrie and A. Simon (LLE)
The Absolute Stimulated Raman Scattering Instability in a Finite Collisional Plasma

11:00 D9 G. McIntosh and J. Meyer (UBC)
The Temporal Growth Rates, Saturation and Decay of Stimulated Raman Scattering in a CO_2 Laser-Produced Plasma

11:15 D10 F.F. Chen (UCLA)
Convective Raman Scatter Below the Conventional Threshold

11:30 D11 H.A. Baldis (NRC), G. Labaune, E. Fabre, F. Briand (E.P.)
Forward and Backward Raman Scattering from 0.26μm Interactions

11:45 D12 P.N. Guzdar, J.F. Drake, Y.C. Lee, (U of Md), C.S. Liu (GAT)
Raman Scattering with a Multimode Random Pump in Laser Produced Plasmas

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Tuesday

E. PARAMETRIC INSTABILITIES (Review) - Chairman H. Baldis (NRC)

p.m.

7:00 W.L. Kruer (LLNL)
Invited review followed by general discussion

F. PARAMETRIC INSTABILITIES, X-RAYS - (Poster)

p.m.

8:30 F1 R.A. London, M.D. Rosen (LLNL)
Modeling of Exploding Foil Targets for Laboratory Soft X-Ray Lasers

F2 S. Maxon, B. MacGowan, P. Hagelstein, R. London, M. Rosen (LLNL)
Investigation of the Mn Pump Line for the Photoresonant X-Ray Laser

F3 R.L. Kauffman, R.W. Lee, K. Estabrook (LLNL)
X-Ray Spectroscopy for Probing Laser Produced Plasma

F4 D. Matthews, M. Rosen, P. Hagelstein, M. Campbell (LLNL)
Description of Laser Producing Plasmas used in X-Ray Laser Research

F5 R. Benattar (EP), O.L. Landen, J.D. Kilkenny, K. Estabrook, R.W. Lee (LLNL)
Soft X-Ray Imaging of Laser-Produced Plasmas

F6 F.J. Marshall, M.C. Richardson (LLE)
Uniformity of X-Ray Flux from Gold Coated Spherical Targets

F7 A. Decoster (CEA-Limeil)
Kinetic Description of Laser Plasmas

F8 M. Casanova (CEA-Limeil), G. Laval, R. Pellat, D. Pesmé (EP)
Self-Generated Loss of Coherency in Brillouin Scattering and Reduction of Reflectivity

F9 G. Bonnaud (CEA-Limeil)
Competition of Stimulated Raman Scattering with Stimulated Brillouin Scattering

F10 F. Martin, T.W. Johnston, H. Pépin, P. Lavigne (INRS), G. Mitchel (IREQ)
Absolute Growth in Stimulated Brillouin Scattering

F11 P. Lavigne, S. Aithal, H. Pépin, D. Pascale, P. Alaterre, F. Martin (INRS)
Suprathermal Electron Production at 10.6μm

p.m.

8:30

F12 C. Coté, P. Lavigne, P. Alaterre (INRS), R. Decoste (IREQ)
Reduction of the Hot Electron Production with Increasing Pulse Risetime in the CO_2 Laser-Solid Target Interaction

F13 C.L. Shepard, G.E. Busch, E.F. Gabl, R.J. Schroeder, J.A. Tarvin (KMSF)
Raman Scattering in Thin Foil Plasmas Irradiated with 0.53μm Laser Light.

F14 E.F. Gabl, G.E. Busch, R.J. Schroeder, C.L. Shepard, J.A. Tarvin (KMSF)
Three-Halves ω_0 Spectrum for Laser Irradiated Thin Foil Targets

G. HYDRODYNAMICS (Oral) - Chairman : R.G. Evans (RAL)

a.m.

8:30 G1 M.C. Richardson, R.L. Hutchison, R.L. Keck, H. Kim, S.A. Letzring, F.J. Marshall, R.L. McCrory, P. McKenty, J.M. Soures, C.P. Verdon (LLE)
24 Beam, 2kJ UV Implosion Experiments with OMEGA

8:45 G2 F.J. Marshall, M.C. Richardson, P.A. Jaanimagi, R.L. Keck, H. Kim, S.A. Letzring, R.S. Marjoribanks, R.L. McCrory, P.W. McKenty, J.M. Soures, C.P. Verdon (LLE)
Multi-Beam-UV-Irradiated High Aspect Ratio Targets

9:00 G3 M.C. Richardson, O. Barnouin, P.A. Jaanimagi, R.L. Keck, H. Kim, S.A. Letzring, F.J. Marshall, R.L. McCrory, P. McKenty, J.M. Soures, C.P. Verdon, B. Yaakobi (LLE)
Ablative Fusion Targets Driven by the 24 Beam OMEGA System

9:15 G4 C. Yamanaka, T. Yamanaka, S. Nakai, K. Nishihara, K. Mima, H. Nishimura, H. Azechi, N. Miyanaga, H. Niki, M. Nakai, M. Yamanaka, Y. Izawa, Y. Kato, M. Mochizuki, M. Nakatsuka, T. Yabe (ILE)
Wavelength Dependences of Implosion Properties in Gekko Laser Fusion Experiments

9:30 G5 H. Nishimura, H. Azechi, K. Tanaka, M. Nakai, Y. Kitagawa, H. Shiraga, K. Kato, T. Yamanaka, C. Yamanaka (ILE)
Study of Suprathermal Electron Generation in Cannonball Targets

p.m.

9:45 G6 M.H. Emery and J. Gardner (NRL)
Theory and Simulation of Strongly Inhibited Rayleigh-Taylor Growth with 0.25 micron Lasers

10:00 Coffee Break

10:30 G7 R. Fedosejevs, P.D. Gupta, R. Popil, Y.Y. Tsui, A.A. Offenberger (U of A)
Ablation Measurements Using a KrF Laser at Intensities of 10^{11} - 10^{13} W/cm^2

10:45 G8 R.S. Craxton, J. Delettrez, R.L. Keck, R.L. McCrory, M.C. Richardson, W. Seka, J.M. Soures (LLE)
Simulations of Absorption at 351nm on Spherical Targets

11:00 G9 R. Epstein, J. Delettrez, M.C. Richardson, B. Yaakobi (LLE)
Numerical Simulation and Target Design for Laser-Imploded Cylindrical Plasmas

11:15 G10 A.J. Schmitt, S. Bodner, J.H. Gardner (NRL)
Spherically Symmetric Illumination of Laser Fusion Pellets with the ISI Laser

11:30 G11 J.P. Sheerin, D.R. Nicholson, G.L. Payne, L.M. Duncan (U of Iowa)
Observations of Nonlinear Phenomena During Ionospheric Modification

H. HYDRODYNAMICS (Review) - Chairman : B. Ripin (NRL)

p.m.

7:00 R.G. Evans (RAL)
Invited review followed by general discussion

I. HYDRODYNAMICS, TRANSPORT (Poster)

p.m.

8:30 I1 R. Marchand, A. Birnboim, C.E. Capjack (U of A)
Radiation and Heat Transport in a KrF Produced Plasma

I2 R. Rankin, R. Marchand, A. Birnboim, C.E. Capjack (U of A)
Ion-Electron Diffusion and Equilibration in 2-D Hydrodynamic Codes

p.m.

8:30 I3 J. Meyer (UBC), R. Rankin, R. Marchand, C.E. Capjack (U of A)
Hydrodynamic Evolution of a Helium Gas Jet

I4 R. Popil, P.D. Gupta, R. Fedosejevs, A.A. Offenberger (U of A)
Time Resolved X-Ray Emission Observations of KrF Laser Ablation Rates

I5 P.D. Gupta, Y.Y. Tsui, R. Popil, R. Fedosejevs, A.A. Offenberger (U of A)
Ion Expansion Characteristics in KrF Laser Plasma Interaction

I6 J.H. Rogers, K. Mizuno. J.S. DeGroot (UCD)
Electron Heat Transport in a Microwave Driven Plasma

I7 S. Jorna and L. Wood (U St. A)
Solution of the Fokker-Planck Equation in Spherical Coordinates

I8 D. Colombant, J. Gardner, W. Manheimer (NRL)
Studies of Rayleigh-Taylor Instabilities in Spherical Geometry

I9 M.C. Richardson, O. Barnouin, R. Epstein, P.A. Jaanimagi, R.S. Marjoribanks, J.M. Soures, B. Yaakobi (LLE)
Laser Imploded Cylindrical Plasmas

I10 P. Celliers, A. Ng, D. Parfeniuk (UBC)
Shock Waves Generated by a Shaped Laser Pulse

I11 S.V. Coggeshall, W.C. Mead, B. Bezzerides (LANL)
A Proposed Long-Scale-Length Plasma Experiment for a 5kJ KrF Laser System

I12 W.C. Mead (LANL)
Acceleration of Planar Foils with KrF Laser Light

I13 D. Parfeniuk, A. Ng, P. Celliers, L. DaSilva (UBC)
Observation of Radiative Preheat in Rear Surface Reflectivity Measurements

I14 L. DaSilva, A. Ng, D. Parfeniuk, P. Celliers (UBC)
Simulations of Rear Surface Temperature and Reflectivity Measurements in Laser-Irradiated Targets

I15 A. Friedman and E.A. Williams (LLNL)
A Statistical Model for the Scattering of Laser Light by Density Fluctuations

J. TRANSPORT (Oral) - Chairman F. Mayer (KMSF)

a.m.

8:30 J1 T.H. Kho and M.G. Haines (IC)
Kinetic Transport of Electrons and Magnetic Field in Laser-Plasmas

8:45 J2 S.R. Goldman, W.C. Mead, P.D. Goldstone (LANL)
Energy Transport and Spatial Structuring in High-Z Targets

9:00 J3 O. Barnouin, J. Delettrez, L.M. Goldman, R. Marjoribanks, M.C. Richardson, J.M. Soures, B. Yaakobi
Thermal Transport Measurements in 24-Beam, UV Irradiation of Spherical Targets

9:15 J4 A. Birnboim, R. Marchand, C.E. Capjack
Modelling of Radiation Transport in Laser-Produced Plasmas

9:30 J5 J.M. Wallace (LANL)
Non-Local Energy Deposition in High-Intensity Laser-Plasma Interactions

9:45 J6 G.D. Enright and N.H. Burnett (NRC)
Effect of an External Magnetic Field on Superhot Electron Production and Transport

10:00 Coffee Break

10:30 J7 J.P. Matte, T.W. Johnston (INRS), J. Delettrez, R.L. McCrory (LLE), M. Lamoureux, R. Yin, C. Moller (LSAI)
Electron Heat Flow in Laser-Target Interaction

10:45 J8 R. Cauble (BRA), W. Rozmus, A.A. Offenberger (U of A)
Transport Properties of Dense Plasmas

11:00 J9 J. Delettrez, P.A. Jaanimagi, B.L. Henke, M.C. Richardson (LLE)
Temporal Dependence of the Mass Ablation Rate in UV Laser Irradiated Spherical Targets

11:15 J10 E.A. Williams, J.R. Albritton (LLNL), K. Swartz (U of R), I.B. Bernstein (Yale)
Electron Heat Transport by not quite Maxwell-Boltzmann Electrons

11:30 J11 P.A. Holstein, J. Delettrez, K. Swartz, S. Skupsky J.P. Matte (LLE)
Study of Delocalized Heat Flux With and Without Hydrodynamic

11:45 J12 G. Thiell, D. Juraszek, B. Meyer, M. Mucchielli (Limeil)
On Hydrodynamic Energy Transfer Between Two Foils of a Laser Irradiated Double-Foil Target at 0.35μm Wavelength

Thursday

K. TRANSPORT (Review) - Chairman : T.W. Johnston (INRS)

p.m.

7:30 D. Forslund
Invited review followed by general discussion

L. DISCUSSION & POST-DEADLINE PAPERS - Chairman : J. Meyer (UBC)

9:00 - Next Year's Meeting

- Followed by Post-Deadline Papers

Friday

M. INSTABILITIES, MAGNETIC FIELDS, WAVES (Oral)

- Chairman : A.A. Offenberger (U of A)

a.m.

8:30 M1 E.M. Epperlein, T.H. Kho, M.G. Haines (IC)
Kinetic Model for the Collisional Weibel Instability in Laser-Plasmas

8:45 M2 R.W. Short (LLE)
The Weibel Instability Driven by Hot Electrons in the Plasma Corona

9:00 M3 L. Montierth and R. Morse (U of Arizona)
Rayleigh-Taylor Instability of Bumps

9:15 M4 G. Thiell and B. Meyer (Limeil)
Thermal Instabilities as an Explanation of Jet-Like Structures Observed on Laser Irradiated Thin Planar Targets at 1.06μm and 0.35μm Wavelengths

9:30 M5 J. Brackbill (LANL), B. Colombant (NRL), N. Grandjouan, F. Amiranoff (EP)
Nernst Term and Magnetic Fields in Laser-Heated Plasmas

9:45 M6 R.J. Mason and J.M. Wallace
Collisional and Density Gradient Effects on B-Field Generation, Surface Transport, and Fast Ion Blow-off in Laser Produced Plasmas

10:00 Coffee Break

10:30 M7 F. Brunel (NRC)
Strong Laser Absorption on a Plasma with a Sharp Density Gradient

a.m.

10:45 M8 S.J. Gitomer and R.D. Jones (LANL)
Modelling Fast Ion Expansion in Laser Produced Plasmas

11:00 M9 J.H. Gardner, S.E. Bodner, M.H. Emery (NRL)
Theoretical Prospects for High Gain Laser Fusion with Direct Drive

11:15 M10 F.J. Mayer (KMSF)
Energy Transduction in Pellet-Injected Plasmas

11:30 M11 J.D. Simpson (KMSF)
Integrating Cylinder for ICF Light Balance Measurements in Mirror Illumination Systems

11:45 M12 R.D. Jones (LANL)
Electrostatic Surface Waves

12:00 M13 P.L. Mascheroni and M.A. Mahaffy (LANL)
Numerical Studies on Laser Target Interaction

Session A
(oral)

Beat Waves, SBS

Monday, 8:30 am

Chairman: L.M. Goldman (LLE)

COLINEAR BEAT-EXCITATION OF RELATIVISTIC PLASMA WAVES*

C. E. Clayton, C. Joshi, C. Darrow, D. Umstadter, and F. F. Chen
University of California, Los Angeles, CA 90024

A high phase velocity plasma wave, suitable for the acceleration of electrons, has been excited and studied in experiments at UCLA. The plasma wave is excited by the optical mixing of two co-propagating electromagnetic waves. A 2 nsec CO_2 laser pulse containing the wavelengths 9.6 μm and 10.6 μm, with line energies of 4 and 12 J, respectively, is injected into a plasma where the plasma frequency equals the difference frequency of the two laser lines. The wave is diagnosed by small-angle collective Thomson scattering which permits both ω and k resolution of the wave. The length (along the CO_2 axis) and time duration of the plasma wave are also measured, allowing an estimate of the amplitude of the wave as $\tilde{n}/n_o$ 1-3% which, through Poisson's equation gives a longitudinal electric field of E_ℓ = 0.3-1 GeV/m.

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* Work supported by DOE contract DE-AT03-83ER40120, NSF grant ECS 83-10972 and the LLNL University Research Program.

CONTROLLED STUDIES OF WAVE-WAVE COUPLING PROCESSES IN BEAT-WAVE LASER DRIVEN PLASMA

C. Darrow, D. Umstadter, C. Clayton and C. Joshi
University of California, Los Angeles, CA 90024

Experiments have been recently conducted to study wave-wave coupling in an underdense ($\omega_o/\omega_p = 10$) hydrogen plasma driven by a high intensity ($I = 10^{13}$ W/cm^2) CO_2 laser operating in both single (10.6 μm) and double frequency (9.6 and 10.6 μm) modes.

Thomson scattering at 7½ degrees has been employed to verify the existence of short wavelength plasma waves (5 μm from SRS) and ion waves (SBS) as well as a counterlinear, optically mixed slow wave (v = c/20). In addition, Thomson scattering at 7 mrad has been used to demonstrate the feasibility of beat excitation of a high phase velocity electron plasma waves (v = c). These "fast waves" are observed to saturate at amplitudes (1-3%) below those predicted by fluid theory (8%). Because of the high phase velocities of these fast waves conventional damping mechanisms are inapplicable and one is lead to consider other mechanisms to explain this discrepency. One possible mechanism is Quasi-Resonant Mode Coupling (QRMC) whereby fast waves (short k modes) couple energy to slow waves (long k modes) in the presence of an ion perturbation (SBS). This mechanism is attractive since the required constituent waves have already been observed to occur in our experiment.

Results and interpretations of data from recent experiments will be presented.

Saturation of Large Amplitude Plasma Waves

R Bingham
R A Cairns*
R G Evans

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England

Abstract

Saturation of waves of large phase velocity, such as in the beat wave accelerator, occurrs by a detuning of the wave at large amplitude. Analytic calculation and computer models show that the frequency shift is due to a competition between the relativistic mass increase and a Doppler shift caused by wave induced plasma drift. This drift is a new feature of the analysis and is of more general application including current drive in Tokamaks.

* Department of Mathematics, University of St Andrews.

SELF-FOCUSING AND FILAMENTATION OF INTENSE LASER LIGHT

W. B. Mori, C. Joshi and J. M. Dawson
University of California, Los Angeles, CA 90024*

D. W. Forslund and J. M. Kindel
Los Alamos National Laboratory, Los Alamos, NM 87545

Various regimes of whole beam self-focusing and filamentation are illustrated using two dimensional computer simulations. The PIC code WAVE with self-consistent motion calculated on a cartesian mesh is used. Intense laser beams, ~10^{15} W/cm^2 for CO_2 parameters, are incident onto a very underdense, $\omega_p/\omega_o = 1/5$, homogeneous plasma. In all cases the lasers have S polarization while in most cases $v_o/v_{th} >> 1$. The laser beams self-focused and/or filamented from both relativistic and ponderomotive effects. When two frequency illumination is used to stu y t e beat wave accelerator the presence of the resonant large amplitude plasma wave enhances both types of self-focusing/filamentation mechanisms. While relativistic self-focusing may be advantageous for laser plasma accelerators the simulations clearly show that the opposite is true for ponderomotive self-focusing. A channel that disrupts the resonant plasma wave can develop within an ion plasma period.

*This work is supported by DOE contract no. DE-AT03-83ER40120.

Absolute and Convective Parametric Instability in Homogeneous Plasma Bounded in Two Dimensions

R. L. Berger

KMS Fusion, Inc., Ann Arbor, MI 48106

ABSTRACT

We solve the two coupled, linear, first-order differential equations that describe the parametric interaction of two modes with a pump wave of fixed amplitude in two dimensions. The plasma is homogeneous and finite with dimensions L_x and L_y in the x and y directions, respectively. One mode, with amplitude a_1 and group velocity $\vec{v}_1$, propagates in the positive x and y directions with initial value specified at $x = 0$, $0 < y < L_y$. Convective amplification occurs when the other mode, with amplitude a_2 and group velocity $\vec{v}_2$ also propagates in the positive x direction. We specify its initial value at $x = 0$ and find the general solution for the amplitudes a_1 and a_2. There is a point on the boundary at $x = L_x$ or $y = L_y$ for which the mode a_1 experiences the largest amplification. However, this may not be a good measure of pump depletion. Of more interest is the total energy in mode a_1 leaving the gain region at $x = L_x$ and $y = L_y$ relative to its initial energy at $x = 0$. This value naturally approaches the value obtained for a plasma finite in x and unbounded in y as

$$L_y/L_x \gg \left|\frac{v_{1y}}{v_{1x}} - \frac{v_{2y}}{v_{2x}}\right| .$$

Absolute modes may exist if the second mode has the group velocity components $v_{2x} < 0$ and $v_{2y} < 0$. The solution for a_1 is found in terms of the initial value of a_1 at $x = 0$ and the final value of a_2 at $x = 0$. We look for absolute modes by imposing the boundary conditions that $a_1 = 0$ at $x = 0$ and $a_2 = 0$ at $y = L_y$ and $x = L_x$. This procedure leads to an integral eigenvalue equation for $a_2(x=0,y)$. As $L_y \rightarrow \infty$, $a_2(x = 0,y)$ is constant and the eigenvalues give the threshold for absolute modes in a one-dimensionally bounded plasma. The eigenfunction solutions in two dimensions are currently being investigated.

CAVITON COLLAPSE OF SRS BY SBS

C. H. Aldrich, B. Bezzerides, D. F. DuBois, and H. A. Rose

University of California
Los Alamos National Laboratory
Los Alamos, NM 87545

Simulations show that the ion waves resulting from Stimulated Brillouin Scatter (SBS) can trigger the collapse of the plasma waves excited y St m a ed Raman Scatter e scuss e effect of this collapse mechanism on the hot-electron spectrum produced by the electrostatic waves and observed in particle simulations. A fluid model for the coupling of the ion fluctuations to the plasma waves is used to establish the necessary conditions on the SBS to induce collapse of the plasma waves produced by SRS.

BRILLOUIN - LIKE SCATTERING FROM ION SOUND WAVES NEAR CRITICAL DENSITY

G.R.MITCHEL, IREQ, VARENNES, QUEBEC, CANADA
T.W.JOHNSTON, INRS-ENERGIE, VARENNES, QUEBEC, CANADA

MODEL PROFILES WITH VARIOUS WAVELIKE DENSITY MODULATIONS ARE PROPAGATED FOR INTEGRAL NUMBERS OF SLOW OSCILLATION CYCLES. THE COMPLEX WAVE RETURNED IS ANALYZED AT EACH TIME (ASSUMING A MOMENTARILY FROZEN PROFILE, JUSTIFIABLE IF CS/C IS SMALL) FOR AMPLITUDE AND PHASE BEHAVIOUR TO GIVE EQUIVALENT FREQUENCY SPECTRA, NORMALIZED TO THE EM WAVE FRE-QUENCY. THE CODE WAS CHECKED TO GIVE THE SBS RESULT FOR LOW DENSITY UNIFORM PLASMA. SIGNIFICANT FREQUENCY SHIFT IS OBTAINED FOR ION SOUND WAVE AMPLITUDES LARGE ENOUGH (E.G. 5%) THAT GRAD N CHANGES SIGN NEAR CRITICAL DENSITY DURING THE MODULATION. THE FREQUENCY SPECTRA ARE NOTICEABLY ASYMMETRIC, WITH A PEAK AT A FRACTION OF THE NORMAL BRILLOUIN SHIFT AND A TAIL EXTENDING THROUGH THE INCIDENT LASER FREQUENCY.

END OF DATA

THE TEMPORAL GROWTH RATE AND SATURATION BEHAVIOUR OF STIMULATED BRILLOUIN SCATTERING IN A CO_2 LASER-PRODUCED PLASMA*

J.E. Bernard and J. Meyer

Dept. of Physics, University of British Columbia,
Vancouver, B.C., Canada, V6T 2A6

The temporal growth rate and saturation behaviour of stimulated Brillouin scattering (SBS) were studied in a CO_2 laser (2 ns, $I = 10^{12} - 10^{13}$ W/cm^2) produced nitrogen-helium plasma ($n_e \leq 0.4 n_{cr}$, $T_e \simeq 300$ eV). Time resolved, ruby laser Thomson scattering was used to study the temporal growth of the SBS driven ion acoustic waves. The initial growth was exponential in time and had a temporal growth rate which agreed within a factor of two with the absolute growth rate predicted for a finite interaction region. The instability saturated at backscatter reflectivity and ion acoustic fluctuation levels of $R < 10\%$ and $\delta n/n \simeq 17\%$ respectively. The level of the saturated fluctuations, as well as the observation of second harmonic generation in the ion wave spectrum, multiple peaks in the backscatter spectrum, and temporal variations in the ion acoustic fluctuation level are supportive of saturation through ion trapping.

*Work supported by a grant from NSERC Canada

First LLE paper

THE EFFECT OF MULTIPLE BEAMS ON PARAMETRIC INSTABILITIES

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Direct drive fusion requires the use of multiple beams to obtain uniformity of illumination. It is important to assess the effect of these beams as multiple pumps for parametric processes. As an initial model we consider processes driven by two pumps. Growth rates and thresholds for the two pump case will be presented. Implications for the changes in growth rates and thresholds in the presence of more than two beams will be discussed.

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Session B
(review)

Beat Waves
F.F. Chen (UCLA)

Monday, 7:00 pm

Chairman: T.J.M. Boyd (UCNW)

Session C
(oral)

X-rays

Monday: 8:30 pm

Chairman: M.G. Haines (IC)

ENHANCED THOMSON SCATTERING THEORY APPLIED TO EIGHT EXPERIMENTS

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ABSTRACT

The onset of an instability, such as the $2\omega_p$ at the $n_c/4$ surface, usually leads to wave breaking and the emission of hot electron pulses which can profoundly influence instability thresholds and scattering behavior elsewhere in the plasma. In particular, enhanced Thomson scattering (via the plasma line) can occur and this has been used to explain the observation of the SRS instability well below the theoretical threshold(1). A simple model of the hot electron pulses based on measured values of the hot and cold electron temperatures, T_h and T_c, has yielded good agreement with experimental observation of the Raman spectral frequency bands. The agreement has continued , even for experiments which are clearly above the SRS threshold, with the enhanced noise likely acting as a "seed" for the SRS growth.

We will show details of the successful comparison of this theory with six experiments carried out on SHIVA, ARGUS, NOVETTE(2), and GDL(2), and also with an upscattering feature seen at Garching. In addition, a recent experiment using 6 beams of OMEGA (at 0.35μ) will be discussed and compared with the theory.

(1) A. Simon and R.W. Short, Phys. Rev. Lett. 53, 1912 (1984).

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

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ANALYSIS OF THE X-RAY EMISSION FROM 0.26 μm NOVETTE IRRADIATED PLANAR GOLD TARGETS

E. K. Stover and W. C. Mead
Elmer
University of California
Los Alamos National Laboratory
Los Alamos, NM 87545

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Lawrence Livermore National Laboratory
Livermore, CA 94550

Gold flat targets have been irradiated at the Novette Laser facility with 0 to 1.5 kJ of 0.26 m laser ~1 ns pulse length.[1] We com are calculated conversion efficiency, hard and soft x-ray spectra, and x-ray images wit the ata. u lovolt x-ray measurements taken at incident intensities in the 0^{1} to 3 × 10^{15} w/cm^2 range for one detector angle (60^{o}) indicate gr ater than previously observed for 0.35 μm and 0.53 μm ight. kilovolt emission observed at 60^{o} to the target nor al is with 2-D LASNEX calculations to infer total x efficiency.

*Aracore, Inc.
[1]R. L. Kauffman, et al, Twenty-Sixth Annual Meeting, Division of Plasma Physics, Oct. 29-Nov. 2, 1984.

GOLD DISK IRRADIATIONS AT 2ω, 3ω, 4ω*

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A. Friedman, E. A. Williams, and W. L Kruer
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Livermore CA 94550
and
W. C. Mead, E. Stover
Los Alamos Natonal Laboratory
Los Alamos, NM 87545

ABSTRACT

We have measured absorption, x-ray conversion efficiency and signatures of parametric instabilities from gold disc irradiations at 2ω on Novette.[1] Also, the x-ray conversion efficiency at 4ω has been measured.[2] We present further analysis of this data and comparisons with LASNEX calculations using the new 3-D laser ray trace package with its variety of scattering options.[3] Planning for NOVA gold disc irradiations at 3ω will also be discussed; here the emphasis will be on the plasma parameters accessible with the variety of pulse shapes possible for NOVA irradiations.

*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.

1. R. P. Drake, R. E. Turner, B. F. Lasinski, K. G. Estabrook, E. M. Campbell, C. L. Wang, D. W. Phillion, E. A. Williams, and W. L. Kruer, Phys. Rev. Lett. 53, 1739 (1984).

2. R. L. Kauffman, R. P. Drake, R. E. Turner, B. F. Lasinski, G. T. Tirsell, J. Smith, W. C. Mead and E. Stover, BAPS 29, 1183 (1984).

A. Friedman and E. A. Williams, LLNL Laser Program Annual Report, 1984, and A. Friedman, BAPS 29, 1325 (1984).

THEORETICAL AND EXPERIMENTAL STUDY OF X RAY CONVERSION EFFICIENCY IN 0.26 μm LASER IRRADIATED TARGETS

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F. Cottet0, J.P. Romain0

We have studied both experimentally and theoretically the X-ray conversion efficiency for laser irradiated targets at 0.26 μm. Experiments were done at the GRECO ILM laser facility (Palaiseau) with intensities about 2.E14 W cm^{-2} and targets covering a wide range in Z (from aluminium to uranium). One of the aims of these experiments was to understand and optimize the choice of target material to get maximum X-ray emission in a given spectral range.

Plasma X-ray emissions were recorded using K edge spectroscopy with as much as ten channels giving a full coverage of the 50 eV - 6 keV range. We then used computer reconstruction to get the detailed emission spectra, and the conversion efficiency in a given spectral range. In all cases, observed efficiencies showed strong variations with Z, with distinct maxima for certain elements.

Theoretical simulation of plasma emissions were performed using a simple Z dependent atomic physics model. The ionization and energy levels were computed using a screen-hydrogenic model approach. The distribution for ionization charge states was then calculated using a simple, modified-Saha equation, together with CR-modelling for excited levels. Contributions of the various emission processes are then obtained taking into account some of the plasma reabsorption effects. The model is time independent, with plasma temperature and density as input.

Comparison of time averaged experimental and theoretical spectra revealed that for all Z, plasma emission could be accounted for by two emissive zones, with temperatures around 200 eV and 500 eV respectively. The variations with Z of the conversion efficiencies in low and high energy domains enabled us to determine ionization model parameters and also confirmed two temperature model. The ability of of the validity of the such a simple model to predict results with reasonable accuracy and the "universality" of the parameters might be related to the plasma conditions encountered at 0.26 μm. However, there is also evidence that our model could be used for different intensities and wavelengths by only setting the density and temperature parameters.

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LANGMUIR COLLAPSE IN LASER-PLASMA INTERACTIONS

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The phenomena of Langmuir collapse provides a mechanism for producing spiky, intermittent electric fields in plasmas which are spatially uniform on the average. The electric field spikes associated with collapsing cavitons can efficiently accelerate electrons and the resulting burnt-out density cavities can provide a high level of small scale density fluctuations which effect large scale transport and are nucleation sites for future cavitons. The production of such states in the nonlinear stage of moderately driven parametric instabilities and the relative insensitivity of the long time turbulent state to the linear instabilty stage will also be discussed.

X-RAY EMISSION FROM LASER-HEATED SPHERICAL TARGETS

by

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A model has been developed for calculating x-ray line emission from spherical plasmas.

The main features of this method are:

1) Plasma parameters are obtained from a 1d Lagrangian hydrodynamics and heat flow code.

2) Multi-frequency groups: the line structure can be reproduced with the desired accuracy by adjusting the number of frequency groups.

3) Self consistent, time dependent excited level populations and radiation fluxes: the code starts with coronal populations, calculates the ensuing radiation flux, and then recalculates the populations and so on, iterating until convergence is reached.

4) Geometrical groups of rays grouped by spherical impact parameter.

5) Line broadening due to ionic thermal agitation and Doppler shift due to the net plasma flow velocity. The flow velocity shift is easily included thanks to the multi-frequency group treatment.

The method has been applied to an aluminum target, and the results are in good agreement with previous experimental work. The total energy, summed over all lines, (as well as the line intensity ratios (which are a sensitive measure of agreement with experiment) were predicted with good accuracy. The pictures that would be seen by a pin-hole camera are also calculated

Session D
(oral)

SRS, 2-plasmon Decay

Tuesday, 8:30 am

Chairman: A. Simon (LLE)

ZOHAR Simulations of Raman Sidescattering and Two-Plasmon Decay*

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ABSTRACT

With parameters motivated by recent experiments, two-dimensional kinetic simulations of Raman scattering and two-plasmon decay have been resumed, using the ZOHAR code. We check linear threshold theory and nonlinear saturation mechanisms, consider the requirements for realistic simulations, and examine the mechanisms leading to weak heating in the underdense plasma as commonly observed in experiments.

With typical electron temperature of 2 keV and illumination intensities given by $I\lambda^2 \leq 10^{15}$ (W/cm^2), where λ is the wavelength in μm, the spatial scale lengths ($\cong 200c/\omega_0$) are chosen to place the instability only slightly above its density gradient threshold. The plasma is initialized as a planar self-similar flow, shifted in velocity such that the positions of the $0.15n_c$ (for Raman) and $0.25n_c$ (for two-plasmon) surfaces remain fixed. Plasma flows into the simulation region at the high-density end with speed $< c_s$, and out at the low-density end with speed $> c_s$. Due to this velocity gradient and the small values of $v_0^2/v_t^2 \propto I\lambda^2/T_e$, Brillouin backscatter is below threshold.

The ZOHAR simulations support the Afeyan/Williams linear theory for gradient thresholds for Raman sidescattering. The effect of the periodicity of the simulation, and the roles of ion response and plasmon damping on the heated electrons will be discussed.

*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.

Mode Coupling from Plasma Waves to Ion Waves in Two-Plasmon Decay

D.M. Villeneuve and H.A. Baldis

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We report on our continued experimental studies of mode coupling between plasma waves driven by two-plasmon decay (TPD) and ion waves. The primary diagnostic is the simultaneous time-resolution of ion waves and two sets of plasma waves, k-resolved in the range $(2-16)k_o$. We have measured the spectra for waves travelling at 25°, 45° and 60° to k_o, in order to determine the two-dimensional nature of the wave spectrum driven by TPD. The spectra at all angles were qualitatively similar, showing that plasma waves are produced over a broad range of angles, not just at 45° as is often assumed. This agrees with theoretical predictions of TPD growth rate and saturation. The frequency spectrum of the waves, measured at the same time by means of an OMA, showed the expected asymmetry between satellite shifts, but the asymmetry did not vary consistently between observation angles.

The ion wave spectrum showed two distinct components which were correlated in time with the plasma waves. The larger-k component had $k_i \approx (1-1.5)k_p$, which is less than the $k_i \approx 2k_p$ expected from the beating between two opposite-travelling plasma waves. On a few shots, a decay of the ion waves to smaller wavenumber was observed. The other component had a smaller wavenumber, of the order of a few k_o. The origin of both types of ion waves will be discussed.

COMPUTER SIMULATIONS ON TWO PLASMON DECAY

J. M. Kindel and D. W. Forslund
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W. B. Mori, C. Joshi and J. M. Dawson
University of California, Los Angeles, CA 90024

We present computer simulations of the $2\omega_p$ instability in both unmagnetized and magnetized plasmas. Typical parameters were $k_oL = 125$ at $n_c/4$, $M_i/m_e = 1836$, $T_e = T_i = 2.5$ keV and $I\lambda^2 = 3.4 \times 10^{15}$. As in previous work[1] good agreement with the warm fluid theory is observed for the linear growth and gradient thresholds of the instability. In contrast with ref. 1 particle trapping appears to be the dominant saturation mechanism. For times up to 1500 ω_o^{-1} the presence of very large magnetic fields lowers the saturation amplitude of the density oscillations, thereby, minimizing the initial impulse given to the ions. For longer times this may effect the profile steepening and the eventual absorption.

This work is supported by Los Alamos National Laboratory and LLNL University Research Program. This work performed under the auspices of the U. S. Department of Energy.

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1 A. B. Langdon and B. F. Lasinski, Phys. Rev. Lett. 43, 133 (1974).

Absolutely Unstable Two-Plasmon Decay in Two Dimensions

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KMS Fusion, Inc., Ann Arbor, MI 48106

ABSTRACT

The absolute instability criteria for two-plasmon decay (TPD) in a homogeneous plasma form the basis for analysis of this instability in weakly inhomogeneous plasma[1]. Previous analysis has considered a plasma with inhomogeneity in the direction of propagation of the laser (x) but uniform in the direction of the laser electric field (y). In this case, the absolute modes with the maximum growth rates satisfy exact frequency matching.

We have obtained the absolute instability condition for TPD in two dimensions in the homogeneous plasma limit from the 2-d Briggs criteria[2]. The additional constraint imposed by requiring absolute instability in the y direction restricts the 2-d absolute instablility to modes with nonzero frequency mismatch and complex wavevector components. For a given laser intensity, plasma density, and temperature, a unique solution exists for the (complex) wavevectors associated with the unstable Langmuir wave pair, the frequency mismatch, and the growth rate.

In the limits of short (k_y>>1) or long (k_y<<1) wavelength TPD modes, approximate analytic solutions to the 2-d Briggs conditions will be presented. For short wavelength modes, only a small frequency mismatch is required and the growth rates are not substantially decreased from the values obtained in 1-d. The spectrum of unstable modes is changed, however. In general both components of the wavevectors are complex for 2-d absolutely unstable modes and the real frequency shifts are increased from the 1-d values. For long wavelength modes, the required frequency mismatch is large enough to stabilize the modes, and no 2-d absolutely unstable modes are found. Numerical solutions of the full equations have been obtained and are in good agreement with the analytic approximations. The numerical solutions in the intermediate region (k_y=1) will be discussed.

1. C. S. Liu and M. N. Rosenbluth, Phys. Fluids 19, 967 (1976); B. F. Lasinski and A. B. Langdon, in Lawrence Livermore National Laboratory Report No. UCRL-50021-77, 1977, p. 4-49; A. Simon, R. W. Short, E. A. Williams and T. Dewandre, Phys. Fluids 26, 3107 (1983).

2. R. J. Briggs, Electron-Stream Instabilities in Plasmas, MIT Press, Cambridge, Massachusetts, 1964, p. 39.

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Anomalous Absorption Conference
Banff, Alta., Canada
June 23-28, 1985.

Raman Scattering in Laser-Poduced Plasmas

by
W. Seka, L.M. Goldman, A. Simon, F.J. Marshall,
M.C. Richardson, and R. Bahr.
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Rochester, NY 14623

Abstract

We report on Raman scattering from laser plasmas generated with the six and 24-beam OMEGA UV laser system. The signals generally associated with the convective Raman instability are frequently better interpreted as enhanced Thomson scattering from an anisotropic, "bump-on-tail" electron distribution. These "hot" electrons are typically accelerated by wave breaking of $2\omega_p$ plasma waves near $n_c/4$. The predicted spectra contain two frequency bands corresponding to up and downscattering with frequencies between $\omega_o/2$ and ω_o, and ω_o and $2\omega_o$. We present experimental evidence for both of these features. For high intensity shots the downscattered Raman component may also serve as seed for the convective Raman instability with its concomitent strong angular dependence. Experimental evidence for this behavior will also be presented.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC03-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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STIMULATED RAMAN SCATTERING FROM A PLASMA IN THE PRESENCE OF FILAMENTATION

H.C. BARR, T.J.M. BOYD and G.A. COUTTS

UNIVERSITY OF WALES, U.C.N.W., BANGOR, WALES.

Much attention has been directed lately towards stimulated Raman scattering in the extensive underdense plasmas characteristic of laser fusion targets. While most of this work has been concerned with the Raman instability in isolation from other processes which may occur simultaneously in the underdense plasma such as Brillouin scattering or filamentation, there is nevertheless evidence from backscattered Raman spectra consistent with the onset of filamentation. It is timely therefore to examine how stimulated Raman scattering is affected by a competing instability.

We approach this using a simple model which provides information about Raman characteristics in a plasma with a finite amplitude transverse sinusoidal density ripple of wavenumber $\underline{K}$. The ripple which causes light to refract and give rise to filaments has a similar but more dramatic effect on the Raman generated plasma waves. The driven plasma wave at wavenumber $\underline{k}$ will couple to disturbances at $\underline{k} \pm n \underline{K}$. Landau damping is thereby increased by coupling to shorter wavelengths. It also becomes possible to frequency match with several normal modes of this inhomogeneous plasma, each of which will be composed of different combinations of Fourier modes $\underline{k} \pm n \underline{K}$. Thus new decay possibilities arise. For parameters typical of recent experiments in which filamentation has been observed the coupling can be strong giving rise to strong focussing of the plasma waves in the density troughs, their width being determined by Landau damping.

We have investigated the growth, frequency and emission levels of the Raman instability in the presence of such a transverse finite amplitude density ripple.

Threshold Conditions for Raman Scattering in Exploding Foils

J. A. Tarvin, Gar. E. Busch, E. F. Gabl, R. J. Schroeder, and C. L. Shepard

ABSTRACT

The laser and plasma conditions at the onset of Raman scattering have been measured in plasmas formed from thin-foil targets. The most important observation of the experiment is that the density-gradient scalelength at onset is independent of intensity. One would expect the scalelength at onset to be inversely related to the intensity, since the convective gain for stimulated Raman scattering (SRS) is proportional to the product of intensity and scalelength. Because the observed behavior is so different from the expected, one may suspect that some other mechanism is triggering SRS or is producing plasma waves which cause unstimulated Raman scattering. However, no mechanism seems consistent with all the data.

The SRS spectrum was typically 100 nm wide. The mean wavelength varied from 720 nm for the least massive targets to 800 nm for the most massive. As in previous experiments, the entire spectrum of scattered light appeared simultaneously. Although one might expect an enhancement of scattering at the wavelength corresponding to the maximum density in the plasma, none was observed.

The targets were Al disks 0.1 to 0.3 μm thick and 200 to 500 μm in diameter mounted on 0.1 μm polymer films. The laser wavelength was 526 nm. Raman scattering was observed for nominal intensities from 10^{14} W/cm^2 to 5×10^{14} W/cm^2.

The major diagnostics were streaked optical spectroscopy, stereo photography of the Raman source, and holographic interferometry. Streaked spectroscopy indicated the onset time and stereo photography showed where the scattering occurred. Interferometry provided the density and density-gradient scalelength at the time and place of onset. For the intensity at onset, (which varied from 2×10^{14} W/cm^2 to 2×10^{15} W/cm^2) we used the peak intensity at the time of onset in the plane which was parallel to the target surface and which contained the Raman source.

THE ABSOLUTE STIMULATED RAMAN SCATTERING INSTABILITY IN A FINITE COLLISIONAL PLASMA

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ABSTRACT

The nonlinear saturation of the absolute stimulated Raman scattering (SRS) instability is considered in a finite homogeneous plasma. The amplitude of the incident wave exceeds the absolute instability threshold by the fractional amount Δ ($\ll 1$). A single backscattered wave and a single plasma wave grow until time-asymptotic saturation occurs. The reflected light intensity is determined analytically and is proportional to Δ. We also determine the spatial variation of the saturated wave amplitudes. The reflected intensity is compared to the values predicted for the convective instability, for the same incident intensity. In short plasmas, i.e., ones which extend over only a few convective gain lengths, the reflected intensity is much higher when the absolute instability threshold is exceeded.

A reflection coefficient for the temporal SRS instability has recently been calculated[1] in the highly unstable regime ($\Delta \gtrsim 1$), and is proportional to $\Delta/(1+\Delta)^2$. Note, that as a function of increasing incident intensity, the reflected intensity reaches a maximum and decreases thereafter. This type of behavior has recently been observed in long plasma scale-length experiments[2]. We will discuss the corresponding expression for the reflection coefficient when both spatial and temporal effects are important, as is the case for the absolute SRS instability discussed above.

(1) C.J. McKinstrie and A. Simon, submitted to Phys. Fluids.
(2) M.J. Herbst et al., Phys. Rev. Lett. 52, 192 (1984).

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

THE TEMPORAL GROWTH RATES, SATURATION AND DECAY OF STIMULATED RAMAN SCATTERING IN A CO_2 LASER-PRODUCED PLASMA*

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Electron plasma waves (epws) generated by stimulated Raman scattering (SRS) in a CO_2 laser produced plasma have been studied by picosecond resolution Thomson scattering. Both the spatial and $\mathbf{k}$ vector evolution of the driven waves in the density region $.16 < n/n_{cr} < .25$ is investigated. ($n_{cr} = 10^{19} cm^{-3}$). The instability is shown to grow in this density region at rates ($\gamma/\omega_o \simeq 6 \times 10^{-4}$) which is about an order of magnitude lower than predicted theoretically and is seen to spread to longer wavevectors at speeds corresponding to the group velocity of the epws. The fluctuations saturate at $\delta n/n \simeq 3\%$ and are rapidly quenched probably as a result of profile modification due to the two plasmon decay instability which is active at the same time. The absence of a gap in the fluctuation spectrum is attributed to the fact that, in our experiment, SRS starts before the stimulated Brillouin scattering does. The growth of SRS in the convective regime at intensities below the inhomogeneous threshold is likely caused by the propagation of waves generated near $.25n_{cr}$ into lower density regions.

* Work supported by a grant from NSERC Canada

ABSTRACT

CONVECTIVE RAMAN SCATTER BELOW THE CONVENTIONAL THRESHOLD*

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Numerous observations of stimulated Raman scattering have been reported from experiments on solid targets, on underdense plasmas made from solid or foam targets, and on underdense gaseous targets, under conditions both above and below the so-called "absolute" threshold for convective instability. We compare these results with a formula valid for both regimes, taking care to set the number of e-foldings above noise to a reasonable value above unity. We than find that many, if not most, observations show SRS occurring below this threshold. By retaining a root of the dispersion equation representing modes localized to a damping length, we find a possible explanation for the below-threshold behavior of SRS.

* Supported by NSF Grant ECS-83-10972 and LLNL University Research Program.

15th Anomalous Absorption Conference
Banff, Alberta
June 24-28, 1985

FORWARD AND BACKWARD RAMAN SCATTERING FROM 0.26 μm INTERACTIONS

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Ecole Polytechnique
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Forward and backward stimulated Raman scattering has been studied using 0.26 μm laser radiation. Thin foils were irradiated with up to 25 J in a 600 psec FWHM pulse, producing a plasma which became underdense before the peak of the laser pulse. The spectrum of the Raman emission at densities $< N_c/4$ was time resolved, in both the forward and backward directions. Contrary to experiments performed at higher irradiances on longer scale length plasmas, the Raman light starts in a narrow density region (at approximately 0.2 N_c), and it is observed to shift in time towards lower densities (as low as 0.06 N_c). For the backscatter light, the width of the spectrum at any given time is typical $\Delta\omega/\omega \lesssim 0.016$. A sharp cut off is observed on the high density side. The results are consistent with the hydrodynamics of the expanding plasma, assuming that the instability occurs only at the top of the plasma profile. The energy spectrum of the high energy electrons emitted from the plasma has also been measured, indicating temperatures consistent with heating from Raman plasma waves.

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Raman Scattering with a Multimode random Pump in Laser Produced Plasmas

by

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and

C.S. Liu

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The study of Raman scattering in laser produced plasmas is an active area of research. Recent work by Menyuk et al.[1] has provided a threshold for the instability for a coherent pump in an inhomogeneous medium. However the pump is in reality is not a single coherent mode but consists of a finite band width $\Delta\omega(\Delta\omega/\omega_o\sim .001 \sim .005)$ with random phase. We have developed a time dependent numerical code for studying the Raman instability in an inhomogeneous plasma in which the pump is considered as a superpositions of a large number of modes (with either commensurate or non commensurate frequencies) around the mode with frequency ω_o. We will present results on the modification of the threshold for the Raman instability for the different incoherent ppump models.

1) C.Y. Menyuk, N.M. El-Siragy and W.M. Manheimer NRL Report 5483

Tuesday, 7:00 pm

Chairman: H. Baldis (NRC)

Session F
(poster)

Parametric Instabilities, X-rays

Tuesday, 8:30 pm

MODELING OF EXPLODING FOIL TARGETS FOR LABORATORY SOFT X-RAY LASERS*

R. A. London and M. D. Rosen

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Livermore, California

ABSTRACT

We derive a simple model for the hydrodynamic behavior of a laser driven exploding foil soft x-ray laser target. Temporal histories of the temperature, density, and laser absorption are compared with LASNEX calculations. The simple model provides scaling relations for the behavior of the foils as the laser wavelength, pulselength, and intensity, and/or the foil material and thickness are varied. These scaling relations can then be used in the design of optimal gain targets under a wide variety of input conditions.

*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.

INVESTIGATION OF THE Mn PUMP LINE FOR THE PHOTORESONANT X-RAY LASER*

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ABSTRACT

Calculations using the LASNEX and XRASER codes are presented which yield the intensity, width, and Doppler shift of the 2p-3d line of Be-like Mn at 12.643A. These results are compared to measurements made at KMS where a Mn flashlamp was irradiated by a 120 ps laser pulse with $\lambda = 0.53\,\mu$ and an intensity 2×10^{14} W/cm^2. Contributions to the pump line from plasma regions with large velocity gradients along the line of sight will be discussed.

*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.

X-RAY SPECTROSCOPY FOR PROBING LASER PRODUCED PLASMA*

R. L. Kauffman, R. W. Lee, and K. Estabrook

Lawrence Livermore National Laboratory
University of California
Livermore, California 94550

ABSTRACT

Time histories of x-ray line intensities from laser produced plasmas have been analyzed using a detailed model of the energy level kinetics coupled with a hydrodynamics model. In the experiment 1-2 μm thick CH foils doped with low concentrations of sulfur were irradiated with 3.5 kJ of 2ω in a 1 ns Gaussian pulse using one beam of the Novette laser. A time resolved crystal spectrograph measured the time histories of the sulfur K x-ray spectrum. Details of the experiment and preliminary results were presented at the previous conference (14th Annual Anomalous Absorption Conference, May 1984). The line intensities from He-like and H-like sulfur have been modeled in detail by solving the time-dependent rate equations for sulfur coupled with two-dimensional hydrodynamic modeling using LASNEX. The model predicts most of the features of the data well. The foil burn-through time and coronal temperatures are predicted by the modeling using a flux limiter from 0.03 - 0.1. This model also agrees with other measurements on the experiment. Enhanced ionization durin the rise time of the pulse is not predicted by the model but can be explained by non-local transport of thermal electrons in the tail of the distribution. Such non-local transport cannot be modeled using a single temperature thermal electron distribution approximation as done in LASNEX. This enhanced ionization is an example of the power of x-ray spectroscopy as a diagnostic probe.

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

DESCRIPTION OF LASER PRODUCING PLASMAS USED IN X-RAY LASER RESEARCH*

D. Matthews, M. Rosen, P. Hagelstein, and M. Campbell

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ABSTRACT

We require specially prepared laser produced plasmas to investigate the amplified stimulated emission process. We will review the state of our designs and measurements on (1) uniform density and temperature exploding-foil targets, (2) photo-pumped targets, and (3) hydro dynamically confined targets. In each case, we have special requirements on the density and temperature desired, the gradients permissible and the time-evaluation of both. Current, misunderstood behavior will also be discussed.

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

SOFT X-RAY IMAGING OF LASER-PRODUCED PLASMAS*

R. Benattar†, O. L. Landen, J. D. Kilkenny,
K. Estabrook, and R. W. Lee

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Livermore, California 94550

ABSTRACT

Pin hole camera images were obtained from 0.53 μm laser solid interaction with soft x-ray imaging by reflection off narrow band pass multi-layer mirrors centered on Lithium like Aℓ, Si and Mg lines. With tight focusing of the laser beam, soft x-ray emission comes from a region much larger than the focal spot diameter. Measurements of the effective spreading as a function of pulse length are presented. Comparison will be made with predictions of the size of the x-ray emitting region with the measured intensity distribution far from the center of the focal spot.

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

†Ecole Polytechnique, Palaiseau, France.

UNIFORMITY OF X-RAY FLUX FROM GOLD COATED SPHERICAL TARGETS

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Rochester, New York 14623-1299

ABSTRACT

The 24 beam OMEGA UV laser system has been used to irradiate gold coated spherical targets in uniform and non-uniform configurations. Images of the resultant 1 ~ 3 keV x-ray emission recorded by pinhole cameras and x-ray microscopes have been analyzed to estimate energy deposition uniformity.

Typical targets investigated are 600 μm diameter solid plastic spheres coated with 300 Å of gold and with plastic overcoats of 0 to 2 μm. The targets are irradiated with up to 24 beams of 351 nm light at intensities of 10^{13} to 10^{15} Watts cm^{-2}. The level of nonuniformity in laser intensity necessary to produce a measurable nonuniformity in x-ray flux will be estimated.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Kinetic description of laser plasmas

Alain Decoster
CEA-Limeil, BP27, 94190 Vileneuve-Saint-Georges, France

The laser-created plasma is described at an intermediate level between hydrodynamics and kinetic theory. Hydro equations determine the fluid density, velocity, and temperature(s) ; they need an electronic heat flux and an energy source term (laser inverse bremsstrahlung absorption) ; these come from a kinetic calculation of the electron distribution function (Fokker-Planck equation with Landau collision terms). The neutrality assumption is made a priori, avoiding the electric field calculation.

A one-dimensional code has been written, with all basic ingredients to describe laser-target interaction. In order to stay close to the classical theory, the code is working now with the diffusion approximation for kinetic electrons (while the code of J.P.Matte et al. is hyperbolic). Compared to a flux-limited multigroup diffusion code for fast electrons, this one extends to all electrons, and uses complete nonlinear Landau collision terms with all desirable conservation and local equilibrium properties. The implicit treatment of collisions allows us to tackle collisional situations without time-step reduction.

We plan to present a typical computer run, with comparisons with fluid simulations.

SELF-GENERATED LOSS OF COHERENCY IN BRILLOUIN SCATTERING AND REDUCTION OF REFLECTIVITY

M. CASANOVA

C.E.A. Centre d'Etudes de Limeil - Valenton,
BP. 27, 94190 Villeneuve St Georges, France

and

G. LAVAL, R. PELLAT and D. PESME

Centre de Physique Théorique, Ecole POLYTECHNIQUE
Plateau de Palaiseau, 91128 Palaiseau Cedex, France

Low reflectivity of stimulated Brillouin scattering is shown to result from wave interaction inconherency caused by the ion sound wave nonlinearity . First, the Brillouin reflectivity is numerically found to display a chaotic time evolution at laser fluxes below those at which ion sound wave harmonic generation takes place . At these fluxes, the scattered light exhibits a spiky frequency spectrum . Scaling laws for the reflectivity and the spectrum are given . Second, the effect of ion sound wave harmonic generation is studied for higher fluxes .

COMPETITION OF STIMULATED RAMAN SCATTERING WITH STIMULATED BRILLOUIN SCATTERING

G. BONNAUD

COMMISSARIAT A L'ENERGIE ATOMIQUE
CENTRE D'ETUDES DE LIMEIL-VALENTON
B.P. 27 - 94 190 - VILLENEUVE-ST-GEORGES

Recent experiments have shown the interplay between the two scattering instabilities : Raman scattering and Brillouin scattering (1) . We have examined this interplay by the use of 1 D 1/2 particular simulations. The effect of the ratio of electron temperature and ion temperature, the influence of inhomogeneity and of the finite length of the plasma have been considered. The fast electron production and its time evolution have been studied specially.

(1) C.J. WALSH, D.M. VILLENEUVE, H.A. BALDIS, Phys. Rev. Lett. 53, 1445 (1984)

ABSOLUTE GROWTH IN STIMULATED BRILLOUIN SCATTERING

F. Martin, T.W. Johnston, H. Pépin, P. Lavigne

INRS-Energie, P.O. 1020, Varennes, Québec, Canada, J0L 2P0

and

G. Mitchel

IREQ, P.O. 1000, Varennes, Québec, Canada, J0L 2P0

ABSTRACT

We have extended the theory of LRW[1] for SBS in an inhomogeneous plasma to oblique incidence taking into account possible convective growth normal to ∇n. A more general formulation for the wavenumber mismatch K is derived. Maximum growth for the absolute instability ($dK/dx = 0$) is shown to occur for antiparallel group velocities of the two daughter waves and for the maximum allowable value of θ_{out} consistent with the two previous conditions. θ_{out} is the angle between the scattered wavevector and $\vec{\nabla} n$ or $\vec{M}$. The dependence between Mach number M, $R = n/n_c \cdot L_u/L_n$ and θ_{out} is presented as a function of the angle of incidence θ_{in}. This model is in good agreement with the experimentally measured angular distribution of energy scattered in the specular quadrant assuming that the forward scattered wave is specularly reflected.

[1] C.S. Liu, M.N. Rosenbluth, R.B. White, Phys. Rev. Lett. 31, 697 1983).

SUPRATHERMAL ELECTRON PRODUCTION AT 10.6 μm

P. Lavigne, S. Aïthal, H. Pépin, D. Pascale, P. Alaterre, F. Martin
INRS-Energie, Université du Québec, Varennes, Québec JOL 2PO

The forward and backward electron distribution from ultra-thin carbon foils have been characterized as a function of laser irradiance up to 2×10^{14} W/cm^2 at 10.6 μm. Electrons with energy as high as 2.5 MeV have been observed in the forward direction at $\approx 10^{14}$ W/cm^2.

To study the suprathermal electron production mechanisms and, relate the results to forward Raman, the target transmission has been measured. The electron distribution from thicker targets which were not becoming transparent during the laser pulse has also been characterized. Finally, prepulse and two wavelength irradiation effects have been investigated.

APPL/34

REDUCTION OF THE HOT ELECTRON PRODUCTION WITH INCREASING PULSE RISETIME IN THE CO_2 LASER-SOLID TARGET INTERACTION

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and

R. Decoste
IREQ, Varennes, Québec, JOL 2PO

The influence of increasing the laser pulse risetime from 300 ps to 2 ns on the physics of laser-plasma interaction was studied at 10.6 μm. We worked in a regime of strong profile modification and our attention was focussed on the interplay between the laser ponderomotive force and the plasma kinetic pressure, and on the consequences of this competition on absorption mechanisms. It is expected that an increase in pulse risetime will reduce the profile steepening at the critical density and will lowered the hot electron production due to resonance absorption. Varying the pulse risetime is expected to have a stronger effect than adding a pre-pulse.

The peak irradiance was about 10^{14} W/cm^2. The diagnostics used included differential calorimetry (ions and diffused light), filtered charge collection and X-ray spectroscopy. Results show that the hard X-ray intensity decreases substantially with longer risetime while the absorbed energy stays the same. Addition of a pre-pulse, which lets the plasma cool down, does not significantly modify the X-ray emission. Comparisons between these results and the 1-d hydrodynamic code FILM will be discussed.

APCC/34

Raman Scattering in Thin Foil Plasmas Irradiated with 0.53 μm Laser Light

C. L. Shepard, Gar E. Busch, E. F. Gabl, R. J. Schroeder, and J. A. Tarvin

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ABSTRACT

We have studied stimulated Raman scattering in experiments where thin (~ 0.2 μm) Al foils were irradiated with 0.53 μm laser light. Time resolved Raman spectra and Raman images were obtained along with plasma density distributions from a four-frame/shot holographic system. The spectra show that while all wavelengths of Raman light start nearly simultaneously, they do not cease simultaneously. Rather, the longest wavelengths turn off earliest and shorter wavelengths end monotonically later in time. Preliminary analysis of the data shows that this turn off behavior is due to the diminution in time of the peak plasma density. A simultaneous comparison of peak plasma density and maximum Raman wavelength in a spectrum gives an estimate of plasma temperature, about 2.0 keV.

Three-Halves ω_0 Spectrum for Laser Irradiated Thin Foil Targets

E. F. Gabl, Gar. E. Busch, R. J. Schroeder, C. L. Shepard, J. A. Tarvin

KMS Fusion, Inc., Ann Arbor, MI 48106

ABSTRACT

The 3/2 ω_0 spectrum has been measured for thin foil targets irradiated simultaneously at ω_0 and 2 ω_0. The incident wavelengths were respectively 1.053 μm and 0.5265 μm. The average intensity was from 1 x 10^{13} W/cm^2 to 5 x 10^{14} W/cm^2 for ω_0. The targets were aluminum with thickness from 0.11 μm to 0.26 μm and diameters from 200 μm to 500 μm. Time integrated spectra are presented. The characteristic double-lobed emission spectrum is observed to have a predominant red-shifted portion and asymmetrical splitting. Stereoscopic images are used to determine the location of the emission. Regions of high beam intensity correlate with the emission. Density and scalelength are obtained from interferograms and turn on times are determined from 0.702 μm streaks. These are used to calculate two-plasmon decay thresholds. The measured threshold lies below the theoretical limit. It appears to be independent of intensity, occurring at a scalelength of about 50 μm. These data will be compared to Raman thresholds for similar thin foil experiments.

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Session G
(oral)

Hydrodynamics

Wednesday, 8:30 am

Chairman: R.G. Evans (RAL)

"24 Beam, 2 kJ, UV Implosion Experiments with OMEGA"

M.C. Richardson, R.L. Hutchison, R.L. Keck, H. Kim,
S.A. Letzring, F.J. Marshall, R.L. McCrory,
P. McKenty, J.M. Soures, and C.P. Verdon

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Rochester, New York 14623

ABSTRACT

The 24 beam OMEGA laser system, which has recently undergone full up-conversion to 351 nm has been used to investigate the implosions of several types of DT filled spherical targets. Energies in excess of 2 kJ in 600-700 ps pulses have been deposited onto targets 200-800 μm in diameter with beam-to-beam energy variances of approximately 3%.

A broad array of plasma, nuclear and time integrated and time resolving x-ray diagnostics have been used to assess the hydrodynamics and final core conditions of the implosions. Shell and fuel areal densities where measured with neutron activation of ^{28}Si[1] and scattered fuel ion spectrometry (knock-on),[2] respectively.

Detailed one-dimensional and two-dimensional hydrodynamic computations of these experiments have been made to assess the effects of irradiation nonuniformities on implosion symmetry.

(1) S.M. Lane, E.M. Campbell, C. Bennett, Appl. Phys. Lett. 37, 600 (1980).

(2) S. Kacenjar, S. Skupsky, A. Entenberg, L. Goldman, and M.C. Richardson, Phys. Rev. Lett. 49, 463 (1982).

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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MULTI-BEAM-UV-IRRADIATED HIGH ASPECT RATIO TARGETS

F.J. Marshall, M.C. Richardson, P.A. Jaanimagi,
R.L. Keck, H. Kim, S.A. Letzring, R.S. Marjoribanks,
R.L. McCrory, P.W. McKenty, J.M. Soures, and C.P. Verdon

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ABSTRACT

The implosions of large diameter (600-800 microns), high-aspect-ratio (< 300), DT-filled glass microballoon targets at modest intensities (2 x 10^{14} W/cm^2) has been investigated with the new 24 beam, 2kJ, UV (351 nm) OMEGA laser system. For these targets radiational heating rapidly decompresses the thin glass shell, the subsequent implosion proceeding with a much reduced in-flight aspect ratio, reducing the target's sensitivity to illumination nonuniformities arising from the multiple overlapping laser beams.

The character of these implosions has been investigated with a wide variety of nuclear, plasma and x-ray diagnostics. These include time-resolved x-ray diagnostics and techniques to directly determine the fuel and shell areal densities. Neutron yields in excess of 1.5 x 10^{11} have been recorded. These results are compared with predictions of one-dimensional and two-dimensional hydrodynamic code calculations to assess the level of target uniformity maintained during the implosion.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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ABLATIVE FUSION TARGETS DRIVEN BY THE 24 BEAM UV OMEGA SYSTEM

M.C. Richardson, O. Barnouin, P.A. Jaanimagi, R.L. Keck, H. Kim, S. A. Letzring, F.J. Marshall, R.L. McCrory, P. McKenty, J.M. Soures, C.P. Verdon, and B. Yaakobi

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ABSTRACT

Optimal thermonuclear burn in direct-drive laser fusion targets is created in ablatively-driven targets which maintain a low temperature at the fuel/shell interface and produce high densities of the compressed fuel without the onset of fluid instabilities. These conditions are more likely to be maintained in targets which have a low initial aspect ratio, and a low-Z ablator which minimizes fuel preheat during the implosion.

We report on an initial experimental and theoretical investigation of ablatively driven targets irradiated with 2 kJ, 351 nm, 600 ps radiation from the 24 beam up-converted OMEGA laser system at intensities in the range 4-8 x 10^{14} W/cm^2. A large array of nuclear plasma and x-ray (time-resolving and time-integrated) diagnostics have been used to investigate the performance of two simple types of DT filled ablative targets, (a) thick walled (1-4 μm) glass micro-balloons of diameter 300-500 μm, and (b) thin (1 μm) glass walled microballoons overcoated with various thicknesses (1-10 μm) of low-Z (CH) material. These experiments are complemented by detailed one-dimensional and two-dimensional hydrocode studies, to assess the affects of irradiation nonuniformities on implosion symmetry.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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Nishimura

Wavelength Dependences of Implosion Properties in
Gekko Laser Fusion Experiments

C. Yamanaka, T. Yamanaka, S. Nakai, K. Nishihara, K. Mima,
H. Nishimura, H. Azechi, N. Miyanaga, H. Niki, M. Nakai,
M. Yamanaka, Y. Izawa, Y. Kato, M. Mochizuki, M. Nakatsuka,
T. Yabe, GOD-, M-, T- and C-Groups

Institute of Laser Engineering, Osaka University,
Suita, Osaka 565, Japan

We have conducted series of 1μm- and ~~four~~ series of 0.53μm- laser experiments using the Gekko XII system(E_L≃20kJ), and 0.35μm experiments using the Gekko MII(E_L≃1kJ). Studies were wavelength dependences of various implosion properties such as (1) absorption, (2) hydrodynamic efficiency (heat transport and ablation rate), (3) implosion efficiency (neutron yields, achieved ρ and ρR values), and (4) implosion uniformity.

Classical absorption was dominant in low irradiance(≃10^{14}W/cm^2) and long pulse(≃1ns)cases, thus over 80% of absorption was achieved by 0.53 and 0.35μm lasers under these conditions. Measurements of ablated fluid velocities, time- and space-resolved temperature and density profiles of targets irradiated by a 0.53μm laser showed 2-3times larger mass ablation retes and pressures than those of 1.05μm laser, and the same heat flux limitation(f=.03∿.06). The ratio of internal energy of imploded core to the absorbed energy, which corresponds to total coupling efficiency, was 4.5% for the 0.53μm laser. The implosion uniformity and stability are investigated by using modulated-surface and density-layered targets. The details of experimental data and analysis will be presented.

This paper is prepared for 15th Annual Anomalous Absorption Conference on 23-28 June, 1985, at Banff, Canada.

Study of Suprathermal Electron Generation in Cannonball Targets

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Abstract

We report a study of suprathermal (Ts = 20∿ 300keV) electron production in the Cannonball targets in Gekko experiments. Since November 1983, we have carried out over sixteen series of experiments by using 1.05, 0.53 and 0.35μm lasers. In these experiments, the temperature and energy conversion of superthermal electrons were observed by means of x-ray spectrometers (hν = 5∿500keV) and electron spectrometers (ε = 0.04∿1.4MeV). These data showed remarkable temperatures (T_S = 200∿350keV) and energy conversion rates ($U/E_T = 10^{-5}\sim 10^{-4}$J/J str.) for Cannonball-structure targets comparing with nominal targets (T_S = 20∿200keV and $U/E_T = 10^{-8}\sim 10^{-5}$), where U was the overall electron energy derived from electron spectrometer and E_T was the incident energy. Additional measurements of scattered light energy and spectra showed strong correlations of superthermal electron conversion with SRS and $3/2\omega_o$ light as a function of cavity width. These experimental data as well as $3/2\omega_o$ images of the targets conclusively indicated that these superthermal electrons were mainly generated near the holes of Cannonball-outer shell where laser were focused up to 2×10^{17}W/cm^2 due to the parametric processes under $n_c/4$ region. The coupling of these suprathermal electrons to an inner shell or fuel are still under investigation.

This paper is prepared for the 15th Annual Anomalous Absorption Conference on 23-28 June, 1985, at Banff, Canada.

Theory and Simulation of Strongly Inhibited Rayleigh-Taylor Growth with 0.25 micron Lasers

by

Mark H. Emery and John H. Gardner
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The Rayleigh-Taylor (RT) instability is a potential obstacle to laser fusion since it can cause the shell to fracture, the fuel to mix with the shell material or it can cause a nonuniform implosion that would severely reduce the energy gain of the fusion pellet. The RT instability will ultimately dictate the allowed aspect ratio for the target and thus control the hydrodynamic efficiency.[1] We derive the growth rate for the RT instability directly from the vorticity equation for a thin fluid with an exponential density gradient bounded on both sides by fluids of constant density. We will present results and discuss the effect on the growth rate of the thickness of the layer and the convection of vorticity away from the unstable layer as a result of the ablation process and compressibility. The analytic results agree well with the numerical simulations and show that the RT growth in laser-driven ablatively-accelerated targets is reduced below the classical value by nearly a factor of four for 1/4 micron laser light. These results provide further evidence for the viability of thin, high-aspect ratio shells in directly driven laser fusion.

1. J. Gardner et al., this meeting.

This work was supported by the US Department of Energy and Office of Naval Research

Ablation Measurements Using a KrF Laser at Intensities of 10^{11}-10^{13} W/cm^2

R. Fedosejevs, P.D. Gupta*, R. Popil, Y.Y. Tsui
and A.A. Offenberger

Department of Electrical Engineering,
University of Alberta, Edmonton, Canada, T6G 2G7

Ablation measurements will be reported on solid aluminum targets irradiated with a Raman compressed KrF laser pulse in the intensity range of 10^{11} to 10^{13} W/cm^2. Experiments were conducted using both ion blowoff diagnostics from single element targets and time resolved X-ray emission measurements from layered targets. The results of these experiments will be compared with each other and with one dimensional ablation models. In general the agreement is good between the observations and the 1D models. The resultant mass ablation rate scaling and ablation pressure scaling with laser intensity will be presented and discussed. In addition anomalous behaviour seen in some of the ion measurements will be discussed in terms of lateral transport effects for small focal spots.

* On leave from Bhabha Atomic Research Centre, Bombay, India.

15th Annual Anomalous Absorption Conference
Banff, Alberta, Canada
June 23-28, 1985

Simulations of Absorption at 351 nm on Spherical Targets

R.S. Craxton, J. Delettrez, R.L. Keck, R.L. McCrory, M.C. Richardson, W. Seka and J.M. Soures

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Replace

M3

ABSTRACT

Simulations are presented of the absorption of 351-nm laser radiation by spherical plastic and nickel targets,[1] irradiated with 6-24 beams of the OMEGA laser system. The simulations include refraction and inhibited thermal transport. The effects of refraction, plasma scale length and target Z are examined. For nickel targets, agreement with experiment is obtained when using Rosseland-averaged (rather than Planck-averaged) multigroup opacities. This result appears to be consistent with the finding of Mead et al.[2] that when Rosseland opacities are used to model aluminum, the predicted line emission (near 2 keV) is lower by a factor of 10.

1 M.C. Richardson et al., Phys. Rev. Lett. 54, 1656 (1985).

2 W.C. Mead et al., Phys. Fluids 27, 1301 (1984).

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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NUMERICAL SIMULATION AND TARGET DESIGN FOR LASER-IMPLODED CYLINDRICAL PLASMAS

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The characteristics of plasmas formed from laser-driven implosions of cylindrical targets are studied using one-dimensional hydrocode simulations. The implosive motion of the heated target material and the axial symmetry of the plasma are properties not shared by exploding-foil plasmas. These properties can be exploited to control the plasma lifetime and transverse scale lengths which, in addition to optimum average ionization states, are important characteristics of plasmas used as x-ray laser media. The analysis includes atomic rate-equation calculations of the relevant ionization species populations within these plasmas.

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

15th Annual Anomalous Absorption Conference 1985

Banff, Canada

"Spherically Symmetric Illumination of Laser Fusion Pellets with the ISI Laser"*

A.J. Schmitt, S. Bodner and J.H. Gardner **

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Success in direct drive laser fusion requires highly symmetric deposition of laser energy on the plasma surface of the pellet target. The induced spatial incoherence (ISI) technique [1] promises this smoothness on each driver beam by time averaging rapidly varying random spatial fluctuations in the intensity. The smooth profiles of these individual beams must then be combined on the surface of the laser fusion pellet to give the required uniform energy deposition. We investigate the uniformity that results when typical ISI beam profiles (comprised of overlapped sinc^2 shapes) are targeted onto pellets using a .25μm laser in a 32 beam symmetric illumination system. The FAST1D laser-plasma hydrodynamics code supplies the pellet's density and temperature distributions at different times during the implosion. The beams are raytraced through the plasma corona, depositing energy via inverse bremmstrahlung. Varying the beam spot size and tilting the echelon steps (broadening the beam shape), we find optimum parameters for illumination uniformity and total energy deposition. The spectral composition and beam misalignment are also investigated.

[1]. R.H. Lehmberg and S.P. Obenschain, Opt. Comm. 46, 27 (1983).

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

** Laboratory for Computational Physics

OBSERVATIONS OF NONLINEAR PHENOMENA DURING IONOSPHERIC MODIFICATION

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Ionospheric modification by high-power radio waves reveals a complex tapestry of nonlinear effects (e.g., filamentation, self-focusing, heated electrons, profile modification, parametric instabilities, soliton collapse and more). Several theories have been proposed to explain various features observed in the experimental data. We have made very high resolution (temporal and spatial) radar measurements of the HF interaction region. This technique complements spectral studies previously made and together they may provide a means of testing at least some of the features of the various theoretical models proposed. Results from a recent series of tests performed at Arecibo Observatory will be presented and compared with past experiments and existing theories. Theoretical developments aimed at refining experimental tests of theory will also be detailed.

Session H
(review)

Hydrodynamics
R.G. Evans (RAL)

Wednesday, 7:00 pm

Chairman: B. Ripin (NRL)

Session I
(poster)

Hydrodynamics, Transport

Wednesday, 8:30 pm

RADIATION AND HEAT TRANSPORT IN A KrF PRODUCED PLASMA

R. Marchand, A. Birnboim,* and C.E. Capjack

Department of Electrical Engineering, University of Alberta, Edmonton, Alberta, T6G 2G7

A newly developed radiation transport model is used in the MEDUSA code to analyze radiation and classical (flux-limited) energy transport in a planar laser-produced plasma. The radiation model accounts for 19 continuum energy groups, ranging from 0.3 to 10 kev, and 20 lines. Results are presented for aluminum targets illuminated with a KrF laser. The contributions of radiation and heat transport are calculated and compared at various times for a number of laser intensities. Regimes are identified where one process dominates over the other one.

*On leave from ADA, P.O. Box 2250 (24), Haifa 31021, Israel

ION-ELECTRON DIFFUSION AND EQUILIBRATION IN 2-D HYDRODYNAMIC CODES

R. Rankin, R. Marchand, A. Birnboim,* C.E. Capjack
Department of Electrical Engineering, University of Alberta, Edmonton, Alberta, T6G 2G8

The problem of diffusion and rapid equilibration between ions and electrons in two-dimensional hydrodynamic codes is addressed using three different numerical approaches. The methods are all based on a simultaneous solution of the ion and electron diffusion equations in which equilibration between the species is calculated implicitly. Previous approaches to this problem have involved decoupling the ions and the electrons and solving the diffusion equation for each separately, followed by an ad-hoc procedure in which the species are equilibrated for an arbitrary timestep size DT. Such a procedure, while computationally straightforward, suffers from the defect that in cases of rapid equilibration the method either fails to converge or can overshoot the true solution and in some cases lead to negative temperatures. In other words, the aim of such techniques, which is to prevent the timestep being limited by the timescale for equilibration, can often fail in precisely the situation which they were intended to deal with. These problems are overcome using a fully implicit scheme in which diffusion and equilibration are calculated simultaneously. We compare three numerical schemes (a) diffusion of Te and Ti using the ICCG method of Kershaw (b) a splitting method in which diffusion in the two spatial directions is done separately leading to inversion of banded 5-diagonal matrices by Gaussion elimination (c) an iterative method which is particularly simple to implement and does not require large scale inversion methods. Results are presented comparing the efficiency of the schemes as regards convergence and accuracy applied to model problems.

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HYDRODYNAMIC EVOLUTION OF A HELIUM GAS JET

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Experimental and computational results are presented for the interaction of a CO_2 laser of intensity 10^{14} W/Cm^2 with a Helium gas jet. The computational modelling is done using a two-dimensional hydrodynamic code in which a laser is made incident on a preformed plasma at 0.5 of the critical density for 10.6 um radiation. A comparison is made between experimentally determined density and temperature profiles and those obtained from the simulations. Such calculations are useful to determine optimal conditions in the plasma for experimental investigation of parametric processes such as stimulated Raman scattering and the two-plasmon decay instability. Comparison between the experimental and simulation results is used as a basis for determining scalings for various hydrodynamic variables of interest.

Time Resolved X-ray Emission Observations of KrF Laser Ablation Rates

R. Popil, P.D. Gupta*, R. Fedosejevs and A.A. Offenberger.

Department of Electrical Engineering
University of Alberta, Edmonton, Canada, T6G 2G7

Preliminary results on ablation rate determination from time resolved X-ray emission observations of multi-layered targets are reported. A Raman compressed KrF laser pulse at intensities of up to 10^{13} W/cm^2 irradiates gold-aluminum-gold slab targets and the resultant X-ray emission is recorded on an X-ray streak camera with $\sim$ 15 ps resolution. The X-ray emission shows a pronounced temporal modulation from both the target layers and the intensity modulations in the incident laser pulse. Ablation rates are determined from the enhanced transient features observed from the multi-layered targets. The ablation area is measured from X-ray pinhole photographs correlated with simultaneous equivalent focal plane camera measurements. The results agree favourably with steady state one dimensional models. In addition the electron temperature, X-ray intensity scaling and X-ray conversion efficiency as determined by X-ray continuum measurements will be reported.

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* On leave from Bhabha Atomic Research Center, Bombay, India.

Ion Expansion Characteristics in KrF Laser Plasma Interaction

P.D. Gupta*, Y.Y. Tsui, R. Popil, R. Fedosejevs
and A.A. Offenberger

Department of Electrical Engineering,
University of Alberta, Edmonton, Canada, T6G 2G7

A study is presented of the ion expansion characteristics in plasma created from planar aluminum targets by a Raman Compressed KrF laser (λ=268 nm) in the intensity range 10^{11}-$2x10^{13}$ W/cm^2. Arrays of differential energy calorimeters and Faraday cups were used to map the energy and velocity distribution of ions in the expanding plasma. Faraday cup signals exhibit a two peak behaviour, which depends on the laser intensity and the focal spot size. Details of the velocity distributions, angular distributions and energy partition of ions in the two peaks will be presented. Time and space integrated values of mass ablation rate and ablation pressure are derived from this data and the scaling of these parameters with laser intensity is obtained. The results of the large focal spot interaction are observed to be in good agreement with those expected from one dimensional models based on inverse bremsstrahlung absorption in the underdense region of plasma. Departures observed in the small focal spot interaction are discussed in terms of the lateral transport effects.

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* On leave from Bhabha Atomic Research Centre, Bombay, India.

ELECTRON HEAT TRANSPORT IN A MICROWAVE DRIVEN PLASMA*

J. H. Rogers, K. Mizuno, and J. S. DeGroot

Department of Applied Science

University of California at Davis

Temporal and spatial measurements of electron heat transport are made in the U.C.D. Aurora device. In this device, microwaves heat a region of underdense plasma. The transport of the absorbed energy into an overdense collisional plasma ($T_e \gtrsim 0.1 eV$, $n_e \gtrsim n_c = 1.8 \times 10^{10} cm^{-3}$, so $\lambda_e \gtrsim 1$ cm) is measured using planar Langmuir probes. The microwave absorption can be collisional (inverse bremsstrahlung) or collective (resonance absorption or parametric instabilities) depending on the plasma density scale length. The microwaves propagate in a plasma filled waveguide and are cut off at $n_e \simeq 0.7 n_c$. Only collisional absorption is observed for longer (L > 50cm) density scale lengths. Collective effects dominate absorption for shorter density scale lengths. Thus, the Aurora device models some of the phenomena[1-3] that are believed to be important in the transport of absorbed laser energy into the overdense plasma in a laser driven pellet.

1. J. P. Matte, T. W. Johnston, Phys. Rev. Lett. 53, 1461, (1984).

2. J. R. Albritton, Phys. Rev. Lett. 50, 2078 (1983).

3. R. J. Mason, Phys. Rev. Lett. 47, 652 (1981).

Work supported by Lawrence Livermore Laboratory Under Intramural Order, No. 3965705.

SOLUTION OF THE FOKKER-PLANCK EQUATION IN SPHERICAL COORDINATES

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University of St. Andrews

ABSTRACT

The Fokker-Planck equation was solved numerically in one spatial dimension for the case of spherical geometry. A two boundary heating problem was studied with the plasma initially at 100eV then one boundary heated to 200eV. We have investigated the effects of varying the inner radius, for a fixed plasma width, on the propagation of the temperature front across the plasma. Our results indicate that the heating, at the cold boundary, is reduced for the case of a high degree of sphericity. We present results for the case of (a) planar geometry and (b) spherical geometry with inner radius 20μm, for a plasma width of 12μm.

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Studies of Rayleigh-Taylor Instabilities in Spherical Geometry*

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We have developed a 1D linear perturbation code for the study of Rayleigh-Taylor instabilities in spherical geometry. The reasons for developing this tool in addition to the other codes available in our laboratory, are numerous: economy - flexibility - benchmarking and overcoming numerical problems with treating long wavelength perturbations.

However, some problems have been encountered in the development of this code. As in the case of the 2D code,[1] extremely good resolution must be achieved in the unstable region (cells must be ¼ μ or less thick). Unlike in a full non-linear code, lack of feedback of the perturbation in the equilibrium solution requires that the equilibrium solution must be smooth enough in order to prevent spurious growth, which also leads toward the direction of greater resolution. A complete report on the status of this effort will be presented.

1. M. Emery, J. Gardner and J. P. Boris, Phys. Rev. Lett. 48, 677 (1982).

** Laboratory for Computational Physics
* Work supported by the U.S. Department of Energy

LASER IMPLODED CYLINDRICAL PLASMAS

M.C. Richardson, O. Barnouin, R. Epstein, P.A. Jaanimagi, R.S. Marjoribanks, J.M. Soures, and B. Yaakobi

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ABSTRACT

An experimental and theoretical investigation is made of high density, high temperature linear plasmas, produced in the implosion of cylindrical shell targets, to determine their suitability as potential x-ray laser media. Four orthogonal, line focused, 351 nm beams from the OMEGA laser system, have been used to implode 2 mm long, 70 μm diameter, thin (0.3 μm) aluminum cylindrical targets. Time-resolved and time-integrated x-ray spectral and photographic characteristics are compared to hydrodynamic and atomic physics calculations.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

SHOCK WAVES GENERATED BY A SHAPED LASER PULSE

P. Celliers, A. Ng, and D. Parfeniuk

Physics Department, U.B.C., Canada

To study multiple shock propagation in solids, we have irradiated planar glass targets with a temporally-shaped, 0.53μm laser pulse. The shaped pulse was obtained by beam-stacking two 2ns (FWHM) pulse which were separated in time by 2-4ns with an intensity ratio of 5-10. Maximum irradiance on target was $< 10^{14}$ W/cm^2. The target was side-illuminated simultaneous with a 5700Å dye laser probe beam. Streak shadowgraphy measurements showed a clear trajectory of the shock front propagating through the target. The second shock wave generated by the higher intensity portion of the shaped laser pulse was observed to overtake the weaker first shock. An important parameter characterizing the double shock waves is this shock collision time. The experimental results will be compared with 1-dimensional hydrodynamic simulations

A PROPOSED LONG-SCALE-LENGTH PLASMA EXPERIMENT FOR A 5 KJ KRF LASER SYSTEM

by

S. V. Coggeshall, W. C. Mead, and B. Bezzerides

Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Abstract

A KrF laser target shooter which will deliver 5 kJ in 5 ns is currently under construction at Los Alamos National Laboratory. We are beginning to numerically explore the production of long-scale-length plasmas using these predicted parameters. We present 1-D and 2-D LASNEX calculations of plasma formation from thin foil irradiations and discuss the expected plasma conditions and laser-plasma interaction processes.

ACCELERATION OF PLANAR FOILS WITH KrF LASER LIGHT

W. C. Mead

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Los Alamos has begun construction of a 5 kJ, 5 ns KrF laser for ICF studies. This talk will discuss early LASNEX calculations assessing the pressures, accelerations, velocities, and density profiles which are attainable using such laser pulses. Implications for study of fluid instabilities will be discussed.

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OBSERVATION OF RADIATIVE PREHEAT IN REAR SURFACE REFLECTIVITY MEASUREMENTS

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Previous measurements of shock-induced luminescence from the rear surface of planar targets have indicated the presence of radiative preheat particularly at high irradiances or for high Z targets. Because of the relatively weak luminosity, it was difficult to characterize the level of preheat. On the other hand, rear surface reflectivity measurements appeared to provide much greater sensitivity to the preheat conditons. In this experiment, planar targets of Al, Cu, and Mo were irradiated with 2ns, 0.53μm laser light at intensities $< 1 \times 10^{14}$ W/cm^2. This produced a shock wave propagating at a speed $< 2 \times 10^6$ cm/s. The rear surface of the target was illuminated at normal incidence with a 2ns, 0.57μm dye laser probe beam which was time-delayed to coincide with the shock breakout. Temporally and spatially resolved mesurements of the reflectivity of the target rear surface were obtained. At low irradiance or for the lower Z targets, the rear surface reflectivity was observed to drop rapidly at the time of shock breakout, decreasing by a decade in typically 100ps. At high irradiance or for the higher Z targets, the rear surface reflectivity was observed to decay relatively slowly long before the shock breakout. This was attributed to radiative preheat. The results were also compared with 1-dimensional hydrodynamic simulations.

SIMULATIONS OF REAR SURFACE TEMPERATURE AND REFLECTIVITY MEASUREMENTS IN LASER-IRRADIATED TARGETS

L. DaSilva, A. Ng, D. Parfeniuk, and P. Celliers

Physics Department, U.B.C., Canada

This work is motivated by recent experiments in rear surface temperature and reflectivity measurements in planar targets irradiated with a 2ns (FWHM), 0.53μm laser pulse. These measurements were used in the study of the equation of state of dense matter and energy transport processes such as shock propagation and radiation transport. The rarefaction of the shock (or radiation) heated target rear surface was studied using a one-dimensional hydrodynamic code incorporating a flux-corrected transport numerical scheme. The luminous radiation emitted by the surface reaching a remote detector was calculated. This was then used to determine the temporal variation of the spectral and brightness temperature. The time-integrated spectral temperature was also computed to simulate actual experimental measurements where a finite measurement time was required. Results of the simulations showed good agreement with experiments. Furthermore, the reflectivity of a probe laser beam (at normal incidence) from the unloading target rear surface was also calculated. Comparison of the simulations to experiments showed the presence of significant target preheat for high Z targets at irradiance exceeding 10^{13} W/cm^2.

A STATISTICAL MODEL FOR THE SCATTERING OF LASER LIGHT BY DENSITY FLUCTUATIONS*

Alex Friedman and Edward A. Williams

Lawrence Livermore National Laboratory
Livermore, California

ABSTRACT

A macroscopic simulation program such as LASNEX must necessarily employ a computational mesh which is too coarse to resolve the density structure near critical density. Thus, we must model the effects of subgrid scale density ripples due to uneven illumination, hydrodynamic instability, etc. To this end we have developed a statistical model for the refractive scattering of laser light off random density clumps in the subcritical medium, and have incorporated it into the 3d raytrace package.[1]

The model[2] describes scattering along the entire ray path, and assumes the correlation length of the refractive scattering force in a Langevin equation is much shorter than the scale length. (These assumptions were also made in the work of Epstein and Craxton.[3]) The amplitude of the density fluctuations varies in space with a parameterized dependence upon local plasma conditions. After each step, the ray receives an impulse along each coordinate direction, given by a Gaussian random variate with an rms corresponding to the net effect of the many density fluctuations presumed to have been encountered during the step. The velocity is then rescaled for energy conservation. The zero-order refraction is self-consistently included in the calculation. Our analysis of the procedure has been successful in explaining the spread of a ray bundle injected at various angles of incidence into a linear profile.

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*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.

1. A. Friedman, LLNL Laser Program Annual Report 1983, Pp. 3.51-55.

2. A. Friedman and E. A. Williams, LLNL Laser Program Annual Report 1984.

3. R. Epstein and R. S. Craxton, LLE Review, July-Sept. 1983, p. 26.

Session J
(oral)

Transport

Thursday, 8:30 am

Chairman: F. Mayer (KMSF)

Kinetic transport of electrons and magnetic field in laser-plasmas.

T.H. Kho and M.G.Haines

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Abstract

Kinetic transport of electrons and a transverse magnetic field in the overdense plasma is studied by solving the electron Vlasov-Fokker-Planck equation numerically. Non-local transport in steep temperature gradients limit the heat flux parallel to ∇T, $\vec{q}_{\perp}$, as well as the the Righi-Leduc heat flux perpendicular to both ∇T and $\vec{B}$, to small fractions of the free streaming heat flow. The magnetic field is convected down the temperature gradient by the Nernst effect with a velocity v_N which is found to be approximately that associated with $\vec{q}_{\perp}$. This result, which is predicted by linear transport theory, is found to hold even when the heat flux is strongly nonlinear (flux-limited). The convection velocity v_N is consequently limited to a small fraction of the electron thermal velocity determined by the flux-limited heat flux. These results show that flux-limiters, which have been used extensively with $\vec{q}_{\perp}$, are also necessary in the evaluation of the Righi-Leduc heat flux and v_N in fluid code calculations.

ENERGY TRANSPORT AND SPATIAL STRUCTURING IN HIGH-Z TARGETS

"Bob"

S. R. Goldman, W. C. Mead, and P. D. Goldstone

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Los Alamos National Laboratory
Los Alamos, NM 87545

M. C. Richardson
University of Rochester

The University of Rochester Omega system at a wavelength of 0.35 μm, total energy of 250-325 joules and pulse width of 0.6 ns has been used to illuminate both gold and layered gold-on-CH targets with nearly spherical symmetry at peak intensities of 4×10^{13} and 4×10^{14} W/cm^2. The experiments have been modeled with LASNEX. The deconvolution of the broad-band detector results to yield the x-ray conversion efficiency (x-ray energy out from target/absorbed laser energy) is examined in detail. The analysis of measurements of the decrease in conversion efficiency with decreasing gold layer thickness provides a consistent picture of energy penetration in the plasma. X-ray emission arises near the critical surface at the higher intensity, and from a more extended source region at the lower intensity. This result is tested by examination of time traces of spatially integrated x-ray spectral cuts, as well as time integrated x-ray pinhole photographs in the keV range, and x-ray streak photographs. Relevance to the determination of the electron thermal flux limiter for these experiments is also assessed.

Thermal Transport Measurements in 24-Beam, UV Irradiation of Sperical Targets

O. Barnouin, J. Delettrez, L.M. Goldman, R. Marjoribanks,
M.C. Richardson, J.M. Soures, B. Yaakobi

U. of R.

ABSTRACT

Thermal transport was studied in spherical irradiation geometry using the 24 U.V. beams of the OMEGA laser system. Mass-ablation rates were obtained using x-ray line spectroscopy data as well as charge collectors over the power density range 10^{14} - 10^{15} W/cm^2. The mass ablation rate obtained from these two methods of measurements are compared and differences between transport measurements at 1054 and 351 nm irradiations are discussed. We comment on the effect of irradiation non-uniformity on the results.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

MODELLING OF RADIATION TRANSPORT IN LASER-PRODUCED PLASMAS

A. Birnboim,* R. Marchand, and C.E. Capjack

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A model for radiation energy transport in laser produced plasmas has recently been implemented in the one-dimensional MEDUSA code. The continuous spectrum is divided into 19 energy groups ranging from 300 ev to 10 kev, and the line spectrum is approximated by 20 of the strongest lines (for Al). A detailed account is given for emission and absorption of each line or energy group in every Lagrangian cell as a function of the local plasma parameters. Two transport algorithms are considered, one being an approximate expression of the other. The results obtained in both cases are in excellent agreement, the difference being that the approximate scheme is faster than the more accurate one by approximately one order of magnitude.

The approximate method is used to model planar plasma dynamics in a range of parameters relevant to experiments conducted at the University of Alberta. The results include temperature, density, pressure, and radiated power profiles at various times, as well as instantaneous and time integrated radiation spectra on either side of the target. A post-processor is used to compute the corresponding x-ray energies and spectra through various foils.

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NON-LOCAL ENERGY DEPOSITION IN HIGH-INTENSITY LASER-PLASMA INTERACTIONS

J. M. Wallace

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Electrons heated by the absorption of laser energy on planar targets generate MG magnetic fields which, together with the co-produced electric fields, transport the electrons away from the laser spot. We present a computational model showing that these superthermal electrons deposit their energy into plasma thermal energy in an expanding annular region in the target plane centered at the spot. The model provides a quantitative explanation for some complex and heretofore poorly understood lateral transport phenomenology.

ANOMALOUS ABSORPTION CONFERENCE

EFFECT OF AN EXTERNAL MAGNETIC FIELD ON SUPERHOT ELECTRON PRODUCTION AND TRANSPORT

G.D. Enright and N.H. Burnett

National Research Council of Canada
Division of Physics
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K1A 0R6

Superhot electron production and transport has been studied in CO_2 laser irradiation of cylindrical targets through which is passed a d.c. current of up to 200 Kamp. The resulting magnetic field at the target surface can exceed 200 Kgauss depending on the target diameter. The coupling of superhot electrons into the target has been studied through observations of high Z K yield and the high energy x-ray continuum. Preliminary results indicate that d.c. magnetic fields can affect both the production and transport of very energetic electrons.

ELECTRON HEAT FLOW IN LASER-TARGET INTERACTION

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J. Delettrez, R.L. McCrory
LLE, University of Rochester, Rochester, N.Y., U.S.A.

M. Lamoureux, R. Yin, C. Möller
Laboratoire de Spectroscopie Atomique et Ionique, Orsay, France

Donnez moi

A) Our Fokker-Planck code FPI[1] has been modified to include a fast electron source and the ponderomotive force due to resonance absorption, with parameters $\lambda = 1\ \mu$, $I = 3 \times 10^{14}$ W/cm^2, $Z = 4$. We find a density jump at the critical surface, and a considerable temperature jump as well, when the ponderomotive force is turned on. However, the corona is not hot and heat flow into the cold, dense plasma is not significantly affected.

B) Analysis of the inverse Bremsstrahlung heated electrons simulated in our FPI code[1] show that the distribution function in the corona can be approximated by $Cm \exp(-v^m/v_c{}^m)$ with $m = 2.8$. For different values of $\alpha = Z\, v^2_{quiver}/v^2_{th}$, inverse Bremsstrahlung and electron-electron collisions give the distribution a similar shape, with m varying from 2 for $\alpha = 0$ to 5 for $\alpha \to \infty$, with intermediate values: $m(\alpha = 0.1) = 2.3$, $m(\alpha = 0.4) = 2.8$ and $m(\alpha = 1.2) = 3.3$.

It will be shown that the shape of recombination and Bremsstrahlung emission spectra from such distributions are very different from those due to Maxwellians.

[1]: Phys. Rev. Lett. 53, 1461 (1984).

APJP/34

Transport Properties of Dense Plasmas

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A complete description of transport properties of dense, laser compressed plasmas is presented. The model for electron thermal and electrical conductivity, thermoelectric power and inverse bremsstrahlung absorption coefficient is derived from a memory function kinetic formalism. The formalism admits limits that allow a rigorous definition of the coefficients when the plasma is weakly coupled and provides approximations that permit reliable calculations when the plasma is strongly coupled. In the latter case, use is made of equilibrium correlation functions computed from the hypernetted chain (HNC) approximation. Simple analytical results in terms of a generalized Coulomb logarithm are compared with the HNC calculations. The model yields results in good agreement with molecular dynamic simulations.

Temporal Dependence of the Mass Ablation Rate in UV Laser Irradiated Spherical Targets

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Abstract

In this paper, we present measurements of thermal transport in spherical geometry using time-resolved x-ray spectroscopy. We determine the time dependence of the mass ablation rate ($\dot{m}$) by following the progress of the ablation surface through thin layers of material embedded at various depths below the surface of the target. These measurements made with 6, 12 and 24 UV (351 nm) beams from OMEGA are compared to previous thermal transport data and are in qualitative agreement with detailed LILAC hydrodynamic code simulations which predict a sharp decrease in m after the peak of the laser pulse.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreements No. DE-A508-82DP40175 and No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

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ELECTRON HEAT TRANSPORT BY NOT QUITE MAXWELL-BOLTZMANN ELECTRONS*

E. A. Williams and J. R. Albritton
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and
K. Swartz, University of Rochester, Rochester NY 14623
and
I. B. Bernstein, Yale University, New Haven CT 06520

ABSTRACT

Preliminary code calculations have recently been made with a new fluid heat transport scheme which accounts for the non Maxwell Boltzmann high energy electrons which occur in high flux laser-plasmas. The source of the nonthermal electrons is the spatial transport of the thermal electrons down the steep temperature gradient. The associated Fokker-Planck calculations have been carried out analytically and permit the first principles formulation of a nonlocal (in space) transport description of the evolution of the (generalized) plasma temperature. The underlying theory requires (only) that the number and energy densities of the nonthermal electrons be small while their number and energy density fluxes are not restricted and may dominate the total fluxes. Typical results for laser-plasma parameters of practical interest show heat fluxes significantly reduced from those of the classical fluid transport theory. This may be understood upon reflection on the physics in play. The fluxes in both the classical local theory and our new nonlocal theory are computed from the spatial gradient of the electron energy distribution function. In the classical theory this is proportional to the local gradient of the temperature, so that the classical flux is unlimited. In the nonlocal theory the gradient scale cannot be shorter than the stopping length of high energy electrons in the actual system so that the new nonlocal flux is naturally limited even for temperature discontinuities.

*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.

STUDY OF DELOCALIZED HEAT FLUX WITH AND WITHOUT HYDRODYNAMIC

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S. Skupsky, J.P.Matte**
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We have studied a model proposed by P. Mora and J.F. Luciani for the delocalization of the heat flux.[1,2] This model is used to calculate heat flux in laser-produced plasmas when the mean-free-paths of thermal electrons transporting most of the heat are long compared to local scale lengths. This leads to a non-Maxwellian electron distribution.

First we used this model in a simple heat diffusion code (without ion motion) under various physical conditions and compared the results with Fokker-Planck code simulations.[3] The main parameter of the study is the scale length of delocalization $\lambda_{deloc} = 32 \sqrt{Z+1}\, \lambda_{ei}$. We found that λ_{deloc} must be limited to a maximum value when the temperature is too high and/or when the density is too low. In the case of laser deposition Mora-Luciani have also proposed a delocalized absorption. We tested this addition to the model against results of a Fokker-Planck code. The introduction of the delocalized absorption eliminates a major problem which occurred in the corona with the early delocalization treatment. Finally, we implemented this model in the hydrocode LILAC in order to simulate transport-experiments and to try to interpret burnthrough results.[4]

1. J.F. Luciani, P. Mora, et al., PRL 51, 8 (1983) 1664.
2. J.F. Luciani, P. Mora, et al., Phys. Fluids 28, 3 (1985) 835.
3. J.P. Matte, T.W. Johnston, et al., PRL, 53, 15 (1984) 1461.
4. B. Yaakobi, J. Delettrez, et al., Phys. Fluids 27, 2, (1984) 516.

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This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

ON HYDRODYNAMIC ENERGY TRANSFER BETWEEN TWO FOILS OF A LASER IRRADIATED DOUBLE-FOIL TARGET AT 0.35 μm WAVELENGTH

G. THIELL - D. JURASZEK - B. MEYER - F. MUCCHIELLI

The hydrodynamic behavior of double-foil targets irradiated with 0.35 μm laser wavelength at irradiance of 2×10^{14} $W.cm^{-2}$ has been investigated by means of time and space X-ray backlighting. Comparison with a 1-D lagrangian code shows discrepancies attributed to energy losses in the transfer between two foils. First results obtained with a 2-D code are presented for a single thin target. We infer that the hydrodynamic lateral expansion of the accelerated layer is the dominant process of energy losses.

Session K
(review)

Transport

D. Forslund (LANL)

Thursday, 7:30 pm

Chairman: T.W. Johnston (INRS)

Session L

Discussion, Post Deadline Papers

Thursday, 9:00 pm

Chairman: J. Meyer (UBC)

Session M
(oral)

Instabilities, Magnetic Fields, Waves

Friday, 8:30 am

Chairman: A.A. Offenberger (U of A)

KINETIC MODEL FOR THE COLLISIONAL WEIBEL INSTABILITY IN IN LASER-PLASMAS

E. M. Epperlein, T. H. Kho and M. G. Haines

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A kinetic model for the collisional Weibel instability has been developed, based on a Cartesian tensor expansion of the electron Fokker-Planck (FP) equation. The state of the unperturbed plasma is obtained from a time-dependent one-dimensional FP code with inverse Bremsstrahlung and fixed ions. Growth rates are calculated (within the local approximation) for the overdense region, and compared with results based on small departures from local Maxwellian distributions (i.e. linear transport). The implications of the results to the achievement of inertial confinement fusion are discussed.

THE WEIBEL INSTABILITY DRIVEN BY HOT ELECTRONS IN THE PLASMA CORONA

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Resonance absorption and underdense parametric processes such as two-plasmon decay produce an anisotropic hot electron distribtion in the corona; it has recently been suggested that such distributions may drive an enhanced plasma wave spectrum and thus explain the observations of Raman scattering at pump intensities below the stimulated Raman instability threshold. Such distribution functions may also be expected to be unstable to the Weibel instability, resulting in filamentary hot electron currents and associated magnetic fields. Such fields have previously been observed in Faraday rotation backlighting experiments. Here we consider the thresholds, growth rates, preferred modes, and likely saturation behavior of the Weibel instability as a function of the hot electron distribution fuction. Observations of the resulting magnetic field intensity and structure may provide a useful diagnostic for the hot electrons.

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

RALEIGH-TAYLOR INSTABILITY OF BUMPS

by

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The Taylor unstable growth of localized initial perturbations on ablation accelerated shells is calculated from various assumptions about the dependence of the growth rate on wavelength, $\gamma(K)$. Bumps are seen to spread and early time growth is less than would be predicted by simply using the peak value of γ.

THERMAL INSTABILITIES AS AN EXPLANATION OF JET-LIK STRUCTURES OBSERVED ON LASER IRRADIATED THIN PLANAR TARGETS AT 1.06 μm AND 0.35 μm WAVELENGTHS

G. THIELL - B. MEYER

Filamentary and jet-like structures are observed in the interaction of a laser beam with aluminium and gold targets. The range of irradiance is 10^{13} to 5×10^{14} W cm^{-2} with nanosecond pulses. According to theoretical predictions these structures can be attributed to thermal instabilities. We show that the electrothermal instability grows more probably at the 0.35 μm laser wavelength whilst the magnetothermal instability develops at 1.06 μm. The jet-like structures occurring on the rear side of thin targets are discussed.

Nernst Term and Magnetic Fields in Laser-heated Plasmas*

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D. Colombant, Plasma Physics Div., Naval Research Laboratory
N. Grandjouan, Greco, Ecole Polytechnique
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With a fixed-ion 2D code,[1] we have studied the generation and evolution of B-fields in laser-heated plasmas. Recent emphasis has been placed on the effects of the Nernst term on B-field generation and of the Righi-Leduc term on heat transport.

With the Nernst term turned on, we have looked at the case of uniform target illumination at $\lambda = 1\mu$ with an exponential density profile and a constant initial B-field in the target. We find that although the B-field increases in the overdense region, it does not increase proportionally to the density as mentioned in recent work.[2]

In case of non-uniform illumination, we find that spots of maximum B-field occur also in the overdense region and that the B-field does not strongly inhibit transport into the target. For this latter case, we have also made comparison runs without any B-field but with a variable flux limiter.

1. J. Brackbill, D. Colombant and N. Grandjouan, CECAM report on "The Flux Limiter and Heat Flow Instabilities in Laser-Fusion Plasmas" (1982).
2. A. Nishiguchi, T. Yabe, M. G. Haines, M. Psimopoulos and H. Takewaki, Phys. Rev. Lett. 53, 262 (1984).

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

ORAL SESSION

COLLISIONAL AND DENSITY GRADIENT EFFECTS ON B-FIELD GENERATION, SURFACE TRANSPORT, AND FAST ION BLOW-OFF IN LASER PRODUCED PLASMAS*

John

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The ANTHEM hybrid electron transport code has been used to study surface transport and fast ion blow-off in foil-like targets exposed to 10.6, 1.0 and 0.25 μm light. Subtleties of the modeling are discussed. These include current-corrected Implicit Moment field determinations of the E- and B-fields, alternate fluid and particle treatments for the longest range electrons, and both explicit and implicit particle collision models. We corroborate earlier results that the B-fields tend to confine the blow-off to a jet centered on the laser spot. For targets exhibiting strong internal hot electron collisionality we find that scatter can result in significant hot electron sub-surface transport that competes with the surface transport due to B-fields. Return currents from the cold dense interior of a target are shown to produce rotational resistive E-fields, which can give rise to Megagauss B-fields at steep gradient interfaces well below the critcal surface in a target. This may offer an alternate explanation for the field growth ascribed by others to convection. The ANTHEM results are compared to calculations from a new collisional version of VENUS.

*This work was performed under the auspices of the United States Department of Energy.

Strong Laser Absorption on a Plasma with a Sharp Density Gradient

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Strong energy absorption is possible when an intense electromagnetic wave is incident obliquely on a sharp edged overdense plasma, and if its quiver velocity $v_{osc} = eE/m\omega$ is on the order of the speed of light. The absorption mechanism is through the electrons that are dragged into the vacuum by the normal electric field with a velocity on the order of v_{osc}; after one cycle most of them return to the plasma where their energy is lost. An estimate of the lost energy per cycle is $E_{loss} \simeq N\, m_e\, v_{osc}^2$ where $N = E/4\pi e$ is the number of electrons necessary to shield the field, and which gives $E_{loss} \simeq (v_{osc}/\omega)E_o^2/8\pi$. If we compare this with the incident power $I_o = (E_o^2/8\pi)c$, the absorbed power is $I_{abs} = \alpha\,(v_{osc}/c)I_o$. From numerical simulation, using a $1^2/2$ dimensional electrostatic code with the capacitor model (we also have $\omega_p/\omega_o = 2.5$ and 5), we find that the numerical constant α is approximately 0.5. This mechanism is more efficient than resonant absorption for absorbing energy if $v_{osc}/\omega \geqslant L = (\partial \ln n /\partial x)^{-1}$ since for that parameter the quiver field is as large as the resonant one.

In the concept of a laser/grating accelerator, one would like to use CO_2 lasers which can now achieve intensities of $\sim 10^{15}$ W/cm^2 or $v_{osc}/c \simeq 0.3$. The above mechanism provides a serious limitation of the electric field strength, even with a short pulse. This mechanism might also play a role in the usual CO_2 laser-plasma interaction where strong density profile sharpening ($L \simeq 2$ μm) is observed[1] for a strong pump level. A difference in signature from the usual resonant absorption is that a large amount of hot electrons will be absorbed at the focal point.

1. R. Fedosejevs, M.D.J. Burgess, G.D. Enright and M.C. Richardson, Phys. Rev. Lett., 43, 1664, (1979).

Modeling Fast Ion Expansion in Laser Produced Plasmas*

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Data for emitted fast ions have been gathered for laser matter interaction experiments performed over the past 20 years (Refs. 1 & 2). These data show a strong correlation between the mean energy per AMU E-ion of the fast ions emitted and the hot electron temperature T-hot measured from X-rays. This correlation appears to be independent of laser wavelength, pulse length, target geometry and material. We present here the results of analyzing these data with a number of theoretical models: (1) an isothermal rarefaction model; (2) steady state ablation models with and without flux limitation; and (3) a large scale hydro code run in reduced physics and enhanced physics modes.

These models all show excellent agreement with the data for T-hot above about 20 KeV. This implies that T-hot is responsible for driving the ion flow and channeling most of the absorbed laser energy from hot electrons into ions. For T-hot below about 4 KeV, we find the data can be modeled only by assuming the flow is driven by the background electrons at temperaure T-cold. We use the steady state ablation model without flux limitation (ref. 3) to define this temperature:

$$\text{T-cold} = 2.4\ (I\ \lambda^2)^{2/9}\ r^{4/9}\ \lambda^{-2/3}\ \text{eV},$$

for hydrogen with I the laser intensity in Watts/cm^2, λ the laser wavelength in micrometers and r the radius of the critical density surface in cm.

In the intermediate temperature regime - T-hot between about 4 and 20 KeV - there appears to be an important interplay between the hot and cold electron temperatures and the relative fraction of hot electrons present in the plasma. Thus, only the large scale hydro code run with its full physics complement is capable of modeling the data.

We will discuss the implications of these results for laser fusion power reactors and for hybrid mirror-laser heated pellet reactor schemes.

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[1] S. J. Gitomer, R. D. Jones, F. Begay, A. W. Ehler and J. Kephart, 1983 IEEE International Conference on Plasma Science, San Diego CA, IEEE Conference Record 83CH1847-3, paper 2A4, page 30.
[2] S. J. Gitomer and R. D. Jones, 1984 IEEE International Conference on Plasma Science, St. Louis MO, IEEE Conference Record 84CH1958-8, paper 3S2, page 75.
[3] S. J. Gitomer, R. L. Morse and B. S. Newberger, Physics of Fluids 23 234 (1977).

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

Theoretical Prospects for High Gain Laser Fusion with Direct Drive

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A number of breakthroughs have occurred in the last couple of years, greatly improving the prospect for high gain inertial confinement fusion using the direct drive concept with laser light. The induced spatial incoherence (ISI) technique can produce a sufficiently smooth laser deposition profile (less than 1% rms variation) that only a minimal amount of thermal smoothing is required for the very short wavelength variations. This means that short wavelength lasers can be used in direct drive. Recent results at NRL, on the Rayleigh-Taylor instability, moreover show that the growth rate for short wavelength lasers is even less than for longer wavelengths (0.3 times classical for 1/4 micron laser light). As is well known, the shorter wavelength laser also increases the plasma instability thresholds and this reduces the prospects for hot electron preheat. A combination of shorter wavelength lasers and higher aspect ratio pellets permitted by the lower R-T growth leads to high hydrodynamic efficiencies. Computer simulations indicate that rocket efficiencies as high as 15% are possible for directly driven laser fusion pellets.

KMSF-U1588ab

ENERGY TRANSDUCTION IN PELLET-INJECTED PLASMAS

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ABSTRACT

An unexpected feature of the evaporation of refueling pellets in tokamaks is discussed. Specifically, it is shown that steady-state, spherically symmetric pellet evaporation leads to a process of "energy transduction" that takes energy from stored electron thermal energy and delivers it to evaporation kinetic energy. This is a noncollisional acceleration process and may be usefully employed in various magnetic fusion devices for controlling the partitioning of the machine stored energy. The ion velocities can strongly exceed the background plasma sound velocity (i.e., $v_i \approx 3\ c_s$). Further, it is suggested that energy transduction is responsible for the increased energy confinement time observed in pellet-injected Alcator experiments. Measurements from these experiments are used, first to determine the classical flux-limit parameter, f, and second, to estimate evaporative ion energies. Finally, a number of potentially useful magnetic fusion energy loading schemes that make use of energy transduction will be described.

Integrating Cylinder for ICF Light Balance Measurements in Mirror Illumination Systems

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ABSTRACT

A diagnostic for measuring light scattered from planar targets, using f/0.8 and f/1.8 mirror illumination systems, has been designed and tested. The instrument is a light integrating cylinder, which uses the light integrating principles of the Ulbricht sphere, but which was designed to operate in a reflective illumination environment.

The cylinder has been used to make measurements with both high absorption disk targets, and low absorption foil targets, illuminated with 20-80 J of green (5300 Å) light. The instrument has also been modeled by the KMS "viewfactor" code to determine theoretical integrating performance under a variety of operating conditions. This report discusses design considerations, calibration technique, and evaluates the general performance of the cylinder when used with disk and foil targets. A comparison of the use of this technique in measuring absorption and its use in measuring scattered light only, will be discussed as well.

ELECTROSTATIC SURFACE WAVES

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There are a number of places that surfaces can form during the laser-plasma interaction. This can occur at the critical surface, at the quarter critical surface, and in filaments. The normal modes on surfaces are quite different from those in a homogeneous plasmas, so one might expect such physics issues as parametric coupling to also be different. We have calculated the dispersion and Landau damping for electrostatic surface waves. This differs from previous calculations in that no confining wall is present. The plasma is confined by the inertia of the ions. These results are quite different from the results for the wall confined situation.

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15th ANNUAL

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