INRS ÉNERGIE VARENNES

11th ANNUAL

ANOMALOUS ABSORPTION CONFERENCE

JUIN 2 - 5

MONTRÉAL, 1981

Organisée par:

INRS-ÉNERGIE
(UNIVERSITÉ DU QUÉBEC)

En collaboration avec:

LE DÉPARTEMENT DE PHYSIQUE
UNIVERSITÉ DU QUÉBEC À MONTRÉAL

Université du Québec à Montréal

REMERCIEMENTS

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ELEVENTH ANNUAL

ANOMALOUS ABSORPTION

CONFERENCE

SESSION SCHEDULE

1. SBS, Filamentation, Self-Focussing
Tuesday, June 2, 8:30 - 12:15
Chairman: H.A. Baldis (NRC, Ottawa).

2. Nonlinear Wave Effects Far Away From Incident Laser Frequency
Tuesday, June 2, 14:15 - 16:30
Chairman: L. Goldman (URLLE, Rochester).

2D. DISCUSSION: What can we Learn from Instability Emissions?
Tuesday, June 2, 16:30 - 17:30
Discussion leader: C.E. Max (LLNL, Livermore).

3. Absorption and Reflection Studies
Wednesday, June 3, 9:00 - 10:45
Chairman: E. Fabre (E.P., Palaiseau, France)

P. Poster Session: Microwave, Fast Electrons, Transport
Hydrodynamics, Different Plasmas
Wednesday, June 3, 11:00 - 12:30

4. Heating, Acceleration, Fast Electron Generation
Wednesday, June 3, 14:15 - 18:00
Chairman: R.J. Mason (LANL, Los Alamos).

Transport Experiments
Thursday, June 4, 9:00 - 12:00
Chairman: H. Pépin (INRS-Energie, Varennes)

6. Transport Theory: How Inhibited is your Transport?
Thursday, June 4, 14:15 - 16:15
Chairman: S. Bodner (NRL, Washington, D.C.)

6D. DISCUSSION: Evidence + Theory = ?
Thursday, June 4, 16:15
Discussion leader: R.L. Morse (U. of Arizona).

7. Short Wavelength, Overview
Friday, June 5, 9:00 - 10:30
Chairman: F. Mayer (KMS Fusion).

7D. DISCUSSION: What have we learned?
What are the questions for next year?
Friday, June 5, 10:30
Discussion leader: R.G. Evans (SRC, Rutherford).

ELEVENTH ANNUAL

ANOMALOUS ABSORPTION

CONFERENCE

Tuesday June 2 - Friday June 5th, 1981

Université du Québec à Montréal, Québec, Canada

Salle Marie Gérin-Lajoie, Pavillon Judith Jasmin

Organisée par

INRS-Energie, Université du Québec

En collaboration avec

Le Département de Physique

Université du Québec à Montréal

PRELIMINARY SCHEDULE

MONDAY, June 1st

19:00 - 22:00	Registration/check-in Holiday Inn, Place Dupuis
TUESDAY, June 2	Salle Marie Gérin-Lajoie
8:00 - 11:00	Registration

Session 1: SBS, FILAMENTATION, SELF-FOCUSSING

8:30 - 12:15	Chairman: H.A. Baldis (NRC)
8:30 - 8:45	Welcome and announcements
8:45 - 9:00 1-1:	"Scattered Light Measurements at 1 μm, 0.5 μm and 0.35 μm Irradiations", R.E. Turner, D.W. Phillion, E.M. Campbell, W.C. Mead and F. Ze (Livermore).
9:00 - 9:15 1-2:	"Time Resolved Measurements of Brillouin Backscatter from Plasmas produced by .35 μm Lasers", L. Goldman, K. Tanaka, W. Seka, E. Williams and R. Bingham (Rochester).
9:15 - 9:30 1-3:	"Stimulated Brillouin and Absorption Studies with a Multiline Laser", C. Gouédard (Limeil).

9:30 - 9:45 1-4: "Stimulated Scattering from the Gas Jet Target", D.C. Slater, G.E. Busch, G. Charatis, F.J. Mayer, R.J. Schroeder and J.A. Tarvin (KMS Fusion).

9:45 - 10:00 1-5: "High Intensity Stimulated Brillouin Backscatter from Large f/Number Irradiance at 10.6 μm of Long Plasma Columns", R. Fedosejevs, W. Tighe, D.C.D. McKen and A.A. Offenberger (Univ. of Alberta).

10:00 - 10:15 1-6: "Brillouin Amplification of a Broad-Band Source May Determine Sidescatter Frequency for Oblique CO_2 Laser Incidence on Solid Targets", G.R. Mitchel, B. Grek, T.W. Johnston, H. Pépin and F. Martin (INRS-Energie).

10:15 - 10:30 1-7: "Brillouin Backscatter from a Short-Pulse CO_2 Laser Incident on a Prepulse Plasma", R. Decoste (IREQ), P. Lavigne, H. Pépin and G. Mitchel (INRS-Energie).

10:30 - 10:45 CAFE

10:45 11:00 1-8: "Time Evolution of SBS in Bounded Systems", J.J. Thomson (TRW) and C.J. Randall (Livermore).

11:00 - 11:15 1-9: "Calculations of Brillouin Backscatter in Laser-Produced Plasmas", D.G. Colombant and W.M. Manheimer (NRL).

11:15 - 11:30 1-10: "Laser Beam Steering by Stimulated Brillouin Forward Scatter", C. Randall (Livermore).

11:30 - 11:45 1-11: "Time Dependent Effects in Self Focussed Light Beams", D.J. Nicholas (Rutherford).

11:45 - 12:00 1-12: "Filamentation at Short Wavelengths", R. Bingham, R. Short, E. Williams, D. Villeneuve and M.C. Richardson (Rochester).

12:00 - 12:15 1-13: "Filamentation of Electromagnetic Radiation in Flowing Plasmas", R.W. Short, R. Bingham and E.W. Williams (Rochester).

12:15 - 14:00 DINNER

Session 2: NONLINEAR WAVE EFFECTS FAR AWAY FROM INCIDENT LASER FREQUENCY
14:15 - 16:30 Chairman: L. Goldman (Rochester).

14:15 - 14:30 2-1: "Time Resolved Studies of the Two Plasmon Decay Instability at 10.6 μm", H.A. Baldis and C.J. Walsh (NRC)

14:30 - 14:45 2-2: "Spectrally Resolved Measurements of Raman Backscatter from Plasmas Produced by .35 μm Laser", K. Tanaka, L.M. Goldman, M. Richardson and W. Seka (Rochester).

14:45 - 15:00 2-3: "Propagation Effects on Raman Spectra", E.A. Williams R. Short and R. Bingham (Rochester).

15:00 - 15:15 2-4: "Parametric Effects in Quarter-Critical Plasma", P. Koch (KMS Fusion).

15:15 - 15:30 2-5: "100 keV X-Ray Continuum from Two-Plasmon Decay", J.H. McAdoo and L.M. Goldman (Rochester).

15:30 - 15:45 2-6: "Electron Acceleration by Raman Back and Forward Scatter", N.A. Ebrahim (Yale Univ.), H.A. Baldis (NRC), J.M. Dawson (UCLA), and T. Tajima (Univ. of Texas).

15:45 CAFE

16:00 - 16:15 2-7: "Self-Focussing and High Harmonics Production in CO_2 Laser-Produced Plasmas", R.L. Carman and R.F. Benjamin (Los Alamos).

16:15 - 16:30 2-8: "Harmonic Light - A View of the Critical Surface", B. Bezzerides and R. Jones (Los Alamos).

16:30 2-D: DISCUSSION: WHAT CAN WE LEARN FROM INSTABILITY EMISSIONS?
Discussion leader: C.E. Max (Livermore).

18:00 COCKTAIL PARTY (in lieu of banquet).

WEDNESDAY, June 3

Session 3: ABSORPTION AND REFLECTION STUDIES
9:00 - 10:45 Chairman: E. Fabre (Palaiseau).

9:00 - 9:15 3-1: "A Model of Absorption and Reflection on Intense Laser Light by Long Gradient Length Plasma", T. Speziale, W.B. Fechner and D. Mitrovich (KMS Fusion).

9:15 - 9:30 3-2: "Simulations of Absorption and Reflection of Intense Laser Light by Long Gradient Length Plasma", W.B. Fechner, T. Speziale, D. Mitrovich, D.J. Tanner (KMS Fusion).

9:30 - 9:45 3-3: "Heating in Underdense Plasmas", B. Lasinski, B. Langdon and W. Kruer (Livermore).

9:45 - 10:00 3-4: "Analysis of Light Absorption Experiment at Different Wavelengths", C. Garban-Labaune, E. Fabre, A. Michard, J. Virmont and M. Wenfeld (Palaiseau) C.E. Max (Livermore).

10:00 - 10:15 3-5: "Results of Experimental Target Studies at 0.35 μm", F. Ze, M. Campbell, R. Turner, V. Rupert, C.E. Max, W. Mead and W. Kruer (Livermore).

10:15 - 10:30 3-6: "Interpretation of Argus 3 ω_0 Disc Irradiation Experiments", C.E. Max, W.C. Mead, W.L. Kruer, F. Ze and M. Campbell (Livermore).

10:30 - 10:45 3-7: "0.35 μm Interaction Experiments at LLE", W. Seka, L. Goldman, M. Richardson, J. Soures, B. Yaakobi, T. Boehly, R. Keck, K. Tanaka, D.M. Villeneuve, R. Boni, R. Bingham, S.R. Craxton, J. Delettrez, R.L. McCrory and E. Williams (Rochester).

10:45 CAFE

Session P: POSTER SESSION: MICROWAVE, FAST ELECTRONS, TRANSPORT
11:00 - 12:30 HYDRODYNAMICS, DIFFERENT PLASMAS

P-1 "Study of Microwave Backscatter and Filamentation in a Large Scale Target Plasma", W. DiVergilio, J. Thomson, W. Robinette, H. Goede (TRW).

P-2 "Electron Heating and Heat Transport due to P-Polarized Microwaves of Modest Intensity", K. Mizuno, D. Rasmussen, F. Kehl, J.S. DeGroot, Wee Woo and P. Rambo (U.C. Davis).

P-3 "Stimulated Brillouin Scattering", R.A. James, K. Mizuno, K. Randall and J.S. DeGroot (U.C. Davis).

P-4 "Backscatter and Sidescatter from Preformed (Z pinch) Plasmas", C.J. Walsh, J.E. Bernard and J. Meyer (Univ. British Columbia).

P-5 "Plasma Created by Two-Shock-Wave Collision, as a Target Plasma for Laser-Plasma Interaction Experiment", Z.A. Pietrzyk and R.D. Brooks (Univ. of Washington).

P-6 "Plasma Spectroscopy on a Laser Irradiated Gas Jet", D.L. Matthews, L.N. Koppel (Livermore), D. Slater, F. Mayer, R. Johnson, G. Charatis, G. Busch, J. Tarvin, D. Sullivan and R. Schroeder (KMS Fusion).

P-7 "Acceleration of Fast Electrons in E.M. Fields - Plasma Interaction", X. Fortin (Limeil).

P-8 "HotElectron Transport in Laser Interaction with Solid Targets", H.A. Baldis (NRC), C. Joshi (UCLA), N.A. Ebrahim (Yale Univ.).

P-9 "Time Resolved (~ 20 ps) Thomson Scattering at and Above Critical Density in 10.6 μm Experiments", H.A. Baldis and C.J. Walsh (NRC).

P-10 "Hydrodynamical Description of an Off-Equilibrium Fluid", A. Decoster (Limeil).

P-11 "Numerical Study of Thermal Electron Transport", J. Virmont (Palaiseau), J.P. Matte (INRS-Energie).

P-12 "Steady-State Ablative Flow", D.G. Colombant and W.M. Manheimer (NRL).

P-13 "Flow Analysis in Place Ablative Regime", R. Fabbro et E. Fabre (Palaiseau), C.E. Max (Livermore).

P-14 "Can Targets be Accelerated by Hot Electron Explosions? - An Analytical Model", B. Ahlborn (Univ. British Columbia).

P-15 "Nonlinear Development of Multi-Frequency Rayleigh-Taylor Instability in Ablation Driven thin Shells", C.P. Verdon, R.L. McCrory and R.L. Morse (Rochester).

P-16 "Lagrangian Formulation of the Ponderomotive Force", J. Teichmann (Univ. of Montreal).

P-17 "Cerenkov Masers: A Possible Plasma Heating Source", J. Walsh, J. Branscum, J. Golub, R.W. Layman, D. Speer, S. Von Laven (Dartmouth College).

P-18 "Parametric Instability Cascades: Lotka-Volterra Model for 4 Daughter Pairs and Intrinsic Stochasticity", G. Picard, T.W. Johnston (INRS-Energie).

12:30 - 14:00 DINNER

Session 4: HEATING, ACCELERATION FAST ELECTRON GENERATION
14:15 - 18:00 Chairman: R.J. Mason (Los Alamos).

14:15 - 14:30 4-1: "Hydrodynamic Flos from Laser-Irradiated Foils", M.J. Herbst, J. Grun, R.R. Whitlock, S.P. Obenschain, J.A. Stamper and M. Emery (NRL).

14:30 - 14:45 4-2: "Ablation Driven by Local Conversion of Short Wavelength Laser Light", L. Montierth, R. Morse (Univ. of Arizona).

14:45 - 15:00 4-3: "Internal Heat Deposition in Ablatively Accelerated Targets", B.H. Ripin, E.A. McLean, J. Grun, S.P. Obenschain, J.A. Stamper, M.J. Herbst and R.R. Whitlock (NRL).

15:00 - 15:15 4-4: "Measurements of Mass Ablation Rates and Ablation Pressure in Plane and Spherical Geometry at Various Wavelengths", J.D. Kilkenny, T.J. Goldsack, S.A. Veats (Imperial College), P. Cunningham, C.S. Lewis (Queen's Univ.), M.H. Key, P.T. Rumsky (Rutherford).

15:15 - 15:30 4-5: "Effects of Laser Beam Uniformity on the Acceleration of Ablatively Driven Targets", J. Grun, S.P. Obenschain, B.H. Ripin, M.J. Herbst and E.A. McLean (NRL).

15:30 - 15:45 4-6: "Collisional DC Magnetic Field in Resonance Absorption of Light", J.C. Adam, A. Gourdin-Servenière, P. Mora and R. Pellat (Palaiseau).

15:45 - 16:00 4-7: "Hydrodynamic Efficiency of Laser Irradiated Pellet Targets", C. Yamanaka, N. Nishimura, H. Azechi, H. Fujita, T. Yabe and S. Nakai (Osaka Univ.).

16:00 CAFE

16:15 - 16:30 4-8: "Analysis of the 22X Streaked X-ray Microscope Date: Self Emission r-t Plots of Au Disks, and Backlit r-t Plots of Ablatively Accelerated Al Disks", M.D. Rosen and R.H. Price (Livermore).

16:30 - 16:45 4-9: "Observation of a Two-Component High Energy Electron Distribution in Double-Pulsed CO_2 Laser-Induced Plasmas", F. Begay, D.W. Forslund, smf D.E. Casperson (Los Alamos).

16:45 - 17:00 4-10: "Return Current Electron Streams in High Intensity Laser Target Interaction", N.H. Burnett, N.A. Ebrahim, P.A. Jaanimagi and C. Joshi (NRC).

17:00 - 17:15 4-11: "Non-Random Suprathermal Electron Emission in Resonance Absorption", P. Kolodner (Bell Lab.) E. Yablonovitch (Exxon Res.).

17:15 - 17:30 4-12: "Production of Hot Electrons in a Microwave Plasma Interaction", A.Y. Lee, N.C. Luhmann, B. Gu and M. Rhodes (U.C.L.A.), Y. Nishida Utsunomiya Univ., Japan) S.P. Obenschain (NRL), J.R. Albritton (Livermore), E.A. Williams (Rochester).

17:30 - 17:45 4-13: "Ponderomotive Phase Effects and Electron Acceleration in Resonance Absorption", J. Kupersztych (Limeil).

THURSDAY, June 4

Session 5: TRANSPORT EXPERIMENTS

9:00 - 12:00 Chairman: H. Pépin (INRS-Energie).

9:00 - 9:15 5-1: "Absence of Fast Electrons in Laser-Irradiated Gas-Jet Targets", J.A. Tarvin (KMS Fusion).

9:15 - 9:30 5-2: "Evidence for Classical Electron Thermal Conduction in the Gas Jet Target", F.J. Mayer, G.E. Busch, G. Charatis, D.K. Jarrell, R.J. Schroeder, D.C. Slater, and J.A. Tarvin (KMS Fusion), D.L. Matthews, L.N. Koppel (Livermore).

9:30 - 9:45 5-3: "Transport Studies by Thin Film Irradiation", F. Amiranoff, K. Eidmann, R. Fedosejevs, R. Petsch, R. Sigel, G. Spindler, Y.L. Teng (Garching).

9:45 - 10:00 5-4: "Comparison of Transport Inhibition Measurements by Different Methods", E. Fabre (Palaiseau).

10:00 - 10:15 5-5: "Energy Transport in Laser Irradiated Targets", C. Yamanaka, K. Mima, T. Yabe, T. Mochizuki and H. Azechi (Osaka Univ.).

10:15 - 10:30 5-6: "Suprathermal Electron Transport in CO_2 Laser Target Experiments", J.C. Kieffer, H. Pépin (INRS-Energie), R. Décoste (IREQ).

10:30 CAFE

10:45 - 11:00 5-7: "Enhanced Energy Deposition by Fast Electron from High Intensity Laser Plasma Interactions", J.D. Kilkenny (Imperial College).

11:00 - 11:15 5-8: "Observation of Flux Limitation in Electron Thermal Conduction", B.L. Wright (Los Alamos).

11:15 - 11:30 5-9: "Heat Transport, Ablation Rate and Pressure Measurements in UV-Laser Target Interaction Experiments", B. Yaakobi, T. Boehly, P. Bourke, J. Delettrez, L.M. Goldman, R.L. McCrory, W. Seka and J.M. Soures (Rochester).

11:30 - 11:45 5-10: "Analysis and Simulation of Layered-Slab Transport Experiments at 0.35 μm Wavelength", W.C. Mead, E.M. Campbell, W.L. Kruer, C.E. Max, J.R. Albritton, R.J. Olness, Y.T. Lee (Livermore).

11:45 - 12:00 5-11: "Layered Target Transport Experiments at $3\omega_0$", M. Campbell, W. Mead, P. Lee, G. Stradling, J. Foster, D. Matthews, L. Koppel, J. Trainor, N. Holmes, B. Stevenson, B. Pruett, C. Hatcher, F. Ze and R. Turner (Livermore)

12:00 - 14:00 DINNER

Session 6: TRANSPORT THEORY: HOW INHIBITED IS YOUR TRANSPORT?
14:15 - 16:15 Chairman: S. Bodner (NRL).

14:15 - 14:30 6-1: "Fokker-Planck Simulations of Energy-Transport", A.R. Bell (Rutherford).

14:30 - 14:45 6-2: "Classical Heat Transport by Non Maxwell-Boltsmann Electron Distribution", J.R. Albritton (Livermore).

14:45 - 15:00 6-3: "Analysis of Thermal Electron Transport 'Inhibition' in Laser Plasma Interactions under Various Laser and Target Conditions", J. Delettrez, R.L. McCrory, D. Shvarts, C.P. Verdon, B. Yaakobi (Rochester).

15:00 - 15:15 6-4: "A Self-Consistent Flux-Limited Extension of the Spitzer-Härm Thermal Conductivity in Steep-Temperature Gradients", D. Shvarts, J. Delettrez, R.L. McCrory, C.P. Verdon (Rochester).

15:15 - 15:30 6-5: "Thermal Transport Inhibition in Laser Produced Plasmas", R.J. Mason (Los Alamos).

15:30 CAFE

15:45 - 16:00 6-6: "Comments on Recent Laser-Matter Interaction Experiments", P. Hammerling (La Jolla Inst.).

16:00 - 16:15 6-7: "Hot Electron Transport in Thin Planar and Spherical Systems", M.A. True (KMS Fusion).

16:15 6-D: DISCUSSION ON TRANSPORT: EVIDENCE + THEORY = ? Discussion leader: R.L. Morse (U. Arizona).

CASH BAR

FRIDAY, June 5

Session 7: SHORT WAVELENGTH OVERVIEW
9:00 - 10:30 Chairman: F. Mayer (KMS Fusion)

9:00 - 9:15 7-1: "Propagation of Relativistically-Intense, Very Short Pulses", B. Langdon and J. Pettibone (Livermore).

9:15 - 9:30 7-2: "Theoretical Interpretation of Short Wavelength Interaction Experiments", R.S. Craxton, J. Delettrez, R.L. McCrory, D. Shvarts, R. Keck and W. Seka (Rochester).

9:30 - 9:45	7-3:	"Transport Inhibition and Wavelength Dependence", R. Fabbro, E. Fabre, M. Amiranoff, C. Garban-Labaune, J. Virmont and M. Wenfeld (Livermore).
9:45 - 10:00	7-4:	"2-D Fluid Simulations of Non-Uniformly Irradiated Targets for Inertial Fusion", R.G. Evans (Rutherford), A.J. Bennet, G.J. Pert (Univ. of Hull).
10:00 - 10:15	7-5:	"Scaling of Physical Processes in Gas Jets to the Next Generation Targets", R.L. Berger, L.V. Powers (KMS Fusion).
10:15		CAFE
10:30	7-D:	DISCUSSION: WHAT HAVE WE LEARN? WHAT ARE THE QUESTIONS FOR NEXT YEAR? Discussion leader: R.G. Evans (Rutherford).
		SITE AND DATE FOR NEXT MEETING.

SESSION 1

SBS, FILAMENTATION, SELF-FOCUSSING

Tuesday, June 2

8:30 - 12:15

H.A. BALDIS

National Research Council

Ottawa

LAWRENCE LIVERMORE LABORATORY

Laser Program

SCATTERED LIGHT MEASUREMENTS AT 1 μm, 0.5 μm, AND 0.35 μm IRRADIATIONS

R.E. Turner, D.W. Phillion, E.M. Campbell, W.C. Mead, and F. Ze, LLNL, Livermore, Ca. 94550.

Scattered light measurements have been obtained during recent Argus experiments at 1ω, 2ω, and 3ω. Gold, titanium, and beryllium disks were irradiated at intensities of 3×10^{13} to 3×10^{15} W/cm^2, with energies of up to 40 J in 700 psec (90 J in the case of 1ω). In the 1ω experiments, temporally and spectrally resolved backscatter measurements were made for SBS; cooled InAs detectors with interference filters were used for spectral measurements of SRS; the level and time history of the 3/2 harmonic emission were measured, as well as the spectral and temporal history of the second harmonic emission. Similar measurements were made during the 2ω and 3ω experiments, except for the harmonic emissions. We discuss possible interpretations of the data as it relates to conditions in the underdense plasma region, noting, among other things, the competition between inverse bremsstrahlung and the parametric instabilities, especially for high Z targets and short laser wavelengths. Estimates are obtained for the electron temperature at quarter critical density from the Raman data. The amount of 3/2 harmonic emission is compared with the level of Raman scattering, and with the energy in fast electrons as inferred from hard X-ray data.

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

June 2-5, 1981

Montreal, Quebec, Canada

TIME RESOLVED MEASUREMENTS OF BRILLOUIN BACKSCATTER FROM PLASMAS PRODUCED BY .35 μm LASERS*

by

L. Goldman, K. Tanaka, W. Seka, E. Williams, and R. Bingham
Laboratory for Laser Energetics
University of Rochester

We have measured the time behavior of backscattered light from planar targets illuminated with .35 μm laser light. The measurements were made with a resolution of 1 Å in the spectral region about the incident frequency. The experiments examined the intensity range between 2 X 10^{13} and 2 X 10^{15} W/cm^2 on targets of CH, Ni and Au. The target angle was varied from 0° to 60° with respect to the target normal. The backscattered light collected by the f/12 focusing lens was spectrally resolved in a 1 meter grating spectrometer and recorded with a 20 psec resolution streak camera equipped with an S-20 photo cathode. The total backscatter intensity increased with pulse duration, incident intensity, and reduced target Z; however, the Brillouin backscatter component never exceeded 2 percent of the incident energy. For normal incident targets the observed spectra showed a rapid broadening with a strong shift to the blue. This blue shift had a maximum of 15 Å on CH targets with a mean shift of 9 Å. These blue shifts are too large to be accounted for by a Doppler shift from the moving critical surface. One possible explanation is that we are observing Brillouin scattering from the underdense plasma at approximately 0.1 n_c which grows from a Fresnel reflection at a density jump at 0.25 n_c due to the self-steeping of the profile induced by the $2\omega_p$ instability. For targets at greater than 10° to the normal, the spectra tend to be shifted to the red rather than the blue. This would be consistent with a Brillouin scatter from the density region nearer n where the flow is expected to be about sonic. The duration of the backscatter is shorter than the incident pulse and is centered about the peak intensity. Higher Z targets show shorter time reflections and reduced intensities consistent with the shorter density scale lengths expected for those targets.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

STIMULATED BRILLOUIN AND ABSORPTION STUDIES WITH A MULTILINE LASER

C. Gouédard + J. Kupersztych

Centre d'Etudes de Limeil, C.E.A., France

STIMULATED BRILLOUIN SCATTERING AND ABSORPTION STUDIES WITH A MULTILINE 1.06 m Nd-LASER

C. GOUEDARD
J. KUPERSZTYCH
CEA, LIMEIL

Stimulated Brillouin Scattering (S.B.S.) saturation by means of an amplitude modulation of the laser radiation is presented.

Theoretically, the growth rate γ_B of Stimulated Brillouin Scattering in an inhomogeneous plasma is essentially determined by density gradient. This is due to the fact that energy and momentum conservation can only be satisfied over the "coherence length" Λ coh $= \left(\frac{Lc}{\omega} \frac{n}{n_c}\right)^{12}$, which plays the role of an effective dissipation mechanism. As a consequence, γ_B is space varying as $\left[n/nc/\left(1 - \frac{n}{n_c}\right)\right]^{12}$ An effective saturation mechanism of S.B.S. can therefore be obtained over some distance by modulating the laser amplitude such that $\Delta T < 2\pi/\gamma_B$ (where ΔT denotes the mean period of the modulation). As a result, more laser energy can reach the critical region where inverse Bremsstrahlung is competitive, yielding absorption increase.

Experimental work displays first a method for achieving a multiline laser radiation at 1.06 µm. The Nd-glass oscillator is allowed to deliver several coherent lines (up to 20 A separated) in a 1 ns, time-modulated pulse. During amplification, the radiation experiences an additionnal spectral broadening due to self phase modulation in the glass amplifiers.

Plane target interaction experiments were performed with such a spectrum composed of ≃ 10 lines 2 Å separated. A strong reducing of Brillouin scattering is evidenced at fluxes 10^{14} - 10^{16} W/cm^2. The target being tilted 45° from the laser axis, in order to separate the backscattered lobe, more than 50 % reduction of backscattering is observed. In normal incidence configuration, the overall absorption is increased, especially above 10^{15} W/cm^2 where Brillouin scattering is important without temporal modulation in the incident pulse. Influence of this modulation on backscattered spectrum is also studied.

All the results are interpreted in terms of a saturation of Brillouin scatter in the underdense plasma, leading to an increased energy reaching the critical surface where strong absorption occurs.

STIMULATED SCATTERING FROM THE GAS JET TARGET*

D. C. Slater, Gar. E. Busch, G. Charatis, F. J. Mayer, R. J. Schroeder,
and
J. A. Tarvin

KMS FUSION, INC.

Recent experiments at KMS employing a gas jet target will be described in several papers at this conference. The target consists of high pressure gas flowing into vacuum through a small (~ 150 μm) orifice. The molecular density distribution in the flowing gas has been determined by holographic interferometry, and in the region of interest the density gradient length is roughly equal to the orifice diameter. The laser optic axis is colinear with the gas flow axis, and the light is focused by an f/5 optic into the orifice, at intensities of 10^{15} to 10^{16} W/cm^2. *The laser-plasma interaction thus occurs in a region of long scale length, without requiring the ablation of a solid surface.*

Two interaction processes that were investigated are stimulated Brillouin scattering and stimulated Raman scattering. The angular distribution of scattered light is strongly peaked in the backward direction: about 90% of the scattered light is collected by the focusing mirror. Side-scatter at 90° was extremely weak. The spectrum of backscattered light showed both unshifted and redshifted components. Backscattered energy fractions were measured over a wide range of incident intensities for 1.05 μm light on hydrogen and nitrogen gas, and for 0.53 μm light on nitrogen. The backscattered fraction versus intensity curves were identical for all three cases. The backscattered fraction saturated at approximately 50% for intensities above ~ 5 x 10^{15} W/cm^2. We believe that stimulated Brillouin scattering is the dominant reflection mechanism.

In experiments with 0.53 μm incident light, emitted light in the 0.5 to 1.1 μm region was examined for evidence of stimulated Raman scattering. No Raman light was observed in the backscatter direction to the level of $\sim 10^{-4}$ of the incident light.

*Prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

High Intensity Stimulated Brillouin Backscatter from Large f/Number Irradiance at 10.6μm of Long Plasma Columns

R. Fedosejevs, W. Tighe, D.C.D. McKen and A.A. Offenberger

Department of Electrical Engineering
University of Alberta, Canada

The interaction of a 200J, 1μs, CO_2 laser pulse with a low density magnetically confined plasma column ($N_e \sim 10^{18}$ cm^{-3}) has shown peak backscatter reflectivities of up to 25%, far higher values than previously observed.[1,2,3] These large signals are attributed to a combination of higher focal spot intensity and the increased gain length obtained using diffraction limited long focal length (f/15) optics.

The experiments were conducted on a hydrogen puff filled solenoid system. The peak incident power was 500MW and focal spot intensities ranged from 10^{10} to 10^{12} W/cm^2. The resultant plasma column was studied interferometrically and with streak photography for fill densities of up to 30 Torr and magnetic fields up to 70 KG.

The backscatter signal showed a combination of prompt and delayed spikes with sufficient feedback intensity to modulate the incident laser pulse itself. Time integrated spectral measurements were made and will be presented together with a comparison to previous measurements and theory.

1. A.A. Offenberger, M.R. Cervenan, A.M. Yam and A.W. Pasternak, J. Appl. Phys. 47, 1451 (1976).
2. J.J. Turechek and F.F. Chen, Phys. Rev. Lett. 36, 720 (1976).
3. R.S. Massey, Z.A. Pietrzyk and D.W. Scudder, Phys. Fluids 21, 396 (1978).

BRILLOUIN AMPLIFICATION OF A BROAD-BAND SOURCE MAY DETERMINE SIDESCATTER FREQUENCY FOR OBLIQUE CO_2 LASER INCIDENCE ON SOLID TARGETS

G.R. Mitchel, B. Grek, T.W. Johnston, H. Pépin, F. Martin

INRS-Energie

The spectrum of near-10.6 μm light scattered on the specular side of target normal has a frequency shift consistent with the calculated Brillouin frequency shift at that angle. For the calculation the (hot) electron temperature is that inferred from X-rays, the plasma flow direction (normal to the target) from ion collection, and the Mach number (slightly supersonic) from SBS backscatter spectra. The spectral widths in both cases indicate that Brillouin scatter must be fed by a broad-band noise source, presumably broad-band scatter (rather than a shifted, narrow line), emanating from near n_{crit}. This signal is subsequently amplified in the corona. The amplifier bandwidth, hence an equivalent "ion temperature", rises with incident laser power (faster than the hot electron temperature) while fractional scattered light levels remain about the same. We estimate that Brillouin amplification on the specular side of target normal could as much as double an original scatter source strength of 30% of the incident energy, to reach the 60% scatter levels observed experimentally.

BRILLOUIN BACKSCATTER FROM A SHORT-PULSE CO_2 LASER INCIDENT ON A PREPULSE PLASMA

R. Decoste
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P. Lavigne, H. Pépin, G. Mitchel
INRS-Energie, Varennes, Qué. Canada

A long preformed plasma with a critical density is created with a short prepulse incident on a solid target before the arrival of the main-laser pulse. Different preformed plasma conditions are parametrized by varying the prepulse energy (25mJ - 5J) and the delay between the two pulses (0-17nsec). The main-pulse intensity is varied in the $I\lambda^2$ intensity range between 1 and 20 x 10^{14}W μ^2/cm^2, keeping the prepulse conditions fixed. We describe mostly backreflected energy measurements supported by some typical backreflected light spectra. For each delay, the main-pulse backreflection is observed to saturate both as a function of increasing prepulse energy and main-pulse intensity, contrary to glass laser experiments. Reflectivities as high as 40% are observed in a quick burst of light shorter than the incident 2-nsec pulse. We also investigated the effect of a critical surface near the backscattering region in the underdense plasma by varying the focal position of the laser beam with respect to the target surface. Enhanced backscatter due to the presence of a critical surface appear to be superimposed on the scattering already taking place in the underdense plasma. Backscattered light spectra indicate that heavy ion Landau damping is present in all cases discussed above.

TIME EVOLUTION OF SBS IN BOUNDED SYSTEMS

I. J. Thomson - TRW, Redondo Beach, CA

C. J. Randall - LLNL, Livermore, CA

The classical theory of stimulated Brillouin scattering (SBS) of Forslund, Kindel and Lindman (Phys. Fluids 18, 1002 (1976)) has often been used to interpret backscatter measurements in experiments and computer simulations. The growth rates they obtain are correct after an initial transient time. This transient time, however, may be very significant in microwave plasma experiments, computer simulations or very short pulse width laser experiments. We solve the time and space equations for SBS in a finite length system allowing for: 1) distributed ion noise, 2) a boundary value for the backscattered wave and 3) an initial ion density fluctuation. The first source model corresponds to the thermal fluctuations in any plasma or simulation. The second source model corresponds to a reflected wave from a critical density surface, or, in a simulation, reflection from the plasma edges or from imperfect numerical boundaries (Langder & Lasinski, Methods in Computational Physics, Vol. 16). The third source might correspond to a standing ion wave set up by chamber reflections in a microwave experiment (Mase, Luhmann, et al, Phys. Rev. Lett 45, 795 (1980)).

We derive explicit equations for the time evolution of the reflectivity, showing an initially larger growth rate than that of Forsland, et al, which approaches theirs time-asymptotically. The transient period is about the time it takes an ion wave to traverse the system, L/c_s, where L is the system length and c_s the sound speed.

CALCULATIONS OF BRILLOUIN BACKSCATTER IN LASER-PRODUCED PLASMAS*

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Naval Research Laboratory
Washington, D. C. 20375

Stimulated Brillouin backscatter is calculated in an inhomogeneous laser produced plasma for various gradient scalelengths. Equations for the spatial dependence of the incident, reflected and sound wave are numerically integrated through the underdense plasma. Effects investigated are ion heating, non-linear sound wave dissipation, flow velocity magnitude and gradient, electron heating and broad band incident laser light. It is found that backscatter does not depend strongly on the first two effects. The reason is that in an inhomogeneous medium, increasing the dissipation decreases the strength, but increases the width of the interaction, so that the spatially integrated effect is nearly the same. On the other hand, we find that the effects of velocity gradient and broad band light can be very important in reducing the backscatter. Comparisons are also made with data taken at NRL.

* This work is supported by the Department of Energy.

LASER BEAM STEERING BY STIMULATED BRILLOUIN FORWARD SCATTER*

Curt Randall

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Livermore, California 94550

Abstract

Whenever two laser beams intersect in a plasma the resulting ponderomotive beat wave drives up a grid of ion acoustic fluctuations which in turn can scatter energy from one laser beam into another. This process is essentially stimulated Brillouin scatter with a much enhanced noise level. We have previously considered the case of anti-parallel propagation where one of the beams is the incident laser light while the other is the specularly reflected light.[1] Here we consider arbitrary angles of intersection, and in particular, small intersection angles where the beams are nearly parallel. Nonlinear frequency shifts in specularly reflected laser light will also be discussed.

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

[1] Theory and Simulations of Stimulated Brillouin Scatter Excited by Non-Absorbed Light in Laser Fusion Systems, C. J. Randall, J. R. Albritton, J. J. Thomson, UCRL-84330

TIME DEPENDENT EFFECTS IN SELF FOCUSSED LIGHT BEAMS

D J Nicholas

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Abstract

The wave equation is solved numerically, in the paraxial approximation, for an initially isothermal plasma. Transient effects in the laser beam and plasma are studied by taking into account, in a 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 and therefore predicts an additional self focussing mechanism as distinct from the traditional phase retardation due to an intensity dependent index of refraction. The results are compared with previous steady-state solutions to these problems.

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

June 2 - 5th, 1981

Montreal, Quebec, Canada

FILAMENTATION AT SHORT WAVELENGTHS*

By

R. Bingham, R. Short, E. Williams, D. Villeneuve, M. C. Richardson

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

Filamentation in plasmas produced by short wavelength lasers is investigated theoretically and experimentally. The wavelength dependence of the two principal filamentation mechanisms, namely the ponderomotive force and Joule heating are examined and deductions made on their relative importance for current short wavelength experiments. It is found theoretically that the Joule heating mechanism is dominant for short wavelengths and high Z materials while the ponderomotive force becomes more important at longer wavelengths and low Z materials.

Preliminary evidence for the formation of filamentary structures in plasmas produced in high Z planar targets by 0.5 ns, 0.35 μm laser radiation at intensities up to 2 x 10^{15} W/cm^2 will be presented.

*This work is supported by the sponsors and participants of the Laser Fusion Feasibility Project of the Laboratory for Laser Energetics.

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June 2-5, 1981

Montreal, Quebec, Canada

FILAMENTATION OF ELECTROMAGNETIC RADIATION IN FLOWING PLASMAS

by

R. W. Short, R. Bingham, and E. A. Williams

Laboratory for Laser Energetics
University of Rochester

Calculations of the filamentation instability in collisionless plasmas generally use a simple hydrostatic pressure balance equation to represent the response of the plasma to the ponderomotive force. In general the plasma will be moving with respect to the filaments, however, and so it is more appropriate to use hydrodynamic equations to determine the plasma response. When this is done it is found that thresholds, growth rates, and mode structures can all be significantly altered by finite flow velocities. The dependence of these effects on wavelength, intensity, flow velocity, and damping will be discussed.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

SESSION 2

NONLINEAR WAVE EFFECTS FAR AWAY
FROM INCIDENT LASER FREQUENCY

Tuesday, June 2

14:15 - 16:30

L. GOLDMAN
Laboratory for Laser Energetics
U. of Rochester

TIME RESOLVED STUDIES OF THE TWO PLASMON DECAY INSTABILITY AT 10.6μm.

H. A. Baldis and C. J. Walsh
Division of Physics,
National Research Council
OTTAWA Canada.

ABSTRACT

Time resolved Thomson scattering has been used to study the evolution of the two plasmon decay instability in a 10.6μm interaction experiment. The target is a preformed, laser produced plasma with a long density scale length ($L/\lambda \sim 30$) along its axis. The CO_2 laser is focussed in a direction perpendicular to this axis. The CO_2 laser energies used ranged up to $\sim$30J in a $\gtrsim$1 ns pulse, giving focussed intensities of $10^{12} < I < 2 \cdot 10^{14}$ Wcm^{-2} with a 50 cm. focal length NaCl lens.

Thomson scattering enables direct measurements to be made of thermal and non-thermal fluctuations in the plasma with a spatial resolution $(100\mu m)^3$. We have used a streak camera to time resolve the scattered spectra with a resolution $\sim$20ps. The probe laser wavelength is 0.53μm. Non thermal electron and ion fluctuations associated with the two plasmon decay have been observed at $n_c/4$, over a range of incident 10.6μm intensities. Saturation of the electron wave amplitude has been seen for $I \sim 5.10^{13}$ Wcm^{-2}, at a level $\sim 2.5 \cdot 10^4$ times above that of the thermal electron fluctuations. At intensities $> 5 \cdot 10^{13}$ Wcm^{-2}, non thermal ion fluctuations are also observed with a well defined threshold. Their onset is delayed with respect to the electron fluctuations by a time which decreases with increasing laser power. Observations indicate that the ion fluctuations play an important role in the saturation of the two plasmon decay instability. The results, therefore, may provide the first experimental comparison with computer simulations in which such a saturation mechanism has been observed[1].

[1] A. B. Langdon, B. Lasinski and W. L. Kruer, Phys. Rev. Lett 43 133 (1979)

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

June 2-5, 1981

Montreal, Quebec, Canada

SPECTRALLY RESOLVED MEASUREMENTS OF RAMAN BACKSCATTER
FROM PLASMAS PRODUCED BY .35 μm LASER*

by

K. Tanaka, L. M. Goldman, M. Richardson, and W. Seka
Laboratory for Laser Energetics
University of Rochester

Time integrated spectrally resolved measurements between 4000 and 7000 Å have been made of backscattered and sidescattered light from laser produced plasmas illuminated with .35 μm laser light. Planar CH, Ni and Au targets were irradiated at intensities ranging from 2 X 10^{13} to 2 X 10^{15} W/cm^2 and a pulse width of 450 psec. Very clear evidence is found of threshold behavior for both an absolute and a convective Raman instability. The details of the scattered spectrum strongly suggest the presence of density profile steeping at $n_c/4$ as has been predicted in plasma simulations.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124

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

June 2-5, 1981

Montreal, Quebec, Canada

PROPAGATION EFFECTS ON RAMAN SPECTRA†

by

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Laboratory for Laser Energetics
University of Rochester

Spectra and gain profiles from stimulated Raman scattering in laser-produced plasma are computed, and compared with experiments using 0.35 μm irradiation on flat targets on the GDL laser system at LLE. It is found to be crucial to account for refraction of the scattered light. Effects of Landau damping, inverse bremsstrahlung absorption, and density gradients are accounted for, as is the effect of varying the angle of incidence of the laser.

†This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

"Parametric Effects in Quarter-Critical Plasma"

P. Koch

KMS Fusion, Inc., Ann Arbor, Michigan, USA

ABSTRACT

At the quarter-critical point, the electric field of backscattered stimulated-Raman radiation acts as a quasi-homogeneous pump, capable of exciting the parametric decay instability in plasma of sufficiently long scale length. This parasitic effect can be of importance if the initial noise at ion-acoustic frequencies dominates that at the plasma frequency or if the initial noise level is high enough at all frequencies. Several other waves are mutually resonant at this unique point and their relevance to the time-behavior of the transmitted laser pulse is discussed.

Abstract Submitted for the Eleventh Annual Conference on Anomalous Absorption of Elecyromagnetic Waves*

June 2-5, 1981

Montreal, Quebec, Canada

100 KEV X-RAY CONTINUUM FROM TWO-PLASMA DECAY

J. H. McAdoo and L. M. Goldman
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University of Rochester

The 100 keV region of the x-ray continuum from a Nd laser produced plasma was measured with a pair of absorber ratio filters. A $1/T^2$ dependence of integrated x-ray energy on the spectrum temperature was observed. Prepulses which effected the 10 keV fast ion spectrum had no effect on the x-rays. These phenomena are consistent with the two-plasmon decay instability. The laser pulse widths were 30 to 70 psec and the intensity near 10^{16}W/cm^2. Near 70 psec the nature of the spectrum changes radically, suggesting a second instability at work.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

11th ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION
OF ELECTROMAGNETIC WAVES

June 2-5, 1981

Université du Québec a Montréal
Québec, Canada

ELECTRON ACCELERATION BY RAMAN BACK AND FORWARD SCATTER

N. A. Ebrahim, Yale Univ., H. Baldis, NRC, C. Joshi,
J. M. Dawson, UCLA, T. Tajima, U. of Texas

Raman backscatter from laser-produced plasmas has been under intense investigation lately because of its potential role in scattering a significant fraction of the incident laser light as well as being a source of high energy electrons. In a CO_2 laser-heated plasma ($n < n_c/4$, $T_e \sim 200$ eV) for instance, Raman-heated electron distributions have characteristic heated electron temperatures between 10 and 20 keV with maximum electron energies of the order 200 keV.

The Raman forward scattering instability (RFS), on the other hand, has received relatively little attention because of its comparatively unimportant role in such low temperature underdense plasmas. However in spite of the lower growth rate RFS can dominate backscatter in hot tenuous plasmas ($T_e \sim 20$ keV) because of the synchronism between the plasma wave and the electromagnetic waves and the lower Landau damping rate. The most striking feature of RFS is the generation of super-relativistic energy electrons by trapping. Thus the potential role of RFS in the laser electron accelerator concept and as a laser-fusion pellet preheat source needs to be investigated.

In this paper we describe experimental and computer simulation studies of RFS in hot ($T_e \sim 20$ keV), long scale length underdense plasmas. The role of RFS in relativistic electron generation was investigated experimentally by irradiating ultrathin carbon foils (130 Å) by intense, $v_o/c \sim 0.3$, 700 ps (FWHM) CO_2 laser pulses. During the risetime of the pulse the plasma becomes underdense with $T_e \sim 20$ keV. Fast electron emission spectra measured at 5° in the forward direction show a Maxwellian distribution with temperatures of 90 - 100 keV. Electrons with energies out to 1.4 MeV were observed in the forward direction. For comparison, in the backward direction the electron spectra had characteristic temperatures of 50 keV with maximum energies of 600 - 800 keV. Computer simulations employing a 1-D relativistic electromagnetic code with the parameters $n_e/n_c \sim 0.2$, $T_e \sim 20$ keV and $v_o/c \sim 0.3$ show that stimulated Raman scattering instability is indeed responsible for the production of very energetic electrons. The electromagnetic spectrum is found to be sharply peaked at discrete wavenumbers $k_n = k_o + n\underline{k}_p$ where $\underline{k}_p = \omega_p/c$. The downward cascade seems to dominate although a small amount of energy is upconverted. The spectral density $s(\underline{k}, \omega)$ for the electrostatic component shows no significant energy in the wavenumber $(\underline{k}_o + \underline{k}_s)$ - i.e. the backscatter plasma wave. On the other hand the wavenumber $(\underline{k}_o - \underline{k}_s)$ - i.e. forward scatter plasma wave is very intense. This strongly suggests that backscattering is saturated at a very low level and the downward photon cascade and the strong electron heating observed is indeed due to forward Raman scattering.

SELF-FOCUSING AND HIGH HARMONICS PRODUCTION IN CO_2 LASER-PRODUCED PLASMAS*

R. L. Carman and R. F. Benjamin

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

ABSTRACT

In recent studies of harmonic generation by CO_2 laser-produced plasmas, up to ~ 50 harmonics have been efficiently generated. Experimentally examined scaling laws suggest that for irradiances $I > 10^{15}$ W/cm^2, deviations from theoretical expectations occur. Also, high resolution spectroscopic studies of the 16th through 20th harmonics have found two distinct frequency modulations. The data is consistent if self-focusing and laser filamentation is occurring. A theoretical discussion of plausibility as well as supporting experimental data will be presented to partially substantiate this hypothesis.

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

HARMONIC LIGHT - A VIEW OF THE CRITICAL SURFACE

B. Bezzerides, R. Jones

Los Alamos National Lab.

D I S C U S S I O N :

WHAT CAN WE LEARN FROM INSTABILITY EMISSIONS?

Discussion leader: C.E. Max

Lawrence Livermore National Lab.

SESSION 3

ABSORPTION AND REFLECTION STUDIES

Wednesday, June 3

9:00 - 10:45

E. FABRE

Ecole Polytechnique

Palaiseau

"A Model of Absorption and Reflection of Intense Laser Light by Long Gradient Length Plasma"

T. Speziale, W. B. Fechner, D. Mitrovich

KMS Fusion, Inc., Ann Arbor, Michigan, USA

ABSTRACT

Processes affecting absorption and scattering of intense laser light by long gradient length plasmas are discussed. A model for reflection by Brillouin scattering in an absorbing plasma is presented which includes an extended background source of scattered radiation. The reflection coefficient is shown to be sensitive to the noise level only when the Brillouin gain length is comparable to the absorption length. Strong field corrections to absorption by inverse bremsstrahlung are shown to enhance optical penetration by the incident light diminishing the ability of inverse bremsstrahlung to compete with Brillouin scattering. The incorporation of the model into simulations of the recently conducted gas jet experiments at KMSF is discussed.

"Simulations of Absorption and Reflection of Intense Laser Light by Long Gradient Length Plasma"

W. B. Fechner, T. Speziale, D. Mitrovich, D. J. Tanner

KMS Fusion, Inc., Ann Arbor, Michigan USA

ABSTRACT

The results of simulations designed to study the absorption and scattering of laser light in the recently conducted gas jet experiments at KMSF are presented. The model employed includes inverse bremsstrahlung with strong field corrections and Brillouin scattering with an extended noise source for scattered radiation. Plasma conditions within the interaction region are determined, to a large extent, by the conduction of heat into the non-illuminated portion of the gas jet. The density profile employed in the simulations is modeled after the experimentally measured profile. Near the critical surface the absorption length falls below the plasma length scale, so that the competition between absorption and Brillouin scattering must be considered. The variation of the reflection coefficient with laser intensity, atomic number, noise level, electron temperature, and ion temperature is studied. Our results are compared to the data from the gas jet experiments.

HEATING IN UNDERDENSE PLASMAS*

Barbara Lasinski, Bruce Langdon, and William Kruer

University of California, Lawrence Livermore National Laboratory
Livermore, California 94550

Abstract

We present an update of our ZOHAR simulation study of the high frequency parametric instabilities which occur at or below quarter-critical density. For the large volume of underdense plasma in long pulse length irradiations, the main concern is the production of a significant hot ($>$ 50 keV) electron component. We will discuss scaling laws for hot electron production by the 2 ω_{pe} and Raman instabilities for intensities $\sim 10^{15}$W/cm^2 and background temperatures from 3-10 keV.

*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

ANALYSIS OF LIGHT ABSORPTION EXPERIMENTS AT DIFFERENT WAVELENGTHS

C. GARBAN-LABAUNE, E. FABRE, A. MICHARD, J. VIRMONT
(Ecole Polytechnique, Palaiseau, France)

C.E. MAX
(L.L.N.L., USA)

We analyse the experimental results concerning light absorption dependence with laser wavelengths (0.26 μm, 0.53 μm, 1.06 μm), and also irradiances, pulse durations and target materials. Numerical simulations of laser light absorption including only inverse Bremsstrahlung calculation and an approximate model for resonance absorption, show that the significant increase of absorption for short wavelengths, low intensities and long laser pulses can be completely explained by the increase of inverse Bremsstrahlung efficiency, if the flux is not inhibited for 0.53 μm and 0.26 μm. Recent results with various Z targets at 0.53 μm and with two pulse durations (80 ps and 160 ps), confirm this hypothesis. An analytical modeling of absorption in agreement with experimental result will be presented. Brillouin scattering which has been detected as a significant loss mechanism for long pulses at 1.06 μm has been studied in experiment with prepulse technique at 0.26 μm ; recent results will be presented.

RESULTS OF EXPERIMENTAL TARGET STUDIES AT 0.35 μm*

F. Ze, M. Campbell, R. Turner, V. Rupert
C. Max, W. Mead, W. Kruer

University of California
Lawrence Livermore National Laboratory
P. O. Box 5508
Livermore, California 94550

ABSTRACT

We present some of the major results of recently completed experimental target studies at LLNL using frequency tripled 1.064 μm Argus laser. In particular, results of absorption and x-ray emission measurements will be shown. Our data show that for high Z plasmas both the absorption and sub-keV x-ray conversion efficiencies are enhanced at 0.355 μm relative to 1.06 μm and 0.53 μm and that they are less sensitive to both the irradiation intensity and angle of incidence variation (up to 45^{o}). Relatively high absorption coefficients for low Z targets were also measured. We further present data displaying a dramatic decrease in the generation of hot electrons at 0.35 μm.

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

INTERPRETATION OF ARGUS 3 ω_0 DISC IRRADIATION EXPERIMENTS*

C. E. Max, W. C. Mead, W. L. Kruer, F. Ze, and M. Campbell

University of California, Lawrence Livermore National Laboratory

Livermore, California 94550

Abstract

We analyze recent Argus disc irradiations at $\lambda_L = 0.35\,\mu m$. Important features of the observed scaling with laser wavelengths are in agreement with theoretical predictions and with computer calculations using LASNEX: the laser light absorption and x-ray emission increase at short laser wavelength, while the production of suprathermal electrons decreases. In other areas such as the intermediate-energy x-ray spectrum, we find significant discrepancies between the model and the experiment. We discuss some possible explanations for these discrepancies.

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

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Montreal, Quebec, Canada

0.35 μm INTERACTION EXPERIMENTS AT LLE*

by

W. Seka, L. Goldman, M. Richardson, J. Soures, B. Yaakobi, T. Boehly,
R. Keck, K. Tanaka, D. M. Villeneuve, R. Boni, R. Bingham, S. R. Craxton
J. Delettrez, R. L. McCrory, E. Williams
Laboratory for Laser Energetics
University of Rochester

An overview of the LLE 0.35μm interaction experiments will be presented. Key elements are absorption, electron transport, and light scattering measurements at intensities between 10^{13} and 3.10^{15} W/cm^2 and pulse widths between 90 and 450 psec. All experiments were carried out on a single beam frequency-tripled Nd:glass laser facility. The targets were planar glass targets overcoated with CH, Ni, and Au.

For the absorption measurements a box calorimeter was used which was capable of simultaneous measurements of the scattered light and plasma energies. Absorption fractions of 55 to 95% were observed for 400 to 450 psec UV laser pulses on planar CH targets between 10^{13} 2.10^{15} W/cm^2. Nickel and gold targets showed absorption fractions between 65 and 98% over the same parameter range. The measurements agree well with calculations using inverse bremsstrahlung absorption, a flux limiter of f=0.03, and a 15% dump at critical. The latter is negligible in the intensity range covered here. For short pulses somewhat lower absorption fractions are observed (37 to 85% for CH and 50 to 93% for Ni) over the same parameter range.

Scattered light measurements have shown clear threshold behavior for the absolute and convective stimulated Raman instabilities. SRS energy conversion efficiencies are estimated to lie in the 10^{-4} range with evidence of saturation around that level.

Stimulated Brillouin scattering is a negligible loss factor in our experiments. Typically less than 2% of the incident light could possibly be attributed to SBS.

X-ray burn-through experiments have been made to determine the electron heat transport inhibition. The results agree well with a recent self-consistent model of electron heat transport and are consistent with a flux limiter of f=0.03.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

POSTER SESSION

MICROWAVE, FAST ELECTRONS,

TRANSPORT, HYDRODYNAMICS

DIFFERENT PLASMAS

Wednesday, June 3

10:45 -

STUDY OF MICROWAVE BACKSCATTER AND FILAMENTATION IN A LARGE SCALE TARGET PLASMA

W. DiVergilio, J. Thomson, W. Robinette, H. Goede

TRW, Los Angeles

ELECTRON HEATING AND HEAT TRANSPORT DUE TO P-POLARIZED MICROWAVES OF MODEST INTENSITY*

K. Mizuno, D. Rasmussen, F. Kehl, J. S. DeGroot,
Wee Woo, and P. Rambo

P-Polarized microwaves ($v_o/v_{eo} < 1$, $fI\lambda^2/T_e^{3/2} < 1 \times 10^{11}$ $(W/cm^2)(\mu m^2)/eV^{3/2}$, $\omega_o/2\pi = 1.2$ GHz) are applied to an essentially collisionless, inhomogeneous plasma in the U. C. Davis PROMETHEUS I device. We observe that absorption, electron heating and electron heat transport depend strongly on the length of the underdense shelf. We can control the length of the underdense shelf by controlling the initial plasma density profile. For a short shelf ($L/\lambda_{De} \lesssim 200$), resonance absorption is the dominant mechanism of electron heating. We observe strongly heated suprathermal electrons ($T_H/T_c \lesssim 10$) with a relatively low density ($n_H/n_c \lesssim 0.1$). Only low level ion turbulence is observed consistant with the observed weakly heated thermal electrons. These results agree very well with recent computer simulation calculations and theoretical estimates using a wave breaking model. The results change drastically, as the underdense shelf is lengthened. A parametric instability is observed on the underdense shelf and absorption first increases and then decreases with shelf length. Near maximum absorption, the suprathermal electrons have a lower temperature and a much higher density than for pure resonance absorption. Also, strong ($\Delta n/n \approx 0.2$), nearly isotropic, ion turbulence and strong thermal electron heating is observed on the underdense shelf. The thermal electron heat flux is strongly inhibited on the underdense shelf.

* Work supported by Lawrence Livermore National Laboratory under Intramural Order 9910209 and by Los Alamos Scientific Laboratory under Contract 4-X60-2531P-1.

MICROWAVE MODELING OF STIMULATED BRILLOUIN SCATTERING IN LASER DRIVEN PELLETS

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We are investigating Stimulated Brillouin Scattering (SBS) in the U. C. Davis CERBERUS device. This microwave-plasma interaction system is designed to model SBS in laser driven pellets. A variable diameter ($D/\lambda_o \lesssim 4$), parallel beam of high power ($v_o/v_e < 0.5$) microwaves (frequency = 3.6 GHz) is incident onto an underdense plasma with variable flow velocity. To model reflections from the critical surface, the microwaves are almost totally reflected by a grid so that a standing wave pattern is set up in the plasma (the sides of the cylindrical experimental tank have been lined with microwave absorber to prevent cavity effects). Dipole probes and Langmuir probes are used to measure the temporal and spatial profile of the microwave electric field and plasma density. The resulting ponderomotive force produces the resonant ion wave required to scatter the microwaves in a transient process due to the fast rising microwave pulse. We find that for high enough powers, the microwave electric field in the plasma decreases on the ion time scale (~ μsec). After this time, the microwave electric field decreases with distance into the plasma. The scale length for the microwave attenuation decreases with microwave power. In addition, large amplitude ($\delta n/n \approx 10\%$) ion waves are observed in the plasma. The ion wave amplitude also decreases with distance into the plasma.

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† University of California, Lawrence Livermore Laboratory, Livermore, California 94550. Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

Backscatter and Sidescatter from preformed (Z pinch) plasmas

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Spectrally analysed measurements near ω_0 have been made of both backscatter and 90^o sidescatter of 10.6 μm light from a Z pinch plasma. The Z pinch is formed in Helium gas, and at maximum compression has a temperature $\sim 40 - 50$ ev, and electron density $>10^{19}$ cm^{-3}. The mode locked CO_2 laser produces a train of pulses 2.2 nsec wide with $\sim$ 15 nsec between pulses, and when focussed by a 50 cm KCl lens, intensities up to $\sim 2.10^{12}$Wcm^{-2} are obtained. The saturation in the fraction of backscattered light, and corresponding increase in the width of the scattered spectrum, are consistent with ion trapping models. Higher levels of backscatter are seen when the laser is focussed off the axis of the Z pinch, possibly because the interaction lengths are longer there. Sidescatter observations also depend strongly upon where the laser is focussed. Measurements of the level of the sidescatter and its spectrum will be presented and discussed.

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PLASMA CREATED BY TWO SHOCK WAVE COLLISION, AS A TARGET PLASMA FOR LASER-PLASMA INTERACTION EXPERIMENT*

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Two shock tubes similar to Marshal guns are used to produce a target plasma. Abel inverted double pulse holographic interferometry shows that by adjusting the fill pressure and the spacing between the shock tubes the fully ionized plasma electron density and its radial gradient can be varied independently. An electron density of $6 \cdot 10^{17} cm^{-3}$ and a gradient of $5 \cdot 10^{17} cm^{-4}$ is realized for a fill pressure of 5 Torr of H_2 with 1/4 n_{ec} ($2.5 \cdot 10^{18} cm^{-3}$) expected for higher fill pressures. This plasma will be used as a target for a one kilojoule 10.6μ CO_2 e-beam laser pulse. Forward, side and backward scattered radiation will be dispersed to record stimulated Raman scattered spectra.

*This work was funded by the United States Department of Energy in support of the DOE Inertial Confinement Fusion program.

PLASMA SPECTROSCOPY ON A LASER IRRADIATED GAS JET*

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ABSTRACT

The laser irradiated gas jet is an outstanding plasma x-ray line source whose benefits will be discussed. We have determined density and temperature gradients for a laser heated gas jet by using spatially-resolved x-ray line spectroscopy. We have simultaneously measured the density gradient by utilizing laser interferometry. We studied argon, SF_6 and neon gases that were ionized by a 0.5 TW laser operated at λ =0.53 μm and λ = 1.06 μm. Line emission from He- and H-like configurations dominated the emission spectrum for the lower Z gases. Electron temperatures as high as $T_e \sim 700$ eV were observed at the critical electron density for laser absorption.

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

ACCELERATION OF FAST ELECTRONS IN E.M. FIELDS - PLASMA INTERACTION

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The acceleration of electrons by an e.m. field near the cut-off density is studied by means of an analytic model considering separately the ponderomotive force influence on very slow particles and the resonant field influence on the others. The sin $\omega_o t$ variation of the field is taken into account. An evaluation of gradients and temperatures for the interaction zone permits to give the energy spectra of fast electrons for some configurations. The main results are presented and simple approximations lead to scale laws for the main characteristics of the phenomena :

- flux limit factor introduced in the theory (calculated by comparison with results of simulations) :

$$f \propto (W_L \lambda_o^2)^{0.106} \lambda_o^{1.5}$$

- gradient and temperature of the plasma :

$$\frac{L}{\lambda_o} \propto (W_L \lambda_o^2)^{-0.31}$$

$$T_c \propto (W_L \lambda_o^2)^{0.35}$$

- temperature of the suprathermal electrons

$$T_h \propto (W_L \lambda_o^2)^{0.34}$$

11th ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION
OF ELECTROMAGNETIC WAVES

June 2-5, 1981

Université du Québec a Montréal
Québec, Canada

HOT ELECTRON TRANSPORT IN LASER INTERACTION WITH SOLID TARGETS

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It is well known that when high-intensity ($v_o/v_e >> 1$) laser radiation is incident on a solid target, strong density profile modification at the critical density surface results in the preferential coupling of a large fraction of the absorbed laser energy into a hot electron distribution. The understanding of energy transport by hot electrons in these plasmas is crucial for the interpretation of many current laser interaction experiments and laser equation-of-state studies. Until very recently it was generally believed that the hot electrons generated near the critical density surface, distributed the energy in two ways. They either transported the energy into the target interior ahead of the ablation shock front and preheated the target[1] or they accelerated the corona ions, via the ambipolar potential set up by electrons attempting to escape the target.[2] However recent experimental work has pointed to a number of other possible avenues for energy loss[3] which make an important contribution in the proper partitioning of the absorbed energy.

In this paper we present the first measurement of the absolute energy deposition by fast electrons as a function of depth from the target surface in the intensity regime of interest to CO_2 laser fusion. This is achieved by recording the K_α spectra from planar multilayer targets using a PET crystal spectrograph. The K_α fluor layers were 2 μm Ni and 3 μm Ti chosen to have high K_α yields for electrons and low yield for thermal radiation pumping, separated by an Aℓ layer of variable thickness between 0 and 4 μm. In addition a 0.75 μm Aℓ layer in front of the multilayer target was used as the ablator. CO_2 laser pulses, 700 ps (FWHM) with intensities between $10^{16} < I\lambda^2$ (W cm^{-2}μm^2) $< 10^{17}$ were used in these studies. The source broadened K_α lines confirm our previous conclusion that hot electrons deposit energy in an area much larger than the focal spot size where they are produced. Absolute estimate of the hot electron preheat will be given. The implications of these studies to the studies of shock wave generation by CO_2 laser driven hot electron micro-explosions[4] and fast ion losses are also discussed.

[1]J.D. Hares, J.D. Kilkenny, M.H. Key, and J.G. Lunney, Phys. Rev. Lett. 42, 1216 (1973).

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[4]N.H. Burnett, G. Josin, B. Ahlborn, and R. Evans, Appl. Phys. Lett. 38, 226 (1981).

TIME RESOLVED (~20 ps) THOMSON SCATTERING AT AND ABOVE CRITICAL DENSITY IN 10.6 μm EXPERIMENTS

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ABSTRACT

The technique of Thomson Scattering is a powerful diagnostic for probing collective modes in a plasma. By coupling the spectrograph to a streak camera, time resolved scattered spectra with a resolution ~ 20 ps can be obtained. This has permitted a study of the evolution of non thermal fluctuations induced by a CO_2 laser ($10^{12} < I < 2.10^{14}$ Wcm^{-2}) at $n_c/4$ (paper 2-1, this meeting). Studies of non thermal ion and electron fluctuations observed at critical density and above will be reported here.

These studies have been conducted in a laser-produced, preformed plasma with a scale length $L/\lambda \sim 30$. The maximum density in the plasma as seen by the CO_2 laser could be varied between N_c and $n_c/10$. When the scattering volume is placed so as to overlap the CO_2 focal volume, strong electron and ion fluctuations are observed, with no significant delay between their onset. The propagation of ion fluctuations into regions of higher density has also been seen. This has been accomplished by focussing the CO_2 laser at its critical density surfact in the plasma and by placing the Thomson scattering volume in regions where $N_e > N_c$. Some implications of these results will be presented.

HYDRODYNAMICAL DESCRIPTION OF AN OFF-EQUILIBRIUM FLUID

A. Decoster

Centre d'Etudes de Limeil, C.E.A.

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HYDRODYNAMICAL DESCRIPTION OF A FLUID OFF EQUILIBRIUM

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Classical hydrodynamics is no longer valid for a fluid far from Maxwellian equilibrium (steep gradients, strong anisotropy or heat flux, ...). If however the distribution function F is regular enough, one needs not resort to the more complicated kinetic description; it is possible to keep a fluid description, with equations governing not only density, velocity and pressure/energy, but also heat flux (like in Grad's method) or even higher moments of F.

We present methods for constructing such a system of equations in a consistent way. For example, we give an analytic form of a distribution function $F(\vec{v},\vec{x},t)$ which depends on 14 independent parameters

$$n(\vec{x},t)=\int F d^3v,\ u_i(\vec{x},t)=\frac{1}{n}\int v_i F d^3v,\ P_{ij}(\vec{x},t)=m\int (v_i-u_i)(v_j-u_j) F d^3v,$$

$$q_i^*(\vec{x},t)=\frac{m}{2}\int (v_i-u_i)(\vec{v}-\vec{u}).P^{-1}.(\vec{v}-\vec{u}) F d^3v,\ R^*(\vec{x},t)=m\int\left[(\vec{v}-\vec{u}).P^{-1}.(\vec{v}-\vec{u})\right]^2 F d^3v,$$

and which is always positive for any allowed values of these moments. Moments of the kinetic equation give a set of fluid equations, which is closed using the (closed-form) expressions of higher order moments of F as functions of the lower ones. This F is flexible enough to describe a wide range of distribution functions, from waterbag to Maxwellian and to Lorentzian (long wings), and from symmetrical to asymmetrical (any heat flux). It is this flexibility of F which allows to use the fluid description in all cases where the actual F has a reasonably smooth shape. The system of 14 equations is checked to be always hyperbolic.

With collision terms calculated from the given form of F, one would get a fluid description which should be appropriate to e.g. laser-plasma experiments, except for kinetic features like very fast particles and turbulence effects.

11^{th} Anomalous Absorption Conference, Montreal, June 2-5, 1981. Poster

"Numerical Study of Thermal Electron Transport"

J. Virmont

Ecole Polytechnique, France

et

J.P. Matte

INRS-Energie, Varennes

ABSTRACT

Heat conduction down a steep temperature gradient is numerically simulated with a Fokker Planck code. The effects of the boundary conditions and of the length of the simulation region on the flux limit factor have been studied.

STEADY-STATE ABLATIVE FLOW*

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A model describing a planar steady-state ablative flow in laser-produced plasma is presented and applied to the NRL low irradiance ablative acceleration experiments. A characteristic of that model is that it depends only on three parameters: the target material and the laser wavelength and irradiance. Special attention has been given to the interface between the different interaction regions, namely the accelerated slab, the ablation front and the underdense plasma.

An extension of this model to 2D is performed in order to study the effects of non-uniform illumination of the target by the laser light. Linearized perturbations in the transverse direction (perpendicular to the direction of light propagation) are assumed. Only solutions which decay from the critical surface inwards are retained in the analysis. Pressure non-uniformity at the ablation surface vs. its correspondent at the critical surface is given as a function of mode wavenumber in the transverse direction. Pressure fluctuation at the critical surface is derived in terms of the laser irradiance fluctuation. Comparisons are also made with more elaborate numerical results and with experimental data from NRL.

* This work is supported by the Department of Energy.

FLOW ANALYSIS IN PLANE ABLATIVE REGIME

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C.E. MAX
(L.L.N.L., USA)

We present analytical solutions discribing the macroscopic parameters such as : coronal temperature, ablation pressure and mass ablation rate in a plane steady state model in the ablative regime, as a function of laser wavelength, intensity and flux limit number [1]. The comparison of these results with the hydrodynamic simulations show an excellent agreement. The conditions of applications of these results to the acceleration of slab targets is discussed : we point out the necessity of using short laser wavelength in order to reach the maximum hydrodynamic efficiency of 32 % given by our model and confirmed by the simulations.

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TARGET ACCELERATION BY HOT ELECTRON EXPLOSION

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Hot electron explosion, which have been observed in CO_2 laser-plasma experiments with substantial preheating, are incapable of accelerating cold material for use in laser fusion compression experiments, since the shock wave never detaches from the heating region, and the accelerated material is continually lost to the rear. However, a series of very short and successive laser pulses could conceivably generate a sequence of successive shocks, as required for quasi-adiabatic supercompression.

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

June 2-5, 1981

Montreal, Quebec, Canada

NONLINEAR DEVELOPMENT OF MULTI-FREQUENCY RAYLEIGH-TAYLOR INSTABILITY IN ABLATION DRIVEN THIN SHELLS†

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University of Rochester

Two dimensional numerical simulations of multi-frequency Rayleigh-Taylor instability in ablation driven thin shells are presented for a range of laser irradiances, (2.5×10^{14} - 1.0×10^{15} W/cm^2) and perturbation wavelengths, ($0.90 \leq k\Delta x \leq 3.14$). Results are shown to be in general agreement with the nonlinear evolution of single frequency simulations[1]. However, for a given shell thickness and fundamental perturbation wavelength, the multi-frequency simulations show an increase in the rate at which the shell thickness decreases compared to that observed for the fundamental frequency alone. These results will be shown to be in agreement with inviscid incompressible results obtained using boundary integral techniques[2]

† This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124 and by the sponsors and participants of the Laser Fusion Feasibility Project of the Laboratory for Laser Energetics.

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2. G. R. Baker, D. J. Meiron, and S. A. Orszag, Phys. Fluids 23, 1485 (1980).

*Department of Nuclear Engineering, University of Arizona.
Additional support for this work has been provided under subcontract 9245009 with LLNL.

LAGRANGIAN FORMULATION OF THE PONDEROMOTIVE FORCE*

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Abstract

A generalization of the Euler-Lagrangian formalism is developed to analyse the ponderomotive force in case of multi-fluid stationary isontropic MHD flow. The Lagrangian framework allows a fully self-consistent description of the ponderomotive force acting on the unit volume of an unbounded plasma with nonuniform density and temperature situated in generally nonuniform magnetostatic field.

Components of the force corresponding to previous theories are identified and new terms are discussed.

* This work was supported in part by a research grant from the Natural Sciences and Engineering Research Council of Canada.

Cerenkov Masers: A Possible Plasma Heating Source

J. Walsh, J. Branscum, J. Golub, R.W. Layman,
D. Speer, S. Von Laven

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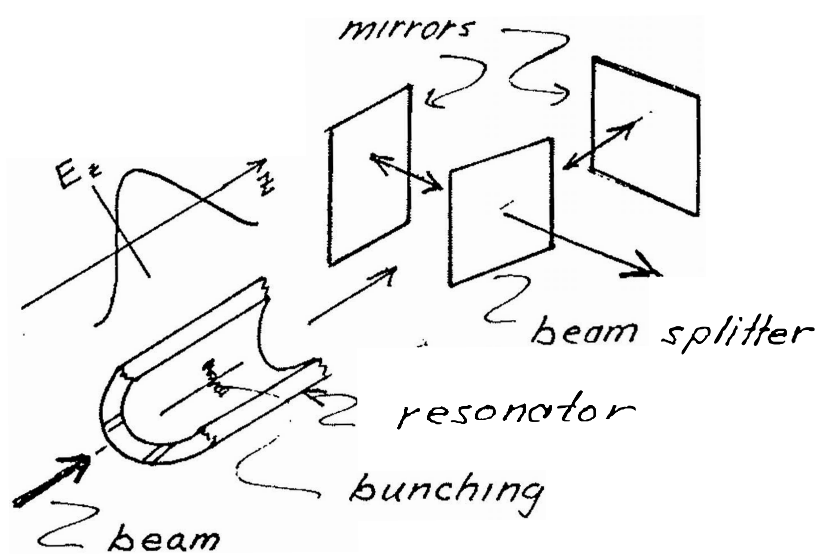
Hanover, N.H.

A Čerenkov maser consists of an electron beam, a dielectric resonator and output coupling optics. The beam velocity can exceed the phase velocity of the wave in this system, and when it does, a coherent instability leads to beam bunching and a transfer of energy to the wave. The field in the beam channel is also evanescent. The decay rate, however, scales as k/γ where k is the axial wavenumber of the wave and γ is the ratio of the energy of the electron and its rest mass. Hence by using mildly relativistic electron beams (γ = 1.1-1.6) good beam-to-wave coupling can be obtained in the lower mm part of the spectrum. Depending upon their complexity and ultimate performance characteristics, devices of this kind may have a number of applications in plasma diagnostics and heating.

In order to test the basic ideas underlying such devices, a high-voltage (400 Kv max.) pulse transformer-based e-beam generator has been used to drive tubular quartz resonators. At the present time, coherent output has been obtained over the range 10mm-1.5mm. A summary of theoretical expectations and recent experimental results will be presented.



Čerenkov Maser

Work supported in part by: AFOSR Grant #77-3410B, ARO Grant #DAAG-29-79-C-0203 and ONR Grant #N00-14-79-C-0760.

PARAMETRIC INSTABILITY CASCADES: LOTKA-VOLTERRA MODEL FOR 4 DAUGHTER PAIRS AND INTRINSIC STOCHASTICITY

G. Picard, T.W. Johnston

INRS-Energie, Varennes

Parametric decay chains (such as SBS with electromagnetic or electrostatic plasma waves as pumps), when the each daughter phonon is heavily damped, form a chain of time-dependent Lotka-Volterra equations (first invoked with two members to explain regular predator-prey cycles). Even numbers of equations are known to allow an invariant, while 2 equations give the classic Lotka-Volterra single frequency oscillation. (We have found the 2 equations can be put in nonlinear Hamiltonian form using the logarithm of the usual variables.) Investigating 4 equations we find (on using the invariant and Poincaré sections) nested tori of the KAM type and an increasing prominence of island formation and intrinsic stochasticity as the value of the invariant is increased, just as has been found for nonlinear Hamiltonian systems. Given this complicated behaviour in the temporal problem, the spatio-temporal problem is likely to be even more intractable.

SESSION 4

HEATING, ACCELERATION

FAST ELECTRON GENERATION

Wednesday, June 3

14:15 - 18:00

R.J. MASON

Los Alamos National Lab.

11th Annual Anomalous Absorption Conference

Montreal, Quebec, Canada

Hydrodynamic Flow from Laser-Irradiated Foils*

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and M. Emery

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A novel diagnostic technique, employing x-ray imaging and targets fabricated with locally-deposited tracer material, allows observation of the streamlines of material flow from laser-irradiated planar targets.[1] Studies of the flow are conducted using a Nd laser ($\tau \simeq 3.5$ nsec FWHM, $\lambda = 1.054\mu m$) with focal diameters (90% energy content) between 100 and 1500μm, intensities between 5×10^{12} and 6×10^{14} W/cm^2, and input f/numbers between 6 and 24. The streamline pattern appears approximately constant in shape with dimensions that scale with focal spot radius. An interesting resemblance of the flow pattern near the target surface to the Laplacian pattern of incompressible fluid flow is noted. These measurements provide a check for multidimensional hydrodynamics codes. In addition, they allow us to begin to experimentally address in a quantitative manner the implications of the flow pattern for laser-matter interaction experiments using planar targets and the relevance to scaling between planar and spherical geometry.

+Mission Research Corporation, Alexandria, VA
*Work supported by U.S. Department of Energy and Office of Naval Research

1. M.J. Herbst and J. Grun, NRL Memorandum Report No. 4436 (1981).

ABLATION DRIVEN BY LOCAL CONVERSION OF SHORT WAVELENGTH LASER LIGHT

L. Montierth, R. Morse

U. Arizona

Internal Heat Deposition in Ablatively Accelerated Targets*

B.H. Ripin, E.A. McLean, J. Grun+, S.P. Obenschain,

J.A. Stamper, M.J. Herbst, and R.R. Whitlock

Naval Research Laboratory, Washington, D.C. 20375

The preheat level in a laser fusion target must be kept very low (a few eV) to assure a near isentropic compression to high-density and, therefore, a high-gain implosion. Time-resolved pyrometric temperature measurements of the rear (inner) surface of ablatively accelerated targets[1] indicate temperatures in the few electron-volt range for targets ablatively accelerated to high speeds (>150 km/sec) under our irradiance conditions (1.05 μm, few x 10^{13} W/cm^2, ~3-nsec laser pulses).[2]

Here, an independent measure of the target's internal temperature is used to corroborate the pyrometric results; this technique employs a specialized double-target, designated HA, which slices the accelerated target and allows monitoring of the subsequent expansion, and hence its internal properties.

The observed preheat levels in aluminum targets, under our irradiation conditions, can be accounted for by radiant heating from the soft x-ray flux emitted by the several hundred electron volt underdense plasma, and possibly by some shock wave heating.[1] We will discuss experiments, using different target materials (eg. Al, C, CH, Li), which differentiate between these mechanisms.

*Research sponsored by the US DOE and ONR.
+Mission Research Corp., Alexandria, VA

1. E.A. McLean, S.H. Gold, J.A. Stamper, R.R. Whitlock, H.R. Griem, S.P. Obenschain, B.H. Ripin, S.E. Bodner, M.J. Herbst, S.J. Gitomer, and M.K. Matzen, Phys. Rev. Lett. 45, 1246 (1980).

2. S.P. Obenschain, J. Grun, B.H. Ripin and E.A. McLean, Phys. Rev. Lett. 1981, (accepted for publication).

MEASUREMENTS OF MASS ABLATION RATES AND ABLATION PRESSURE IN PLANE AND SPHERICAL GEOMETRY AT VARIOUS WAVELENGTHS

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P. Cunningham, C.S. Lewis, *Queen's University Belfast*
M.H. Key, P.T. Rumsby, *Rutherford Laboratory*

Plane tragets have been irradiated at 1.05μm, 0.53μm and 0.35μm over an intensity range of 10^{13} - 10^{15} W cm^{-2} and spherical tragets have been irradiated at an absorbed irradiance of 10^{13} - 10^{14} W cm^{-2} at 1.05μm and 0.53μm. The mass ablation rate has been measured by X-ray streak spectroscopy with plane targets and by X-ray streak spectroscopy and ion emission with spherical targets.

For plane targets the specific mass ablation rates $\dot{m}_s$ scale weakly with the absorbed intensity. Specifically

$$\dot{m}_s = 0.98 \times 10^5 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.23}\ \mathrm{gm\ cm^{-2}\ s^{-1}}$$
$$\dot{m}_s = 1.4 \times 10^5 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.35}\ \mathrm{gm\ cm^{-2}\ s^{-1}}$$
$$\dot{m}_s = 2.4 \times 10^5 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.35}\ \mathrm{gm\ cm^{-2}\ s^{-1}}$$

for λ = 1.05, 0.53 and 0.35μm respectively. The scaling of the ion velocity is essentially independent of absorbed intensity. It is argued that this weak scaling of the ion velocity is a manifestation of radial transport of energy. Pressures can be derived, in the absence of this radial transport, from a simple rocket model and are

$$p = 4.4 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.63}\ \mathrm{Mbar}$$ 80
$$p = 5.3 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.68}\ \mathrm{Mbar}$$ 121
$$p = 6.9 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.68}\ \mathrm{Mbar}$$ 158

for 1.05μm, 0.53μm and 0.35μm respectively.

Spherical targets have been irradiated with 6 laser beams at 1.05μm and 0.53μm. The symmetry allowed the absorbed energy and the specific mass ablation rate to be accurately measured from the ion emission. The mass ablation rate was also measured by streaked X-ray spectroscopy giving values that are ∿30% higher. The mass ablation rates and ion velocity scale much more strongly than for the plane target experiments; specifically

$$\dot{m}_s = 0.86 \times 10^5 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.80}\ \mathrm{gm\ cm^{-2}s^{-1}}$$
$$\dot{m}_s = 0.95 \times 10^5 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.82}\ \mathrm{gm\ cm^{-2}s^{-1}}$$
$$v = 4.4 \times 10^7 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{0.2}\ \mathrm{cm\ s^{-1}}$$
$$v = 4.2 \times 10^7 \; (I_{abs}/10^{13}\ \mathrm{W\ cm^{-2}})^{.15}\ \mathrm{cm\ s^{-1}}$$

for λ = 1.05μm and 0.53μm respectively. There is good agreement with theory and numerical simulation and values of ablation pressures are derived, once the separation of the critical and ablation surfaces is allowed for. In this intensity regime there is little dependence of $\dot{m}_s$ or the flux limit.

Effects of Laser Beam Uniformity on the Acceleration of Ablatively Driven Targets*

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Successful compression of the fuel in a hollow fusion pellet requires that the pellet shell be imploded uniformly and that it reach velocities consistent with the specific energy of the compressed fuel. It is possible, however, that hydrodynamic instability or non-uniformity in the laser beam degrades the implosion uniformity and disrupts the acceleration of the shell.

We have measured[1] the velocities and velocity uniformities of planar targets accelerated by a laser pulse (τ = 3-4 nsec, λ = 1.05μm) to speeds (>150 km/sec) near those required for laser fusion. We have also measured the effects of nonuniformities intentionally introduced into the laser beam on the target acceleration and have observed significant smoothing of small scalelength ($\lesssim$200μm) laser nonuniformities and increasing smoothing with increasing irradiance.

To do these experiments we used a double-foil technique[2] that permits spatially and temporally resolved observation of the dense part of the accelerated target. Presently, we are performing experiments to further validate this technique and to corroborate our results. These include using tracer material implanted into the target[3] to spatially resolve the ablation plasma flow from its surface when it is irradiated by a nonuniform laser beam, diagnosing the thermal expansion of the accelerated target, and using stepped impact foils to measure the impulse of the accelerated target. Our latest results will be presented.

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

[a]Mission Research Corporation, Alexandria, VA.

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COLLISIONAL DC MAGNETIC FIELD IN RESONANCE ABSORPTION OF LIGHT

J.C. ADAM, A. GOURDIN-SERVENIERE, P. MORA*, R. PELLAT

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**C.E.A., 94190 Villeneuve St Georges, France.*

We reconsider the problem of magnetic field generation in resonante absorption of light by a plasma, taking collisions into account. We check theoretical predictions [1] using a 2D fully electromagnetic particle simulation code with fixed ion background. A weak rate of collision is shown to be sufficient to modify completely the magnetic field structure with respect to the collisionless case [2]

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Hydrodynamic Efficiency of Laser Irradiated Pellet Targets

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Abstract

The wavelength dependence of the hydrodynamic ablation process has been studied in the range of 1 to 0.5 μm. The heat penetration in a target is greater at shorter wavelength laser. However longer wavelength laser produces a larger amount of hot electrons which have a longer penetration in a target. The contribution of hot electrons alters the nature of ablation. At the laser intensity of 10^{14} W/cm^2, the ablation process is controlled by heat transport by cold electrons for 0.53 μm and 1.06 μm lasers and is managed by hot electrons for 10.6 μm laser.

In a model prediction, the ablation velocity monotonically increases with increasing laser wavelength with a scaling of $\lambda^{2/3}$, because the cut off density decreases. The observed velocity increases for laser wavelength from 0.5 μm to 1 μm, however it decreases again at 10.6 μm. This is due to hot electron driven ablation. Simulation and experimental results are in good accordance.

Hydrodynamic efficiency can be improved greatly by a new concept of pellet design: cannonball like configuration. The detail of this scheme is also presented.

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ANALYSIS OF THE 22X STREAKED X-RAY MICROSCOPE DATA: SELF EMISSION r-t PLOTS OF Au DISKS, AND BACKLIT r-t PLOTS OF ABLATIVELY ACCELERATED Al DISKS*

M. D. Rosen and R. H. Price

University of California
Lawrence Livermore National Laboratory
Livermore, California 94550

Abstract

The 22X streaked x-ray microscope has recently provided r-t information for targets irradiated with the SHIVA laser system at LLNL. The spatial & temporal resolution are about 4 μm and 15 ps respectively. We have observed the 1.5 KeV self emission from Au disks irradiated in the 10^{14}-10^{15} W/cm^2 range. A thin (~ 40 μm) emission region is observed to lift off the face of the disk and propagate towards the laser at nearly constant velocity throughout the laser pulse. The velocity does scale from shot to shot with peak irradiance as $I^{0.45}$. Simulations using 2-D LASNEX reproduce this behavior using the standard disk model[1] which includes inhibited transport. Models without inhibition, however, transport energy deeper into the target, thus creating a wide emission region that stays near the face of the disk, two features that disagree with the observations.

We have also observed, with x-ray sidelighting, the motion of laser accelerated Al disks. The measured terminal velocity of near 10^7 cm/sec is close to that predicted by simple models and LASNEX simulations.

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

[1] M.D. Rosen et. al. Phys. Fluids 22, 2020 (1979).

OBSERVATION OF A TWO COMPONENT HIGH ENERGY ELECTRON DISTRIBUTION IN DOUBLE-PULSED CO_2 LASER-INDUCED PLASMAS*

Fred Begay, David W. Forslund and Donald E. Casperson

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ABSTRACT

Experimental results on a two component high energy electron distribution measured in double-pulsed CO_2 laser-produced plasma at laser irradiances ~ 10^{16} W/cm^2 will be presented. The hot electron temperature distributions were inferred from the analysis of measured proton velocity distributions.

Results on the analysis of stimulated scattering instabilities in the underdense regions of the expanding plasma will be discussed.

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

RETURN CURRENT ELECTRON STREAMS IN HIGH INTENSITY LASER TARGET INTERACTION

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X-ray streak photography of the interaction of a nanosecond CO_2 laser pulse with large diameter foil targets shows the presence of an annular x-ray emitting region which expands away from the focal spot with a velocity up to 10^9 cm/sec. This region exhibits laser polarization dependent asymmetry and it is postulated that it is formed by a return current of fast electrons bombarding the front of the target foil. It appears likely that this phenomenon is responsible in part for anomalous lateral energy transport and magnetic field generation in such experiments. A local region of bright x-ray emission is also observed from a 250 μm diameter region surrounding the focal spot which agrees well with the observed region of strong shock heating in such targets.

Non-Random Suprathermal Electron Emission in Resonance Absorption

Paul Kolodner
Bell Laboratories
Murray Hill, NJ 07974

Eli Yablonovitch
Exxon Research and Engineering
Linden, NJ 07036

ABSTRACT

We describe a model calculation of a non-random process by which laser-produced plasmas emit energetic electrons, and we report experimental evidence for this effect. Electron emission is dominated by a 1- to 2-psec burst coincident with the first appearance of a critical surface during the initial stages of target breakdown. At each instant during this burst, all emitted electrons have the same energy. The time-integrated energy spectrum measured far from the target exhibits a suprathermal tail due only to the integrated temporal variation of the electron energy, and not to statistical processes. The hot-electron temperature thus produced shows a very weak dependence on laser pulse energy.

PRODUCTION OF HOT ELECTRONS IN A MICROWAVE PLASMA INTERACTION*

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Y. Nishida
Utsunomiya University, Japan

S.P. Obenschain
Naval Research Laboratory

J.R. Albritton
Lawrence Livermore National Laboratory, Livermore, CA

E.A. Williams
University of Rochester, Rochester, New York

We report here the first detailed measurements of the wavebreaking time, electric field growth and hot electron temperature in a microwave plasma interaction. The measurements were restricted to the first 100-1000 waveperiods. In addition, the power levels were low enough that the interaction was not dominated by density profile modifications. One therefore anticipates that the cold plasma analytic theory of wavebreaking will well describe the experiment. The effects of finite pump bandwidth on the above-mentioned processes were also investigated in detail.

The microwave radiation is incident on an inhomogeneous plasma with $\eta_{vac} = E_o^2/8\pi nKT_e \leq 2 \times 10^{-3}$ for the measurements described here. Since $v_{o,vac} / v_{te} << 1$, one might expect plasma wave convection to limit the field growth. Although we in fact observe an initial slowdown in the electric field growth apparently due to plasma wave convective loss, the measured (and calculated) quiver velocity in the field of the electrostatic waves exceeds thermal and the plasma behaves as if cold. Specifically, we find that for the case of a narrowband pump the measured wavebreaking time, electric field growth, and maximum hot electron temperature are all in excellent agreement with analytic predictions. Furthermore, we have measured the absolute power spectrum of the electrostatic waves and find that the first few harmonics have the same amplitude as predicted by cold plasma wave steepening calculations.

Finally, the effects of finite bandwidth have been examined experimentally, for $\Delta\omega/\omega_o$ up to 10%. Specifically, we find that the change in wavebreaking time, electric field and maximum hot electron energy E_{max} are all well described by the analytic theory. In addition, we find that $T_{hot} \propto (\Delta\omega/\omega_o)$ while $E_{max} \propto (\Delta\omega/\omega_o)^{-0.67}$. The difference is not surprising since, not only does the cold plasma model not describe the thermalization process, at these bandwidths the resonance interval becomes broader than the particle excursion in the wave field and electrons may ride more than a single wave in traversing the field structure in breaking.

*Work supported by U.S. DOE and U.S. AFOSR.

PONDEROMOTIVE PHASE EFFECTS AND ELECTRON ACCELERATION IN RESONANCE ABSORPTION

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An electron interacting with a high-frequency electromagnetic field experiences a ponderomotive phase gradient force together with the usual ponderomotive intensity gradient force when dissipation is taken explicitly into account. This property is shown to have important consequences upon laser-electron coupling in two cases of interest : a traveling plane wave and the resonantly-driven electrostatic field that occurs in resonant absorption situations. In particular, it is shown that an initially slow electron crossing the resonance region suffers a significant acceleration towards the vacuum.

SESSION 5

TRANSPORT EXPERIMENTS

Thursday, June 4

9:00 - 12:00

H. PEPIN

INRS-Energie, Varennes

ABSENCE OF FAST ELECTRONS
in
LASER-IRRADIATED GAS-JET TARGETS

by

J. A. Tarvin, KMS Fusion, Inc.

Few hard x-rays are emitted by a gas-jet target irradiated at either 1.05 μm or 0.53 μm. With the assumption that the suprathermal electrons dissipate all their energy in the plasma,[1] one can show that the total flux of fast electrons is more than two orders of magnitude below the flux inferred from x-ray data for solid glass targets. Even if the fast electrons are not bound to the gas target by a sheath potential, they must radiate as they leave the plasma. For an argon target irradiated at 0.53 μm, the radiation by this process is enough for us to conclude that the flux of fast electrons is still a factor of one hundred less than the flux from a solid target.

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H. Brysk, Phys.Rev.Lett. 37, 1242 (1976).

*Prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

ABSTRACT

EVIDENCE FOR CLASSICAL ELECTRON THERMAL CONDUCTION IN THE GAS JET TARGET*

by

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D. L. Matthews and L. N. Koppell

Lawrence Livermore National Laboratory

The long density gradient gas target has been successfully employed to examine absorption and backscatter phenomena (see (1) and other papers of this conference). Using time-integrated x-ray imaging and spatially resolved x-ray spectroscopy, we have examined the size, the energy content, and the scaling of the heated plasma near the critical surface. Since the heating and energy transport take place on a time scale much faster than the hydrodynamic time scale, it is possible to apply simple model estimates of the dimensions and scaling of a non-linear thermal conduction heat front. We find good agreement between the observed size of the heated plasma and the theoretical size based on classical electron thermal conductivity. We present estimates of the heat flux and compare it to saturated classical heat flux ($f = 0.6$). If the saturated thermal conduction heat front [(2)] was strongly inhibited ($f = 0.03$), we show that an excessively high electron temperature would be required in contradiction to the observations.

Finally, we present a few remarks on the implications of gas target experimental observations to target designs which do not require early ablation for early deposition.

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(2) J. J. Thomson, Anomalous Absorption Conference, Tucson (1978).

*Prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

Transport Studies by Thin Film Irradiation

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Plastic film targets (0.1 - 20 μm thickness) were irradiated by the iodine laser Asterix III. Standard irradiation conditions were: 100 J/300 ps laser pulse, 400 μm focal spot diameter, intensity 2 x 10^{14} Wcm^{-2}. The energy transfer to the accelerated foil material was measured by calorimetry as a function of foil thickness. The time-history of foil acceleration was followed by high-speed photography using dye laser background illumination. The results are compared to numerical simulations taking into account electron heat flux limitation and fast electron preheat.

Energy Transport in Laser Irradiated Targets

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T. Mochizuki and H. Azechi
Institute of Laser Engineering, Osaka University
Suita, Osaka, Japan

Abstract

One- and two-dimensional transports of hot electrons are studied by the simulation and theoretical analysis. In one-dimensional case, Lagrangian hydro code, in which hot electron are treated by multi-group model, shows that a steep density profile is created near the critical point, and that this is associated with hot electron trapping and cold electron heating due to a large electric field which is enhanced by anomalous resistivity to the return current. A significant fraction of hot electron energy is transferred to thermal electrons through Joule heating.

In two-dimensional case, electromagnetic filamentation instability[1)] is driven unstable due to collisional scattering of hot electrons. This process is simulated by two-dimensional, Eulerian fluid code and the ablation pressure nonuniformity caused by the heat flux filamentation is estimated. The formation filamentation has also experimentally investigated.

References
1) T. Mochizuki, et al., Japanese Journal of Appl. Phys., 19 (1980) L645.
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SUPRATHERMAL ELECTRON TRANSPORT IN CO_2 LASER TARGET EXPERIMENTS

J.C. Kieffer, H. Pépin
INRS-Energie
R. Décoste
IREQ

The energy transport of hot electron in layered targets has been determined for 10.6 μm interaction at 2 10^{13} W/cm^2 from the hard X-ray continuum spectra. The targets are made of various plastic layers (0.1 μm - 50 μm) deposited on a gold substrate. The X-ray spectra are recorded from 1 keV to 50 keV by a multichannel system.

The experimental X-ray spectra of gold for various thicknesses of plastic are analyzed using a 1D model of electron penetration and hot electron spectrum deformation in solid matter. The absolute energy deposition by the hot electrons as a function of depth from the target surface is calculated. About 10% of the incident laser energy is deposited by the suprathermal electrons into the target; 9% of the incident laser energy is dissipated in the first 25 μm of plastic (half of the observed penetration). The results are discussed using various electron distributions and in the light of X-ray angular distribution measurements.

ENHANCED ENERGY DEPOSITION BY FAST ELECTRON FROM HIGH INTENSITY LASER PLASMA INTERACTIONS

J.D. Kilkenny

Imperial College, London

OBSERVATION OF FLUX LIMITATION IN ELECTRON THERMAL CONDUCTION

B.L. Wright

Los Alamos National Lab.

LA-UR-81-1583

Abstract Submitted for
The Eleventh Annual Anomalous Absorption Conference
June 2-5, 1981, Montreal

OBSERVATION OF FLUX LIMITATION IN ELECTRON THERMAL CONDUCTION*

B. L. Wright, J. C. Ingraham, R. S. Massey, and H. Dreicer
Los Alamos National Laboratory

Electron heat flow parallel to $\vec{B}$ has been studied on a fully-ionized plasma column under conditions for which the electron-electron mean free path, ℓ_{ee}, is not small in comparison with the electron temperature gradient scale length. A microwave resonator is used to apply a localized heating pulse to the plasma. Both the heater resonator and an additional sensor resonator are then used to make nonperturbing measurements of the electron temperature as a function of time at two points along the column. The measurement is based on the $T^{-3/2}$ dependence of the plasma ac resistivity. Langmuir probes are also used to provide radial profiles of electron temperature and density. We compare our resonator data with the radially averaged predictions of a one-dimensional heat flow code based on the Spitzer collisional transport model. In order to incorporate the transition to large ℓ_{ee}, the code has provision for limiting the heat flux to a collisionless transport rate, $\beta nkT\sqrt{kT/m}$ (where β is an adjustable parameter). Because strong heating in the experiment is accompanied by parametric instability and the generation of measurable populations of suprathermal electrons, the energy deposition associated with these electrons has also been included. For cases of weak heating we confirm the classical, collisional model. In cases of strong heating, however, we find that values of the flux-limit parameter β in the range 0.3 to 0.6 are required to fit the data.

*Work performed under the auspices of USDOE.

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

June 2-5, 1981

Montreal, Quebec, Canada

HEAT TRANSPORT, ABLATION RATE AND PRESSURE MEASUREMENTS IN UV-LASER TARGET INTERACTION EXPERIMENTS*

by

B. Yaakobi, T. Boehly, P. Bourke, J. Delettrez, L. M. Goldman
R. L. McCrory, W. Seka, and J. M. Soures
Laboratory for Laser Energetics
University of Rochester

The thermal conductivity in UV laser matter interaction experiments was determined from x-ray burn-through measurements. The 0.35μm radiation from a frequency tripled Nd:glass laser was incident on flat, plastic-coated targets. The hydrogen and helium-like Si spectra were measured as a function of plastic thickness at intensities ranging from 10^{13} to 10^{15} W/cm^2 and pulse with between 90 and 450 psec. Comparison of the experimental spectra with calculations yields an effective thermal electron flux limiter of f=0.03. This value is obtained over the whole range of laser parameters investigated here.

The pressure near the ablation surface was determined using two methods:

1. From $P=N_ekT$ where N_e and T were deduced from various silicon x-ray line intensity ratios, and
2. from $P=(d/dt)\int v\,(dm/dv)dv$, where the relative velocity spectrum was measured by a charge collector and the total ablated mass from the spectroscopic burn-through measurements. Both methods show good agreement with simulations: the pressure increases with the irradiance line $\sim I^{2/3}$ and reaches (30 ± 15) MBar at 10^{15} W/cm^2.

*This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124

ANALYSIS AND SIMULATION OF LAYERED-SLAB TRANSPORT EXPERIMENTS AT 0.35 μm WAVELENGTH*

W. C. Mead, E. M. Campbell, W. L. Kruer, C. E. Max,
J. R. Albritton, R. J. Olness, and Y. T. Lee

University of California, Lawrence Livermore National Laboratory
Livermore, California 94550

Abstract

We analyze irradiations of beryllium-coated aluminum disk targets using the frequency-tripled Argus laser at 0.35 μm wavelength, 3 x 10^{14} W/cm^2 intensity, 30 J energy, and 700 ps pulse duration.[1] The f/2 beam was P-polarized at 30° incidence angle.

Targets with beryllium coating thicknesses of 0., 0.6, 1.8, and 6.0 μm were used to obtain axial transport information. We compare the absolute levels and the coating-thickness dependence of sub-keV and keV x-ray emission with LASNEX calculations. The sub-keV measurements show that a Be-layer thickness of 0.9 μm (+0.4, -0.25 μm) reduces the Al x-ray emission by one e-folding. The observed emission "attenuation" depth is shallower than that obtained in LASNEX calculations using nominal transport inhibition.

We analyze observations of shock-wave transit-times obtained from rear-surface optical pyrometry. Preliminary results indicate shock strengths of ~ 20 Mb.

X-ray images of targets surrounded by large titanium shields show evidence for lateral energy transport outside the initial beam-heated region. We interpret these images by comparisons with two-dimensional calculations using various heating and transport models.

We discuss the mechanisms involved. Finally, we compare the results with previous 1.06 μm transport experiments.[2]

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

[1] E. M. Campbell, et al., this conference.

[2] D. L. Banner, W. C. Mead, E. M. Campbell, and W. L. Kruer, in Laser Program Annual Report ~ 1979, Lawrence Livermore National Laboratory Rpt. UCRL-500-21-79 (1980), p. 6-12.

LAYERED TARGET TRANSPORT EXPERIMENTS AT 3 ω_0*

M. Campbell, W. Mead, P. Lee, G. Stradling,
J. Foster**, D. Matthews, L. Koppel, J. Trainor,
N. Holmes, B. Stevenson, B. Pruett, C. Hatcher,
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ABSTRACT

The results of electron transport experiments conducted with the frequency tripled Argus Laser will be presented. The experiments were conducted at a fixed intensity and pulse width (FWHM) of approximately 3×10^{14} W/cm^2 and 600 to 700 psec respectively. These irradiation conditions were chosen to study electron transport in the moderate intensity, highly collisional laser plasma-interaction regime which will be encountered in future target designs.

To explore axial transport a variable thickness beryllium layer is coated onto an aluminum substrate. The effectiveness of electron heat conduction is studied by measuring the fall-off in aluminum X-ray yield (line and continuum) as the beryllium thickness is increased.

Lateral conduction is examined by placing the axial transport target onto a titanium disk. The laser is focused onto the beryllium coated aluminum and X-ray emission from titanium serves as the signature of lateral transport.

Additional measurements include: X-ray images from both a microscope and a pinhole camera, temporal history of the sub-kilovolt X-ray emission from soft X-ray streak camera, and the average velocity of the shock launched by the rapid laser ablation of the front surface of the target obtained with an optical streak camera.

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

** AWRE, England

SESSION 6

TRANSPORT THEORY :

HOW INHIBITED IS YOUR TRANSPORT?

Thursday, June 4

14:15 - 16:15

S. BODNER

Naval Research Lab.

Washington, D.C.

FOKKER-PLANCK SIMULATIONS OF ENERGY-TRANSPORT

A.R. Bell

SRC Rutherford Lab., Oxfordshire

FOKKER-PLANCK SIMULATIONS OF ENERGY TRANSPORT

A R Bell

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United Kingdon

Abstract

The effect of density gradients and bulk plasma flow on electron energy transport is examined by numerical solution of the Fokker-Planck equation for electrons in one spatial and two velocity dimensions. The ions are treated as an adiabatic fluid, with electron-ion momentum transfer mediated by both collisions and electric field. Electron-ion thermal energy exchange is neglected. The program is initialised to model the disassembly of a slab of plasma which is initially at a few times critical density. Energy is deposited in the sub-critical region and transferred to higher densities by thermal electron energy transport. The evolution of temperature, density and flow profiles is discussed, and the results compared with a flux-limited description of energy transport.

CLASSICAL HEAT TRANSPORT BY NON MAXWELL-BOLTZMANN ELECTRON DISTRIBUTION*

J. R. Albritton

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Livermore, California 94550

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

Annual Conference on Anomalous
Absorption of Electromagnetic Waves

June 2-5, 1981

Montreal, Quebec, Canada

ANALYSIS OF THERMAL ELECTRON TRANSPORT "INHIBITION" IN LASER PLASMA INTERACTIONS UNDER VARIOUS LASER AND TARGET CONDITIONS†

by

J. Delettrez, R. L. McCrory, D. Shvarts*, C. P. Verdon, and B. Yaakobi
Laboratory for Laser Energetics
University of Rochester

We analyze the electron thermal transport in laser plasma interactions in light of recent models describing inhibited transport.[1] The thermal front penetration depth, the peak coronal electron temperatures, and the absorption fraction for "flux-limiter" values of 0.03 to 0.1 are compared with the values obtained with a self-consistent model of the reduction of the Spitzer-Härm conductivity in steep temperature gradients[1-3]. For a laser intensity of 6×10^{14} W/cm^2 and a pulse length of 500 psec on Beryllium targets the results of the self-consistent reduction model agree well with those of the flux-limit model for flux limiters near 0.06. Under these conditions the mean free path of the electrons carrying most of the energy does not exceed the temperature gradient scale length. Conditions in the thermal heat front are presented for various laser pulse widths, intensities, and target materials. A comparison with preliminary results from transport experiments at a laser wavelength of 0.35 μm on the GDL laser system at LLE will be presented.

†This work is supported by the sponsors and participants of the Laser Fusion Feasibility Project of the Laboratory for Laser Energetics.
*Permanent address: Nuclear Research Center, Negev, Israel.

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

June 2-5, 1981

Montreal, Quebec, Canada

A SELF-CONSISTENT FLUX-LIMITED EXTENSION OF THE SPITZER-HÄRM THERMAL CONDUCTIVITY IN STEEP-TEMPERATURE GRADIENTS†

D. Shvarts*, J. Delettrez, R. L. McCrory, and C. P. Verdon
Laboratory for Laser Energetics
University of Rochester

The breakdown of the Spitzer-Härm (S-H) derivation of electron thermal conductivity, for steep temperature gradients, was found to be related to the fact that the particle flux in the S-H diffusion formulation is unbounded, resulting in unphysically large particle and heat fluxes. A simple extension to the S-H theory is derived by properly applying a flux limit to the anisotropic portion of the electron distribution function[1], and results in a self-consistent flux-limited local description of the electron thermal conductivity in steep temperature gradients. This local extension results in a new upper bound for the local heat flux, substantially lower than that given by a "free-streaming" limit, and an order of magnitute reduction from the S-H thermal heat flux. The reduction accounts for most of the "inhibition" previously required in the interpretation of high power laser produced plasma experiments. The inclusion of the non-local contributions from long mean-free-path electrons, treated by a multi-group transport model, results in increased thermal front gradient lengths, and a reduction of the front propagation speed.

†This work is supported by the sponsors and participants of the Laser Fusion Feasibility Project of the Laboratory for Laser Energetics.

*Permanent address: Nuclear Research Center, Negev, Israel.

1. D. Shvarts, J. Delettrez, R. L. McCrory, and C. P. Verdon, "Self-Consistent Reduction of the Spitzer-Härm Electron Thermal Heat Flux in Steep Temperature Gradients", *submitted for publication* (March, 1981)

THERMAL TRANSPORT INHIBITION IN LASER PRODUCED PLASMAS*

by

Rodney J. Mason

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Los Alamos, NM 87545

ABSTRACT

Laser driven thermal electron transport inhibition has been studied using a self-consistent PIC Collisional (Monte Carlo) model for all the electrons and PIC hydrodynamics for the ions. The model includes the effects of electron-ion and electron-electron scatter, electron-electron drag towards a local Maxwellian, self-consistent E, ponderomotive force and inverse-bremsstrahlung absorption. The E fields are calculated by the implicit moment technique.[1] The transport is limited to Brownian diffusion speeds, and Ohm's last currents in highly collisional regions.[2]

Comparison of the model's results with those from single group flux-limited diffusion shows that the Monte Carlo treatment heats relatively more matter at great depths to low temperatures and less matter near a target surface to high temperatures. This is especially evident in the presence of a density jump -- as established near critical by the ponderomotive force. Furthermore, the E field to draw a return current down thru such density jumps and into the heating region traps and inhibits the lower energy heated thermal electrons. Finally, we show that the use of a flux lmit factor of f = 0.03 (f = 0.6 is classical) can bring the single group diffusion and Monte Carlo results into some accord.

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

1. R. J. Mason, J. Comp. Phys., in press and LA-UR-80-2171.

2. R. J. Mason, in the proceedings of the ANS/ENS International Topical Meeting on "Advances in Nuclear Engineering Problems," Munich, W. Germany, April 27-29, 1981, and LA-UR-81-95.

COMMENTS ON RECENT LASER-MATTER INTERACTION EXPERIMENTS

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Recent laser matter ablation experiments at the Ecole Polytechnique, the SRC Rutherford Laboratory, and the U.S. Naval Research Laboratory are analyzed using simple models. The observed scaling laws are consistent with the first two groups' experiments being performed under conditions appropriate to the Chapman-Jouguet regime, while the NRL results lie in a conduction dominated region. This difference in scaling laws is associated with the laser intensity being either above or below the threshold for thermal flux inhibition.

"Hot Electron Transport in Thin Planar and Spherical Systems"

M. A. True

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ABSTRACT

In high intensity laser fusion experiments, the hot electrons produced by resonance absorption can traverse the entire target if the target is thinner than the electron mean-free-path. Under such conditions, we compare the hot electron transport in planar and spherical geometry. In planar geometry, the competition between collisional drag in the dense interior of the target and the work done on the fast ion blowoff is illustrated by the solution of the bounce-average kinetic equation. In spherical geometry, the hot electron transport is similar to the planar transport when the electron orbits are radial. The scattering of hot electrons into more circular orbits changes the balance of thermalization to fast ion work. We examine various scattering mechanisms in the corona and their influence on the hot electron transport.

DISCUSSION ON TRANSPORT:

EVIDENCE + THEORY = ?

Discussion leader: R.L. Morse

U. of Arizona

SESSION 7

SHORT WAVELENGTH OVERVIEW

Friday, June 5

9:00 - 10:30

F. MAYER

KMS Fusion

PROPAGATION OF RELATIVISTICALLY-INTENSE, VERY SHORT PULSES*

Bruce Langdon and J. Pettibone

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Abstract

We have studied, with the kinetic plasma simulation code ZOHAR, the propagation of relativistically-intense ($1 < q_e E/\omega m_e c < m_i/m_e$) pulses of very short duration (a few cycles). Propagation above the (linear theory) cutoff at critical density, and comparisons between linear and circular polarization, and between one-and two-dimensional simulations are of interest.

*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

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

June 2-5, 1981

Montreal, Quebec, Canada

THEORETICAL INTERPRETATION OF SHORT WAVELENGTH INTERACTION EXPERIMENTS†

by

R. S. Craxton, J. Delettrez, R. L. McCrory, D. Shvarts*, R. Keck and W. Seka
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Extensive calculations of the absorption of short wavelength laser radiation, particularly at 0.35 μm, have been performed using the Eulerian hydrocode SAGE, modeling primarily inverse bremsstrahlung. The absorption is found to be a sensitive function of the flux-limiter f used to describe the reduction of the electron heat flux Q from Spitzer's value. ($Q \sim f \cdot nkT (kT/m^{\frac{1}{2}})$. Predictions using f=0.03 have been found to agree very closely with recent LLE absorption experiments at 0.35 μm, on planar CH and Ni targets for laser pulses of 90 and 450 psec, and also with similar experiments performed elsewhere. The physical basis of using f=0.03 will be discussed.

X-ray spectra (1-10 keV) from CH targets at 0.35 μm from recent experiments have been examined. The relative importance of the contributions from the hot coronal plasma and the cooler supercritical plasma is discussed, and the sensitivity of the spectrum to target geometry, flux limiter, etc. is examined. Recent experimental measurements have been obtained from filtered PIN diodes, and are fitted well with 2-temperature spectra. Various simulations agree very closely with one another, and with the experimental data.

†This work is supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124.

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TRANSPORT INHIBITION AND WAVELENGTH DEPENDENCE

R. FABBRO, E. FABRE, F. AMIRANOFF, G. GARBAN-LABAUNE
J. VIRMONT, M. WEINFELD
(G.I.L.M., Ecole Polytechnique, Palaiseau, France)

C.E. MAX
(L.L.N.L., USA)

Analysis of transport inhibition has been made by comparison of the results on thin foils experiments and their numerical hydrodynamic simulations [1]. These studies have been made at 3 different wavelength : 1.06 μm, 0.53 μm, 0.26 μm, and irradiance ranging from 10^{14} - 10^{15} W/cm^2. The main conclusion is that heat flux inhibition occurs at all wavelength : at 1.06 μm, strong inhibition of both thermal ($f \lesssim 0.01$) and suprathermal electrons is observed. At 0.26 μm, fast electrons transport is negligible and the resulting flux limit number f is such that $0.03 \lesssim f \lesssim 0.08$.

From these experiments a scaling low of mass ablation rate has been deduced :

$$\dot{m}\ (\mathrm{kg/s/cm^2}) \simeq 110 \left(\frac{\phi_a(\mathrm{W/cm^2})}{10^{14}}\right)^{1/3} \lambda_{\mu m}^{-4/3}$$

This larger mass ablation rate and the observation of comparable expansion velocities of thermal plasma component evidence larger ablation pressures for short wavelength. Preliminary experiments on shock front velocity determination in solids seem to confirm this results.

[1] Rapport d'activité GRECO 1980 (Ecole Polytechnique) page 98 and 107.

2-D Fluid Simulaitions of Non-Uniformly Irradiated Targets for Inertial Fusion

R G Evans   Rutherford Laboratory

A J Bennett
G J Pert   University of Hull

In order to study the thermal conduction smoothing in non-uniformly irradiated ICF targets we have performed a large number of 2-D simulations on the CRAY-1 computer at Daresbury. The code used is an Eulerian MHD code developed at the University of Hull employing donor cell differencing and FCT to solve the advection equations and including a dynamic rezoning option. The code is routinely run without the MHD calculations and spot checks are made of the influence of the magnetic field terms on the thermal transport and hydrodynamics. A typical simulation time for the stripped-down version of the code is 20 mins for a 1.5ns calculation on a 50 x 100 spatial mesh.

We have used the code to simulate sinusoidal modulations of the driver intensity, of different amplitude of modulation, spatial wavelength, laser wavelength and have also simulated particle beam driven targets.

The particle beams and short wavelength lasers place very severe constraints on driver uniformity and ICF pellets using these drivers may well need to be indirectly driven by thermal radiation. Laser wavelengths of 1 μm and longer sustain large amounts of thermal conduction smoothing but are susceptible to fast electron generation and other collective phenomena such as Stimulated Brillouin Scattering.

It remains possible that a laser wavelength of $\sim$0.5 μm will produce acceptable thermal conduction smoothing, absorption and fast electron production at an irradiance of $\sim 2.10^{14}$ W cm^{-2}. Such a system will be useful for proof of principle, and basic physics experiments. Further experimental data on thermal smoothing and SBS is necessary before further extrapolations can be made.

"Scaling of Physical Processes in Gas Jets to the Next Generation Targets"

R. L. Berger and L. V. Powers

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ABSTRACT

A great deal of the plasma processes that are expected to play a role in long-pulse, large-target experiments are being studied in experiments on low density gases ejected from high pressure plenums — the gas jets. These experiments are able to control the density scale length and ionization appears to be complete. Obviously, there is little or no hydrodynamic flow which has played an important role in controlling the percentage of Brillouin scattering in short pulse experiments, but may not in long pulses on large targets. We report the scaling of Raman scattering, two plasmon decay, Brillouin, parametric decay, filamentation, resonant absorption, and heat transport from gas jets to the next generation experiments.

MEASUREMENTS OF THE RATE OF SIDEWAYS SPREADING OF ENERGY BY FAST ELECTRONS FROM THE 1.05μm IRRADIATION OF PLANE TARGETS

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It is shown that high $I\lambda^2$ irradiation of plane targets results in a fast-electron cloud, spreading sideways with a velocity of 2×10^8 cm s^{-1}. This electron cloud deposits ~2J in the target. Thomson parabola measurements show that fast ions come from a similar size region and imply that for long pulses a substantial fraction of the absorbed energy is being lost sideways.

D I S C U S S I O N :

WHAT HAVE WE LEARNED?

WHAT ARE THE QUESTIONS FOR NEXT YEAR?

Discussion leader: R.G. Evans

SRC Rutherford Lab.
Oxfordshire

11th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

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JOHNSTON, Tudor Wyatt, INRS-Energie, Université du Québec	1-6, P-18
KIEFFER, Jean-Claude, INRS-Energie, Université du Québec	5-6
LAVIGNE, Pierre, INRS-Energie, Université du Québec	1-7
MARTIN, François, INRS-Energie, Université du Québec	1-6
MATTE, Jean-Pierre, INRS-Energie, Université du Québec	P-11
MITCHEL, Garry R., INRS-Energie, Université du Québec	1-6, 1-7
PEPIN, Henri, INRS-Energie, Université du Québec	1-6, 1-7, 5-6
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