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LOS ALAMOS

12TH ANNUAL ANOMALOUS ABSORPTION CONFERENCE

MAY 10-13, 1982

SANTA FE, NEW MEXICO

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

TWELFTH ANNUAL
ANOMALOUS ABSORPTION
CONFERENCE

MAY 10-13, 1982

SANTA FE HILTON INN

SANTA FE, NEW MEXICO

ORGANIZED BY

LOS ALAMOS NATIONAL LABORATORY

LOS ALAMOS, NEW MEXICO 87545

TWELFTH ANNUAL

ANOMALOUS ABSORPTION

CONFERENCE

PRELIMINARIES

SUNDAY, MAY 9

19:00-21:00

Registration/Check-in
Hilton Hotel-Lobby
Hor d'oeuvres - and Cash Bar

MONDAY, MAY 10

8:00-11:00

Registration

All Oral Sessions will be held in the Peralta-DeVargas Room of the Hilton Inn. Posters will be displayed in the Promenade Hallway and Onate Room.

TWELFTH ANNUAL

ANOMALOUS ABSORPTION

CONFERENCE

SESSION SCHEDULE

A Stimulated Scatter and Filamentation
Monday, May 10, 8:30 - 12:30
Chairman: W. Manheimer (NRL)

B Hydrodynamics and Implosion Symmetry
Monday, May 10, 14:00 - 16:30
Chairman: D. J. Nicholas (Rutherford)

CD DISCUSSION - Ablation, Uniformity, Symmetry
Monday, May 10, 16:30 - 17:30
Discussion Leader: R. L. McCrory (Rochester)

D Experimental Modeling, Diagnostics, and Cryogenics
Tuesday, May 11, 8:45 - 12:15
Chairman: T. W. Johnston (INRS)

E Hot Electron Generation and Thermal Transport
Wednesday, May 12, 8:45 - 12:15
Chairman: W. Kruer (Livermore)

F Hot Electron Transport
Wednesday, May 12, 14:00 - 16:00
Chairman: A. B. Langdon (Livermore)

GP Poster Session - SBS, Harmonic Emission, Two-Plasmon Instability
Wednesday, May 12, 16:00 - 17:30

HD DISCUSSION - Electron Transport
Wednesday, May 12, 17:30 - 18:15
Discussion Leader: F. J. Mayer (KMSF)

I Fast Ions, Hot Electrons
Thursday, May 13, 8:45 - 11:00
Chairman: A. A. Offenberger (Univ. of Alberta)

JP Poster Session - SBS, Self-Focussing, Hydrodynamics and Transport
Thursday, May 13, 11:00 - 12:15

KD DISCUSSION - What Has Been Learned, Future Prospects, and Arrangements for Next Meeting
Thursday, May 13, 12:15 - 1:00
Discussion Leader: B. Ahlborn (Univ. of British Columbia)

Session A: STIMULATED SCATTER AND FILAMENTATION

8:30-12:30		Chairman: W. Manheimer (NRL)
8:30-8:45		Official Welcome S. Rockwood (Los Alamos)
8:45-9:00	A-1	"Generation of Enhanced-Scalelength Plasmas, and Zeeman Study of Magnetic Fields," J. A. Stamper, E. A. McLean, S. P. Obenschain (NRL), H. R. Griem (Univ. of Maryland), C. K. Manka, D. W. Droemer (Sam Houston Univ.), and M. J. Herbst (NRL).
9:00-9:15	A-2	"Backscatter and Profile Measurements in Enhanced-Scalelength Plasmas," M. J. Herbst, E. A. McLean, J. A. Stamper, S. P. Obenschain, P. G. Burkhalter, D. Duston (NRL), J. Grun (MRC), R. R. Whitlock, and B. H. Ripin (NRL).
9:15-9:30	A-3	"Observations of Nonlinear Ion Waves and Saturation of SBS," C. J. Walsh and H. A. Baldis (NRC).
9:30-9:45	A-4	"The Effect of Self-generated Magnetic Fields on Stimulated Raman Scattering," H. C. Barr (UCLA).
9:45-10:00	A-5	"Experimental Study of Raman Scattering from Long Scale-length Underdense Plasmas," R. Fedosejevs, A. A. Offenberger, W. Tighe, and W. Rozmus (Univ. of Alberta).
10:00-10:15	A-6	"Vlasov Simulation of Stimulated Raman Scattering," E. Hiob and A. J. Barnard (Univ. of British Columbia).
10:15-10:30	A-7	"The Raman Instability Can be Absolute Below Quarter Critical," P. Koch (KMSF), and E. A. Williams (Rochester).
10:30-10:45		COFFEE BREAK
10:45-11:00	A-8	"Absolute and Convective Coupled Mode Instabilities with Amplitude and Phase Coupling Nonuniformities," T. W. Johnston, G. Picard, J. P. Matte (INRS), V. Fuchs, M. Shoucri (IREQ).
11:00-11:15	A-9	"Frequency Broadening Arising from Filamentation in a Laser Plasma Corona," R. W. Short and E. A. Williams (Rochester).
11:15-11:30	A-10	"Wavelength Dependence of Light Filamentation in Laser Plasmas," D. J. Nickolas (Rutherford).

11:30-11:45	A-11	"Radiation Cooling Driven Instability of Ablative Flows," L. Montierth, R. Morse, G. Sowers, and H. Takabe (Univ. of Arizona).
11:45-12:00	A-12	"Laser Plasma Interaction Phenomena at Ultra High Intensities," M. D. J. Burgess, R. Dragila, R. H. Enns, G. B. Gillman, B. Luther-Davies, K. A. Nugent, and G. J. Tallents (Australian Nat'l. Univ.)
12:00-12:15	A-13	"Nonlinear Interaction Mechanisms in UV Laser Plasmas," W. Seka, L. M. Goldman, M. C. Richardson, J. M. Soures, D. M. Villeneuve, B. Yaakobi, R. S. Craxton, J. Delettrez, R. L. McCrory, R. Short, E. A. Williams, T. Boehly, R. L. Keck, K. Tanaka, and R. Boni (Rochester).
12:15-12:30	A-14	"Angular Dependence of the Amplification of Brillouin Scattered Light for an Isothermal Rarefactions," R. L. Berger (KMSF).
12:30-14:00		LUNCH

Session B: HYDRODYNAMICS AND IMPLOSION SYMMETRY

14:00-16:30		Chairman: D. J. Nicholas (Rutherford)
14:00-14:15	B-1	"Two-Dimensional Hydrodynamic Effects in Single Beam Laser-Plasma Interaction Experiments," R. S. Craxton and R. L. McCrory (Rochester).
14:15-14:30	B-2	"Theoretical Interpretation of Multi-Dimensional Effects of OMEGA Uniformity Experiments," R. L. McCrory, C. P. Verdon, K. Lee, J. Delettrez, M. C. Richardson, D. M. Villeneuve, and J. M. Soures (Rochester).
14:30-14:45	B-3	"Uniformity of Illumination and Thermal Smoothing for Laser Driven Fusion," S. Skupsky and K. Lee (Rochester).
14:45-15:00	B-4	"Irradiation Uniformity of Spherical Targets on OMEGA," D. M. Villeneuve, W. Friedman, J. Hoose, M. C. Richardson, S. Letzring, R. Hutchison, K. Lee, S. Skupsky, R. L. McCrory, and J. M. Soures (Rochester).
15:00-15:15	B-5	"Linear and Nonlinear Aspects of Hydrodynamic Instabilities in Laser Ablation," M. H. Emery, J. P. Boris, A. L. Cooper, and J. H. Gardner (NRL).
15:15-15:30	B-6	"Symmetry Aspects of Ablative Accelerations," W. M. Manheimer, D. G. Colombant, and J. Gardner (NRL).

15:30-15:45		COFFEE BREAK
15:45-16:00	B-7	"Numerical Simulations of Rayleigh Taylor Instabilities," R. G. Evans (Rutherford).
16:00-16:15	B-8	"Experiments on the Rayleigh-Taylor Instability of Ablatively Accelerated Targets," J. Grun (MRC), M. J. Herbst, E. McLean, S. P. Obenschain, B. H. Ripin, J. Stamper, R. R. Whitlock, and F. Young (NRL).
16:15-16:30	B-9	"Inside Surface Taylor Instability," L. Montierth, R. Morse, E. Parlette (Univ. of Arizona), and C. Verdon (Rochester).

Session CD: DISCUSSION - ABLATION, UNIFORMITY, SYMMETRY

16:30-17:30	Discussion Leader: R. L. McCrory (Rochester)
17:45	COCKTAIL PARTY

TUESDAY, MAY 11

Session D: EXPERIMENTAL MODELING, DIAGNOSTICS AND CRYOGENICS

8:45-12:15		Chairman: T. W. Johnston (INRS)
8:45-9:00	D-1	"Uniform Laser Ablative Acceleration of Targets at $10^{14}W/cm^2$," S. P. Obenschain, R. R. Whitlock, E. A. McLean, B. H. Ripin (NRL), R. H. Price, D. W. Phillion, E. M. Campbell, and M. D. Rosen (Livermore).
9:00-9:15	D-2	"NRL-LLNL Double Foil Experiments: Optical Streak Camera Measurements of the Preheat, Impact Time, Shock Strength, and Uniformity of Acceleration," D. W. Phillion (Livermore), E. A. McLean, S. P. Obenschain, R. R. Whitlock (NRL).
9:15-9:30	D-3	"X-Ray Backlighting of Ablatively Accelerated Targets at Irradiances up to $10^{14}W/cm^2$," R. Whitlock, S. P. Obenschain, B. H. Ripin, E. A. McLean (NRL), R. H. Price, E. M. Campbell, D. W. Phillion, and M. D. Rosen (Livermore).
9:30-9:45	D-4	"Analysis of the Joint NRL-LLNL Ablation and Symmetrization Experiment on Shiva," M. D. Rosen, E. M. Campbell, R. H. Price, D. W. Phillion, K. G. Estabrook (Livermore), S. P. Obenschain, R. R. Whitlock, E. A. McLean, and B. H. Ripin (NRL).

9:45-10:00	D-5	"Beam Structure Effects on CO_2 Laser Light Spherical Shell Interaction," P. L. Mascheroni, D. W. Forslund, J. M. Kindel, E. J. Linnebur, and E. L. Lindman (Los Alamos).
10:00-10:15	D-6	"Uniform Compression of Large Aspect Ratio Targets Driven by Nanosecond, 24 Beam Laser Pulses from OMEGA," M. C. Richardson, S. Letzring, D. M. Villeneuve, B. Yaakobi, A. Entenberg, S. Kacenjar, R. Marjoribanks, R. Hutchison, J. Delettrez, R. L. McCrory, and J. M. Soures (Rochester).
10:15-10:30	D-7	"Coronal Electron Temperature Measurements in UV Laser Plasmas," R. L. Keck, L. M. Goldman, M. C. Richardson, W. Seka, K. Tanaka, D. Villeneuve, and E. A. Williams (Rochester).
10:30-10:45		COFFEE BREAK
10:45-11:00	D-8	"Optical Studies of Density and Magnetic Fields in Laser-Produced Plasmas," J. Stamper (NRL).
11:00-11:15	D-9	"Cryogenic Target Design and Simulation," J. T. Larsen, R. R. Johnson, and W. B. Fechner (KMSF).
11:15-11:30	D-10	"Physics of the Cryogenic Layer," W. B. Fechner, J. T. Larsen and R. R. Johnson (KMSF).
11:30-11:45	D-11	"Implosion Experiments with Cryogenically-Cooled Spherical Targets," D. Slater, J. Tarvin, G. Charatis, P. Rockett, C. Shepard, R. Johnson, E. Storm, and R. Schroeder (KMSF).
11:45-12:00	D-12	"1.05 μm Laser-Driven, Cryogenic Implosions of Thick-Walled Glass Microballoons," P. Rockett, J. Tarvin, C. Shepard, D. Slater, and E. Storm (KMSF).
12:00-12:15	D-13	"Effects of Laser Pulse Rise Time and Irradiation Symmetry on Microballoon Implosion in Exploding Pusher Regime," C. Bayer, D. Billon, J. L. Bocher, P. Combis, G. Coulaud, M. Decroisette, P. Genta, P. A. Holstein, D. Juraszek, D. Lambert, J. Launspach, and R. Vezin (Limeil).

TUESDAY AFTERNOON FREE

WEDNESDAY, MAY 12

Session E: HOT ELECTRON GENERATION AND THERMAL TRANSPORT

8:45-12:15		Chairman: W. Kruer (Livermore)
8:45-9:00	E-1	"Relativistically Enhanced Resonant Absorption," D. W. Forslund (Los Alamos).
9:00-9:15	E-2	"A Consistent 1-D Model for Resonantly Heated Electron Distributions," S. J. Gitomer and B. Bezzerides (Los Alamos).
9:15-9:30	E-3	"Generalized Weibel Instability in a Laser Produced Plasma," V. K. Tripathi and P. O. Hinger (U. of Md.).
9:30-9:45	E-4	"Comparison of Microwave - Plasma Interaction Experiments and Computer Simulations," H. Huey, A. Y. Lee, N. C. Luhmann, Jr. (USLA), Y. Nishida (Utsunomiya Univ.), S. P. Obenschain (NRL), and C. Randall (Livermore).
9:45-10:00	E-5	"Positron Production by Hot Electrons," A. G. Petschek and G. T. Schappert (Los Alamos).
10:00-10:15	E-6	"Fokker-Planck Simulation of Electron Heat Transport with Temperature and Density Gradients," J. P. Matte (INRS), J. Virmont (E. Polytechnique), T. W. Johnston (INRS), J. Delettrez and R. L. McCrory (LLE).
10:15-10:30	E-7	"Classical Heat Transport by Non Maxwell-Boltzmann Electron Distribution," J. R. Albritton (Livermore).
10:30-10:45		COFFEE BREAK
10:45-11:00	E-8	"Heat Flux Limitation for an Anisotropic Velocity Distribution," I. P. Shkarofsky (MPB Technology).
11:00-11:15	E-9	"Flux Inhibition and Underdense Absorption by Return Current Driven Ion Turbulence - Status of the Theory and Experiments," W. M. Manheimer and D. G. Colombant (NRL).
11:15-11:30	E-10	"Energy Transport and Partitioning in Nanosecond 1 μm Spherical Target Irradiation Experiments," J. Delettrez, B. Yaakobi, M. C. Richardson, T. Boehly, R. S. Marjoribanks, S. Letzring, R. Hutchinson, R. L. McCrory, J. M. Soures (Rochester), and G. D. Enright (NRC). (Rochester).
11:30-11:45	E-11	"Transport in Nanosecond 1.06 μm Pulse Irradiation," B. Yaakobi (Rochester).

11:45-12:00 E-12 "Analysis of Layered Disk Transport Experiments at 1.06- and 0.35 μm," W. C. Mead, E. M. Campbell, W. L. Kruer, and R. E. Turner (Livermore).

12:00-12:15 E-13 "Theory and Simulation Studies on Two Dimensional Hot Electron Transport and Non-Uniform Illumination Effects," K. Mima, T. Yabe, H. Takabe, K. Nishihara, and S. Ido (Univ. of Osaka).

12:15-14:00 LUNCH

Session F: HOT ELECTRON TRANSPORT

14:00-16:00 Chairman A. B.Langdon (Livermore).

14:00-14:15 F-1 "Hot Electron Transport Thru Thin Foils," R. J. Mason (Los Alamos).

14:15-14:30 F-2 "Two Dimensional Hot Electron Behavior," P. Mora (CEA) and R. Fabbro (E. Polytechnique).

14:30-14:45 F-3 "Hot Electron Diffusion and Related Ablation Behavior of a 10.6 μm Laser Irradiated Target," H. Nishimura, H. Daido, K. Mima, M. Yagi, F. Matsuoka, K. Yamada, R. Tateyama, K. Ogura, H. Azechi, K. Imasaki, H. Takabe, S. Nakai, and C. Yamanaka (Osaka Univ.)

14:45-15:00 F-4 "Hot Electron Distribution Function in High Z Materials," E. L. Lindman (Los Alamos).

15:00-15:15 F-5 "Hot Electron Studies in CO_2 Laser Produced Plasmas," G. A. Kyrala (Los Alamos).

15:15-15:30 F-6 "Hot Electron Transport in CO_2 Laser Plasma," J. C. Kieffer, M. Piché, P. Lavigne, J. P. Matte, H. Pépin (INRS), and R. Décoste (IREQ).

15:30-15:45 F-7 "Magnetic Field Induced Surface Transport on Laser Irradiated Foils," J. U. Brackbill and D. W. Forslund (Los Alamos).

15:45-16:00 COFFEE BREAK

Session GP: SBS, HARMONIC EMISSION, TWO-PLASMON INSTABILITY

16:00-17:30 Poster Session

GP-1 "Fundamental and Second Harmonic Backscatter Measurements from CO_2 Laser Plasma Interactions," D. E. Casperson (Los Alamos).

GP-2 "Spatial Dependence of Backscattered and Sidescattered Spectra from CO_2 Laser Plasmas," F. Martin, J. Sabbagh, H. Pépin, and P. Lavigne (INRS).

GP-3 "Stimulated Brillouin Scattering of Multi-Line Laser Light in a Flowing Plasma Corona," E. A. Williams and R. W. Short (Rochester).

GP-4 "Stimulated Brillouin Backscatter in Long Scale Length Laser Produced Plasmas," D. G. Colombant, J. Gardner, and W. M. Manheimer (NRL).

GP-5 "Stimulated Brillouin Scattering Driven by a Standing Electromagnetic Wave," R. A. James, K. Mizuno, J. S. DeGroot (Davis), and C. J. Randall (Livermore).

GP-6 "Thomson Scattering from SBS Induced Ion Fluctuations," R. Giles and A. A. Offenberger (Univ. of Alberta).

GP-7 "Intrisically Non-Steady Stimulated Brillouin Scatter Induced by Plasma Critical Surface," C. J. Randall and J. R. Albritton (Livermore).

GP-8 "First-Order Refractive Effects of Density Fluctuations on Light Rays in a Plasma," R. Epstein and R. S. Craxton (Rochester).

GP-9 "High Harmonic Generation of Intense Laser Radiation," C. Grebogi, V. K. Tripathi, and H. H. Chen," (Univ. of MD).

GP-10 "Harmonic Emission from Uniformly Illuminated Spherical Targets," J. E. Rizzo, S. Letzring, and M. C. E. Richardson (Rochester).

GP-11 "Measurements of the Two-Plasmon Parametric Decay Instability," K. Mizuno (Davis), D. Rasmussen (Oakridge), J. S. DeGroot, and E. W. Y. Ng (Davis).

GP-12 "Two-Plasmon Decay Instability Driven by Traveling and Standing Waves," W. Woo, P. Rambo, and J. S. DeGroot (Davis).

GP-13 "Non-resonant Two-Plasmon Decay in Hot Plasmas," L. V. Powers and R. L. Berger (KMSF).

GP-14 "Experimental Observations of 2 Linear Growth of the Two Plasmon Decay Instability," H. A. Baldis and C. J. Walsh (NRC).

GP-15 "Experimental Observations of Parametric Instabilities at $N_e < N_c/4$ Using Thin Foil Targets," E. M. Campbell, D. W. Phillion, and K. G. Estabrook (Livermore).

GP-16 "Improved Threshold Criteria for the Inhomogeneous $2\omega_p$ Instability," A. Simon, E. Williams, T. Dewandre, and R. L. McCrory (Rochester).

GP-17 "Stimulated Raman Scattering in the Presence of Stimulated Brillouin Scattering," F. F. Chen and H. C. Barr (UCLA).

Session HD: DISCUSSION-ELECTRON TRANSPORT

17:30-18:15 Discussion Leader: F. J. Mayer (KMSF)

THURSDAY, MAY 13

Session I: FAST IONS, HOT ELECTRONS

8:45-10:45 Chairman: A. A. Offenberger (Univ. of Alberta).

8:45-9:00 I-1 "Measurement of Absorption and Fast Ion Loss in High Energy Experiments at Helios," J. F. Kephart, S. Gitomer, D. Bach, and G. Kyrala (Los Alamos).

9:00-9:15 I-2 "Plasma Jet Formation in CO_2 Laser Plasma Interactions," A. Hauer and W. Ehler (Los Alamos).

9:15-9:30 I-3 "A Simple Model for Fast Ion Losses from Thin Shell Targets," M. Alme (MRC).

9:30-9:45 I-4 "Multi-Ion Hydrodynamics in a Hot-Electron Driven Corona," R. F. Stellingwerf (MRC).

9:45-10:00 I-5 "Comparison of Electron Transport Experiments at Laser Wavelengths of 1.06 μm and 0.35 μm," E. M. Campbell, W. C. Mead, R. E. Turner, F. Ze, G. Stradling, D. L. Matthews, G. Tirsell, B. Pruett, P. H. Lee, G. Hermes, and D. W. Phillion (Livermore).

10:00-10:15 I-6 "Mapping of Fast-Electrons Energy Deposition in Laser Target Interaction," F. Amiranoff and A. Poquerusse (E. Polytechnique).

10:15-10:30 I-7 "Theoretical/Experimental Status of our Knowledge of Ion Stopping Power in Partially Ionized Plasmas," T. A. Mehlhorn (Sandia).

10:30-10:45 I-8 "Beam and Deposition Stability in Light Ion Fusion Targets," J. A. Swegle (Sandia).

10:45-11:00 I-9 "An Intense Ion Diode Produced by a CO_2 Laser," C. Barnes, E. Lindman, D. Forslund, J. Brackbill, K. Lee, J. Kindel, M. Klein, T. H. Tan, J. Kephart, W. Ehler, D. Bach, G. Kyrala, D. Giovanielli, and H. Rutkowski (Los Alamos).

11:00-11:15 COFFEE (overlaps posters)

Session JP: SRS, SELF-FOCUSSING, HYDRODYNAMICS AND TRANSPORT

11:00-12:15 Poster Session

JP-1 "Raman Scatter in Large Underdense Plasmas," W. Kruer and K. Estabrook (Livermore).

JP-2 "Raman Back and Forward Scatter of CO_2 Light from a Gas Jet Target," J. Meyer (Univ. of British Columbia).

JP-3 "Stimulated Raman Scattering in the Presence of Ion Acoustic Fluctuations," W. Rozmus, R. Fedosejevs, and A. A. Offenberger (Univ. of Alberta).

JP-4 "Hot Electron Production and Raman Scattering Below Quarter Critical Density," R. D. Brooks (Univ. of Washington).

JP-5 "Time Resolved SRS Measurements from 0.53 μm Laser Plasma Experiments," R. E. Turner, D. W. Phillion, E. M. Campbell, and K. G. Estabrook (Livermore).

JP-6 "Influence of Inverse Bremsstrahlung on Wavelength Scaling for Reactor Size Spherical Targets," J. H. Gardner, M. J. Herbst, and M. H. Emery (NRL).

JP-7 "Transient Self-Focusing," A. J. Schmitt and R. S. B. Ong (Univ. of Michigan).

JP-8 "Acceleration of Targets by Steady Ablation and Impact," B. Ahlborn, J. Kwan and P. Ng. (Univ. of British Columbia).

JP-9 "Analytical Model for a Laser-Driven Implosion of Microballoons," X. Fortin, P. Aussage, D. Babonneau, M. Bordier, and G. DiBona (Limeil).

JP-10 "Tokamak Pellet Evaporation Experiment and the Classical Flux Limit Parameters," F. J. Mayer (KMSF).

JP-11 "Time Resolved X-ray Line Diagnostics of Laser-Produced Plasmas," R. L. Kauffman, D. L. Matthews (Livermore), J. D. Kilkenny, and R. W. Lee (Blackett Lab.)

JP-12 "Streaked Free-Bound Spectra From Coronal Plasmas for Studying Electron Distributions," D. L. Matthews, R. L. Kauffman (Livermore), J. D. Kilkenny, and R. W. Lee (Blackett Lab.)

JP-13 "Suprathermal X-Ray Spectra From Laser-Plasma Interaction," C. L. Wang and J. Harte (Livermore).

Session KD: DISCUSSION-WHAT HAS BEEN LEARNED, FUTURE PROSPECTS AND ARRANGEMENTS FOR NEXT MEETING

12:15-1:00 Discussion Leader: B. Ahlborn (Univ. of British Columbia).

SESSION A

STIMULATED SCATTER AND FILAMENTATION

MONDAY, MAY 10

8:30 - 12:30

W. MANHEIMER

NAVAL RESEARCH LAB.
WASHINGTON, DC

Abstract Submitted for the 12th Annual
Conference on Anomalous Absorption of Electromagnetic Waves

May 10-13, 1982
Sante Fe, New Mexico

GENERATION OF ENHANCED-SCALELENGTH PLASMAS, AND ZEEMAN STUDY OF MAGNETIC FIELDS[+]

J.A. Stamper, E.A. McLean, S.P. Obenschain, H.R. Griem,[*]
C.K. Manka[**], D.W. Droemer[**], and M.J. Herbst

Using non-uniform laser illumination on flat targets, with moderate laser energies (200J), we have produced enhanced density scalelengths; e.g. in excess of 0.5mm at 0.1 of critical density. These enhanced scalelengths are of interest in simulating large, high-gain pellets, especially their potential impact on a variety of convective plasma instabilities. Although we expect that the more gentle gradients would reduce the self-generated magnetic fields, we have, nonetheless, for the first time, used the Zeeman effect to observe these fields. These density and magnetic field studies use the NRL Pharos II laser (50 to 500J in 4 nsec at 1.054 μm), focused onto carbon or polystyrene foil targets. A large focal spot (~1mm) is obtained by placing the targets in the quasi-near field of the f/6 focusing lens.

The diagnostics include spectroscopy and short-pulse laser probing. Space- and time-resolved measurements, for both polarizations, were made of the 2271-2278 Å, C V triplet ($2s\,^3S_1 - 2p\,^3P_{2,1,0}$) emission. Interferometric (density) and Faraday rotation (magnetic field) measurements were made with laser probing at the second (5270 Å) and third (3513 Å) harmonic wavelengths. The spectroscopic density (Stark effect) and magnetic field (Zeeman effect) results are compared with those from laser probing.

Shearing interferometry with the third harmonic probe has shown that the axial density gradient scalelength can be significantly enhanced by blocking the central part of the laser beam to produce an annular focus. Apparently, the central part of the plasma is hydrodynamically confined by the peripheral plasma. The larger radial temperature gradients, due to the beam blockage, should enhance any magnetic field generation. Nevertheless, the Zeeman and Faraday rotation studies both show that the fields are smaller than for the earlier studies with short pulses and high irradiance.

[+]Work supported by the U.S. Department of Energy.

[*]Dept. of Physics, University of Maryland, College Park, MD.

[**]Dept. of Physics, Sam Houston State University, Huntsville, TX.

Abstract Submitted for the 12th Annual Conference
on Anomalous Absorption of Electromagnetic Waves
May 10-13, 1982
Sante Fe, New Mexico

Backscatter and Profile Measurements in Enhanced-Scalelength Plasmas

M.J. Herbst, E.A. McLean, J.A. Stamper, S.P. Obenschain,
P.G. Burkhalter, D. Duston, J. Grun[+], R.R. Whitlock and B.H. Ripin

U.S. Naval Research Laboratory, Washington, D.C. 20375

To better simulate laser coupling with the underdense plasma surrounding a fusion reactor pellet, experiments should have longer inhomogeneity scalelengths than have been produced in the past. With reactor pellet radii of a few millimeters and driver pulse lengths in excess of 10 nsec, hydrodynamics codes predict density gradient scalelengths in excess of 1mm in the underdense plasma.[1] Density scalelengths of 100 μm were recently generated in experimental simulations of reactor pellets at KMS.[2] However, the effect of plasma flow, believed to be an important factor in Brillouin scattering,[3] was not simulated in those experiments. Plasmas with enhanced density gradient scalelengths and finite velocity gradients are currently being produced at NRL using our 4 nsec, 1.054 μm laser.[4] Measurements of backscatter from these enhanced-scalelength plasmas are underway and will be discussed.

If results of these experimental simulations are to be scaled to the reactor regime, detailed measurements of plasma profiles must be made. Therefore, we are developing new diagnostic techniques for measurement of density, temperature, and velocity profiles. Improved x-ray spectroscopic measurements in these plasmas are obtained using collisionally confined tracers in the blowoff plasma;[5] the current status of efforts to extract density and temperature profiles from these measurements will be reported. We infer time-averaged velocity profiles through the use of hydrodynamic flow visualizations;[6] newer tracer techniques which should allow time-resolved measurement of the velocity profile will be described. These improved profile measurements will allow better comparison with the hydrodynamics and plasma codes that are used to scale results to reactor scalelengths.

*Work supported by U.S. Dept. of Energy and Office of Naval Research

+Mission Research Corp., Alexandria, VA.

1. J. Gardner, private communication.
2. J.A. Tarvin, et al., Phys. Rev. Lett. 48, 256 (1982).
3. W.M. Manheimer and D.G. Colombant, Phys. Fluids 24, 2319 (1981).
4. J.A. Stamper, et al., paper presented at this meeting.
5. M.J. Herbst, et al., NRL Memo Report 4812 (1982, to be published).
6. M.J. Herbst and J. Grun, Phys. Fluids 24, 1917 (1981).

OBSERVATIONS OF NON LINEAR ION WAVES AND SATURATION OF SBS

C.J. Walsh and H.A. Baldis

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K1A 0R6

The growth of ion waves at a wavenumber of $2k_{pump}$ in a CO_2 laser-plasma interaction has been studied using Thomson scattering. The observations were resolved in time and in k space. The former was accomplished by using a streak camera as discussed previously.[1] The k resolution was achieved by imaging the distribution of scattered light across the collection lens inside the plasma onto the entrance slit of the streak camera. When the scattering angle θ is small, this allows a correspondence between $|k|$ and points across the slit of the streak camera to be made. A range of k's from $\sim k_{pump}$ to $\sim 6k_{pump}$ was covered simultaneously with a time resolution $\sim$30 psec.

Our observations at a scattering probe wavelength λ_{probe} = 0.53 μm show that a well defined ion wave with $k_w \simeq 2k_{pump}$ is present when the CO_2 laser ($\lesssim$30 J, 1 nsec) interacts with a pre-formed plasma of peak density $\sim$(0.1-0.2) n_c (CO_2). At incident CO_2 energies $\gtrsim$ 5 J, harmonic generation occurs, evidenced by a second ion wave at $4k_{pump}$ being seen. At the highest CO_2 energies, a strong time modulation of the ion wave intensity is also observed, with periods ranging from $\sim$150 psec at 10 J incident to $\sim$50 psec at 30 J incident. Finally, from scattering observations at 0.53 μm and 10.6 μm (where a saturated reflectivity $\sim$6-10% was observed), we conclude that the active SBS region is $\sim$30 μm in length, with an average density fluctuation $\sim$(10-20)%. The size of this active region is much less than the plasma density scale length ($\gtrsim$ 300 μm).

1. H.A. Baldis, C.J. Walsh and R. Benesch, Appl. Opt. 21 297 (1982).

THE EFFECT OF SELF-GENERATED MAGNETIC FIELDS ON STIMULATED RAMAN SCATTERING

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ABSTRACT

The existence of magnetic fields can lead to frequency splitting of Raman scattered light from the quarter critical density surface ($n_c/4$) of laser produced plasmas.

The basic process is examined in a simple geometry. Laser light (extraordinary wave) propagates normal to a weak magnetic field ($\omega_{ce} << \omega_{pe}$). Near $n_c/4$ the Raman instability (SRS) is absolute with the scattered light close to its reflection point. For exact backscatter the decay is into an extraordinary wave and upper hybrid wave yielding a blue shift of $\omega_{ce}/4$ additional to a characteristic red shift of $9V_e^2/8$ expected from SRS. For exact sidescatter (observed along the target normal since refraction is strong) the decay is into an upper hybrid wave and either a right or left circularly polarized electromagnetic wave, one being blue shifted the other red shifted by $\omega_{ce}/4$ relative to the unmagnetized case. Thus a frequency splitting is anticipated with peak separation of $\omega_{ce}/2$ [$\Delta\lambda$ = 213 (B_o/1 MG) Å for λ_o = 1.06 μ]. The magnetic field also suppresses the Landau damping of the plasma wave which is propagating almost perpendicular to it.

EXPERIMENTAL STUDY OF RAMAN SCATTERING FROM LONG SCALE-LENGTH UNDERDENSE PLASMAS

R. Fedosejevs, A. A. Offenberger, W. Tighe, W. Rozmus

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Edmonton, Alberta, T6G 2G7, Canada

We report on experimental studies of Raman scattering (SRS) from long scale length magnetically confined plasma irradiated by a moderate intensity CO_2 laser beam. A long pulse (2μsec) E-beam excited CO_2 laser produced groups of 5 nsec laser pulses (due to stimulated Brillouin backscatter feedback into the laser resonator[1]) which were focussed by means of a 1.5m, f/15 mirror into a magnetically confined (63 kG) hydrogen plasma of density $1.5 - 4.5 \times 10^{17}$ cm^{-3} and temperature of 45 eV. Spectral and temporal measurements of the backscattered radiation collected by the input focusing optics clearly demonstrated the features expected for Raman instability. Above a threshold intensity of 4×10^{10} W/cm^2 the reflectivity showed a quick rise to a saturated value of 0.7% which varied little over the intensity range of $0.8 - 2.5 \times 10^{11}$ W/cm^2.

The experimental results are analyzed using an absolute SRS growth model. The onset of this instability is affected by a number of factors including the finite interaction length, background density fluctuations due to strong SBS and reduction of collisional damp due to transient heating of the electrons. When the damping due to SRS production of hot electrons[2] is taken into account good agreement is found between experiment and theory.

[1] R. Fedosejevs, W. Tighe, D.C.D. McKen and A.A. Offenberger, Opt. Comm. 40, 35 (1981)

[2] K. Estabrook, W.L. Kruer and B.F. Lasinski, Phys. Rev. Lett. 45, 1399 (1980)

"VLASOV SIMULATION OF STIMULATED RAMAN SCATTERING"

Eric Hiob and A.J. Barnard

ABSTRACT

Stimulated Raman Scattering is studied in a number of one-dimensional simulations by integrating the Vlasov equation in configuration space.

We observe that for sufficiently large pump fields, trapping of electrons in plasma waves can accelerate a large fraction of the electron population to approximately twice the wave phase velocity. This results in the non-linear saturation of the plasma waves and hence the saturation of SRS, and in the generation of a stream of very energetic electrons, especially for forward SRS.

The Raman Instability Can be Absolute Below Quarter Critical*

by

P. Koch+ and E. A. Williams
Laboratory for Laser Energetics
University of Rochester
Rochester, New York

The absolute or convective nature of an instability in the presence of an inhomogeneous medium or driver is in largest part determined by the physically dictated boundary conditions. In stimulated Raman scattering the same electrostatic wave may be involved both in forward and backward scatter, so that when this wave is insufficiently damped both interactions must be included together in any global viewpoint.

We find that in the case of an infinite plane-wave pump incident on a monotonic density profile the two interactions are involved in a feedback loop. Growth is absolute (above the usual "convective threshold") for a quantized but closely spaced set of scattered frequencies. This contradicts the result obtained by applying the boundary conditions at infinity separately to forward and backward scatter.[1]

When the pump wave has a finite spot size outgoing-wave boundary conditions must be applied at the edges of the illuminated region. This has several notable effects, one of them being convective growth of side-scattered waves in the transverse direction, rather than the absolute growth in time found in the plane-wave case.

1. C.S. Liu, M.N. Rosenbluth and R.B. White, Phys. Fluids 17, 1211 (1974).

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124.

+KMS Fusion, Inc.

Abstract for the 12 Annual Anomalous Absorption Conference
May 10-13 1982, Santa Fe, New Mexico

Absolute and Convective Coupled Mode Instabilities with Amplitude and Phase Coupling Nonuniformities

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V. FUCHS, M. SHOUCRI
Institut de Recherche d'Hydro-Québec
Varennes, Québec, Canada

In order to arrive at general criteria for absolute instability we have looked at a number of models. Some of the models are:

coupling phase: - $\frac{1}{2}k'x^2$ (also smoothly joined with different k' or with hyperbolic transitions) and $\frac{1}{2}k'x^2(1+\varepsilon x^2)$

coupling amplitude: - slab, Gaussian, Lorentzian, sinusoidal modulation on uniform coupling, and some combinations of these with first order smooth joints.

The models have been looked at via direct numerical integration and the analytic models have also been studied using the interactive WKB routine developed by R. White. The WKB growth rates agree well with the numerical results.

The criteria obtained will also be the discussed.

Frequency Broadening Arising from Filamentation in a Laser Plasma Corona*

by

R. W. Short and E. A. Williams
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University of Rochester
Rochester, New York

Experimental observations show that specularly reflected light is sometimes spectrally broadened by an amount several times the expected Doppler shift due to Brillouin scattering or critical surface motion.[1] We investigate the possibility that this broadening may be due to the filamentation instability. Light trapped in a filament may be regarded as propagating in a waveguide. If the radius of the filament changes in time, the axial wavenumber of the waveguide mode will change, resulting in a changing optical path length for the guide and thus a frequency shift for the light. The changes in filament radius may be caused by the formation, temporal oscillation, and possible instability, breakup, and reformation of the filaments. We estimate the likely extent of the resultant spectral broadening and compare with experimental results.

*This work was supported by the U.S. Department of Inertial Fusion Project under contract number DE-AC08-80DP40124.

1. K. Tanaka, L. M. Goldman, W. Seka, R. Bingham, R. Short, and E. A. Williams, Bull. Am. Phys. Soc. 26, 954 (1981).

WAVELENGTH DEPENDENCE OF LIGHT FILAMENTATION IN LASER PLASMAS

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ABSTRACT

The temporal development of a self focused light filament is followed in a fully ionised plasma by solving numerically the wave equation in the paraxial approximation. Transient effects in the laser beam and plasma are studied by taking into account, in self-consistent manner, the proper motion of the plasma in an intense em wave. This coupling provides transverse and time dependent phase variations across the beam profile which are intensity dependent. The spatial and temporal development of filamentary light, at the three wavelengths 1054 nm, 527 nm and 351 nm is compared and contrasted. In addition, the results obtained at 1054 nm are compared with previous steady-state solutions.

Radiation Cooling Driven Instability of Ablative Flows

by

L. Montierth, R. Morse, G. Sowers and H. Takabe*
University of Arizona

Spherically symmetric ablative flows which are otherwise stable are shown to be made unstable by radiative cooling near the ablation front. A spherical harmonic perturbation analysis based on zero order steady flow solutions has shown maximum growth rates for $\ell > 10$ when an appreciable fraction of the thermal energy conducted inward through the sonic point is emitted as radiation. Maximum growth rates are of the order of $10\ \tau_H^{-1}$ where the hydrodynamic transit time is $\tau_H \equiv (r_s - r_p)/v_s$, r_s and r_p are the sonic and pellet ablation front radii respectively, and v_s is the sonic point velocity.

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LASER PLASMA INTERACTION PHENOMENA AT ULTRA HIGH INTENSITIES

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The ANU neodymium glass laser currently operates at intensities up to 3 x 10^{18} Wcm^{-2}.

One of the main aims of the experimental program has been to characterise the plasma itself in the intensity range 10^{14}-10^{18} Wcm^{-2} By using very small targets (8 μm diameter carbon fibres, irradiated end-on) and fourth harmonic holographic interferometry, supercritical densities are clearly resolved even at the highest intensities. At least three distinct temperatures are evident, with superhot values exceeding 100 keV. These are determined with the aid of a four channel high energy X-ray spectrometer (90-250 keV) supplementing a seven channel p-i-n diode array. Similar temperature features have been observed with the Faraday Cup ion energy spectrometer array.

Harmonic emission, particularly $\omega_L/2$ attributed to Stimulated Raman Scattering, has also been studied as a function of intensity.

Both s- and p-polarised radiation have been used and the differences in behaviour for each of the above will be mentioned.

Where possible, the results will be compared in detail with those from other laboratories.

Nonlinear Interaction Mechanisms in UV Laser Plasmas*

by
W. Seka, L.M. Goldman, M.C. Richardson, J.M. Soures, D.M. Villeneuve, B. Yaakobi, R.S. Craxton, J. Delettrez, R.L. McCrory, R. Short, E.A. Williams, T. Boehly, R.L. Keck, K. Tanaka, and R. Boni.
University of Rochester, Laboratory for Laser Energetics
Rochester, N.Y. 14623

We have investigated a number of nonlinear interaction processes in UV laser plasmas. This report will concentrate on recent SRS studies and indirect evidence for plasma filamentation.

Interaction experiments were carried out using a single beam, frequency tripled Nd:glass laser at UV (0.35 μm) energies up to 50 J on target and pulse widths ranging from 0.1 nsec to 1 nsec. Intensities on target ranged from 10^{13} W/cm^2 to 3×10^{15} W/cm^2.

Stimulated Raman scattering (SRS) has been observed to originate at electron densities between 0.01 and 0.25n_c (n_c = critical electron density for 0.35 μm radiation). In these experiments, spectrally and temporally resolved back- and side- scattered SRS data show that SRS does not generally operate over large regions of space and/or time simultaneously. The SRS process appears to scintillate suggesting that turbulence may create local density plateaus where the SRS threshold is exceeded during brief periods of time.

Evidence of filamentation has been obtained from analyses of the angular distribution of the light scattered from the plasma due to either Raman or $2\omega_p$ instabilities or both. In the absence of filamentation, for a 1-D plasma, the distribution is expected to peak towards the normal of the target (backscattering) at $\omega_o/2$. The convective Raman signals at higher frequencies are expected to exhibit side-scatter peaks near the refractive cut-off for the particular frequencies under investigation. These distributions are essentially independent of the angle of incidence of the laser. Such behavior has been observed for 0.5 nsec irradiation. For 1 nsec irradiation the distribution changes, exhibiting strongly increased backscatter through the focusing lens independent of the scattered light wavelength or the angle of incidence of the laser. The 0.5 nsec data indicated similar, though much weaker, scattering lobes towards the lens. Filamentation of the incident laser light in the underdense region at and below $n_c/4$ appears to explain the observations.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

"Angular Dependence of the Amplification of Brillouin Scattered Light for an Isothermal Rarefaction"

R. L. Berger

KMS Fusion, Inc., Ann Arbor, Michigan USA

ABSTRACT

The corona of a laser fusion plasma is well approximated by an isothermal rarefaction at the temperature determined either by inverse bremsstrahlung absorption or resonant absorption. We consider the Brillouin scattering of the laser wave in this flowing plasma including the effect of a finite laser spot diameter. For large spots and for a normally incident laser, maximum amplification occurs for scattering in the forward direction at nearly 90^{o} to the density gradient. Moreover forward scattering has larger amplification than backscatter.

SESSION B

HYDRODYNAMICS AND IMPLOSION SYMMETRY

MONDAY, MAY 10

14:00 – 16:30

D. J. NICHOLAS

RUTHERFORD AND APPLETON LAB.
OXFORDSHIRE, UNITED KINGDOM

Two-Dimensional Hydrodynamic Effects in Single Beam Laser-Plasma Interaction Experiments*

by

R. S. Craxton and R. L. McCrory
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University of Rochester
Rochester, New York

Calculations have been performed with the Eulerian hydrocode SAGE to examine two-dimensional hydrodynamic effects associated with single beam interaction experiments. In a variety of cases in which the laser spot size is small compared with plasma expansion distances, where the laser irradiates a pre-formed plasma, or where there is spatial structure across the laser focal distribution, a cratering of the critical surface may occur even in the absence of ponderomotive force and refraction. Preliminary ray-tracing calculations will be presented illustrating the additional role of refraction in these situations.

*This work was supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124.

Theoretical Interpretation of Multi-Dimensional Effects of OMEGA Uniformity Experiments

by

R. L. McCrory, C. P. Verdon, K. Lee, J. Delettrez,
M. C. Richardson, D. M. Villeneuve, and J. M. Soures
Laboratory for Laser Energetics
University of Rochester
Rochester, New York

In a series of recent experiments on the 24 beam 1.05 μm OMEGA facility, the uniformity of energy deposition on a spherical target by symmetrically focused beams is being examined in considerable detail. In present experiments where large targets ($\leq$ 700 μm diameter), energies up to 3kJ, and irradiances up to 4×10^{14} W/cm^2 range have been used, we are primarily concerned in determining the sensitivity of direct drive ablatively accelerated targets to specific variations in illumination uniformity and symmetry.

The dominant spherical harmonic mode number inferred from measurement and calculation[1] for energy balanced beams has been found to be $\ell \sim 8$ with an RMS amplitude $\sim$ 6%. We discuss two-dimensional simulations to demonstrate the hydrodynamic response of a target to this kind of irradiation variation using the two-dimensional ORCHID code. Secondly, x-ray microscope images from experiments show significant stalk effects, particularly in experiments where irradiation with a significant component of $\ell \sim 1$ is deliberately arranged. We will present a theoretical interpretation of stalk effects seen in OMEGA experiments.

1. S. Skupsky and K. Lee, "Uniformity of Illumination and Thermal Smoothing for Laser Driven Fusion", *this conference*.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Uniformity of Illumination and Thermal Smoothing for Laser Driven Fusion*

by

S. Skupsky and K. Lee
Laboratory for Laser Energetic
University of Rochester
Rochester, New York

The spatial variation of nonuniformities from multiple beam illumination of spherical targets is examined using a spherical harmonic decomposition of the 3-dimensional illumination pattern. Assuming perfect beam balance, $\ell = 8$ is found to be the dominant mode, with an RMS variation of ~6%, for the 24 beam OMEGA laser system. The magnitude of this mode is sensitive to focus and the radial-intensity-profile of individual beams. Lower order modes are produced predominately by energy imbalance between the beams and by target misalignment. The present beam imbalance for OMEGA introduces a ~ 2% RMS variation for the $\ell = 2$ mode. Since the lower order modes are the most difficult to smooth, the results suggest that beam balance and alignment are more important than ideal radial-beam-profiles for laser driven fusion.

Estimates are made to determine the amount of smoothing possible for each mode. When the heat-flow becomes flux-limited, the distance needed for smoothing is found to be much shorter than previously estimated, using classical transport. The $\ell = 8$ mode can be attenuated 10-fold at moderate laser intensities (~ 5×10^{14} W/cm^2) for short wavelength ($\lambda = 0.35 \mu m$) illumination.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Irradiation Uniformity of Spherical Targets on OMEGA*

by

D.M. Villeneuve, W. Friedman, J. Hoose, M.C. Richardson, S. Letzring,
R. Hutchison, K. Lee, S. Skupsky, R.L. McCrory, and J.M. Soures
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Present estimates of the degree of irradiation uniformity required for direct drive laser fusion targets indicate that non-uniformities greater than a few percent will degrade the spherical implosion. Up to the present time no experimental studies have been directed at determining the sensitivity of spherical targets to known degrees of illumination uniformity. In this paper we report initial studies of this issue, performed with the 24 beam 1.05μm OMEGA laser system with 1 nsec pulses of energy up to 2.8 kJ at intensities of 1 - 4 x 10^{14} Wcm^{-2} on large initial aspect ratio targets (R/ΔR $\lesssim$ 250) having diameters up to 670μm.

By careful analysis of the target plane intensity distribution of each beam, and with the use of a spherical superposition code, the on-target intensity distribution, and energy deposition may be deduced for various irradiation conditions. The variation in intensity across the target surface is also analyzed through spherical harmonic decomposition of the intensity distribution. For the present conditions, rms values of low order modes of ∿ 1% were estimated. The sensitivity of target performance, as determined through x-ray microscopy, neutron yield, and coronal plasma characteristics, for specific irradiation conditions were studied with DT filled targets of 400μm diameter and 1μm wall thickness. The effects of the variation of the focus of individual beams were examined and a comparison between 6, 12 and 24 beam irradiation geometries made. These are compared to the predictions of one and two dimensional hydrodynamic code calculations.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Linear and Nonlinear Aspects of Hydrodynamic Instabilities in Laser Ablation

by

Mark H. Emery, Jay P. Boris, Arnold L. Cooper and John H. Gardner
Naval Research Laboratory
Washington, D.C. 20375

We report on our investigation of the Rayleigh-Taylor (R-T) and Kelvin-Helmholtz (K-H) instabilities for single mode perturbations for a series of wavelengths in the parameter regime $1/2 < \lambda/\Delta R < 5$, where λ is the wavelength of the perturbation and ΔR is the cold foil thickness. We again find linear growth rates well below classical values (by a factor on the order of 3-4). We also find a cutoff in the growth rates for wavelengths less than the foil thickness. The striking result is the dominance of nonlinear effects; i.e., the K-H instability, for the short wavelength perturbations. Although the linear growth rates increase as $k^{1/2}$ up to the cutoff the K-H instability dominates at large k, drastically reducing the penetration rate of the dense spike below its free fall value and effectively doubling the aspect ratio of the foil. In other words, it is the long wavelength perturbations that are most effective in destroying the symmetric implosion of the shell. The vortex structure generated from the baroclinic nature of the flow will be presented and discussed.

SYMMETRY ASPECTS IN ABLATIVE ACCELERATION

W. M. Manheimer, D. G. Colombant and J. Gardner
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Washington, D.C. 20375

There are at least two possible causes for asymmetry in ablative acceleration of a laser produced plasma. First of all, the absorbed laser irradiance may be nonuniform and secondly, the acceleration itself may be unstable due to Rayleigh Taylor instability. One way to study those processes is via fluid simulation. However analytic theory can also shed light on these two processes.

For the case of nonuniform illumination, steady state solutions of the fluid equations in two dimensions relate the perturbed ablation pressure at the ablation surface to the perturbed ablation pressure at the critical surface. The perturbed ablation pressure at the critical surface is then related to the perturbed absorbed laser irradiance by making use of the Mach 1 condition at the perturbed critical surface. Calculations show that the decay of ablation pressure in the fluid is governed by a complex interaction between sound waves and thermal waves. The cloudy day effect, namely that a transverse perturbation with wave number k decays away from the critical surface as exp-kx, proves to be a fairly poor approximation. Calculations of perturbed pressure at the ablation surface will be presented and compared with the NRL experiment.

The formulation of the Rayleigh Taylor problem turns out to depend sensitively on the laser wavelength. For short wavelength laser light, the critical and ablation surfaces are near each other so perturbed quantities are carried away by a nearly uniform supersonic flow. For a longer wavelength laser, the critical and ablation surfaces are far apart and the outward flow is subsonic and gradients are very large. We have modeled each case with a contact discontinuity in density, temperature and normal flow velocity at the ablation surface. For the case of subsonic flow, the ablative flow turns out to be destabilizing. Thus any stabilization results principally from gradients near the ablation surface. For supersonic flow, the ablative flow is stabilizing at short wavelength, and the dispersion relation turns out to be

$$\gamma^2 = kg - \left(\frac{\rho A}{\rho s}\right) k^2 c_s^2 M^2 \frac{(M^2 - 1)^{3/2}}{5 + 3M^2}$$

where M is the isothermal Mach number, c_s is the isothermal sound speed, $\rho A(s)$ is the density of the light (heavy) fluid. The stabilizing effects of compressibility in the heavy fluid and thermal conduction in the light fluid are also calculated.

Numerical Simulations of Rayleigh Taylor Instabilities

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Abstract

The development of the Rayleigh Taylor instability at the ablation front is followed using a 2D Eulerian code - POLLUX. The instability is initiated by modulating the target surface or the incident laser intensity so that a comparison of the severity of these effects can be made.

Some simulations show features that might be explained as a Kelvin Helmholtz instability but a closer analysis shows that these are due to the presence of spatial harmonics of the R-T eigen-function in the initial perturbation. The short wavelength vorticity is advected with the fluid flow into the "spikes" and broadens the tips forming "mushroom" like features.

Abstract Submitted to the 12th Annual Conference on the Anomalous Absorption of Electromagnetic Waves

May 10-13, 1982

Sante Fe, New Mexico

EXPERIMENTS ON THE RAYLEIGH-TAYLOR INSTABILITY OF ABLATIVELY ACCELERATED TARGETS*

by

J. Grun[+], M.J. Herbst, E. McLean, S.P. Obenschain, B.H. Ripin, J. Stamper, R.R. Whitlock, F. Young

Hydrodynamic instabilities may severely limit the gain achievable with moderate-aspect-ratio fusion pellets. To date, however, only a few experimental studies of such instabilities have been performed.[1,2]

We are studying the characteristics of planar targets with periodically varying mass/area perturbations[1] which have been accelerated to $\sim 1 \times 10^7$ cm/sec by 1.05 μm, 5 nsec FWHM laser pulses. To permit a parametric study, the target acceleration, and the magnitude and periodicity of the mass/area perturbations are varied. We are looking for signs of hydrodynamic instabilities, such as the Rayleigh-Taylor, in the hot, laser-side and the cooler, rear-side of the target by: (1) using plasma tracers[3] to measure the plasma flow resulting from possible bubble-spike formation, and (2) measuring target nonuniformity or disassembly with double foil[4] and x-ray backlighting techniques. Latest results will be presented.

---

*Work supported by the U.S. Department of Energy and the Office of Naval Research.

[+]Mission Research Corporation, Alexandria, VA.

1. B.H. Ripin, et al., Bull. Am. Phys. Soc. 25, 946 (1980).

2. J. Grun, et al., Bull. Am. Phys. Soc. 26, 1023 (1981); A. Raven, et al., Phys. Rev. Lett. 47, 1049 (1981).

3. M.J. Herbst and J. Grun, Phys. Fluids 24, 1917 (1981).

4. S.P. Obenschain, et al., Phys. Rev. Lett. 46, 1402 (1981);48 709(E) (1982);
J. Grun et al., NRL Memo 4747, March 1982 (submitted to the Phys. of Fluids).

Inside Surface Taylor Instability

by

L. Montierth, R. Morse, E. Parlette and C. Verdon*
University of Arizona

Studies of the non-linear development of Raleigh-Taylor instability on the inside surface of an imploding shell have been done with a two-dimensional, cylindrically symmetric, triangular zoned hydrodynamics code using a self-similar zero-order spherically symmetric implosion solution and an incompressible, m = o, spherical harmonic perturbation. The purpose of this study was to identify modes of failure caused by Taylor instability during the final declaration phase as the relatively dense shell compresses the fuel core. In this idealized study the fuel core is taken to have zero density. Two measures of the potential for failure are calculated, as a function of time, PdV work done on the fuel volumes, and the surface area of the pusher, fuel interface. The latter is thought to be important as a measure of the potential for loss of heat from the fuel to the pusher. Qualitative differences in non-linear development are found between cases in which the sign of the perturbation is such as to increase or to decrease the radius of the interface on the cylindrical axis. Behavior of the failure criterial, including these qualitative differences, will be discussed.

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SESSION CD

DISCUSSION:

ABLATION, UNIFORMITY, SYMMETRY

MONDAY, MAY 10

16:30 – 17:30

DISCUSSION LEADER:

R. L. MCCRORY

UNIVERSITY OF ROCHESTER
ROCHESTER, NY

SESSION D

EXPERIMENTAL MODELING, DIAGNOSTICS AND CRYOGENICS

TUESDAY, MAY 11

8:45 – 12:15

T. W. JOHNSTON

INRS-ENERGIE
VARENNE, QUEBEC, CANADA

UNIFORM LASER ABLATIVE ACCELERATION OF TARGETS AT 10^{14} W/cm^{2}*

S.P. Obenschain, R.R. Whitlock, E.A. McLean and B.H. Ripin

Naval Research Laboratory, Washington, D.C.

R.H. Price, D.W. Phillion, E.M. Campbell and M.D. Rosen

Lawrence Livermore National Laboratory, Livermore, CA

We present results from a joint NRL-LLNL experiment which employed a beam cluster of the Shiva Nd-glass laser to ablatively accelerate thin foil targets. The high energies available (3-4 kJ) allowed us to simultaneously use relatively high irradiance (10^{14} W/cm^{2}), large focal diameters (1mm) and long laser pulse durations (3 nsec). The long scalelength blow-off plasma genera e under these conditions allows smoothing of laser nonuniformities due to lateral energy flow. However, the long scalelengths also may be conducive to deleterious plasma instabilities. In this and the following papers concerning this experimental series we discuss the observed laser-plasma interaction, target preheat, ablation pressures, and symmetrization.

The results in general appeared favorable for direct illumination pellet fusion. During this study, targets were ablatively accelerated to high velocities with velocity profile uniformity approaching that required for high gain pellet implosions. There was more hot-electron production (3% of laser energy deposited in a 10 KeV electron distribution) and scattering of the incident laser radiation than was observed in earlier experiments at NRL with a similar focal diameter and laser pulse duration but with irradiances near 10^{13} W/cm^{2}. However, these deleterious effects do not have sufficient amplitude to pose a serious problem for the fusion application, at least through the irradiance level and plasma scalelengths encountered in this experiment.

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

NRL-LLNL Double Foil Experiments: Optical Streak Camera Measurements of the Preheat, Impact Time, Shock Strength, and Uniformity of the Acceleration*

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Abstract

The preheat and shock breakouts were observed with an absolutely calibrated optical streak camera looking at the imaged blue light from the target rear surface. The rear surface preheat at $\rho \cong 1/30$ gm/cm^3 was measured for both the target and impact foils. The preheat was localized to about the spot diameter of one millimeter. Although the edge of the foil was heated, there was little heating at the center of the foil from run-around by the energetic electrons produced at the front (laser-irradiated) surface. For single foils, there was substantial heating from a sharp shock which broke out very early in the laser pulse. We will present measurements on the uniformity of the acceleration, the shock strengths and breakout times, and lateral transport. The absorption was $65 \pm 15\%$ for all the experiments. The energy in Raman light between 1.5 μm and 2.5 μm was determined to be less than 1 J/sr, but the $2\omega_{pe}$ instability did occur at a high level, since 0.03% of the incident light energy appeared as $3\omega_0/2$ light. The analysis of these results is presented in the next paper by M.D. Rosen, et al.

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract #W-7405-ENG-48.
**Naval Research Laboratory, Washington, D.C.

12th Annual Anomalous Absorption Conference
May 10-13, 1982, Santa Fe, NM

X-RAY BACKLIGHTING OF ABLATIVELY ACCELERATED TARGETS AT IRRADIANCES UP TO 10^{14} W/cm^2*

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Planar foil targets were illuminated by one cluster (10 beams) of LLNL's Shiva Nd:glass laser, yielding 3-4 kJ of 1.06 micron light in a 3 nsec pulse. Irradiances up to 10^{14} W/cm^2 were achieved with large spots (1 mm diameter) to reduce (but not eliminate) the influence of edge effects. The illuminated foil targets were imaged by an x-ray microscope[1] onto an x-ray streak camera to achieve a spatial resolution of 7 microns (at the target) and a temporal resolution 20 ps. The other cluster (8 beams) of Shiva produced an x-ray pulse of 3 keV Pd lines to backlight the accelerated foil target. Streaked x-ray shadow images of the high density regions of ablatively accelerated single foil targets show velocities of 10^7 cm/s. Double foil collisions were also investigated. At the time of the collision, a large increase in the temperature of the second foil was observed, evidently the result of a high pressure shock. An ablation pressure of 6 Mbar, deduced from the trajectory of single foil targets, will be compared with calculations of varying complexity, including LASNEX runs. Results will also be compared with previous findings at lower irradiances using NRL's Pharos II Laser.[2-4]

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* Work is support by the U.S. Department of Energy.

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ANALYSIS OF THE JOINT NRL-LLNL ABLATION AND SYMMETRIZATION EXPERIMENT ON SHIVA*

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(LLNL)

and

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ABSTRACT

We present a barrage of simple analytic models and complex 1-D and 2-D LASNEX simulations to aid in the analysis of the joint NRL-LLNL experiment, in which symmetrization and ablative acceleration properties of carbon foils (irradiated at 10^{14} w/cm^2 on SHIVA) were measured. Preheat measurements on single foils are explained in terms of an ablation driven shock followed by hot electron heating. Preheat and shock breakouts measured on the backs of double foils are similarly attributed to hot electron heating, and shocks due to the impact of the two foils. The shock breakout times are shown to be sensitive to the preheat levels.

The first foil's hydro motion is measured with streaked X-ray (3 keV) shadowgraphy. We present detailed 2-D LASNEX simulations, post-processed to mimic the X-ray backlighting, that match the experiments. Various 2-D effects will be discussed and the code's scaling predictions for pressure versus laser intensity will be presented. A critical parameter for symmetrization is the distance from critical to the ablation surface. LASNEX values (1-D planar, 1-D spherical, 2-D) for that parameter will be presented and compared with steady state analytical model predictions and LASNEX scaling of that quantity with laser intensity.

As there is evidence for stimulated scattering and some reduced absorption in the experiment, its origins and implications will be discussed. The nature and origin of the hot electrons will also be speculated upon, as they seem too hot (≃10 keV) to be attributed to resonance absorption.

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

BEAM STRUCTURE EFFECTS ON CO_2 LASER LIGHT SPHERICAL SHELL INTERACTION

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E. J. Linnebur, and E. L. Lindman
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Los Alamos, NM 87454

The basic experimental set up is that of a CO_2 laser light beam directly impinging on a high Z spherical shell. The laser light is assumed focused at the center of this spherical shell but we have considered different thicknesses and diameters for the same.

The simulations are two dimensions and takes into account the effects of laser light beam structure, laser plasma instabilities, and self-generated magnetic fields.

A brief description of the theoretic framework will be presented in addition to comparison of the simulation results with the experimental data.

Uniform Compression of Large Aspect Ratio Targets Driven by Nanosecond, 24 Beam Laser Pulses from OMEGA*

by

M.C. Richardson, S. Letzring, D.M. Villeneuve, B. Yaakobi,
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We report initial investigations of the uniform implosion of spherical shell targets have $R/\Delta R \overset{\sim}{<} 250$, at intensities of $1 - 4 \times 10^{14}$ Wcm^{-2}. Glass microballoon targets of diameters up to 670μm, filled with D_2, DT or DT/Ar mixtures, some having various high Z or low Z layers were irradiated with energies up to 2.8 kJ in ∿ 1nsec. A large array of diagnostics were used including scattered reaction product analysis, multichannel x-ray microscopy and time resolved x-ray spectroscopy. With overall absorption in the range 35-55%, the implosions were best modeled in 1 D by assuming predominant inverse bremsstrahlung absorption and inhibited thermal transport. Analysis of scattered deuterons and tritons produced a direct measurement of core ρR, giving a value of > 10^{-3} gm cm^{-2}, corroborated by density estimates made from Ar line emission. The temporal features of the core stagnation have been investigated with time resolved x-ray spectroscopy, and compared with our dimensional code predictions.

This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Coronal Electron Temperature Measurements in UV Laser Plasmas*

by

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University of Rochester, Laboratory for Laser Energetics
Rochester, N.Y. 14623

In this paper, we present electron temperature measurements obtained from three different diagnostics, i.e. x-ray continuum radiation between 4 keV and 200 keV, electron spectra between 10 and 400 keV, and SRS spectra between ω_o and $\omega_o/2$ (350 and 700 nm). The measurements are characteristic of various regions in the plasma and range from 0.6 to 40 keV. The experiments were carried out using 0.5 and 1 nsec pulses with energies $\leq$50J on flat CH targets and at a wavelength of 351 nm. Intensities have been varied between 10^{13} and $2\text{x}10^{15}$ W/cm^2.

Electron temperatures in laser plasmas may be measured in a variety of ways, each method yielding temperatures characteristic of a different region inside the plasma. Electron temperatures obtained from x-ray continua have been interpreted using a two-temperature electron distribution. The cold temperature (0.6 to 0.8 keV) corresponds to the temperature at or above n_c (n_c=critical density for 351 nm radiation). The hot electron temperature (20 to 40 keV) is characteristic of part of the electron distribution in the corona. It is thought to be generated by nonlinear interaction processes between the laser light and the plasma, although the present experiments have not allowed a clear attribution to a single source. Temperature measurements obtained from electron spectroscopy, on the other hand, give information of the distribution of the energetic electrons which escape the target potential. Thus electron spectroscopy supports T_h measurements made using hard x-ray continua and has yielded temperatures around 50 keV.

Nonlinear interaction processes such as SRS can also be effectively used to determine the electron temperature in the corona. At threshold, the peak of the spectral distribution of the scattered light due to the convective Raman instability is initimately related to the background electron temperature in the interaction region. Comparing model calculations with observed SRS spectra at threshold has allowed us to ascribe a background electron temperature of about 1.5 keV at $n_e \simeq 0.1 n_c$.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

OPTICAL STUDIES OF DENSITY AND MAGNETIC FIELDS IN LASER-PRODUCED PLASMAS

by

J. Stamper

Naval Research Laboratory
Washington, DC

"Cryogenic Target Design and Simulation"

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ABSTRACT

KMSF is actively investigating the dynamics of cryogenic shell implosions. The goal is to develop an understanding of their implosion efficiency, stability and preheat. Numerical simulations of recent experiments show a sensitivity of performance on laser wavelength and pulse shape as well as target parameters. We present models for the absorption and thermal/superthermal transport which give agreement with experiment. Examination of the computer studies shows the shell dynamics vary from the familiar exploding pusher, to the exploding ablator, to the nearly ablative implosion. Estimates of the precision required in pulse tailoring are presented along with some considerations about diagnostic requirements, uncertainties and measurability.

"Physics of the Cryogenic Layer"

W. B. Fechner, R. R. Johnson, J. T. Larsen

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ABSTRACT

Recent laser fusion experiments and numerical simulations suggest an increase in fuel compression results from glass microballoon targets which have a cryogenic fuel layer rather than a gaseous fill. We present a study of fuel adiabats for a variety of targets and laser conditions, following them to peak compression. End points of the compression histories readily demonstrate the improved performance expected for certain cryogenic targets. We examine the adiabats to isolate the relative importance of initial conditions, superthermal electron preheat and thermal electron transport in target performance.

Implosion Experiments
with Cryogenically-Cooled Spherical Targets

by

D. Slater, J. Tarvin, G. Charatis, P. Rockett,
C. Shepard, R. Johnson, E. Storm, and R. Schroeder

KMS Fusion, Inc., Ann Arbor, Michigan 48106

ABSTRACT

Implosion experiments currently in progress at KMS bring together for the first time three design features expected to increase the compressed fuel density achieved in direct-illumination, spherical target experiments. They are: 1) a solid DT fuel layer achieved by cryogenic cooling, 2) use of 0.53 μm laser light, and 3) time-tailored laser pulse shaping by means of a pulse stacker.

Experiments to date have compared cryogenic and room-temperature targets with wall thicknesses of 1.8 to 5 μm using 1.05 μm light in flat-topped pulses. As the wall thickness increased, measured implosion times and compressed densities increased for both cryo and non-cryo targets. At all wall thicknesses, cryogenic targets produced higher neutron yields and achieved greater compressed fuel density than room temperature targets, with the differences increasing with target wall thickness.

Some experiments have been performed with modified laser pulse shapes. In general, neutron and x-ray emission from the imploded core are greatly reduced for slowly rising pulse shapes compared to fast-rising pulses, making diagnosis of core conditions difficult.

We anticipate having some data at 0.53 μm wavelength using flat-topped pulses on cryogenic targets. In addition, we will use x-ray line broadening from argon-seeded, DT filled targets to measure fuel density.

1.05μm Laser-Driven, Cryogenic Implosions of Thick-Walled Glass Microballoons

by

P. Rockett, J. Tarvin, C. Shepard, D. Slater, and E. Storm

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ABSTRACT

Cryogenic DT-filled glass microballoon targets were irradiated with uniform illumination in the KMSF Triple Bounce Illumination System at intensities in the mid 10^{15} W/cm^2 range. Target wall thickness was varied from 1.8 μm to 5.2 μm and data was taken for both room temperature and cryogenic fuel. Comparative studies were made of imploded core size, implosion time, stagnation time and alpha energy loss. The emerging picture is of a solid fuel with decreasing preheat as wall thickness increases, rolling inward toward stagnation. Cryogenic targets reached higher compressions than room temperature targets as inferred from x-ray pinhole and streak photography. As wall thickness increased, density appeared to increase and fuel temperature drop as inferred from core dimensions, alpha energy loss, and neutron yield. The uniformity of the cryogenic layer is shown to have a clear impact upon target performance.

XIIth ANNUAL ANOMALOUS ABSORPTION CONFERENCE

MAY 10-13, 1982 - SANTA FE, NEW MEXICO

EFFECT OF LASER PULSE RISE TIME AND IRRADIATION SYMMETRY ON MICROBALLOON IMPLOSION IN EXPLODING PUSHER REGIME

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G. COULAUD, M. DECROISETTE, P. GENTA, P.A. HOLSTEIN,

D. JURASZEK, D. LAMBERT, J. LAUNSPACH, R. VEZIN

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Experiments dealing with the influence of the laser pulse rise time and the irradiation symmetry on exploding pusher type implosions, have been performed with Octal facility (≃ 200 ps pulse duration ; ≃ 100 J incident energy ; 5.10^{14} to 10^{15} $W.cm^{-2}$ energy flux on target). Results are presented and tentatively interpreted in terms of fast electron transport.

On one hand, the evolution of neutron yield versus the absorbed energy is satisfactori by restituted by numerical simulations if a decoupling time of suprathermal preheat is introduced in the codes. On the other hand, symmetrisation processes are qualitatuely discussed around spherical implosions performed with an incident flux reduced by a factor n on one hemisphere.

SESSION E

HOT ELECTRON GENERATION AND THERMAL TRANSPORT

WEDNESDAY, MAY 12

8:45 – 12:15

W. KRUER

LLNL
LIVERMORE, CA

Relativistically Enhanced Resonant Absorption*

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Recent experimental results[1] from the Helios laser system have suggested an increase in absorption with increased intensity in the range of 10^{16} watts/cm^2. Here we suggest several mechanisms which may be responsible for the increase. We present numerical simulations at 2×10^{16} watts/cm^2 of 10 micron light which show 25% absorption at early time which increases to greater than 60% after 5 psec apparently due to an increase in the roughness of the surface. At the same time T_{HOT} increases from about 200 keV to 900 keV. This appears to be an onset of the radiating decay instability[2] at high intensity and sharp gradients. An addition we have observed in fixed ion simulations a large enhancement[3] in absorption when the background plasma temperature is $\gtrsim$500 keV.

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

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A Consistent 1-D Model for Resonantly Heated Electron Distributions*

by

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We report on results obtained using a new model to treat resonance absorption. We solve the equation for the EM wave magnetic field incident upon a ramp plasma. The driving electric field is computed using the wave magnetic field and the integral of the plasma density fluctuations. A standard 1-D particle simulation model,[1] to which the driving electric field is applied, provides the hot electron distribution function. Scaling laws for T_{hot}, cutoff, and absorption are readily obtained. Comparisons with 2-D particle simulations and analytic theory will be presented. The model provides a means to explore electron heating in detail.

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* Work supported by the United States Department of Energy.

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GENERALIZED WEIBEL INSTABILITY IN A LASER PRODUCED PLASMA

by

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University of Maryland
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Abstract Submitted for Presentation at the 12th Annual Anomalous Absorption Conference, May 10-13, 1982, Santa Fe, New Mexico

Comparison of Microwave - Plasma Interaction Experiments and Computer Simulations.*

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University of California, Los Angeles, California 90024

and

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Efforts are underway aimed at making detailed comparisons between microwave-plasma interaction experiments and computer simulations. Two separate experimental arrangements have been chosen for the initial studies. The first experiment is concerned with the details of resonance absorption on the wavebreaking timescale.(1) Using a one-dimensional electrostatic code (ES1) with a moving ion background, details of the interaction process including profile modifications, electric field growth, harmonic generation, finite bandwidth effects and hot electron production are studied and compared with experiment. The second experiment concentrates on the growth and saturation of stimulated Brillouin scattering in an underdense plasma.(2,3) Particular attention is being paid to rescatter together with modifications to the ion distribution function.

(1) Ann Y. Lee, et. al. Phys. Rev. Lett. 48, 319 (1982).
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POSITRON PRODUCTION BY HOT ELECTRONS

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Hot electrons with characteristic energies on the order of 1/2 MeV are detected in targets irradiated by long-wavelength laser beams. Stroscio[1] first investigated the production of positrons in such targets via a two-step process in which a hot electron produces bremsstrahlung, which then "materializes," producing an electron-positron pair. There is, however, another process, "trident production," first investigated by Bhabha,[2] Williams,[3] and Nishina et al[4] in which the pair is produced in the field of the same nucleus as that in whose field the (now virtual) bremsstrahlung is produced. The two-step process leads to a number of positrons proportional to the square of the target thickness, while trident production gives a number linear in target thickness, in each case until absorption in the target becomes important.

We have attempted to estimate the total positron production in laser targets. This is difficult because of a dearth of theoretical or experimental data on trident production near threshold. The lowest energy experiments (2.0-4.0 MeV) by Jacobs et al.[5] were interpreted[6] ignoring trident production, although at 3.5 MeV (but not at 2 MeV) the forward production rate shows a clear transition from yield $\propto$ thickness to yield $\propto$ (thickness)^2 near 70μg cm^{-2} of Au(?). The nonzero intercept of a plot of the derivative of positron yield from 5.8 MeV electrons with respect to target thickness indicates a contribution from trident production comparable to that from the two-step process in 40-80 mg/cm^2.[7] While these measurements are said to compare well with calculations by Löns,[8] it appears to us that the plot of Löns' results in Ref. 7 disagrees with Table 1b of Ref. 8. There is thus considerable confusion.

For electrons in a Maxwell distribution, with $kT \lesssim mc^2$ most of the reaction will happen within about kT of the threshold at 3 mc^2. Thus even the lowest energy data requires extrapolation to yet lower energies. An extrapolation from a rough integration of Löns' differential cross section using a phase space argument gives $\sigma = 1.6 \cdot 10^{-30} W_{MeV}^{7/2}$ with W the energy above threshold. If the electron distribution function f is $N_e e^{-E/kT} d(E/kT)$ with E the kinetic energy of the electron ($= W + 2mc^2$), then the number of positrons produced per unit time, in Cu, would be $\int V N_{Cu}\, \sigma v f dW = 1.6 \cdot 10^{-30}\, c V N_{Cu} N_e (kT)^{7/2} \Gamma(9/2)$ where c is the speed of light, V the volume, so VN_e is the total number of electrons, N_{Cu} the density of Cu nuclei, Γ the gamma function; $\Gamma(9/2) = 3.32$. For elements other than Cu, this result should be multiplied by $(Z/29)^4$. If the total absorbed laser energy $\mathcal{E}$ is put into electrons of energy kT, their number is $\mathcal{E}/kT$. Hence the total number of positrons produced is $6 \cdot 10^8 \mathcal{E}_{kilojoules} (kT_{MeV})^{5/2}$ in Cu. For Pb the numerical factor changes to $4 \cdot 10^{10}$, and for a realistic temperature of 300 keV the number of positrons in Pb would become $2 \cdot 10^9$ per kilojoule of absorbed energy. Using the measured hard x-ray production rate for 8 kilojoules incident and the pair-absorption coefficient of Pb gives $3 \cdot 10^6\, \Delta\ell$ positrons per kilojoule incident where $\Delta\ell$ is the target thickness in μm of normal density Pb for the two-step process. Hence, if our crude estimates of cross sections are approximately correct, trident production dominates except in very large targets.

Another question of interest is the fate of the positrons. For thin targets, the positrons will reach the surface of the target where electric fields will accelerate them outwards. For thick targets, we estimate from reasonable expansion velocities that most positrons slowed down in the target will be annihilated there during the expansion.

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Abstract for the 12 Annual Anomalous Absorption Conference
May 10-13 1982, Santa Fe, New Mexico

Fokker-Planck Simulation of Electron Heat Transport with Temperature and Density Gradients

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*** LLE, Rochester

A Fokker-Planck code has been written to simulate electron heat flow with arbitrary gradient lengths similar to that of Bell et al[1]. However, the temperature gradient is maintained by fixed temperature hot and cold end conditions, rather than by localised heating of the plasma.

We have studied the propagation of a heat front into the cold plasma ($T_{hot\ end}/T_{cold\ end} = 9/1$) in two situations: with a uniform density and with a 1:9 density ratio between the initially hot and cold regions (constant pressure).

In the uniform density case, with an initial temperature gradient length ($\ell_T o$) equal to the mean free path (λ), a f value of .1 is observed if T_{hot} is used to define the free streaming heat flux, but this is 0.2 if local values are used. Increasing $\ell_T o$ to 3λ reduces the f numbers by a factor of 2. In the case with a density gradient ($\ell_T o = \ell_n = 3\lambda$), f is $\simeq 0.1$, but comparison with local values of Te gives f $\simeq 0.3$. The shape of the temperature profile is different in each simulation, ranging from the concave, characteristic of free streaming in the first case to the convex, characteristic of Spitzer-like regimes in the latter.

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[1] A.R. Bell, R.G. Evans and D.J. Nicholas, Phys. Rev. Lett. 46 243 (1981)

CLASSICAL HEAT TRANSPORT BY NON MAXWELL-BOLTZMANN ELECTRON DISTRIBUTION*

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Abstract

Non equilibrium electron distributions resulting from anomalous or collisional laser heating relax toward isotropy roughly Z times faster than toward Maxwell-Boltzmann energy distribution. We consider classical electron heat transport in high-Z plasmas where the distribution is dominantly isotropic but not necessarily Maxwell-Boltzmann.

*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

HEAT FLUX LIMITATION FOR AN ANISOTROPIC VELOCITY DISTRIBUTION*

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ABSTRACT

The classical electron heat conductivity is derived analytically for a biMaxwellian electron velocity distribution function having temperature $T_{\parallel}$ inwards and $T_{\perp}$ sideways. Magnetic fields and electron-electron collisions are omitted and only electron-ion collisions are included presently. We normalize the heat conductivity to that for an isotropic distribution having temperature T, where $T = (2T_{\perp} + T_{\parallel})/3$. The variation of this ratio from the case of $T_{\perp} = T_{\parallel}$ to $T_{\perp} >> T_{\parallel}$ is investigated. For $T_{\perp}$ close to $T_{\parallel}$, the heat conductivity ratio is $0.6\nabla_{\parallel} T_{\parallel}/\nabla T + 0.4\, \nabla_{\parallel} T_{\perp}/\nabla T$ for inward gradients and $0.2\nabla_{\perp} T_{\parallel}/\nabla T + 0.8\nabla_{\perp} T_{\perp}/\nabla T$ for sideways gradients. For $T_{\perp} >> T_{\parallel}$, this ratio varies as $2.58\, (T_{\parallel}/T_{\perp})^{5/2}\nabla_{\parallel} T_{\parallel}/\nabla T + 0.51\, (T_{\parallel}/T_{\perp})\nabla_{\parallel} T_{\perp}/\nabla T$, being greatly limited for these inward gradients, and it is $0.1\nabla_{\perp} T_{\parallel}/\nabla T + 1.775\, \nabla_{\perp} T_{\perp}/\nabla T$ for sideways gradients.

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* Work supported by the U. S. Department of Energy under contract DE-AC08-81DP40162.

FLUX INHIBITION AND UNDERDENSE ABSORPTION BY RETURN CURRENT DRIVEN ION TURBULENCE - STATUS OF THE THEORY AND EXPERIMENTS

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Recently we have published several papers[1-5] concerning electron thermal energy flux inhibition and laser light absorption via return current driven ion acoustic turbulence. The ion turbulence was modeled in either of two ways: 1) A temporally steady state model[2,3] in which the unstable waves spatially amplify from noise. The local growth rate is determined from local fluid quantities; these local fluid quantities are affected by the waves through quasi-linear theory. 2) A time dependent simulation[4,5] in which the waves exist at an assumed amplitude and spectrum wherever they are linearly unstable. These two calculations qualitatively agree with each other.

Some basic predictions of the theory are: 1) The mean free path is anomalously reduced so that a single fluid description is valid for all but the very highest energy electrons. 2) The excited ion waves give flux inhibition and underdense absorption which is most important for low T_i/ZT_e. Typical flux limit parameters are characteristically between 0.05 and 0.1. 3) At high irradiance, there should be a difference between fractional resonant absorption for long and short pulses, which resonant absorption being much more important for short pulses.

Recently there have been a number of experimental results which lend support to this theory. Some of these are: 1) The hard x-ray spectra for short pulse experiments can be accurately modeled.[5] 2) Time resolved experiments on the burn through of thin foils show that the burn through when $n < n_{cr}$ is not sudden but quite gradual.[6] 3) Underdense absorption was shown to be important in a CO_2 laser produced plasma.[7] 4) Experiments[8] on thermal pulse propagation in a laboratory plasma show the flux is inhibited and ion waves are produced if the heating is rapid, so $T_e > T_i$. However for slower heating,[9] where $T_e \sim T_i$, little flux inhibition and no ion turbulence is seen. 5) Experiments have confirmed[10] that at high irradiance, resonant absorption (as measured by the distinction between s and p polarization absorption) is much less important for long pulses than short.

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Energy Transport and Partitioning in Nanosecond 1μm Spherical Target Irradiation Experiments*

by

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We report on the measurement and simulation of the energy absorption, transport, and partitioning in one nanosecond 2-TW spherical experiments performed with the 24-beam OMEGA laser system at the Laboratory for Laser Energetics. Most of the experiments were performed on heavy spherical shells coated with parylene and in a laser intensity range of 10^{14} - 10^{15} W/cm^2. The absorbed energy was measured with an array of 20 plasma calorimeters and the ion velocity spectrum obtained with Thomson parabola ion spectrometers utilizing CR-39 track counters to determine the absolute velocity spectrum of individual ions. Thermal energy transport was measured by registering the signature of burn through to high Z material on time integrating x-ray crystal spectrographs, on time-resolved x-ray streak spectrometer, and with ion spectrometers.

These experiments were simulated with the one dimensional hydrodynamic code LILAC, which includes ray tracing of the laser light and an energy dump into suprathermal electrons at the critical density estimated from a resonance absorption tunnelling formula. Absorption and ion spectrum scaling and energy transport scaling predictions are consistent with predominantly inverse Bremsstrahlung absorption and thermal flux-inhibition.

*This work was partially supported by the U. S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

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TRANSPORT IN NANOSECOND 1.06 μm PULSE IRRADIATION

by

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Institute of Laser Engineering
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Analysis of Layered Disk Transport Experiments at 1.06- and 0.35- μm*

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Livermore, California 94550

Abstract

We discuss results of calculations and experiments performed to study axial and lateral electron transport using layered disk targets of B_e coated on Aℓ, with a surrounding T_i shield.[1] Gaussian 600 ps pulses and f/2 optics were used for two sets of irradiations. Results at incident conditions of 1.06 μm, 90J, and 3 x 10^{14} W/cm^2 are compared with those at 0.35 μm, 30J, and 1 x 10^{14} W/cm^2, providing a wavelength-scaling comparison at constant absorbed intensity.

Two dimensions LASNEX calculations using fairly realistic beam profiles are compared with continuum x-ray imaging of shielded and unshielded targets to set limits on lateral transport.

The fall off of Aℓ continuum- and line- x-ray emission with increasing B_e coating thickness is compared with LASNEX calculations to infer the overall rate of the axial thermal conduction.

Detailed observations of the time-dependence of sub-keV x-ray emission pulses show that the x-ray pulse for 0.35 μm irradiations corresponds closely with the laser pulse shape. At 1.06 μm the x-ray pulse is broader and flatter than the laser pulse, similar qualitatively to the effect reported by McClellan, et al.[2] This phenomenon indicates a strongly time-dependent effect beyond current modelling physics.

[1] reference to last year's Anomalous talk
[2] refer to Physical Review Letters by McClellan, Lee.,

*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.

Theory and Simulation Studies on Two Dimensional Hot Electron Transport and Non-Uniform Illumination Effects

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Recently, a number of theoretical and experimental works have been done to clarify the lateral and longitudinal expansion dynamics of hot electrons generated locally. For an example, 10.6 μm laser experiments and simulation studies indicate that hot electron orbits are modified by self-generated magnetic and electric fields and the heated regions break up into a few hot spots.

This paper presents a new amplification mechanism for the self-induced magnetic fields and the associated filamentation of hot-electron flow by these magnetic fields[1]. The amplification mechanism is due to a spatially non-uniform convection and a consequent piling up of the magnetic field, related to hot-electron energy deposition. Two-dimensional simulations, showing the space time evolution of magnetic field fluctuations, and a theoretical interpretation are provided. At a laser intensity of 10^{15} W/cm^2, it was found that the magnetic fields generated around the critical surface are amplified by a factor 10 through the above new mechanism and bright hot spots are supposed to appear.

The previous work (ref. 1) is extended to include the self-consistent background electron heating and ion dynamics.

References

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SESSION F

HOT ELECTRON TRANSPORT

WEDNESDAY, MAY 12

14:00 – 16:00

A. B. LANGDON

LLNL
LIVERMORE, CA

HOT ELECTRON TRANSPORT THRU THIN FOILS

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A self-consistent scheme has been developed to model electron transport in evolving plasmas of arbitrary classical collisionality. The electrons and ions are treated as either multiple donor-cell fluids, or collisional particles-in-cell. Particle suprathermal electrons scatter off ions, and drag against fluid background thermal electrons. The background electrons undergo ion friction, thermal coupling, and bremsstrahlung. The components move in self-consistent advanced E-fields, obtained by the Implicit Moment Method, which permits $\Delta t \gg \omega_p^{-1}$ and $\Delta x \gg \lambda_D$ -- offering a 10^2 - 10^3-fold speed-up over older explicit techniques. The fluid description for the background plasma components permits the modeling of transport in systems spanning more than a 10^7-fold change in density, and encompassing contiguous collisional and collisionless regions. Results are presented from application of the scheme to the modeling of CO_2 laser-generated suprathermal electron transport in expanding thin foils, and in multi-foil target configurations.

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

Abstract Submitted for the 12th Annual Conference on Anomalous Absorption of Electromagnetic Waves May 10-13, 1982, Santa Fe, New Mexico.

Two dimensional hot electrons behavior

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Rémy Fabbro
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A toroïdal magnetic field (typically 1-2 MGauss) enables to interpret recent results of laser-plane target experiments, i.e. the importance of fast ion losses, the observation of hot electrons lateral transport leading to a ring structure, and the increasing decoupling of the hot electrons with the focal spot when the laser pulse duration is increasing.

Hot Electron Diffusion and Related Ablation Behavior of a 10.6 μm Laser Irradiated Target

H. Nishimura, H. Daido, K. Mima, M. Yagi, F. Matsuoka,
K. Yamada, R. Tateyama, K. Ogura, H.Azechi, K. Imasaki,
H. Takabe, S. Nakai and C. Yamanaka

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Understanding of hot electron transport and its coupling to a bulk plasma is the key issue in the hot electron driven ablation schiem[1),2)]. The hot electron diffusion in over-dense region and lateral flow was experimentally investigated under intense 10.6 μm laser irradiation.

A new method of determining the ablation pressure (shifted x-ray emission imaging[2)]) gave the typical ablation pressure of 10 Mbar and the mass ablation rate of 5×10^5 g/cm^2•sec at the absorbed laser intensity of 3×10^{13} w/cm^2. And these values are consistent with those measured by the spectroscopic and the x-ray backlighting methods. These data show good agreement with a self regulated flow model of hot electron transport.

Dynamics of hot electrons which spread over a lateral direction were investigated by x-ray imaging for infinite- and finite-area size of planer disk targets, and various sphere targets. The observed results together with the analysis on the formation of the hot electron stream and the local fields are presented.

R E F E R E N C E S

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* This abstract is prepared for 12th Annual Anomalous Absorption Conference, May 10 - 13, 1982 at Santa Fė, Hilton Inn

HOT ELECTRON DISTRIBUTION FUNCTION IN HIGH-Z MATERIALS

by

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ABSTRACT

An analytic expression is obtained for the distribution of hot electrons as a function of distance into a cold material slab in which $\nu_E = \gamma_E v^{-\alpha}$ and $\nu_\perp = \gamma_\perp v^{-\beta}$ are the assumed velocity dependences of the energy loss collision frequency and the scattering collision frequency and $\nu_E \ll \nu_\perp$. For a time independent source, a time independent solution exists with a characteristic penetration length equal to $(\lambda_E \lambda_\perp)^{1/2}$ where λ_E and $\lambda_\perp$ are the mean-free-paths corresponding to ν_E and $\nu_\perp$. The distribution function at large distance from the source is proportional to $v^{\alpha-3}$ for v less than a critical velocity. For v greater than the critical velocity, the velocity dependence of the Maxwellian source reappears causing an exponential cutoff.

12th Annual Anomoulous Absorption Conference
Santa Fe, New Mexico
May 10 - 13, 1982

ABSTRACT F-5

HOT ELECTRON STUDIES IN CO_2 LASER PRODUCED PLASMAS*

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We have recently used pinhole imaging of x-rays generated by hot electrons to study the spatial distribution of energy deposition in CO_2 laser interaction with solids. Single beam, and multi-beam irradiation of spheres and flats show interesting deposition patterns that vary slightly with focusing condition and target size. In general one sees a very intense deposition region at and around the laser spot, followed by a ring area that shows no x-rays (or deposition), followed by another ring area that shows intense x-ray generation. When multiple beams are present these areas connect and collide, causing the appearance of a deposition region midway between the laser spots. These observations are in agreement with the results of Forslund and Brackbill, where the self-generated magnetic field builds up quite fast to a steady state thus insulating the immediate vicinity of the laser spot from the fast and slow electrons.

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

Abstract for the 12 Annual Anomalous Absorption Conference
May 10-13 1982, Santa Fe, New Mexico

HOT ELECTRON TRANSPORT IN CO_2 LASER PLASMA

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R. Décoste
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Long-wavelength lasers produce abundant surpathermal electrons, which can be used for the inward energy transport. One controversial aspect of this transport mechanism is the penetration depth and lateral extent of the hot electron penetration with the target surface. As a diagnostic tool, we have been using various types of layered targets and look at the continuum X-ray emission from a high-Z tracing material. For the axial inward transport, various layers of plastic are deposited on either a dielectric (glass) or conducting (Al, Au) high-Z substrate. Similarly the lateral range of hot electrons is detected with a high-Z material located in the target plane away from the laser interaction region. The experiments were performed with a 1 nsec pulse at an irradiance $\sim 5\ 10^{13}$ Wcm^{-2} within a 150 μm focal spot diameter.

In these experiments we demonstrate, in particular, that the hot electron transport is quite affected by the conducting properties of the target material. The hot electron penetration depth into plastic is decreased by a factor of three when the conductor substrate is replaced by a dielectric. As well, with a conductor, the hard X-ray emission diameter is increased about four times over the dielectric case. Conducting targets can provide a return current to the interaction region and prevent large negative charge build-up in depth and outside the spot area.

Magentic Field Induced Surface Transport on Laser Irradiated Foils*

by

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Electrons heated by absorption of laser energy are shown to generate intense magnetic fields which rapidly spread from the edge of the laser spot along the target surface. The fields convectively transport hot electrons and confine a major fraction of the deposited laser energy in the corona. Eventually, this energy is lost to fast ion blow off or deposited at large distances from the spot. This model explains many experimental observations of thermal transport inhibition and fast ion loss.

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

SESSION GP

POSTER SESSION:

SBS, HARMONIC EMISSION, TWO-PLASMA INSTABILITY

WEDNESDAY, MAY 12

16:00 – 17:30

Abstract Submitted for the Twelfth Annual Conference
on Anomalous Absorption of Electromagnetic Waves

May 10 - 13, 1982

Santa Fe, New Mexico

FUNDAMENTAL AND SECOND HARMONIC BACKSCATTER MEASUREMENTS FROM CO_2
LASER PLASMA INTERACTIONS*

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Experimental evidence from the Helios CO_2 Laser Facility using glass microballoon targets with a variety of coating materials and thicknesses shows that light incident at 10^{14} - 10^{16} W/cm^2 directly backscattered into the f/2.4 focussing optics remains a small fraction (2 - 3 percent) of the incident light. Hence most of the laser light which is not absorbed is scattered into angles other than direct back. The data from these targets consistently show that the backscattered fraction and perhaps the angular distribution of scattered light is dependent upon the intensity of the irradiating beams. The fraction of second harmonic in the backscatter is also weakly dependent upon intensity.

Time resolved ω_0 and $2\omega_0$ backscatter from targets of this type show little evidence of the growth of any instabilities during the 1 ns laser pulse. The reflected pulse generally tracks the incident pulse quite smoothly.

The spectrally resolved 10.6 μm backscatter is consistently blue-shifted by 100 Å - 150 Å. Interpretation of these spectra as being dominated by a Doppler-shifted specular component leads to a critical surface velocity of 1.4 - 2.0 x 10^7 cm/sec.

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

Abstract for the 12 Annual Anomalous Absorption Conference
May 10-13 1982, Santa Fe, New Mexico

SPATIAL DEPENDENCE OF BACKSCATTERED AND
SIDESCATTERED SPECTRA FROM CO_2 LASER PLASMAS

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An afocal telescope imaging system has been used to spatially resolve (transverse and normal to the target) the backscattered 10 μm radiation. The scattered radiation has been recorded in the spatial and spectral domain. The best image of the backscattered radiation corresponds to a region about 200 μm away from the target at a flux level of 2×10^{13} W/cm^2. Picosecond interferometry has been used to obtain the corresponding density of 2×10^{18} cm^{-3}.

An iris is used in the image plane of the afocal telescope to select the location along the normal and the transverse dimension of the scattering volume to be spectrally analysed. The dimension along target normal of the scattering volume is set to 100 μm by the depth of focus of the scattered light collecting optics. Spectral measurements of the backscattered radiation show an asymetric red shifted envelope with a long (200 Å) tail towards the red. On closing the iris to limit the transverse dimension of the scattering volume to 75 μm, the spectrum exhibits strong (50%) modulation.

For scattering volumes 100 μm and 200 μm away from the target, on the shots with more than two spectral peaks, the modulation is periodic with a period equal to the difference $(\omega_0 - \omega_B)$ where ω_0 is the incident frequency and ω_B is the Doppler shifted Brillouin corresponding to the peak of the backscattered envelope. For the scattering volume corresponding to the target surface the backscattered spectrum contains only one red shifted (50 Å) peak about twice as wide (50 Å) as the incident radiation. The highest frequency peak shifts towards the blue as the scattering volume is moved away from the target, consistent with corona expansion.

Stimulated Brillouin Scattering of Multi-Line Laser Light in a Flowing Plasma Corona*

by

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It has been suggested recently[1,2] that the problem of stimulated Brillouin scattering could be alleviated by using a multi-line laser. If the frequency separation between lines is greater than the homogeneous SBS growth rate, the SBS process will be approximately independent for each line. Thus if the total laser energy is divided among the lines so that each line individually is below the SBS threshold, there should be no significant scattering.

This conclusion may be modified when the presence of a critical surface and the plasma flow velocity are taken into account. We show that in this case Brillouin scattering may still occur in the form of a parametric interaction between incoming light of one frequency and light of the next higher frequency line reflected from the critical surface. Interestingly enough, however, in this interaction it is the outgoing light which is scattered and returns to the critical surface. Thus the intensity at critical actually increases when this type of Brillouin scattering occurs. We estimate the importance of the effect for parameters relevant to a HF laser.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124.

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STIMULATED BRILLOUIN BACKSCATTER IN LONG SCALE LENGTH LASER PRODUCED PLASMAS

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The longer the scale length of a laser produced plasma, the smaller the irradiance needed for substantial stimulated Brillouin backscatter. Using the technique previously published we examine the backscatter expected in numerically calculated density, temperature and velocity profiles. Calculations will be compared with experiments considering the stabilizing effect of velocity gradient, ion heating and nonlinear effects on the stimulated sound wave. Specifically we find that for the NRL-LLNL joint experiment on ablative acceleration using Shiva, the velocity gradient in the blowoff plasma is strong enough to essentially quench the Stimulated Brillouin backscatter.

POSTER SESSION

STIMULATED BRILLOUIN SCATTERING DRIVEN BY A STANDING ELECTROMAGNETIC WAVE

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Davis, California 95616

and

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We are investigating SBS in the UCD CERBERUS device. A semi-parallel beam of high power ($v_o/v_e \lesssim 1.0$) microwaves ($\omega_o/2\pi = 2.9$ GHz) is incident onto a long ($L/\lambda_o \lesssim 10$), inhomogeneous, underdense plasma. The critical surface in a laser driven pellet is replaced by a grid that reflects the beam and produces a large standing wave (SWR $\lesssim$ 30). The inhomogeneous plasma is created by an electron beam obtained from a pulsed LaB_6 hot cathode. The plasma is flowing due to the axial density gradient. Directional antennae are used to differentiate between the forward and backward traveling microwaves in the experimental region. We find that SBS is strongly driven at high power, resulting in attenuation of the microwaves deep in the plasma. Large amplitude ion waves ($\delta n/n \lesssim 10\%$, $\omega_i \simeq k_i C_s \simeq 2 k_o C_s$) are also observed.

* Work supported by Lawrence Livermore National Laboratory under Intramural Order 9910209.

† Work performed under the auspices of U. S. DOE.

THOMSON SCATTERING FROM SBS INDUCED ION FLUCTUATIONS

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Ruby laser Thomson scattering from a CO_2 laser-produced-plasma has been used to directly measure ion fluctuations driven through Stimulated Brillouin Scattering. The Thomson scattering geometry was chosen to match both magnitude and direction of the wavenumber of the SBS excited ion wave. For CO_2 laser intensities of 3.5×10^{12} W/cm^{-2}, ion fluctuations of $\delta n/n \leq 0.09$ were measured, varying with the Brillouin reflectivity level as expected from the associated change in the ponderomotive force from the beating electromagnetic waves. These levels of ion fluctuation are consistent with a heavily damped, convective model of the Brillouin instability. Time integrated spectral measurements showed a Doppler shift of the Thomson scattered light, predominantly resulting from plasma expansion. The scattered light was also spectrally broadened from the Landau damping of the ion wave. In addition, a high speed streak camera was used to temporally resolve the Thomson scattered light, showing 100 - 200 picosecond rise and fall times and no significant modulations within the 0.4 - 1.5 nanosecond scattered light pulses. These measurements show that the Brillouin scattering quickly evolves into a heavily damped, convective instability.

Intrisically Non-Steady Stimulated Brillouin Scatter Induced by Plasma Critical Surface

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Livermore, California 94550

Abstract

Backscattered light spectra near the laser frequency are often difficult to interpret using typical steady state models of stimulated Brillouin scatter (SBS). For example, spectra from prepulsed targets have shown complex multi-mode structure[1] suggestive of multiple rescatter but with intermode spacing not necessarily harmonic or related to the expected plasma temperature. Time dependent analysis of SBS including non-absorbed light returing from the critical surface has been useful in explaining multimode spectra and departures from linear steady state SBS theory observed in numerical simulations[2] and microwave experiments.[3] However, the predicted nonsteady behavior decays on timescales much shorter than typical laser experiments. Here, we study these time dependent effects in the nonlinear regime by numerical techniques. We investigate the conditions under which nonlinear effects can extend the lifetime of transients to laser fusion timescales, making SBS intrinsically non-steady. Scattered light spectra will be shown and compared with the experimental data.

This model may also be suitable for analysis of spectra from moderate Z-disk targets which are typically red-shifted. However, hydrodynamic simulations show very little SBS gain for red-shifted light.[4] The inclusion of the non-absorbed light returing from the critical surface as a large noise source[4] in a steady state SBS model yields finite scattering levels despite low SBS gain but does not explain the observed red shift since the non-absorbed light is blue shifted in transiting the expanding plasma. We investigate whether the observed red shifts are connected to nonsteady nonlinear behavior of SBS.

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First-Order Refractive Effects of Density Fluctuations on Light Rays in a Plasma*

by

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The propagation of light rays in a plasma has been considered for small density fluctuations superimposed upon a given background density profile. The lowest-order angular spreading, focusing, drift, and spectral broadening effects are calculated in the geometrical optics limit using a statistical random-walk approach. This method is an economical semi-analytic alternative to a purely numerical ray-trace approach. The model is applied to a simple fluctuation spectrum characterized by an RMS amplitude and by a correlation length. Results are presented for the evolution of the intensity profiles of rays incident on a plane-parallel linear-profile plasma slab as a function of the angle of incidence. Comparisons of these results with numerical Monte-Carlo ray-trace solutions show good agreement. For typical scale lengths of laser-driven plasmas, fluctuations as small as a few percent of the critical density can, for example, produce significant angular broadening in the specularly reflected beam, and reduce the sensitivity of the absorption fraction to the incidence angle and polarization, particularly near normal incidence.

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HIGH HARMONIC GENERATION OF INTENSE LASER RADIATION

by

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College Park, MD

Harmonic Emission from Uniformly Illuminated Spherical Targets*

by

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Laboratory for Laser Energetics
University of Rochester
Rochester, New York 14623

The observation of harmonic emission from the corona of laser imploded microballoons is an important diagnostic for inertial fusion. Harmonic generation in specific regions can provide spatial and temporal measurements of these regimes and detail the growth of instabilities under various conditions.

A study has been performed with the 24 beam glass OMEGA laser covering 6, 12 and 24 beam irradiation, 0.7 to 1.3 nsec pulses and total energies up to 2.7 kJ, at intensities of 10^{14} - 10^{15} W/cm^2.

Targets were spherical shells or solid spheres of diameter 400-600μ. Surface materials include CH, Al, SiO_2 and Au. A special modular high resolution camera was constructed to study the $2\omega_o$, $3/_2\omega_o$ and $5/_2\omega_o$ harmonics emitted by the coronal plasma. Space-resolved, and time resolved images, and space resolved and time resolved spectroscopy of the harmonic emissions were studied. The absolute levels were determined with calibrated photodiodes.

Spatial images of the $3/_2\omega_o$ harmonic are consistent with its generation at the $n_{c/4}$ surface. The two component spectra supports generation by of the $2\omega_{pe}$ instability. At lower intensities ($\sim 10^{14}$ Wcm^{-2}) the images of the $2\omega_o$ indicated its generation at the n_c surface. At higher intensities (> 2 x 10^{14} W/cm) there is an increasingly strong generation of $2\omega_o$ in the underdense region up to $n_{c/4}$. Its spectra displays multiple red shifted components, sensitive to target materials and intensity. It is believed that this is the first observation of the generation of integral harmonics at densities lower than n_c.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

MEASUREMENTS OF THE TWO-PLASMON PARAMETRIC DECAY INSTABILITY*

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The two plasmon parametric decay instability is studied in the U. C. Davis PROMETHEUS III device. This device is similar to PROMETHEUS I except the underdense plasma is quite long, $L/\lambda_{De} \lesssim 5000$. The plasma is driven by primarily p-polarized microwaves ($\omega_o/2\pi = 1.2$ GHz or critical density, $\approx 1.8 \times 10^{10}$ cm^{-3} and $v_o/v_e \lesssim 1$). The electron temperature is in the range $1 \lesssim T_e \lesssim 3$ eV. Probes are used to measure the plasma density, electron distribution function, and the local properties of the instability. Measurements of the emission of microwaves with frequencies near $3\omega_o/2$ verify that the instability is not due to the probes. The instability is observed only near the quarter critical surface with a frequency of one-half of the microwave frequency, i.e., $\omega_o/2$. A clearly defined instability threshold is observed. The $\omega_o/2$ waves are observed to grow exponentially and saturate. At high powers ($v_o/v_e \gtrsim 0.3$), strong profile modification is observed near the quarter critical surface. The steady state density profile has a long shelf ($L_s/\lambda_{De} \lesssim 500$) with a shallow density hole near the strongly steepened quarter-critical surface. The $\omega_o/2$ waves are strong throughout the shelf region. Hot electrons are produced with $T_H \propto P_o^{0.5}$ and hot electron densities in the range: $3 < n_H/(n_c/4) < 20\%$. Only weak thermal electron heating and weak ion acoustic turbulence are observed. This is in strong contrast to the strong thermal electron heating and strong ion acoustic turbulence we observe near the critical density.

* Work supported by Lawrence Livermore National Laboratory under Intramural Order 9910209.

† Permanent address: Bldg. 9201-2 MS-2, Fusion Energy Division, Oakridge National Laboratory, Oakridge, Tennessee 37830.

TWO PLASMON DECAY INSTABILITY DRIVEN BY TRAVELING AND STANDING WAVES*

W. Woo, P. Rambo, and J. S. DeGroot
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Davis, California 95616

The two plasmon decay instability is driven by p-polarized standing waves in the U. C. Davis PROMETHEUS III device. Recent results from this device (reported in the previous paper) do not agree with the published theories in which the instability is driven by s-polarized traveling waves. In this paper, we report an analysis of the linear growth and the saturation of the instability driven by p-polarized standing waves. The published theories involve the solution of coupled fourth order differential equations and the solution in k-space which is not applicable to the standing wave case. Instead, a set of simpler coupled second order differential equations are obtained after the growth condition is optimized. A general method to find the eigenvalues from the coupled equations is demonstrated. We also use a one-dimensional particle simulation code to study the non-linear features of the instability. The effect of hydrodynamic flow on the instability is also considered. The application of these results to laser fusion conditions will be discussed.

*Work supported by Lawrence Livermore National Laboratory under Intramural Order 9910209.

"Non-Resonant Two-Plasmon Decay in Hot Plasmas"

L. V. Powers and R. L. Berger

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ABSTRACT

Two-dimensional particle simulations[1] indicate that the non-resonant (convective) two-plasmon decay instability, in which an incident electromagnetic wave decays into a resonant electron plasma wave and a strongly damped electrostatic mode, may be an important source of suprathermal electrons in hot plasmas ($T_e \gtrsim 10$ keV). We derive a set of coupled mode equations for the convective two-plasmon decay process from the Vlasov-Maxwell equations which include a finite pump wavenumber $\vec{k}_0$ and which reduce to the form of Liu and Rosenbluth[2] in the resonant limit. This set of equations is evaluated under conditions where one of the decay waves is strongly damped or non-resonant to obtain amplifications for the non-resonant two-plasmon decay instability in various limits. Amplifications are found to be largest when the resonant (weakly damped) decay wave is sidescattered. Variation of the amplification with background temperature, density of the k-matching point, and wavenumber $\vec{k}$ of the resonant decay wave are discussed.

References:

(1) B. F. Lasinski, A. B. Langdon, and W. L. Kruer, "Heating in Underdense Plasmas", 11th Annual Anomalous Absorption Conference in Montreal, Canada, June 2-5, 1981.

(2) C. S. Liu and M. N. Rosenbluth, Phys. Fluids 19-7, 967 (1976).

EXPERIMENTAL OBSERVATIONS OF LINEAR GROWTH OF THE TWO PLASMON DECAY INSTABILITY

H.A. Baldis and C.J. Walsh

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National Research Council
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K1A 0R6

We have made time resolved observations of the wavenumber (k) spectra of electrostatic waves driven by the $2\omega_p$ instability. Thomson scattering at $\lambda_{probe} = 0.53$ μm was used to probe the e.s. waves directly. A range of wavenumbers from $\sim k_{pump}$ to $6k_{pump}$ was covered simultaneously using a technique described elsewhere.[1] The experiment was performed using a CO_2 laser ($\lesssim$ 30 J, 1 nsec) interacting with a preformed plasma ($n_e \simeq 0.25\ n_c$ peak density, $T_e \simeq T_i \lesssim 100$ eV). Waves travelling at 45^o to $\underset{\sim}{k}_{pump}$, in the plane of $\underset{\sim}{k}_{pump}$ and $\underset{\sim}{E}_{pump}$, were probed by Thomson scattering.

The growth rate of e.s. waves driven by $2\omega_p$ can be written as[2]

$$\gamma = \frac{k_{pump}\ V_{osc}}{4}\left(1 - \frac{12(\sqrt{3}/2)V_{th}^2}{\omega_{pe}\ V_{osc}}\ .\ k_y\right) - \frac{\omega_{pe}}{k_y L} \qquad (1)$$

where k_y refers to the e.s. wave. γ is thus a function of the plasma conditions through T_e and L. Our results are consistent with eq. (1) provided variation in these parameters is allowed for over the timescale of the CO_2 laser pulse. Such variations are consistent with heating estimates by inverse bremsstrahlung, and profile steepening by the $2\omega_p$ waves similar to that seen previously.[3] Briefly, the spectrum of waves seen is broad, starting initially at $\sim 6k_{pump}$, moving then to shorter k's (a heating effect) and finally, after ~200-400 psec, moving back to longer k's (consistent with profile steepening in the plasma).

1. C.J. Walsh and H.A. Baldis, this conference.

2. B.F. Lasinski and A.B. Langdon, Laser Program Annual Report-1977, Lawrence Livermore Laboratory Report No. UCRL-50021-77.

3. H.A. Baldis, J.C. Samson and P.B. Corkum, Phys. Rev. Lett. **41**, 1719 (1978).

Experimental Observations of Parametric Instabilities at $N_e < N_c/4$ Using Thin Foil Targets*

E. M. Campbell, D. W. Phillion, K. G. Estabrook

University of California

Lawrence Livermore National Laboratory

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Abstract

We report scattered light and suprathermal x-ray measurements from thin Formvar foils (7000 Å thick) irradiated with a 3 kJ, 900 psec FWHM, 1.064 μm laser pulse. Peak intensity on target was $2\text{-}3\times10^{15}$ W/cm^2. Computer calculations show the foil to go underdense very early in the laser pulse resulting in a hot (T_e > 2-4 keV), long scale length ($L/\lambda_0 \sim 10^3$) plasma with maximum densities < $N_c/4$.

An array of appropriately filtered calorimeters and pin diodes measured up to 10% of the incident energy as scattered Raman light and .04% as $3/2\omega_0$ light. Fifty joules of Raman light in the forward direction was observed with a narrow spectrum centered at 2.05 μm with a 0.10 μm FWHM. A streak camera simultaneously recorded the $3\omega_0/2$ light, the incident ω light, and the 30-70 keV x-rays. The $3\omega_0/2$ light and x-rays occurred simultaneously at t=-120 psec and lasted only 300 psec FWHM.

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

Improved Threshold Criteria for the Inhomogeneous $2\omega_p$ Instability*

by

A. Simon, E. Williams, T. Dewandre, and R. L. McCrory
Department of Mechanical Engineering
and
Laboratory for Laser Energetics
University of Rochester
Rochester, New York

A previous estimate of the threshold for the $2\omega_p$ instability in a linear density profile,[1] while indicating the correct scaling, may not be accurate in detailing the numerical values of the parameters. Their basic equations have some algebraic errors in them, and more importantly, their perturbation method of estimating the threshold is inconsistent since the "small corrections" in the method must be of the same order as the leading term at threshold.

The correct basic equations (which are now symmetric in the two plasma waves) are combined with a new scaling law for the frequency and wave numbers near threshold to obtain a simplified form of the complete complex potential in a k-space Schroedinger equation. The threshold conditions are then obtained numerically using the interactive code devised by White[2]. Details of the method, scaling laws and numerical results will be presented.

1. C.S. Liu and M. N. Rosenbluth, Phys. Fluids 19, 967 (1979).
2. R.B. White, Journal of Computational Physics 31, 409 (1979).

*This work was supported in part by the U.S. Department of Energy under contract DE-AC02-76ET53032 and in part under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

STIMULATED RAMAN SCATTERING IN THE PRESENCE OF STIMULATED BRILLOUIN SCATTERING

H. C. Barr and F. F. Chen
University of California, Los Angeles 90024

ABSTRACT

The detection and study of Stimulated Raman Scattering (SRS) in small experiments (e.g. CO_2 laser, intensities $\lesssim 5.10^{11}$ watts cm^{-2}) is anticipated to be difficult due to severe convective losses from the resonant region and to damping during convection. Yet there exists experimental evidence for SRS (i) in a regime apparently below the inhomogeneous threshold[1] and (ii) occurring only in the presence of Stimulated Brillouin Scattering[2] (SBS).

We examined initially the effect of SBS on SRS in a homogeneous plasma using a kinetic treatment. The SBS rippled density profile of wavenumber $2k_o$ (k_o, laser wavenumber) allows quasiresonant mode coupling of the SRS driven plasma wave at $k(\simeq 2k_o)$ to disturbances at $k \pm 2nk_o$. Coupling (weak for typical parameters) to shorter wavelength modes leads to a small increase in Landau damping. Since the driven wave at $(\omega, k \simeq 2k_o)$ and that at $(\omega, k \simeq -2k_o)$ can be simultaneously almost resonant, the main effect of the ripple is to cause reflection of the plasma wave via a quasimode at $(\omega, k \simeq o)$. In fact, there exist regimes which result in little reflection, almost total reflection and intermediate regimes for which there is zero net convection of energy. For these latter cases the growth is slower (by comparison with the homogeneous growth rate).

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[1] R. F. Watt, R. D. Brooks and Z. A. Pietrzyk, Phys. Rev. Letts., 41, 170 (1978).

[2] A. A. Offenberger, R. Fedosejevs, W. Tighe, W. Rozmus, University of Alberta report.

SESSION HD

DISCUSSION:

ELECTRON TRANSPORT

WEDNESDAY, MAY 12

17:30 – 18:15

DISCUSSION LEADER:

F. J. MAYER

KMS FUSION
ANN ARBOR, MI

SESSION I

FAST IONS, HOT ELECTRONS

THURSDAY, MAY 13

8:45 – 11:00

A. A. OFFENBERGER

UNIVERSITY OF ALBERTA
ALBERTA, CANADA

MEASUREMENT OF ABSORPTION AND FAST ION LOSS IN HIGH ENERGY EXPERIMENTS AT HELIOS*

J. F. Kephart, S. Gitomer D.Bach
and G. Kyrala

Los Alamos National Laboratory
Los Alamos, NM 87545

ABSTRACT

We have measured the absorption of CO_2 laser light on 25 μm thick gold microballoons and a variety of other targets as a function of intensity by varying both the focus and the laser energy.

The absorption was measured, primarily, by 20 ion calorimeters arranged around the target. This is a direct and absolute measurement of the energy invested in plasma expansion, both thermal and suprathermal. Secondarily, the absorption was measured by observing the ratio of the hard x-ray yield to the hot electron temperature deduced from the slope of the bremstrahlung spectrum between 50 and 500 keV. This ratio is proportional to the amount of energy deposited in the target by collisional stopping of hot electrons. Additionally some of the calorimeters were shielded with 0.5 μm thick Ni foils. These foils served to transmit only fast ions (120 keV protons and other ions of similar velocity).

The absorption for the thick gold shells was found to decrease as $(d)^{-0.3}$ where d is the distance of the target surface to focus over d values ranging from 500 to 2500 μm and as $E^{0.5}$ where E is the laser energy. Over this same range the fraction of energy in fast ions was found to vary as $(d)^{-1.20}$.

For some targets the absorbed fraction of the incident laser energy was measured to be greater than 55%.

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

PLASMA JET FORMATION IN CO_2 LASER PLASMA INTERACTIONS

by

A. Hauer and W. Ehler

Los Alamos National Laboratory
Los Alamos, New Mexico

A SIMPLE MODEL FOR FAST ION LOSSES FROM THIN SHELL TARGETS

M. Alme
Mission Research Corporation
Albuquerque, New Mexico 98108

ABSTRACT

We have implemented in the MACH1 one-dimensional radiation - hydrodynamics code a simple, fast running hot electron model that should provide an accurate description of hot electron driven fast ion losses in thin shell targets illuminated with CO_2 laser light. This spherically symmetric model is well suited to performing parameter studies in which the fraction of the laser energy absorbed and the hot electron generation spectrum are varied in a systematic fashion. The major limitation of the model is that magnetic field effects are not included.

The two key assumptions of the model are as follows. First, we assume that at each instant in time, the hot electron energy spectrum is the same at all points in space. Our second assumption is that the hot electrons are distributed in space according to the following formula:

$$n_{hot}(r,t) = \text{minimum} \begin{cases} Z\, n_{ion}(r,t) \\ n_{hot}^{max}(t) \end{cases} .$$

Note that the hot electron density, n_{hot}, and the ion density, n_{ion}, are functions of space and time, while the maximum hot electron density, n_{hot}^{max}, is a function only of time. These two assumptions allow us to describe the hot electron distribution with an energy dependent global conservation equation - a conservation equation which follows the time evolution of both the total number of hot electrons and the hot electron energy spectrum.

Results from several target simulations will be presented and compared to experiment.

MULTI-ION HYDRODYNAMICS IN A HOT-ELECTRON DRIVEN CORONA

Robert Stellingwerf
Mission Research Corporation
Albuquerque, New Mexico 98108

ABSTRACT

In many instances of laser plasma interaction copious production of superthermal electrons induces a rapidly expanding corona consisting of fast ions. These Ions are accelerated by the electrostatic potenetial that constitute an important diagnostic tool. This effect is most pronounced when a thin target is irradiated by a high intensity CO_2 laser.

When several ion species are present, an interaction takes place that tends to accelerate ions with high Z/A and retard those with low Z/A. A Lagrangian computational scheme has been developed to compute the coronal structure for the multi-ion problem within the framework of a hydrodynamic target simulation. In this way the effects of ponderomotive force, spherical geometry, time dependence and unusual initial conditions can be accurately assessed.

Two test calculations will be discussed in detail, 1) a thin shell CH target with a 100 keV corona, and 2) a thin shell glass microballoon with a 100 Å layer of CH on the surface. The first test can be compared with plane-parallel self-similar solutions for the two ion (C and H) corona. The second test illustrates proton acceleration in a four ion (C, H, Si, and O) simulation. We find significant modification of the ion velocities by the ponderomotive force during the laser pulse, but at late times a velocity structure approaching that of self-similar flow is obtained.

Comparison of Electron Transport Experiments at Laser Wavelengths of 1.06 μm and 0.35 μm*

E. M. Campbell, W. C. Mead, R. E. Turner, F. Ze, G. Stradling,
D. L. Matthews, G. Tirsell, B. Pruett, P. H. Lee,
G. Hermes, D. W. Phillion

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Lawrence Livermore National Laboratory
Livermore, California 94550

Abstract

We present the results of electron transport experiments with incident laser wavelengths of 1.064 μm and 0.355 μm using beryllium coated aluminum targets. The targets were irradiated with 600-700 psec near-Gaussian laser pulses at a peaked absorbed irradiance of $\sim 10^{14}$ W/cm^2.

A wide variety of diagnostics ($0.1 < h\nu < 70$ keV) measured the absolute yield, temporal history, and fall-off of x-ray emission as the Be coating thickness was increased. In addition, the velocity of the shock wave launched by the ablating plasma was also measured using specially fabricated targets and an absolutely timed optical streak camera.

The experimental results will be compared to hydrocode simulations. Emphasis will be placed on a self-consistent matching of the simulations with all of the experimental observables.

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

Mapping of Fast-Electrons Energy Deposition in Laser Target Interaction

F. AMIRANOFF and A. POQUERUSSE

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Laboratoire de Physique des Milieux Ionisés
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Fast electrons created during Laser-Target interactions lose their energy in the corona by acceleration of fast ions or in the target itself close to ("local deposition") or far from ("remote deposition") the focal spot. We measured the K emission from the target, which is typical of fast electrons entering cold material. The local signal was measured with an X ray crystal spectrometer and the remote deposition with a properly filtered X-ray pinhole camera.

Results are obtained at $\lambda = 1.06$ µm laser wavelength, $I \simeq 10^{15}$ W/cm^2 and $\tau = 100$ ps and 200 ps pulselengths, and with plastic coated targets of different Z material. The energy deposited in the target represents a non-negligible fraction of the incident laser energy.

The geometry of the deposition is found to be very dependent on the background pressure in the target chamber because of the free propagation of the fast electrons in a good conducting plasma.

Theoretical/Experimental Status of our Knowledge of Ion Stopping Power in Partially Ionized Plasmas *

Thomas A. Mehlhorn
Sandia National Laboratories
Albuquerque, NM 87185

In recent months we have made exciting strides in our ability to accurately model ion energy loss in partially ionized plasmas. This progress is largely a result of recent experiments which have actually measured the energy loss of deuterons in both mylar and aluminum stopping foils by neutron time-of-flight measurements.[1] These experimental results clearly indicate an enhanced stopping power of a partially ionized plasma as compared to that of a cold solid--as predicted by theory.[2] However, we have found that an increased level of sophistication in our atomic physics modeling is necessary to obtain quantitative agreement between hydrodynamic simulations and experimental measurements. In particular, we have used a Herman-Skillman model of the atom to include the effects of closed sub-shells in our calculations of the average ionization potential ($\overline{I}$) for partially ionized atoms; these $\overline{I}$ values are then used in a standard Bethe model to predict the stopping power of partially ionized atoms. Using these theoretical values for $\overline{I}$, we obtain good agreement with experimentally measured stopping powers. This validation of our calculation for low-Z materials gives us increased confidence in our ability to predict ion energy loss in high-Z materials where similar experiments are planned, but have not yet been completed.

[1] F. C. Young, et al., 1981 IEEE International Conference on Plasma Science, p. 91.

[2] T. A. Mehlhorn, J. Appl. Phys. 52, 1981, p. 6522.

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*This work supported by the U. S. Department of Energy under Contract DE-AC04-76-DP00789.

Beam and Deposition Stability in Light Ion Fusion Targets*

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Sandia National Laboratories
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ABSTRACT

A quantitative review of the plasma stability of beam-target and deposition processes in parameter regimes appropriate to light ion driven inertial confinement fusion targets has been undertaken. The emphasis is on electrostatic and electromagnetic streaming instabilities driven by a charge and current neutralized ion beam. The analysis is conducted under the assumptions that the beam is collisionless and that the target medium is homogeneous and infinite in extent. In the ranges of parameters relevant to the beam and target (1-100 TW/cm^2 power intensity, 4 MeV protons or appropriately scaled voltage for other light ions, solid to one percent solid density of target material, and plasma temperatures between 10 and 1000 eV), none of the streaming instabilities possesses a sufficiently large growth rate to be of concern. Also discussed are two thermal instabilities: a potentially unstable interaction involving ion beam range shortening as the target temperature increases, and a fluid condensation instability. Although no conclusive results regarding the condensation instability in light ion fusion targets are yet available, the range shortening interaction is found to be a stable process.

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*This work supported by the U. S. Department of Energy under Contract DE-AC04-76-DP00789.

AN INTENSE FOCUSED ION DIODE PRODUCED BY A CO_2 LASER*

By

C. Barnes, E. Lindman, D. Forslund, J. Brackbill, K. Lee
J. Kindel, M. Klein, T. H. Tan, J. Kephart, W. Ehler,
D. Bach, G. Kyrala, D. Giovanielli, and H. Rutkowski

University of California
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ABSTRACT

We present evidence from theory and experiment of an intense, focused fast-ion diode with an efficiency of 20-25% of incident CO_2 laser light. A sizeable fraction of incident CO_2 laser light has been shown[1] to go into fast-ion blow off which is moderately well collimated.[2] Recent theoretical modeling[3] has shown that this is larger for smaller laser spots due to intense self-generated magnetic fields. At the same time the emission occurs in a thin layer near the target surface and essentially normal to the target surface. All these features indicate that a high quality diode is set up on the target surface and that a modest curvature of the target surface should produce a focusable ion diode.[4] The chief pro lem of focusability comes from the thermal spread in the beam which is enhanced due to multiple ion charge states in the expanding plasma. The restriction to essentially a single Z/A should greatly improve focusability. Calculations and experiments to verify these effects will be described.

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

1. J. F. Kephart, paper submitted to this conference.

2. A. W. Ehler, High-Energy Ions from a CO_2 Laser-Produced J. App. Phys. 46, 2464 (1975)

3. D. W. Forslund and J. U. Brackbill, Magnetic Field Induced Surface Transport on Laser Irradiated Foils, submitted to Phys. Rev. Letters (1982).

4. J. M. Kindel and E. L. Lindman, Target Designs for Energetic Ion, Nuc. Fus. 19, 596 (1979).

SESSION JP

POSTER SESSION:

SRS, SELF-FOCUSSING, HYDRODYNAMICS AND TRANSPORT

THURSDAY, MAY 13

11:00 - 12:15

Raman Scatter in Large Underdense Plasmas*

W. L. Kruer and Kent Estabrook
University of California, Lawrence Livermore National Laboratory
Livermore, CA 94550

Abstract

The Raman instability can be a significant source of hot electrons in large underdense plasmas irradiated with intense laser light. We discuss simulations and simple theoretical models which shed light on the role of Raman back and forward scatter and the concomitant hot electron generation. Applications are made to some recent experiments.

*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.

RAMAN BACK AND FORWARD SCATTER OF CO_2 LIGHT FROM A GAS JET TARGET

by

J. Meyer

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STIMULATED RAMAN SCATTERING IN THE PRESENCE OF ION ACOUSTIC FLUCTUATIONS

W. Rozmus, R. Fedosejevs and A. A. Offenberger
Department of Electrical Engineering
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Edmonton, Alberta T6G 2G7, Canada

Threshold conditions are analyzed for stimulated Raman backscatter from an underdense plasma in the presence of ion-acoustic fluctuations. These calculations are partly motivated by the experimental observation of SRS[1] in the presence of strong stimulated Brillouin scattering when high power CO_2 laser radiation interacts with a magnetically confined plasma column.

For typical ion-acoustic spectra which could result from SBS, a reduced collisional threshold for the Raman instability is found due to transfer of energy from ion-acoustic fluctuations into Langmuir waves. The influence of ion-turbulence also manifests itself by a small phase shift for the Langmuir wave. This latter effect can play an important role in an inhomogenous plasma since a phase mismatch created by a density gradient can be compensated for by an inhomogeneity in the ion-acoustic spectrum accompanying convective growth of SBS. In this case, when the turbulence exceeds a certain level, convective growth of Langmuir waves can change to an absolute instability.

[1] R. Fedosejevs et al., "Experimental Study of Raman Scattering From Long Scale Length Underdense Plasmas", presented at this Conference.

HOT ELECTRON PRODUCTION AND RAMAN SCATTERING BELOW QUARTER CRITICAL DENSITY

by

R. D. Brooks

University of Washington
Seattle, Washington

Time Resolved SRS Measurements from 0.53 μm Laser Plasma Experiments*

R. E. Turner, D. W. Phillion, E. M. Campbell, K. G. Estabrook

University of California
Lawrence Livermore National Laboratory
Livermore, CA 94550

Abstract

We report temporally and spectrally resolved measurements of stimulated Raman scattering from high intensity, 0.53 μm laser plasma experiments on disk targets. The observed scattering is principally from densities below quarter critical, and is observed to occur simultaneously over a wide range of wavelengths (0.72 μm < λ < 0.9 μm). We compare the observed time history with hydrodynmaic code calculations for the underdense density profile, and with analytical estimates of intensity thresholds.

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

Influence of Inverse Bremsstrahlung on Wavelength Scaling for Reactor Size Spherical Targets*

J.H. Gardner, M.J. Herbst and M.H. Emery

Naval Research Laboratory, Washington, DC 20375

Large scale length plasmas can dramatically affect the absorption processes of high intensity lasers. Deleterious plasma effects such as Brillouin and Raman scattering are strongly influenced by the plasma gradient scale lengths. On the other hand inverse Bremsstrahlung absorption is also increased as the density scale length increases. This process may relax some of the symmetry constraints for short wavelength lasers by moving the absorption region to lower density plasma at radii considerably beyond the critical radius.

In most analytic models scaling laws are derived on the assumption that the absorption takes place at or near the critical surface. We have derived scaling laws using a one dimensional numerical model in spherical geometry which includes both inverse Bremsstrahlung and resonant absorption at the critical surface. We examine the influence of inverse Bremsstrahlung on these scaling laws. Previous results based on a parameter regime where absorption was at or near the critical surface found a strong wavelength (going as $(I\lambda^{3.8})^{.7}$) scaling for the separation distance from ablation to critical surface.[1] This separation distance is important in the smoothing of laser nonuniformities by thermal conduction in direct illumination fusion schemes. We find that for sufficiently large target radii the increased plasma density gradient scale length leads to inverse Bremsstrahlung absorption at radii considerably greater than the critical surface radii thereby increasing the radius of the conduction zone and therefore the thermal smoothing of laser nonuniformities. This is especially true of shorter wavelength laser radiation. By going to sufficiently large radii it may be possible to overcome the short separation distance of ablation to critical surface and regain most of the advantages of short wavelength lasers in terms of reduced deleterious plasma instabilities.

Using the flux-corrected-transport (FCT) hydrodynamics codes developed at NRL we investigate the scaling laws for pressure and separation distance in a regime appropriate to reactor size target design. We look at the effect of inverse Bremsstrahlung on the scaling laws and look for a regime where both the requirements for good smoothing and absorption may be met.

*Work supported by U.S. Department of Energy and Office of Naval Research

[1] J.H. Gardner and S.E. Bodner, Phys. Rev. Lett. 47, 1137 (1981)

Transient Self Focusing.* A. SCHMITT and R.S.B. ONG, University of Michigan.---

The propagation of a laser pulse in an initially cold dense plasma is investigated via the moment method approach to the quasi-optic equations. Both ponderomotive and thermal self focusing are considered in the time dependent case in which the pulse temporal length is of the same order as the plasma hydrodynamic response time. The whole-beam self focusing effects and the distortion and break up of the initially gaussian radial pulse distribution are explored in order to study the onset of beam filamentation. Analytic and numerical results will be presented.

*Supported by grant AFOSR-81-0029

ACCELERATION OF TARGETS BY STEADY ABLATION AND IMPACT

by

B. Ahlborn, J. Kwan, and A. Ng

The Univ. of British Columbia
Dept. of Physics
Vancouver, B.C. Canada

Abstract:

The acceleration of foil targets is at present often interpreted in terms of the rocket model with an ideal rigid "payload". This paper describes the acceleration of real compressible pushers and targets by successive shocks and expansion waves. The forward going shocks accelerate and compress the material whereas the backward traveling expansion waves further accelerate but decompress the material. In our model the laser intensity is assumed to be constant throughout the acceleration time. The strength of the shocks depends on the ablation pressure which is a function of the laser intensity; the strength of the expansion waves is related to the density ratios of the pusher, buffer and target materials. In general, the increase of the pusher velocity is accompanied by a substantial reduction in density, hence placing a limit on the final momentum gain. As a result, the transfer of momentum from the pusher foil onto a stationary target foil during impact is ineffective.

In contrast to the conclusion of the solid rocket model, our results suggest that it is impossible to obtain high compression by the impact of accelerated pusher foils onto stationary targets.

ANALYTICAL MODEL FOR A LASER-DRIVEN IMPLOSION OF MICROBALLOONS

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(FRANCE)

-oOo-

In order to study the implosion of laser-irradiated microballoons, a first stage is to build up a model which describes the implosion of a microballoon subject to a constant pressure. Numerical simulations permit to draw ρT-diagrams for the DT and for the pusher : these show that, after a time t_i, the implosion may be described by an isentropic compression, but with an adapted γ. At this time t_i, the DT has undergone a"preheating" which is modelised so that the initial DT conditions are known before the application of the isentropic compression. The model gives the final compression and temperature of the DT and the number of neutrons produced by the implosion. Comparisons between the results of this model and those obtained by numerical simulations have been made to test the model : they show a good agreement.

The application of this model for the implosion of laser-irradiated microballoons is made by its coupling to an ablation model such as those given in the litterature, giving, specially, the ablation pressure as a function of the power delivered by the laser.

TOKAMAK PELLET EVAPORATION EXPERIMENT AND THE CLASSICAL FLUX LIMIT PARAMETERS

by

F. J. Mayer

KMS Fusion, Inc.
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Time-Resolved X-Ray Line Diagnostics of Laser-Produced Plasmas*

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and
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Abstract

We have examined the underdense plasma conditions of laser irradiated disks using K x-rays from highly ionized ions. A 900 ps laser pulse of 0.532 μm light is used to irradiate various Z disks which have been doped with low concentrations of tracer materials. The tracers whose Z's range from 13 to 22 are chosen so that their K x-ray spectrum is sensitive to typical underdense plasma temperatures and densities. Spectra are measured using a time-resolved crystal spectrograph recording the time history of the x-ray spectrum. A spatially-resolved, time-integrated crystal spectrograph also monitors the x-ray lines. Large differences in Al spectra are observed when the host plasma is changed from SiO_2 to PbO or In. Spectra will be presented along with preliminary analysis of the data.

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

Streaked Free-Bound Spectra From Coronal Plasmas for Studying Electron Distributions*

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Abstract

Langdon[1] has considered the case of laser plasma interaction when $Z(v_0/v_e)^2 \lesssim 1$ and has shown that absorption by inverse bremsstrahlung (I.B.) can lead to a non-Maxwellian velocity distribution. Under such circumstances the origin of this phenomenon stems from the fact that the electron-electron collisions are not rapid enough to Maxwellianize the flat-topped velocity distribution produced by (I.B.). In this work we have attempted to measure the presence of a non thermal electron distribution in the coronal plasma region of a laser heated aluminum disk. We have assured that inverse bremsstrahlung is the dominant absorption mechanism by performing the experiments with λ_L=0.532 μm laser light at intensities high enough ($\sim 10^{16}$ W/cm^2) to satisfy the $(v_0/v_e)^2 \gtrsim 1$ criterion. These experiments are performed by measuring the K-shell recombination radiation using a time-resolved x-ray spectrograph. The shape of the recombination spectrum should be similar to the electron energy distribution function. A complete description of our data will be given including the deviation, if any, from the spectrum associated with a Maxwellian electron distribution.

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

[1] A. Bruce Langdon, Phys. Rev. Lett. 44, 575 (1980).

Suprathermal X-Ray Spectra From Laser-Plasma Interaction*

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Abstract

We present the measurement and code simulation of the suprathermal x-ray spectra from laser-plasma interaction, using the 1.06 μm Shiva laser. The targets included Au, Ni, Cu, Zn, Fe, Pd and Ta micro-disks. The laser intensity, energy and pulse length ranged from 10^{14} to 10^{17} w/cm^2, 0.5 to 4 kJ and 0.6 to 5 ns respectively. The detectors used were filter-fluorescer[1] and hyper-filter-fluorescer[2] spectrometers and filtered NaI (Tl) crystals[1]. The x-ray energy covered was from 6 to 350 keV. The experimental results are compared with the LASNEX code[3] calculation, upgraded with the recent parameterization of the bremsstrahlung spectrum[4].

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

[1]H. N. Kornblum, B. L. Pruett, K. G. Tirsell and V. W. Slivinsky, Bull. Am. Phys. Soc. 23, 806 (1978).

[2]C. L. Wang, Rev. Sci. Instr. 52, 1317 (1981).

[3]G. B. Zimmerman, UCRL-74811, 1973 (unpublished).

[4]I. J. Feng and R. H. Pratt, University of Pittsburgh Physics Department Report PITT-266, 1981 (unpublished).

SESSION KD

DISCUSSION:

WHAT HAS BEEN LEARNED, FUTURE PROSPECTS, AND ARRANGEMENTS FOR NEXT MEETING

THURSDAY, MAY 13

12:15 – 1:00

DISCUSSION LEADER:

B. AHLBORN

UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, CANADA

12th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

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