M D ROSEN

University of California, Davis

Department of Applied Science
Plasma Research Group

TENTH ANNUAL

ANOMALOUS ABSORPTION CONFERENCE

May 27 - 30, 1980

TENTH ANNUAL ANOMALOUS ABSORPTION CONFERENCE

Session Schedule

A. Magnetic Fields, Transport Phenomena
Wednesday, May 28, 8:30 AM - 12:37 PM
Chairman: R. L. Morse, University of Arizona

B. Transport Phenomena, Hydrodynamics
Wednesday, May 28, 2:00 PM - 5:41 PM
Chairman: F. F. Chen, University of California, Los Angeles

C. Laser and Microwave Experiments, Profile Modification and Resonant Absorption
Thursday, May 29, 8:30 AM - 12:28 PM
Chairman: R. P. Godwin, Los Alamos Scientific Laboratory

D. Hot Electrons, Profile Modification, Resonant Absorption, Transport Phenomena
Thursday, May 29, 2:00 PM - 5:30 PM

E. Stimulated Scattering
Friday, May 30, 8:30 AM - 12:32 PM
Chairman: A. B. Langdon, Lawrence Livermore Laboratory

F. Laser Experiments, Stimulated Scattering, Filamentation
Friday, May 30, 2:00 PM - 5:30 PM

TENTH ANNUAL ANOMALOUS ABSORPTION CONFERENCE

May 28 - 30, 1980
Grosvenor Airport Inn
South San Francisco, California

CONFERENCE SCHEDULE

TUESDAY, May 27

6:00 PM - 10:00 PM		Registration/Check-in Grosvenor Airport Inn - Lobby
7:00 PM - 10:00 PM		Cocktail Party/Buffet Grosvenor Airport Inn - Windsor Room

WEDNESDAY, May 28

All Conference sessions will be held in the Windsor Room of the Grosvenor Airport Inn.

8:00 AM - 11:00 AM		Registration/Check-in Grosvenor Airport Inn - Lobby

Session A--MAGNETIC FIELDS and TRANSPORT PHENOMENA (Oral session)--R. L. Morse, Chairman

8:30 AM - 8:53 AM	A-1	"Magnetic Field Generation in Laser Target Plasmas", T. J. M. Boyd.
8:53 AM - 9:16 AM	A-2	"Electromagnetic Oscillating Two Stream Instability of Laser Radiation: A Source of Self-Generated Magnetic Fields", C. S. Liu and V. K. Tripathi.
9:16 AM - 9:34 AM	A-3	"Superthermal Transport Effects on Microtargets Irradiated by 10.6 μm", G. D. Enright, M. D. J. Burgess, P. A. Jaanimagi, R. S. Marjoribanks, D. M. Villeneuve, and M. C. Richardson.
9:34 AM - 9:52 AM	? A-4	"Hot Electron Transport Measurements in CO_2 Laser Produced Plasmas", J. C. Kieffer, F. Martin, T. W. Johnston, H. Pépin, and R. Décoste.
9:52 AM - 10:10 AM	? A-5	"Effect of Laser Wavelength on Interaction and Transport Processes", E. Fabre.
10:10 AM - 10:25 AM		COFFEE BREAK

10:25 AM - 10:38 AM	A-6	"Layered Target Transport Experiments at 1.06 μm", E. M. Campbell, W. Kruer, L. Koppel, G. Tirsell, W. C. Mead, D. Matthews, D. Banner, H. Kornblum, and R. H. Price.
10:38 AM - 10:56 AM	A-7	"Simulations of Layered-Slab Transport Experiments:, W. C. Mead, W. L. Kruer, M. Campbell, and D. Banner.
10:56 AM - 11:18 AM	A-8	"Transport in Steepened Profiles", B. K. Berger and R. L. Berger.
11:18 AM - 11:33 AM	A-9	"Calculations of Heat Flux Limitations in Large Temperature Gradients", A. R. Bell.
11:33 AM - 11:51 AM	A-10	"Full Particle PIC-Collisional Calculations of Electron Transport in Laser Produced Plasmas", R. J. Mason.
11:51 AM - 12:14 PM	A-11	"Transport Inhibition due to Flow-Driven Ion Turbulence at the Shock behind the Critical Surface", F. J. Mayer, D. Mitrovich, L. V. Powers, and T. Speziale.
12:14 PM - 12:37 PM	A-12	"Anomalous Energy Transport in Microwave Plasma Interaction", C. L. Yee and J. S. DeGroot.

Session B--TRANSPORT PHENOMENA and HYDRODYNAMICS (Oral session)--F. F. Chen, Chairman

2:00 PM - 2:08 PM	B-1	"Measurements of Inhibited Heat Transport in a Microwave-Plasma Interaction Experiment", K. Mizuno, J. S. DeGroot, and R. B. Spielman.
2:08 PM - 2:31 PM	B-2	"Scaling Laws for Free and for Tamped Ablation Flow", B. Ahlborn, G. Josin, and N. H. Burnett.
2:31 PM - 2:49 PM	B-3	"Motion and Pressure Measurements on Ablatively Accelerating Targets Using Double-Foils and Particle Diagnostics", J. Grun, S. P. Obenschain, B. H. Ripin, R. Decoste, and M. J. Herbst.
2:49 PM - 3:07 PM	B-4	"Measurement of the Uniformity of Ablative Acceleration Using Single and Double Foil Targets", S. P. Obenschain, J. Grun, J. A. Stamper, and B. H. Ripin.
3:07 PM - 3:25 PM	B-5	"Nonuniformities in X-ray Emission from Ablatively Driven Foil Targets", M. J. Herbst and R. R. Whitlock.
3:25 PM - 3:40 PM		COFFEE BREAK

3:40 PM - 3:58 PM	B-6	"Ion Acceleration Processes in CO_2 Laser-Induced Carbon Plasmas", F. Begay and D. W. Forslund.
3:58 PM - 4:16 PM	B-7	"Simulations of Implosions Driven by a Frequency-Converted Nd-Glass Laser", P. Hammerling, E. Fabre, and J. Virmont.
4:16 PM - 4:39 PM	B-8	"Taylor Instability in Fusion Targets", R. L. McCory, L. Montierth, R. L. Morse, and C. P. Verdon.
4:39 PM - 4:52 PM	B-9	"Growth Rates of Ablation Driven Taylor Instability", L. Montierth and R. Morse.
4:52 PM - 5:15 PM	B-10	"Coronal Modification due to Fast Electron Escape", M. A. True and E. A. Williams.
5:15 PM - 5:28 PM	B-11	"Multiple-Time, Dark-Field Optical Probing Studies of Laser Accelerated Foils", J. A. Stamper and S. H. Gold.
5:28 PM - 5:41 PM	B-12	"Collision of Radiation-Driven Breakdown Waves", B. DeFonseka, T. Carlstrom, and Z. A. Pietrzyk.

THURSDAY, May 29

Session C--LASER AND MICROWAVE EXPERIMENTS and PROFILE MODIFICATION AND RESONANT ABSORPTION (Oral session)--R. P. Godwin, Chairman

8:30 AM - 8:53 AM	C-1	"Recent Topics on Laser Plasma Interactions at Osaka University", Y. Kitagawa, H. Nishimura, H. Azechi, N. Miyanaga, K. Yamada, Y. Kato, M. Yokoyama, and C. Yamanaka.
8:53 AM - 9:11 AM	C-2	"Long Pulse Irradiation of High Z Disks at 0.53 μm: Recent Experiments", V. C. Rupert, E. M. Campbell, D. W. Phillion, and F. Ze.
9:11 AM - 9:29 AM	C-3	"Green-Light Experiments on Spherical Targets", D. C. Slater, J. A. Tarvin, J. D. Simpson, G. Charactis, R. J. Schroeder, and D. Sullivan.
9:29 AM - 9:42 AM	C-4	"High Energy Electrons Generated by Two-Plasmon Decay in 10.6 μm Laser-Plasma Interaction", H. A. Baldis, N. A. Ebrahim, C. Joshi, and R. Benesch.
9:42 AM - 10:05 AM	C-5	"Scaling of Absorption and Stimulated Scattering with λ, I, Z, τ: Theory, Simulation, and Experiment", M. D. Rosen.
10:05 AM - 10:23 AM	C-6	"Microwave Absorption in a Highly Collisional Plasma", W. F. DiVergilio, J. J. Thomson, and R. F. Wuerker.

10:23 AM - 10:40 AM		COFFEE BREAK
10:40 AM - 11:03 AM	C-7	"Profile Modification and Hot Electron Temperature from Resonant Absorption at Modest Intensity", J. R. Albritton and A. B. Langdon.
11:03 AM - 11:26 AM	C-8	"Fluid Steepening and Electron Distributions", B. Bezzerides and S. Gitomer.
11:26 AM - 11:34 AM	C-9	"Profile Modification for Oblique Incidence and Nonlinear Resonant Absorption", F. David, P. Mora, and R. Pellat.
11:34 AM - 11:52 AM	C-10	"Envelope Stability of Plasma Waves Generated by Resonant Absorption in an Inhomogeneous Plasma", J. C. Adam. A. Gourdin Serveniere, and G. Laval.
11:52 AM - 12:10 PM	C-11	"Effect of the Electron Equation of State on the Profile Modification Problem", C. H. Aldrich, R. Jones, and K. Lee.
12:10 PM - 12:28 PM	C-12	"Laser Induced Density Profiles in an Isothermal Plasma", R. Jones, C. H. Aldrich, and K. Lee.

Skip

Session D--HOT ELECTRONS, PROFILE MODIFICATION, RESONANT ABSORPTION, and TRANSPORT PHENOMENA (Poster session)

2:00 PM - 5:30 PM	D-1	"High Energy Electrons Generated by Two-Plasmon Decay in 10.6 μm Laser-Plasma Interaction", H. A. Baldis, N. A. Ebrahim, C. Joshi, and R. Benesch.
	D-2	"2-D Simulations of Quarter-Critical Heating in Large Plasmas", B. F. Lasinski and A. B. Langdon.
	D-3	"Profile Modification for Oblique Incidence and Nonlinear Resonant Absorption", F. David, P. Mora, and R. Pellat.
	D-4	"Effects of Light Polarization on Resonant Absorption", J. Kupersztych.
	D-5	"Two-Dimensional Soliton Collapse in a Nonuniform Plasma", N. R. Pereira and G. J. Morales
	D-6	"Hot Electrons Produced by the Resonant Absorption of a Focused Beam of High Power Microwaves", D. Rasmussen, K. Mizuno, and J. S. DeGroot.

	D-7	"Finite Bandwidth Effects on Resonant Electron Heating", R. B. Spielman, W. M. Bollen, K. Mizuno, and J. S. DeGroot.
	D-8	"Measurements of Inhibited Heat Transport in a Microwave-Plasma Interaction Experiment", K. Mizuno, J. S. DeGroot, and R. B. Spielman.
	D-9	"Cross-Field Electron Transport in a Weakly Magnetized Plasma Driven by s-Polarized Microwaves", T. A. Hargreaves, K. Mizuno, and J. S. DeGroot.
	D-10	"Computer Analysis of Langmuir Probe Data", R. Walraven.
	D-11	"Ion Acoustic Resistivity and Double Layers", C. Barnes.
	D-12	"Electron Cyclotron Damping for Large Wave Amplitude in Tokamak Plasmas", I. Fidone, G. Granata, and R. L. Meyer.
	D-13	"Effect of Finite Electron Drift on the Resonant Excitation of a Nonuniform Plasma", G. J. Morales, B. Lamb, and E. A. Adler.
3:00 PM - 3:30 PM		COFFEE BREAK

FRIDAY, May 30

Session E--STIMULATED SCATTERING (Oral session)--A. B. Langdon, Chairman

8:30 AM - 8:48 AM	E-1	"Time Resolved Backscatter Studies in Laser Plasmas at 1.052 μm and 0.526 μm", E. McGoldrick, A. A. Pugatschew, S. M. L. Sim, A. J. Cole, J. Murdoch, and R. G. Evans.
8:48 AM - 9:01 AM	E-2	"Brillouin Scattering at Arbitrary Angles in Drifting Plasma: Application to experiment", G. Mitchel, T. W. Johnston, B. Grek, H. Pépin, and F. Martin.
9:01 AM - 9:19 AM	E-3	"New Results on Brillouin Scattering", F. F. Chen.
9:19 AM - 9:32 AM	E-4	"Plasma Flow Effects on Langmuir and Ion Acoustic Waves", Wee Woo and J. S. DeGroot.

9:32 AM - 9:50 AM	E-5	"Fluid Simulation of Stimulated Brillouin Backscatter in Laser-Produced Plasmas", W. M. Manheimer and D. G. Colombant.
9:50 AM - 10:08 AM	E-6	"Wavelength Scaling of Brillouin Scattering and Profile Modification by Fluid Simulation", D. J. Tanner, D. Mitrovich, and R. L. Berger.
10:08 AM - 10:25 AM		COFFEE BREAK
10:25 AM - 10:43 AM	E-7	"Effects of Secondary Brillouin Scattering", T. Speziale, R. L. Berger, J. F. McGrath, T. W. Johnston, and G. Picard.
10:43 AM - 11:06 AM	E-8	"SBS in a Microwave-Plasma Interaction: Threshold and Growth Rate", H. Huey, A. Mase, N. C. Luhmann, Jr., W. F. DiVergilio, and J. J. Thomson.
11:06 AM - 11:29 AM	E-9	"SBS Study in Microwave-Plasma Interaction: Saturation and Control", A. Mase, H. Huey, N. C. Luhmann, Jr., W. F. DiVergilio, and J. J. Thomson.
11:29 AM - 11:42 AM	E-10	"Latest Results of LASNEX and Kinetic Simulations of Brillouin and Raman Scattering", K. Estabrook, J. Harte, and W. L. Kruer.
11:42 AM - 12:00 PM	E-11	"Limitations on Brillouin Scattering by Inverse Bremsstrahlung and Ion Heating", R. G. Evans.
12:00 PM - 12:23 PM	E-12	"Nonlinear Behavior of Stimulated Scattering, Self-Focussing and Bubble Formation", J. M. Kindel, C. H. Aldrich, and D. W. Forslund.

Session F--LASER EXPERIMENTS, STIMULATED SCATTERING, and FILAMENTATION (Poster session)

2:00 PM - 5:30 PM	F-1	"Absorption Experiments on CO_2 Laser Produced Plasmas", R. Kristal.
	F-2	"Stimulated Backscatter and Anomalous Absorption of CO_2 Laser Radiation in Gas Targets", A. A. Offenberger and A. Ng.
	F-3	"Efficient Saturation of Parametric Instabilities by the Secondary Decay of Electrostatic Waves", S. J. Karttunen, A. Ng, and A. A. Offenberger.
	F-4	"Brillouin Scattering at Arbitrary Angles in Drifting Plasma: Application to Experiment", G. Mitchel, T. W. Johnston, B. Grek, H. Pépin, and F. Martin.

F-5 "Backscatter of CO_2 Laser Light from an Overdense Z Pinch Plasma", C. J. Walsh, J. Meyer, and B. Hilko.

F-6 "Nonlinear Scattering of Electromagnetic Waves in a Magnetized Plasma", D. P. Tewari and V. K. Tripathi.

F-7 "Stimulated Brillouin Backscatter Behavior Near Threshold", A. J. Barnard.

F-8 "Theory and Simulations of Critical Surface Dominated Stimulated Brillouin Scatter", C. J. Randall and J. J. Thomson.

F-9 "Stimulated Brillouin Scattering in Underdense Plasmas", R. A. James, K. Mizuno, and J. S. DeGroot.

F-10 "Harmonic Generation by Large Amplitude Ion Waves", W. L. Kruer.

F-11 "Filamentation in Collisional ICF Plasmas", A. B. Langdon.

F-12 "Acceleration of Laser-Irradiated Thin Foil Targets", G. Thiell.

F-13 "Energy Transport and Rear Surface Temperature Evolution in Laser-Accelerated Foils", S. H. Gold, E. A. McLean, J. A. Stamper, H. R. Griem, R. R. Whitlock, S. P. Obenschain, B. H. Ripin, and M. J. Herbst.

F-14 "X-Ray Energy Deposition at the Rear Surface of Laser-Accelerated Foils", R. R. Whitlock, S. H. Gold, M. J. Herbst, F. C. Young, E. A. McLean, and J. H. Stamper.

F-15 "Plasma Flow Effects on Langmuir and Ion Acoustic Waves", Wee Woo and J. S. DeGroot.

3:00 PM - 3:30 PM COFFEE BREAK

SESSION A

WEDNESDAY, MAY 28

8:30 A.M. - 12:37 P.M.

R. L. MORSE

UNIVERSITY OF ARIZONA

MAGNETIC FIELD GENERATION IN LASER TARGET PLASMAS

T. J. M. Boyd
School of Mathematics
U.C.N.W.
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ELECTROMAGNETIC OSCILLATING TWO STREAM INSTABILITY OF LASER RADIATION: A SOURCE OF SELF-GENERATED MAGNETIC FIELDS*

C. S. Liu and V. K. Tripathi
Department of Physics and Astronomy
University of Maryland
College Park, Maryland 20742

Abstract

Near the plasma resonance ($\omega_o \gtrsim \omega_p$), a novel electromagnetic oscillating two stream instability of a high power laser beam is found by which the pump wave can decay into a purely growing electromagnetic mode and a plasma wave. The magnetic field of the perturbation couples with the oscillatory drift velocity of electrons to produce a ponderomotive force driving the high frequency sidebands, viz., electrostatic plasma waves. The sidebands couple with the pump to produce a low frequency current driving the instability. The instability exists for $\omega_p < \omega_o < \omega_p\ (1 + 3k^2\lambda_D^2/2)$ with the maximum growth rate $\gamma \sim \omega_p v_o^2/8c^2$; v_e and $v_{\bar{o}}$ are the electron thermal and drift velocities. For a Nd: glass laser $\gamma \simeq 3\times10^{11}\mathrm{sec}^{-1}$ at $\sim 10^{15}$ W/cm^2. In an inhomogeneous plasma the threshold power $\sim 10^{15}$ W/cm^2 for a density scale length ~ 100 μm.

*This work was supported by the Department of Energy, Joint Program of University of Maryland/Naval Research Laboratory, and the Office of Naval Research.

SUPERTHERMAL TRANSPORT EFFECTS ON MICROTARGETS IRRADIATED BY 10.6 μm

by

G.D. Enright, M.D.J. Burgess,
P.A. Jaanimagi, R.S. Marjoribanks,
D.M. Villeneuve and M.C. Richardson

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In the interaction of intense CO_2 laser radiation with solid targets, absorption occurs primarily through collisionless processes which generate energetic electrons. The formation of an expanding superthermal corona and the resulting transport of energy away from the interaction region have been investigated with a variety of diagnostic techniques. The characterization of the fast ion emission, and of the x-ray and visible radiation from microtargets of various geometries has led to an improved understanding of the superthermal energy transport. Picosecond interferometry has been employed to investigate the rapid temporal evolution of the plasma, confirming the rôle played by the superthermal plasma component. In regions remote from the focal zone, it is also possible to estimate the temperature of the high density thermal plasma from the time dependence of the scale length. This method has recently been used to conclude that for ns pulse irradiation of thin-walled glass microballoon targets over 80% of the absorbed energy is decoupled from the dense thermal plasma.

Abstract of presentation for the 10th Anomalous Absorption Conference
San Francisco, May 28-30 1980

Hot electron transport measurements in CO_2 laser produced plasmas

J. C. Kieffer, F. Martin, T.W. Johnston, H. Pépin
INRS-Energie, Université du Québec
Varennes, Qué., Canada, JOL 2PO

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Varennes, Qué., Canada, JOL 2PO

Both inward and lateral transport are characterised for 10.6 μm laser target interaction .

X-ray continuum measurements from layered targets show that with the onset of ponderomotive force effects (6 x 10^{12}W/cm^2), the thermal electron penetration decreases sharply while the suprathermal electron penetration increases more weakly than at lower irradiance.

Lateral transport is studied using plastic steps on a substrate and monitoring the continuum emission at various distances from the discontinuity. These measurements indicate that the energy transported by fast electrons is deposited in a very large area outside the laser plasma interaction region.

Physical implications of inward and lateral transport will be discussed.

λ	ϕ	C_a	T_H	T_c	Echauffage / E_{ABS}	
1	14	.11	6	0.4	.33	.02
1	15	.22	13	0.4	.13	.004
$\frac{1}{2}$	$5\,10^{14}$	.45	6	0.45	.34	.03
$\frac{1}{4}$	10^{14}	.45	1.7	0.5	.48	.14

$E_{chauffage} = T_H$

Echauffage = ~~E_{ABS}~~ × # of electrons × T_H

or # " × T_c

# of electrons known since heating depth is measured.

14 / 3.6 | 500, 36, 140

14 4

$\sqrt[3]{e}$

$\phi \approx f \rho \lambda^{-2} v^3$ $\quad v \sim \frac{\phi^{1/3} \rho^{1/3}}{f^{1/3} \lambda^{+2/3}}$

$d \sim v\tau$

$\phi = f n_c T^{3/2} \sim f \rho T^{3/2} \lambda^{-2}$ $\quad T \sim \left(\frac{\phi}{f \rho \lambda^2}\right)^{2/3}$

$d \sim v\tau \quad \frac{d}{\tau} \sim v \sim T^{\frac{1}{2}} \sim \frac{\phi^{1/3}}{f^{1/3} \rho^{1/3} \lambda^{2/3}}$

EFFECT OF LASER WAVELENGTH ON INTERACTION AND TRANSPORT PROCESSES

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Laboratoire P.M.I. Ecole Polytechnique
Palaisean 91128 France

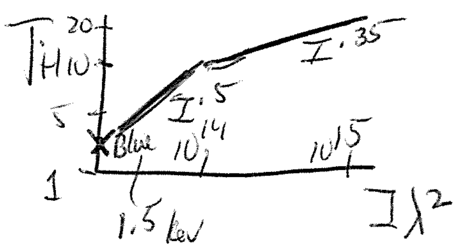
ulbricht sphere

	E(J)	τ	E(J)	τ
1	25	100		
1/2	11	70	32	2NS
1/4	3	50		

CM

absn: usual

possibility of $T_H \sim I^{.5}$ due to I.B. stealing energy so less energy gets to crit, or: T_H is really T_e(corona)



penetration depths: $\sim I^{\alpha} \tau^{\beta} \lambda^{\gamma}$

$$K = \frac{d(\AA)\, \rho_0 (g/cm^2)}{\phi^{1/3}_{(W/cm^2)}\, \lambda_{\mu}^{-4/3}\, \tau_{NS}} = 0.27 = \text{const}.$$

code $\Rightarrow K \sim f^{1/3}$ ∴ you can find the flux limit
flux limit

$\Rightarrow f \approx .03$
at all λs.

Layered Target Transport Experiments at 1.06 μm*

E. M. Campbell, W. Kruer, L. Koppel, G. Tirsell,
W. C. Mead, D. Matthews, D. Banner, H. Kornblum, R. H. Price

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P.O. Box 5508, Livermore, California 94550

The results of recent electron transport experiments conducted at the 1.06 μm Argus facility will be discussed. These experiments are similar to prior work done at N.R.L., and utilized targets consisting of variable thickness CH layers (0, .25 μm, .67 μm, 25 μm) coated on an aluminum substrate. The targets were irradiated with 100 ps (Gaussian FWHM), 10^{15} W/cm^2 pulses (450 μm^{Dia} Focal Spot) and they were oriented at 30° p polarization. A multitude of broad band and high resolution x-ray diagnostics (.2 Kev $\lesssim h\nu \lesssim$ 80 Kev) monitored the x-ray emission as the CH thickness was varied. Both subkilovolt and kilovolt detectors showed a substantial decrease in aluminum x-ray emission with only a .25 μm overlay of CH.

A complete description of these experiments and their results will be discussed.

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

SIMULATIONS OF LAYERED-SLAB TRANSPORT EXPERIMENTS*

W. C. Mead, W. L. Kruer, M. Campbell, and D. Banner

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Lawrence Livermore Laboratory, Livermore, California 94550

Abstract

Recent Argus experiments[1] have employed CH-coated Al disk targets to confirm and extend electron transport experiments performed by workers at N. R. L.[2] The 100 ps, 1×10^{15} W/cm^2 irradiations were performed with large spot diameter (450 μm) and with P-polarized, 30°-incident 1.06 μm light. X-ray diagnostics in both keV and sub-keV regions show that emission from the aluminum is reduced by one e-folding by the addition of a layer of CH 0.11 ± 0.05 μm thick.

We present simulations of this experiment using "standard" LASNEX modelling physics and show that they produce emission attenuation depths considerably larger than seen experimentally. We discuss the possible origins of this discrepancy.

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

1 M. Campbell et al., this conference

2 F. C. Young, R. R. Whitlock, R. Decoste, B. H. Ripin, D. J. Nagel, J. A. Stamper, J. M. McMahon, and S. E. Bodner, "Laser Produced Plasma Energy Transport through Plastic Films," Appl. Phys. Lett. 30, 45 (1977).

Transport in Steepened Profiles*

Beverly K. Berger, Oakland University, Rochester, MI

and

Richard L. Berger, KMS Fusion, Inc., Ann Arbor, MI

ABSTRACT

A solution to the Boltzmann equation for density profiles steepened by the ponderomotive force has been obtained previously[1] when the absorption near the critical surface is weak. In the steepened region the scale length for density variation, L, is smaller than the scattering mean free path, λ, so that, to lowest approximation, the electrons move in the self-consistent fields. Far from this region, it is assumed that the diffusion approximation is valid ($\lambda \ll L$). The matching of the diffusion equations to the solutions in the steepened region can only be done continuously if a boundary layer of thickness $x \sim \lambda/10$ is introduced on both the high and low density sides of the steepened profile. A complete solution is obtained for a model static density profile in which the distribution function of electrons is specified asymptotically far away from the critical region, i.e., $|x-x_c| \gg \lambda$ where x_c is the radius of the critical surface. The density of electrons varies on three different scales: the steep scale at critical, the hydrodynamic scale at large distances from critical, and the scale of the mean free path in between these regions. The heat flow shows a similar variation.

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(1) B. K. Berger and R. L. Berger, Bull. Am. Phys. Soc. 24, 990 (1979).

*This work prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

Calculations of heat flux limitations in large temperature gradients

A R Bell

Science Research Council, Rutherford Laboratory,
Chilton, Didcot, Oxon, England

Abstract

A computer code has been written to solve the Fokker-Planck equation in two velocity dimensions and one spatial dimension and has been used to study the heat flow down a steep temperature gradient. The plasma is initially at a low temperature and is quickly heated at one end of the grid increasing the temperature by a factor of 16. A heat front propagates away from this region and the heat flux is found to be much lower than the free-streaming limit when the temperature scalelength is a few times the mean free path.

LA-UR-80-113

FULL PARTICLE PIC-COLLISIONAL CALCULATIONS OF ELECTRON TRANSPORT IN LASER PRODUCED PLASMAS*

by

Rodney J. Mason
Los Alamos Scientific Laboratory
Los Alamos, NM 87544

Our Monte Carlo (hybrid) model[1] has been extended to include a PIC-collisional treatment for the thermal electrons, freeing the scheme entirely from the need for flux limiters. The ions now move under standard PIC hydrodynamics. An approximate self-consistent E field, relaxing the system to quasi-neutrality, is obtained with the aid of the moment equations. We will discuss the results of simulations with the model that have demonstrated: 1) transient multi-streaming of the colds ejected from the corona, 2) two-stream heating of the return-current thermals, 3) collisional damping of this return current instability, and 4) trapping of the thermals in the potential from the E field for a return current--corroborating our earlier hybrid[1] results for density dips.

1. R. J. Mason, Phys. Rev. Lett. 43, 1795 (1979).

*Work performed under the auspices of the United States Department of energy.

TRANSPORT INHIBITION DUE TO FLOW-DRIVEN ION TURBULENCE AT THE SHOCK BEHIND THE CRITICAL SURFACE

F.J. Mayer, D. Mitrovich, L.V. Powers, T. Speziale

KMS Fusion, Inc.
Ann Arbor, Mich.

Spherically symmetric hydrodynamic code calculations[1,2] as well as theoretical considerations[3] have shown the existence of an overdense bump behind the ponderomotive force-steepened electron density profile. Max and McKee have characterized these profiles as a "shock-plus D-front"; they also mentioned that transport inhibition[4] could be produced by the ion acoustic turbulence which develops downstream of the shock. We have examined the hydrodynamic and heat transport effects that occur if ion turbulence in the shock does lead to reduced thermal conduction. We have used a fine-zoned version of our spherical hydrodynamic code TRHYD in which the ponderomotive force and reduced electron thermal conductivity are allowed to influence the hydrodynamic expansion.

In these simulations, we have reduced the electron thermal conductivity by a factor $(1+\nu_{eff}/\nu_{ei})$ to account for the increased electron collisions on the ion acoustic waves in a region approximately 100 Debye lengths on the downstream edge of the shock. Using Sagdeev's dimensional estimate of $\nu_{eff} \sim \omega_{pi}(E_\phi/N_e\theta_e)$ and an estimate of E_ϕ (the ion acoustic wave energy) equal to the ion energy streaming into the shock i.e., $E_\phi \simeq N_i M_i V_i^2$, we find $\nu_{eff} \sim M_1^2 = V_i^2/C_s^2$ where V_i is the ion flow velocity and C_s is the sound speed. In a simulation with simple inverse bremsstrahlung absorption but with thermal conductivity reduction "turned-off" $(\nu_{eff}/\nu_{ei} = 0)$, a shock is formed but the Mach number just upstream of the shock is small $(M_1 \simeq 1.2)$ and the density jump in the shock is $N_2/N_1 \simeq 2$. We have found the one-fluid model Rankine-Hugoniot jump conditions are satisfied at the shock after the flow has stabilized. With the thermal conductivity reduction "turned-on" the overdense bump becomes a high density spike with a greatly increased shock strength $(M_1 = 3.5)$. The increased density compression $(N_2/N_1 \sim 3)$ is accompanied by greatly increased ion compressional heating. As expected the thin zone of reduced thermal cnductivity increases the electron temperature in the outer corona as well as reducing the energy transport into the cold material. The density spike moves upstream and appears to detach itself from its original association with the critical density surface. Eventually another overdense bump forms near the critical density and begins its own evolution. We show code calculations using this inhibition model for various turbulence-zone thicknesses, turbulence amplitudes and assumptions about superthermal electron deposition.

In code runs at similar intensities, but for very much larger targets the density profile does not develop density spikes, since the flow on the high density side remains subsonic, hence this type of transport inhibition is expected to disappear for reactor size targets.

Finally, we have found that the ion acoustic turbulence, which is driven by the ion-flow into the shock, saturates when the Mach number of the flow into the shock reaches its maximum classical value $(M_1 \simeq 3.5)$.

1. J. Virmont, R. Pellet and P. Mora, Phys. of Fluids 21, 567 (1978).
2. K. Brueckner and R.J. Janda, Nuclear Fusion 17, 451 (1977).
3. C.E. Max and C.F. McKee, Phys. Rev. Lett. 39, 1336 (1977).
4. C.E. Max and C.F. McKee, LLL, Laser Program Annual Report 1977, UCRL-50021-77, pg. 4-55.

ANOMALOUS ENERGY TRANSPORT IN MICROWAVE PLASMA INTERACTION

Charles L. Yee and John S. DeGroot

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Abstract

Assuming quasi-static conditions for the suprathermal electrons heated by resonant absorption or parametric processes, the effects of hot electron trapping in a self-consistent electric field is investigated. For times $t\,\omega_{pi} \leq (M_i/M_e)^{1/2}(V_e/U_{eff})(T_h/T_e)(\omega_{pi}/\omega_B)$ where ω_B is the hot electron bounce frequency and U_{eff} the effective drift, we consider quantitatively the anomalous resistivity associated with ion acoustic turbulence in maintaining a large self-consistent field, $\Delta(e\phi/T_h) \leq 0.5$. The steady state continuity, momentum, energy, and heat flow equations are numerically solved using the standard quasi-linear "collision" operator. We investigate quantitatively the bulk heating of the thermal electrons and the hot/cold heat flow for Q-condition plasma.

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

SESSION B

WEDNESDAY, MAY 28

2:00 P.M. - 5:41 P.M.

F. F. CHEN, CHAIRMAN

UNIVERSITY OF CALIFORNIA, LOS ANGELES

MEASUREMENTS OF INHIBITED HEAT TRANSPORT IN A MICROWAVE - PLASMA INTERACTION EXPERIMENT*

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University of California, Davis
Davis, California 95616

ABSTRACT

P-polarized microwaves ($v_{os}/v_{eo} \lesssim 1$, $\frac{\omega_o}{2\pi} = 1.2$GHZ) are applied to an essentially collisionless, inhomogenous plasma in the U. C. Davis PROMETHEUS I device. Superthermal electrons are heated by resonant absorption and parametric instabilities. In addition, we observe strong heating of the thermal electrons. We find that the density and temperature of the hot electrons, the thermal electron temperature, and dc potential is a function of the length of the underdense shelf. Strong ion turbulence ($\Delta n/n \lesssim 20\%$) is observed on the underdense shelf and near the critical density. These ion waves progagate down the density gradient. The strong ion turbulence scatters the thermal electrons so that the thermal electron heat conductivity is severally limited.[1] However, the heat conductivity of the hot electrons is only slightly inhibited. We have measured the mean-free-time of the electrons in the turbulence as a function of electron energy. The technique is to measure the decay of the electron density and temperature after the microwaves are turned off. We find that the decay time strongly depends on electron energy, as expected. By comparing the data to solutions of the heat diffusion equation, we obtain an average effective collision frequency due to the turbulence $\nu_{eff}/\omega_{pe} \lesssim 10^{-2}$, which is consistent with the amplitude of the ion turbulence.

[1] W. M. Manheimer, Phys. Fluids 20, 265 (1977).

* This work supported by the Lawrence Livermore Laboratory under Intramural Order 6407609 and by the Los Alamos Scientific Laboratory under Contract 4-V60-2531P-1.

† Sandia Laboratories, Albuquerque, New Mexico.

Abstract submitted

For the 10th Annual Conference on Anomalous Absorption of Electromagnetic Waves
San Francisco May 28 - 30, 1980

SCALING LAWS FOR FREE AND FOR TAMPED ABLATION FLOW

by

B. Ahlborn, G. Josin, UBC, Vancouver and
N.H. Burnett, NRC, Ottawa

Can. J. Phys 47 1709 (69)

The parameters of ablation flow depend sensitively on the boundary conditions such as the free stream velocity of the ablated material, u_b. In free flow u_b adjusts itself according to the net amount of power absorbed in the ablation front. In completely tamped flow u_b is zero. A hydrodynamic model for tamped flow is developed and compared with a similar model for free flow, reported earlier.[1] It is found that the ablation pressure in tamped flow depends on the net amount of power and target gas density but not on the exhaust temperature, and it is larger than the exhaust pressure in free flow. The ablation rate is smaller and the velocity of the shock generated by the ablation is larger than in free flow. Tamped flow requires a target with an outer layer which is transparent to the power flux but is not ablated itself. One approximation of this requirement is a double shell structure with holes in the outer shell transmitting radiation onto the ablation surface on the inner shell. Another approximation is the energy deposition by hot electrons inside but not too far away from the surface of the solid ablator material. Since CO_2 lasers at high intensities are known to deposit most of their energies in hot electrons, ablation experiments with these lasers should show features of (partly) tamped flow. Foil acceleration experiments with CO_2 lasers above 10^{14} watt/cm^2 are under way. First indications are that the shock velocities are comparable or higher than reported for glass lasers at similar intensities, by Trainor et al.[2]

References

1) B. Ahlborn and M.H. Key, APS Boston, paper 4Z6, Bul.Am.Phys.Soc., 24,1008(79).
2) R.J. Trainor, et al., Phys.Rev.Let. 42, 1154 (1979).

does V plasma = V dense (x 1 to 2) ... ≈ 5 NS delay vs ≤ 1 NS shock ...

Motion and Pressure Measurements on Ablatively Accelerating Targets Using Double-Foils and Particle Diagnostics J. GRUN*, S.P. OBENSCHAIN, B.H. RIPIN, R. DECOSTE**, M.J. HERBST***, Naval Research Laboratory, Washington, D.C. 20375

For ablatively accelerating pellet shells, the scaling of ablation pressure, mass ablation rate, and blowoff velocity with absorbed irradiance is important. These quantities influence the choice of aspect ratio (R/ΔR) and irradiance compatible with stable and efficient acceleration of the shell to velocities necessary for inertial confinement fusion. We examine these scalings using a 1.05μm, 4nsec duration laser driver. Our measurements utilize disks of varying diameter and wide foils irradiated by laser spot sizes up to 2mm in diameter. The possible influence of finite target geometry or laser spot size is thereby tested. Diagnostics for these experiments include arrays of ballistic pendula, time-of-flight charge collectors, and particle calorimeters.

Properties of targets accelerated to high velocity ($>10^7$ cm/sec) are studied using a unique double-foil technique. In these experiments, a thin foil (impact-plate) is placed behind the target directly accelerated by the laser pulse. The mass and velocity distribution of the target are inferred from observations of the reaction of the impact plate to the striking target.[1] Other applications of this technique, such as the generation of very high pressures, will be discussed.

+Supported by the U.S. Department of Energy
*University of Maryland, College Park, MD.
**Now at IREQ, Varennes, Quebec.
***Mission Research Corp. Alexandria, VA.

1. B.H. Ripin et al., NRL Memo #4212, 1980 (unpublished); also presented at the ICF'80 meeting in San Diego, CA.

Measurement of the Uniformity of Ablative Acceleration Using Single and Double Foil Targets* S.P. Obenschain, J. Grun**, J.A. Stamper and B.H. Ripin, Naval Research Laboratory, Washington, D.C. 20375.

It is important in laser fusion to define realistic requirements for the symmetric implosion of pellets to the required densities and temperatures. The demands on laser induced ablation pressure uniformity are thought to be severe, particularly for the larger aspect ratio pellet designs. The corresponding uniformity requirements on the incident laser beam should be less severe due to smoothing effects of lateral heat flow in the pellet blow-off plasma. The precise symmetrization obtained is likely to involve a complex interaction of many factors including the laser wavelength and intensity, thermal conduction, and the irradiated pellet size. Moreover the possible occurrence of Rayleigh-Taylor instability may make the uniformity constraints more stringent.

At NRL we are studying the ablative acceleration of planar targets to velocities approaching those required for fusion implosions using a multinanosecond 1.05μm laser pulse.[1] By using large focal diameters (~1mm), we are able to determine the effects of relatively long scalelength nonuniformities in the focused laser on the target interaction.

We will present temporally and spatially resolved measurements of the target acceleration as a function of the laser intensity and uniformity. Studies of the collision of ablatively accelerated targets with a second planar target have been particularly useful in determining the properties of the accelerated target.

*Work supported by the U.S. Department of Energy.
**University of Maryland, College Park, MD.

1. B.H. Ripin, R. Decoste, S.P. Obenschain, S.E. Bodner, E.A. McLean, F.C. Young, R.R. Whitlock, C.M. Armstrong, J. Grun, J.A. Stamper, S.H. Gold, D.J. Nagel, R.H. Lehmberg, and J.M. McMahon, Phys. Fluids, (To be published, May 1980).

doesn't seem clear whether its inelastic collision or a snowplow. No velocity doubling but it ain't massive.

Nonuniformities in X-ray Emission from Ablatively Driven Foil Targets

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To simulate the acceleration of spherical shells before spherical convergence effects are important, flat foil CH and Al targets are ablatively accelerated with 100-200J, 4nsec 1.05μm laser pulses. Using pinhole cameras, images of the time-integrated X-ray emission from these targets are obtained. With irradiances between 10^{12} and 2×10^{13} W/cm^2, X-ray emission is observed from positions as far as 400μm from the original foil position in the direction of target acceleration. This is consistent with transit distances of the accelerated target during the laser pulse, given previously reported target velocities.[1-3]

A variety of spatial nonuniformities are observed in these images, some of which are correlated with structure in the focal distribution of the incident laser. Other mechanisms which may contribute to the nonuniform X-ray images include fast particle generation, magnetic fields, and filamentation of the incident laser light. Relevance of the measurements to the problem of uniform acceleration of thin foils will be discussed.

*Mission Research Corporation, Alexandria, VA

1. R. Decoste, et al., Phys. Rev. Lett. 42, 1673 (1979).
2. B.H. Ripin, et al., Phys. Fluids. (May, 1980)
3. B.H. Ripin, et al., NRL Memorandum Report No. 4212 (1980).

ION ACCELERATION PROCESSES IN CO_2 LASER-INDUCED CARBON PLASMAS*

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ABSTRACT

Data on ion acceleration processes which occur in the isothermal expansion of rarified (collisionless) laser-induced carbon plasmas into vacuum are presented. A typical experiment consisted of a single CO_2 laser pulsed beam with 80 J energy and 300 ps risetime focused onto 100 μm diameter areas of pure carbon and polyethylene targets. The Thomson mass analyzer and the cellulose nitrate film particle detector were used to measure the velocity distributions of the plasma ion flows. We observe that pure carbon plasma expands isothermally with an electron temperature of ~ 30 keV and the C^{+6} ions are accelerated to asymptotic kinetic energies of ~ 9 MeV. On the other hand, we observe experimentally that the CH_2 plasma expands isothermally with an electron temperature of ~ 11 keV, and that the presence of hydrogen induces a cut-off in the carbon velocity distribution at a carbon ion velocity of ~ 5 x 10^8 cm/s. A one-dimensional model, which describes the self-similar expansion of a multi-ion quasi-neutral electrostatic plasma, has been developed. Charge exchange and/or recombination effects appear to be important in these plasma flows. Qualitative comments on the coupling of absorbed laser energy into the production of fast ions will be presented. The CH_2 and carbon ion data shows that the absence of hydrogen enhances the conversion of the absorbed laser energy into the expanding fast ions by a factor of ~ 2.

Sees bunching

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

SIMULATIONS OF IMPLOSIONS DRIVEN BY A FREQUENCY-CONVERTED Nd-GLASS LASER

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EDOUARD FABRE
JEAN VIRMONT

Laboratoire De Physique Des Mileaux Ionises
Ecole Polytechnique
Palaiseau, France
Greco Interaction Laser Matiere, CNRS

Numerical simulations of laser-driven glass micro-balloon implosions demonstrate that frequency tripling or (better) quadrupling 1.06 μm laser light considerably improves the efficiency of the implosion. Short wave length illumination can produce, even for relatively thin-wall targets, ablative implosions, having both a high compression and a large neutron yield. The one dimensional code used in these simulations has the usual structure of such codes but also includes multi-group diffusion of the fast electrons with a separate treatment of the low-density region. In this paper we will contrast results obtained for glass and plastic micro-balloons and, in particular, show what happens to the energy initially given to the fast-electrons: the partition between energy given to the thermal electrons, ohmic ($\vec{j} \cdot \vec{E}$) heating, and acceleration of the fast ions. As might have been anticipated, the improved response at higher frequencies results from the combination of the decrease of T_H with wavelength and the reduced preheat of the shell and fuel. The Joule effect and ion acceleration also decrease with wavelength. Further insights into the importance of resistive enhancement of the electric field and the effect of the ohmic losses are obtained by looking at the case of 1.06 μm radiation incident on a planar low density gold target[1].

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[1] D. J. Bond, J. D. Hares, and J. Kilkenny, "A Demonstration of Resistive Inhibition of Laser Plasma Fast Electrons by Low Density Gold Targets," Bull. Am. Phys. Soc. <u>24</u>, 990 (1979).

*Permanent Address: La Jolla Institute, P. O. Box 1434, La Jolla, CA 92038

TAYLOR INSTABILITY IN FUSION TARGETS

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ABSTRACT

Optimum performance in laser driven fusion targets is enhanced by the use of high aspect ratio shells in commonly employed spherically semetric designs. Taylor instability occurs in these systems at 1) the ablation surface when the acceleration is in the same direction as the local density gradient, and 2) later in the implosion process when the fuel decelerates the pusher. Results for a linear stability analysis of the ablation-driven Taylor instability are obtained from a perturbation analysis of the two parameter stationary ablative flow model. The linear growth rates are shown to be in agreement with full two-dimensional numerical numerical simulation. From the linear analysis, the potentially most damaging unstable mode is identified, and full two-dimensional numerical simulations are performed. The two-dimensional calculations determine the nature and saturation behavior associated with the unstable mode. Our results indicate that saturation of the ablatively driven Taylor instability does occur. This saturation occurs at an amplitude which is sufficiently large to be a possible cause of difficulty in using large aspect ratio shells in fusion targets, but is seen to prevent these shells from breaking up and becoming turbulent. It appears plausible that such distorted but laminar, i.e., non-turbulent, shells could be successfully employed in fusion targets.

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GROWTH RATES OF ABLATION DRIVEN TAYLOR INSTABILITY

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ABSTRACT

Growth rates of the Taylor instability in spherical shells imploded by ablation have been calculated. The perturbation method used employs zero order ablative flow solutions obtained from the steady flow model and a spherical harmonic expansion of first order variables. The growth rates and mode form of the fastest growing mode is obtained for each ℓ number and zero order case by advancing the first order equations in time until the mode, while increasing in amplitude, becomes approximately stationary in form. A parameter study of these growth rates will be presented. These growth rates are seen to have a maximum as a function of ℓ and to fall to sero at same finite ℓ as ℓ increases; as seen in earlier linearized calculations based on time dependent zero order solutions. Regions of approximately incompressable behavior, at larger ℓ values, and incompressable behavior, at smaller ℓ values, are identified. The ℓ value at which the fastest growth occurs for a given zero order case is usually found to be in the approximately incompressable region and in the neighborhood of the point where ℓ = A, the aspect ratio.

Coronal Modification due to Fast Electron Escape*

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and

E. A. Williams, University of Rochester, Rochester, NY

ABSTRACT

Return currents to laser fusion targets allow the most energetic electrons to escape, which modifies the usual Boltzmann relation, $n_e = n_o \exp(e\phi/T)$, for the electron response to the electrostatic potential. This, in turn, modifies the Debye sheath which accelerates the outer edge of the corona.

We have solved the Poisson equation in spherical geometry when the electron distribution is cut off at a given escape velocity. The balance between electron loss and collisional repopulation of the loss region removes the finite discontinuity at the cutoff enabling the boundary condition at infinity to be satisfied. The ion acceleration ceases when the potential becomes comparable to the electron escape energy. However, the gross energetics of the ion blowoff is substantially unchanged when the electron cutoff speed is greater than a few electron thermal speeds.

*This work prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

Multiple-Time, Dark-Field Optical Probing Studies of Laser Accelerated Foils*

by J.A. Stamper and S.H. Gold**

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The motion and structure of laser-accelerated foils is studied by dark-field (Schlieren-like), laser probing. The foil targets (4-7 micron of CH or Al) are ablatively accelerated (at 5×10^{12} W/cm^2) by the NRL Pharos II, Nd-phosphate glass laser system at 150 J in 4 nsec and are illuminated side-on by a probing, second-harmonic (5270 A) laser beam, usually consisting of four, half-nanosecond pulses spaced two and a half nanoseconds apart. The deflected light is collimated by a 10 cm focal length (f/2) collection lens and is then focused onto film by a 50 cm focal length lens. An opaque mask is placed either in front of the first lens or at the back focal plane of this lens to obtain a dark field. This allows the leading (bright) edge of the rear-side of the target plasma to be recorded at several times on the same photograph.

The rear side of the target ($n_e \gtrsim 10^{19}$ cm^{-3}) is observed by this technique to be accelerated up to a velocity of about 10^7 cm/sec. Small irregularities (50-100 microns) on the rear-side contour are observed but do not grow on the time scale (2.5 nsec) between probe pulses. In addition, a very fine-scale (5-20 microns) transverse structure, with a filamentary appearance, is observed and is believed to result from plasma inhomogeneities (e.g., plasma turbulence). The filamentary appearance (with lengths typically 100-300 microns) is complicated by contributions due to time-smearing, refraction, diffraction, and focal depth. A variety of experimental results are presented which bear on the nature of the observed structure. These include imaging the Fourier transform plane as well as the object plane and varying the size of the opaque mask, the aperture of the collection lens and the duration of the probe pulse.

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

**NRC/NRL Resident Research Associate.

COLLISION OF RADIATION-DRIVEN BREAKDOWN WAVES

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ABSTRACT

An experimental study of the collision of two strong discontinuities driven by CO_2 laser radiation was done. The simple steady state conservation equations give two solutions to the problem. One is a classical shock or detonation wave with a density jump across the discontinuity. The other is a bleaching wave or supersonic heat wave in which there is no change of density across the heating front. Both types of waves have been observed experimentally. The bleaching wave does not produce a reflected wave after the collision whereas the detonation wave does. The presence or absence of the reflected wave is observed on axial streak pictures. In some cases leakage of laser energy through the plasma before collision creates another breakdown in the undisturbed gas between the waves. Radial holograms of the plasma after collision show a density minimum on axis which can light pipe unabsorbed laser radiation through the plasma. The focusing optics will collect a portion of this radiation and direct it to the laser, creating multiple pass laser heating.

SESSION C

THURSDAY, MAY 29

8:30 A.M. - 12:37 P.M.

R. P. GODWIN, CHAIRMAN

LOS ALAMOS SCIENTIFIC LABORATORY

Recent Topics on Laser Plasma Interactions at Osaka University

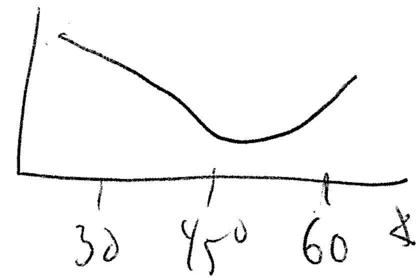
Y. Kitagawa, H. Nishimura, H. Azechi, N. Miyanaga, K. Yamada,
Y. Kato, M. Yokoyama and C. Yamanaka
Institute of Laser Engineering, Osaka University,
Suita, Osaka 565 Japan

[1] The plasma parameters of laser-driven spherical targets in the exploding pusher and ablative compression modes were investigated by x-ray spectroscopic techniques. Argon or neon filled polyethylene coated glass shells were imploded with the 4 beam GEKKO IV laser system($\sim 10^{16}$ W/cm^2). With a polyethylene coating thickness of less than 5 μm, the fuel density was 0.15 gr/cm^3 and the electron temperature was 2 keV, whereas with a 10 μm thick coating, the density became 5 gr/cm^3 at a temperature of 1 keV.

[2] By irradiating polyethylene coated copper foil targets with laser light of 10.6, 1.06 or 0.53 μm wavelength, we investigated the laser wavelength dependence of (1) the absorption, (2) the stimulated Brillouin scattering, (3) the energy transport from the cut off point to the ablation region and (4) the ablation pressure. It became clear that the ablation efficiency is better as the wavelength becomes shorter. The ablation is dominated by the cold electron transport for 1.06 and 0.53 μm and by the hot electron transport for 10.6 μm. The laser intensity dependence of 2 ω_0, 1/2 ω_0 and 3/2 ω_0 harmonics was also investigated.

[3] To investigate the stability of accelerated targets, foil targets with grating type structure were irradiated by CO_2 laser pulses and were measured by 3 channel ruby laser holographic interferometry, which showed the dependence of the blow off plasmas on the period of the grating.

BBS



at 60° turning
point is
at $n_c/4$!!

Long Pulse Irradiation of High Z disks at 0.53 μm: Recent Experiments*

V. C. Rupert, E. M. Campbell, D. W. Phillion, F. Ze
University of California, Lawrence Livermore Laboratory
P. O. Box 5508, Livermore, California 94550

Theoretical studies as well as recent experiments have emphasized the advantages of short wavelength irradiations for efficient laser driven ICF schemes. Hence options for upconverting NOVA, the next generation of glass laser at the Lawrence Livermore Laboratory, are being considered. A set of basic experiments has been defined to provide comparison data between 1.06 μm, 0.53 μm and .353 μm. The scope of these experiments has been purposely restricted rather severely so that a systematic scaling of critical parameters such as absorption, scattering, radiation losses and superthermal electron generation could be obtained in a timely fashion with comparable conditions at all three wavelengths. One beam of the 1.06 μm ARGUS laser has been frequency doubled and various Z disks have been irradiated at intensities varying from 3×10^{13} to 5×10^{15} w/cm^2 and angles varying from 0° to 60°. Results concerning absorption and Brillouin scattering, as well as preliminary data on x-ray spectra will be presented. In general the data are in good agreement with experiments conducted elsewhere. Computational predictions are discussed in a separate paper by K. Estabrook.

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

Match onto French Data

at 10^{16} no difference between green & red.

GREEN-LIGHT EXPERIMENTS ON SPHERICAL TARGETS*

D.C. Slater, J.A. Tarvin, J.D. Simpson, G. Charatis, R.J. Schroeder, D. Sullivan

KMS Fusion, Inc.
Ann Arbor, Mich.

Target response to submicron wavelength laser light is expected to improve relative to longer wavelengths in several ways. Inverse bremsstrahlung absorption and hydrodynamic efficiency should increase, while hot electron production, stimulated Brillouin scattering, transport inhibition, and filamentation should all decrease.(1) Increased absorption and decreased hot electron temperature at 0.53 μm compared to 1.06 μm have been observed on planar plastic targets.(2) The experiments reported here use 0.53 μm light at up to 0.7 TW on DT-filled, spherical glass shell targets, and are compared with closely matched experiments using 1.05 μm light.

The targets for these experiments were mostly 85±5 μm in diameter, filled with approximately 1.5 mg/cm^3 DT gas. Some targets in the range 55±3 μm were used to obtain data at higher irradiance. Two pulse length ranges were chosen: 60-100 psec gaussian shape, and 350-500 psec pulses formed by stacking five single pulses. The shorter pulse experiments used targets with 1 μm wall thickness; longer pulse shots used 4 μm thick targets. The laser power was varied between 0.2 and 0.7 TW to give irradiance values of 6×10^{14} to 7×10^{15} W/cm^2. All experiments used the lens-ellipsoidal mirror optical system which gives uniform illumination at near-normal incidence on spherical targets. The focal spot size at each wavelength was about 15 μm. Laser beam quality was monitored in the near-field, far-field, and at a focal plane equivalent to the target dimension and did not change substantially with wavelength.

The absorbed energy was measured with a plasma calorimeter. Shot-to-shot variations due to asymmetric plasma expansion were removed by averaging over several shots of equal irradiance. A 12 channel K-edge filter PIN diode array measured the x-ray continuum spectrum. The spectra were well matched by a two-temperature bremsstrahlung model. TLD chips were also used to measure x-ray flux. Plasma ion energy was monitored with four charge collectors. Fast ion velocity spectra were obtained with a Thomson parabola analyzer. Reflected light spectra were taken in a time-integrated mode during the 0.53 μm shots and timed-resolved for the 1.05 μm shots. Approximately 200 target shots were available for data analysis.

The experimental results indicate a modest increase in absorbed energy fraction at 0.53 μm, but a very strong (approximately four-fold) decrease in the fraction of suprathermal energy. The hot electron temperature follows the $(I\lambda^2)^{0.4}$ scaling law over the full intensity range at both pulse lengths.

---

[1] C.E. Max and K.G. Estabrook, Lawrence Livermore Laboratory Report UCRL-82671 (1979).

[2] F. Amiranoff, R. Benattar, R. Fabbro, E. Fabre, C. Garban, C. Popovics, J. Virmont, and M. Weinfeld, preprint (1979).

*Work supported by the United States Department of Energy under contract number DE-AC08-78DP40030.

10th ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

May 28-30, 1980

Grosvenor Airport Inn
South San Francisco, California

HIGH ENERGY ELECTRONS GENERATED BY TWO-PLASMON DECAY IN 10.6 μm LASER-PLASMA INTERACTION

H.A. Baldis, N.A. Ebrahim,
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We present the first experimental demonstration of hot electron generation from two-plasmon decay instability at quarter critical density in long scale length ($L/\lambda \sim 25$) plasmas irradiated by intense nanosecond CO_2 laser radiation (5×10^{12} W cm^{-2} < I < 10^{14} W cm^{-2}). The maximum density of the plasma, produced by a 25 nsec glass laser pulse, was varied between 1/10 n_c and 2 n_c. Absolute measurements of the energy spectrum of hot electrons in the range 35 - 450 keV, were made with miniature magnetic focusing spectrometers. We have studied the dependence of the electron spectrum on incident laser intensity, polarization of the electric vector of the incident laser beam, the angular distribution and total energy contained in the hot electron distribution.

Angular measurements of the electron spectrum on a plasma of maximum electron density of 1/4 n_c shows that the hot electron emission is peaked about 45^0 with respect to the $\underline{k}$ vector of the CO_2 laser beam, in both forward and backward directions. Furthermore, measurements of hot electron emission in and out of the plane of polarization of the CO_2 radiation shows that the hot electrons are emitted predominantly in the plane of polarization where the emission is strongest and where the highest energy electrons are observed. These observations together with the correlation of the hot electron emission to the observation of $\frac{3}{2}\,\omega_0$ in the backscattered light give very strong evidence that the observed hot electrons result from the two-plasmon decay instability at quarter-critical density.

*Present address: University of California, Los Angeles, California

SCALING OF ABSORPTION AND STIMULATED SCATTERING WITH λ, I, Z, t: THEORY AND SIMULATION*

M. D. Rosen

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Livermore, California 94550

Abstract

Recently, LLL has obtained absorption data at varying pulses (600 ps - 2 ns), wavelengths (1 μ and 1/2 μ) and disk target Z's (CH to Au). The absorptions were measured vs intensity I. We present LASNEX simulations of these experiments without a self- consistent correction for stimulated scattering, but with corrections for non-linear inverse bremsstrahlung effects. Crudely correcting for the scattering, and comparing with experiments shows, under some circumstances, discrepancies which point to the need for either less severe thermal transport inhibition, or additional absorption mechanisms.

Scaling theories of inverse bremsstrahlung and stimulated scatter are presented. A result of these theories is a scaling prediction for the coronal thermal temperature, $T_e \sim (\lambda IZt)^{1/3}$, which is confirmed by LASNEX simulations.

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

MICROWAVE ABSORPTION IN A HIGHLY COLLISIONAL PLASMA

W.F. DiVergilio, J.J. Thomson, R.F. Wuerker
TRW Defense and Space Systems Group

We report on a novel method of producing a high-density, low temperature plasma employing a standing wave radiation pattern. We propagate microwaves through a gas below the breakdown threshold, illuminating a flat surface. At the peak of the resultant standing wave, the local electric field is above breakdown threshold, producing a plasma localized over a region much less than a quarter of a wavelength. We have analyzed both the resultant absorption and plasma evolution. The absorption fraction, f_a, is $f_a = k_o L \, \mathrm{Im}\,\varepsilon$ for small absorption (L is the plasma axial extent). This plasma is unusual in that the collision frequency ν, is much greater than the microwave frequency, ω, so that $f_a \sim 1/\nu$. Initially $\nu = \nu_o$, the electron-neutral collision frequency. Above threshold, the plasma density increases exponetially until the electron-ion collision frequency dominates or pump depletion sets in. Typical densities and temperatures expected are 10^{15}-$10^{16} cm^{-3}$ and 2-3 eV. We have performed experiments on several gases, including air at .1 atmosphere, with a 200 kW, 3 cm microwave source with pulse durations of .4-10 μsec. We have observed breakdown at the predicted threshold values and are measuring densities, temperatures and absorption fraction. For most gases, the plasma appears to be extremely reproducible and quiescent, except for argon, which exhibits filimentary structures suggestive of MHD turbulence.

This phenomenon is interesting in several respects. It is a simple way of producing a high density, low temperature plasma which may be used as a target for radiation interaction experiments or as a lasing medium. The gas breakdown may produce an intense shock wave, which then will interact with the flat plate target. This may be useful for equation-of-state or materials damage experiments. Finally, the plasma is of intrinsic interest, since it is in the unusual region where the absorption goes inversely as the classical collision frequency.

PROFILE MODIFICATION AND HOT ELECTRON TEMPERATURE FROM RESONANT ABSORPTION AT MODEST INTENSITY*

J. R. Albritton and A. B. Langdon
University of California, Lawrence Livermore Laboratory
Livermore, California 94550

Abstract

Resonant absorption is investigated in driven expanding plasmas. The reaction force to the ejection of hot electrons toward low density via wavebreaking is shown to significantly modify the density profile at critical. This momentum depositon readily exceeds that of the driving laser radiation. New scaling of hot electron temperature with laser and plasma parameters is presented.

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

FLUID STEEPENING AND ELECTRON DISTRIBUTIONS*

by

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Los Alamos Scientific Laboratory
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Los Alamos, NM 87545

A generalization of the oscillating frame transformation is developed to analyze the dynamics of electrons in large amplitude, strongly inhomogeneous fields. It is shown that the deviations of strongly heated particles from the local fluid velocity is exponential in the time integral of the spatial gradient of the fluid velocity. The self-consistent effect of the hot electron pressure on the heating is identified. From this result the maximum velocity multiplication is estimated.

*This work was performed under the auspices of the USDOE.

Abstract Submitted for the 10th Annual Conference on
Anomalous Absorption of Electromagnetic Waves
May 28-30, 1980, South San Francisco, California

Profile Modification for Oblique Incidence and Nonlinear Resonant Absorption

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Patrick Mora
Commissariat à l'Energie Atomique, B.P. 27, 94190 Villeneuve-Saint-Georges, France

and

René Pellat
Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau Cedex, France

The profile modification due to the oblique incidence of a p polarized light on a one dimensional static plasma is studied within a phenomenological model. The resonant absorption and its effect on the nonlinear wave propagation are modelized by an effective collision frequency in the neighbourhood of the critical density. The wave propagation equations are numerically solved in the stationnary self consistent density profile $n(x) = n_o(x) \exp - p\,|E|^2$, where p is the nonlinear parameter and $n_o(x) = (1 + x/L)n_c$ the initial density profile. When p $>$ p critical, there is a jump in the density profile around the critical density, and a surface wave develops which tends to enhance the absorption. A detailed discussion of the relevance of the model is given. In particular, one discusses the importance of the thermal convection of the plasma waves generated at the critical density and the importance of the hydrodynamic expansion of the plasma through the critical density.

Abstract Submitted for the 10th Annual Conference on
Anomalous Absorption of Electromagnetic Waves
May 28-30, 1980, South San Francisco, California

ENVELOPPE STABILITY OF PLASMA WAVE GENERATED BY RESONANT ABSORPTION IN AN INHOMOGENEOUS PLASMA

Jean-Claude ADAM
Anne GOURDIN SERVENIERE
Guy LAVAL

Centre de Physique Théorique, Ecole Polytechnique
91128 Palaiseau Cedex, France

We study the resonant absorption mechanism in an inhomogeneous plasma in cases where the ponderomotive force of plasmas waves leads to modifications of the density profil. The stationary solution are shown to be unstable when dissipation mechanism are neglected. Stable solutions are recovered provided that damping is introduced on both the electron plasma waves and the low frequency density perturbations. Moreover the strength of the non-linearity must not be too large for physically realistic values of damping. We compare the results obtained from fluid equations and particle simulation codes.

EFFECT OF THE ELECTRON EQUATION OF STATE ON THE PROFILE MODIFICATION PROBLEM*

Charles H. Aldrich, Roger Jones, and K. Lee
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Los Alamos, New Mexico 87545

ABSTRACT

We consider the self-consistent profile modification problem of a laser normally incident on the critical surface of an expanding plasma. The density profiles are derived from conservation equations using the wave equation for the laser field. The electrons are modeled as an inertialess fluid obeying either a polytropic or trapped equation of state. The speed of the critical surface and ion velocity profiles are determined by connecting the solution for the critical surface to either a rarefaction wave or compression shock downstream. The results are compared with predictions of the isothermal model.

*This work was performed under the auspices of the U.S.D.O.E.

LASER INDUCED DENSITY PROFILE IN AN ISOTHERMAL PLASMA*

Roger Jones, Charles H. Aldrich, and K. Lee
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ABSTRACT

The absorption and scattering of laser light in laser fusion targets is highly dependent on the exact form of the laser induced density profile. The possible profiles that can exist are examined using a simple isothermal model. It is shown that two of these structures are locally overdense and can exist in an underdense plasma, and thus can have a large effect on the amount of light reaching the critical surface.

*This work was performed under the auspices of the U.S.D.O.E.

SESSION D

Thursday, May 29

2:00 p.m. - 5:30 p.m.

POSTER SESSION

10th ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION
OF ELECTROMAGNETIC WAVES

May 28-30, 1980

Grosvenor Airport Inn
South San Francisco, California

HIGH ENERGY ELECTRONS GENERATED BY TWO-PLASMON DECAY IN 10.6 μm LASER-PLASMA INTERACTION

H.A. Baldis, N.A. Ebrahim,
C. Joshi*, R. Benesch

National Research Council of Canada
Division of Physics
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We present the first experimental demonstration of hot electron generation from two-plasmon decay instability at quarter critical density in long scale length ($L/\lambda \sim 25$) plasmas irradiated by intense nanosecond CO_2 laser radiation (5×10^{12} W cm^{-2} < I < 10^{14} W cm^{-2}). The maximum density of the plasma, produced by a 25 nsec glass laser pulse, was varied between 1/10 n_c and 2 n_c. Absolute measurements of the energy spectrum of hot electrons in the range 35 - 450 keV, were made with miniature magnetic focusing spectrometers. We have studied the dependence of the electron spectrum on incident laser intensity, polarization of the electric vector of the incident laser beam, the angular distribution and total energy contained in the hot electron distribution.

Angular measurements of the electron spectrum on a plasma of maximum electron density of 1/4 n_c shows that the hot electron emission is peaked about 45^0 with respect to the $\underline{k}$ vector of the CO_2 laser beam, in both forward and backward directions. Furthermore, measurements of hot electron emission in and out of the plane of polarization of the CO_2 radiation shows that the hot electrons are emitted predominantly in the plane of polarization where the emission is strongest and where the highest energy electrons are observed. These observations together with the correlation of the hot electron emission to the observation of $\frac{3}{2}\,\omega_0$ in the backscattered light give very strong evidence that the observed hot electrons result from the two-plasmon decay instability at quarter-critical density.

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2-D SIMULATIONS OF QUARTER-CRITICAL HEATING IN LARGE PLASMAS*

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With a view toward interpreting and planning long pulse length experiments characterized by large regions of relatively flat underdense plasma, we have begun a new ZOHAR simulation study of the high frequency parametric instabilities which occur in the neighborhood of quarter-critical density. These processes, the $2\omega_{pe}$ decay and the Raman instability, may absorb a significant amount of the laser light into an unwelcome high energy electron component. Results from 2-D simulations for incident intensities $\sim 10^{15}$ W/cm^2 on flat plasma slabs at $\sim .25\ \rho_c$ and ~ 3 keV background electron temperature will be presented.

Collisional damping of Raman and $2\omega_{pe}$ plays a central role in experiments in which high-Z discs are irradiated by moderate intensity laser light. If we assume the maximum high frequency instability growth rate at quarter-critical, then $\gamma\tau_{ei} = 14\sqrt{I_{14}}\ \lambda_\mu{}^2\ T_e^{3/2} Z^{-1}$ where I_{14} is the intensity in units of 10^{14} W/cm^2, λ_u is the laser wavelength in microns and T_e is the background electron temperature in keV.

In this parameter regime, inverse Bremstrahlung is the dominant absorption mechanism. For linear density gradients and constant background temperature, we estimate an incident intensity threshold for $2\omega_{pe}$ to occur by requiring that the light remaining at quarter-critical satisfy the gradient threshold condition for $2\omega_{pe}$. We find $I \gtrsim 1/2\ I_{14}/\lambda_u^3$, suggesting that prior absorption by inverse Bremstrahlung may reduce the potency of the high frequency instabilities at quarter-critical.

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

PROFILE MODIFICATION FOR OBLIQUE INCIDENCE AND NONLINEAR RESONANT ABSORPTION

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C. E. A.
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EFFECTS OF LIGHT POLARIZATION ON RESONANCE ABSORPTION

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94190 Villeneuve-Saint-Georges, France

Two-Dimensional Soliton Collapse in a Nonuniform Plasma* N. R. Pereira and G. J. Morales, UCLA --. In the past few years the results of analytical and numerical studies have demonstrated that in a uniform plasma a Langmuir wave soliton is unstable to collapse in 2-D. The present study is concerned with the dynamics of the collapse process near the $\omega = \omega_p$ point in a non-uniform plasma. This is a problem of interest in connection with the rippling of the resonance absorption surface in laser-plasma interactions and in RF heating experiments in the laboratory and the ionosphere. The principal effect produced by the density gradient is to enhance the wave convection out of the density cavities generated by the ponderomotive force. The leakage of plasmons out of these cavities opposes the collapsing effect. This work is concerned with the dynamics of this process and the delineation of the parameter space required for the observation of the 2-D collapse.

*Work supported by NSF and ONR.

HOT ELECTRONS PRODUCED BY THE RESONANT ABSORPTION OF A FOCUSED BEAM OF HIGH POWER MICROWAVES*

D. Rasmussen, K. Mizuno, and J. S. DeGroot
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University of California, Davis
Davis, California 95616

ABSTRACT

We are investigating hot electron production and crater formation due to the resonant absorption of a high power focused beam of microwaves in the UCD THOR device. The microwave intensity is high enough ($V_{os}/V_{eo} \lesssim 3$) for small focal spot diameters, ($D/\lambda_0 \gtrsim 1$) and the microwave pulse long enough ($C_s \lesssim \tau_p/D >> 1$) so that craters can be formed due to the ponderomotive force of the electromagnetic waves. Initial measurements indicate hot electron temperatures consistent with temperatures measured in the PROMETHEUS I device, but a different scaling law with power, $T_H \sim P$ 1/4 for $V_{os}/V_{eo} \gtrsim 1$.

*Work supported by the Lawrence Livermore Laboratory under Intramural Order #6407609 and by the Los Alamos Scientific Laboratory under Contract 4-V60-2531p-1.

FINITE BANDWIDTH EFFECTS ON RESONANT ELECTRON HEATING*

R. B. Spielman[a], W. M. Bollen[b], K. Mizuno, and J. S. DeGroot
Department of Applied Science
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Davis, California 95616

ABSTRACT

P-polarized, finite bandwidth microwaves (f_o = 1.2 GHz) are incident on an inhomogeneous plasma in a cylindrical waveguide. The microwaves are mainly absorbed by resonant absorption near the critical surface (where the local plasma frequency, ω_{pe}, equals the microwave frequency, ω_o). We have investigated the effect of finite driver bandwidth on the resonant heating of electrons. We find that hot electron production is strongly affected by microwave bandwidth, the hot electron temperature varies as $T_H \propto (\Delta\omega/\omega)^{-0.25}$. We also observe that the fraction of incident power absorbed remains nearly constant, $A \approx 0.30-0.40$. The hot electron density increases with increasing bandwidth, $n_H \propto (\Delta\omega/\omega)^{0.50}$. The increase in n_H is balanced by the decrease in T_H such that the heat flux ($Q_H \propto n_H T_H^{3/2}$) at the critical surface is nearly constant.

*Work supported by Lawrence Livermore National Laboratory under Intramural Order #2435809 and by Los Alamos Scientific Laboratory under Intramural Order #N28-07476-1.

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MEASUREMENTS OF INHIBITED HEAT TRANSPORT IN A MICROWAVE - PLASMA INTERACTION EXPERIMENT*

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University of California, Davis
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ABSTRACT

P-polarized microwaves ($v_{os}/v_{eo} \lesssim 1$, $\frac{\omega_0}{2\pi} = 1.2$GHZ) are applied to an essentially collisionless, inhomogenous plasma in the U. C. Davis PROMETHEUS I device. Superthermal electrons are heated by resonant absorption and parametric instabilities. In addition, we observe strong heating of the thermal electrons. We find that the density and temperature of the hot electrons, the thermal electron temperature, and dc potential is a function of the length of the underdense shelf. Strong ion turbulence ($\Delta n/n \lesssim 20\%$) is observed on the underdense shelf and near the critical density. These ion waves progagate down the density gradient. The strong ion turbulence scatters the thermal electrons so that the thermal electron heat conductivity is severally limited.[1] However, the heat conductivity of the hot electrons is only slightly inhibited. We have measured the mean-free-time of the electrons in the turbulence as a function of electron energy. The technique is to measure the decay of the electron density and temperature after the microwaves are turned off. We find that the decay time strongly depends on electron energy, as expected. By comparing the data to solutions of the heat diffusion equation, we obtain an average effective collision frequency due to the turbulence $\nu_{eff}/\omega_{pe} \lesssim 10^{-2}$, which is consistent with the amplitude of the ion turbulence.

[1] W. M. Manheimer, Phys. Fluids 20, 265 (1977).

* This work supported by the Lawrence Livermore Laboratory under Intramural Order 6407609 and by the Los Alamos Scientific Laboratory under Contract 4-V60-2531P-1.

† Sandia Laboratories, Albuquerque, New Mexico.

Abstract Submitted
For the Tenth
Annual Anomalous
Absorption Conference
May 28 - 30, 1980

Cross-field Electron Transport in a Weakly Magnetized Plasma Driven by S-Polarized Microwaves.* T. A. HARGREAVES, K. MIZUNO, J. S. DeGROOT, Dept. of App. Sci., Univ. of Calif., Davis. -- We are investigating electron transport across an externally produced magnetic field ($\vec{B} \leq 20$ gauss) in the recentally completed U.C.D. MERCURY device. Magnetic fields are typically $\omega_{ce}/\omega_o \sim$ a few percent, which corresponds to a few megagauss in Nd-glass laser - pellet interactions. The incident S-polarized microwaves ($\omega_o/2\pi = 1.2$GHz, $\vec{k}_o \parallel \nabla n \perp \vec{B}$, power $\leq$ 5kW) drive the parametric decay instability near the critical density which locally heats electrons. It has been shown[1] that ion wave turbulence can enhance electron diffusion across the magnetic field, modifying the electron temperature profile. Probes will be used to measure the effect of the ion wave turbulence on the cross-field electron thermal transport as a function of the incident microwave power. The initial scale length of the plasma density gradient is $L/\lambda_{De} \approx 10^3 - 10^4$.

*Work supported by Lawrence Livermore Laboratory under Intramural Order 6407609.

[1]W. M. Manheimer, C. E. Max, J. Thomson, Phys. Fluids 21, 2009 (1978).

Computer Analysis of Langmuir Probe Data

Robert Walraven

University of California, Davis

A minicomputer can be used to acquire on-line Langmuir probe data and rapidly analyze the data for plasma potential and electron temperature. A model that generates noisy data with known plasma potential and electron temperature was used to develop an accurate, dependable algorithm for reduction of data from a cylindrical probe. Details of the algorithm are presented.

ION ACOUSTIC RESISTIVITY AND DOUBLE LAYERS**

Chris Barnes

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Los Alamos, New Mexico 87545

There is source controversy in the literature concerning the level of anomalous d - c resistivity produced by ion acoustic waves in a counterstreaming plasma and the electron drift velocity at which it becomes appreciable. We previously reported* significant levels of resistivity only when V_d approaches V_{the}. In an attempt to reconcile those results with suggestions that such resistivity are attainable at $V_d \approx V_{the}/10$, we have made further simulation runs. More careful attention was placed on attaining steady state conditions during the runs by either holding V_{the} constant on V_d/V_{the} constant. A number of runs were also made with realistic mass ratios. We found that significant resistivity was reasonable at drifts as low as 0.3 V_{the}, approximately half the drift needed under transient heating conditions.

We also investigated the conditions under which double layers would form in counterstreaming plasmas. Although double layers can be triggered by the large $\delta ni/_{ni}$ associated with ion acoustic waves, the resistivity associated with ion waves also inhibits double layer formation. We found that by maintaining constant V_{the}, double layers formed out of ion acoustic turbulence at $V_d = V_{the}$. With an initial density perturbation, double layers grew at $V_d = 0.7V_{the}$ before competition from ion waves could occur.

*DeGroot, Barnes, Walstead, Buneman; PRL 38, 1283 (1977)

**This work was performed under the auspices of the UDOE.

ELECTRON CYCLOTRON DAMPING FOR LARGE WAVE AMPLITUDE IN TOKAMAK PLASMAS +

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and

LABORATOIRE MILIEUX IONISEES, UNIVERSITE NANCY 1, FRANCE

ABSTRACT

A quasilinear kinetic equation to study the cyclotron wave damping in tokamak plasmas is derived. The correlation between the spatial deposition of the wave energy and the modification of the distribution function in the momentum space is emphasized. This correlation is a consequence of the resonance condition

$$(1+p^2/m^2c^2) - (\omega_c/\omega) - k_{\parallel}p_{\parallel}/m\omega = o, \qquad (1)$$

and the tokamak magnetic field inhomogeneity, $B_t(x) = B_t(o)\ (1-x/R_o$, where p is the particle momentum, ω_c is the cyclotron frequency, $k_{\parallel}$ is the parallel component of the propagation vector, R_o is the torus large radius, and m is the electron rest mass. For perpendicular propagation ($k_{\parallel} = o$) and $\omega = \omega_c\ (o)$, Eq. (1) yields $(p/mc)^2 = -2\ x/R_o$. The latter equation says that, for waves coming from large negative values of x (the high-B_t side of the torus), the wave energy is mainly transfered to the tail of the electron distribution. We solve numerically the quasilinear Fokker-Planck equation for the simple case of the ordinary mode and obtain the amplitude dependent wave damping. We also show that, in the case of the propagation from the high-B_t side of the tokamak, the steady-state is characterized by a superthermal tail in the momentum distribution and that the wave energy is totally absorbed by a small fraction of the electron population with velocity well above the thermal speed.

+ Paper presented at the 10th Annual Conference on Anomalous Absorption of Electromagnetic Waves, May 28-30, 1980, San Francisco, California.

Effect of Finite Electron Drift on the Resonant Excitation of a Nonuniform Plasma* G. J. Morales, B. Lamb, and E. A. Adler, UCLA --. It is well known that the external application of long wavelength radiation of frequency ω to a nonuniform plasma gives rise to the excitation of an electrostatic resonance at that point in the density profile where $\omega = \omega_p(x)$, the local electron plasma frequency. The peak amplitude attained by the driven resonance is limited by the convection of wave energy down the density gradient. The convection is accomplished by a propagating electron plasma wave which is linearly excited by the resonance process when finite temperature effects are taken into account. The present analytical study considers the modification of the linear mode conversion process produced by a small electron drift velocity. Such drifts can be naturally present in the plasma, or can be the result of the resonant absorption process itself. The fundamental role played by the drift is that it can modify the group velocity of the electron plasma wave significantly in the neighborhood of the resonance. It is found that when the drift points down the gradient, the usual Airy pattern is blown down with the drift and the peak amplitude of the electric field is reduced. When the drift points in the direction of increasing density, the Airy pattern is forced to penetrate into the overdense region $\omega_p > \omega$. Since in this case the drift velocity opposes the group velocity of the mode converted wave, a large enhancement of the peak electric field is attained.

*Work supported by ONR and NSF.

SESSION E

FRIDAY, MAY 30

8:30 A.M. - 12:32 P.M.

A. B. LANGDON, CHAIRMAN

LAWRENCE LIVERMORE LABORATORY

Time Resolved Backscatter Studies in Laser Plasmas at 1.052μm and 0.526μm

E McGoldrick, A A Pugatschew, S M L Sim
Essex University

A J Cole, J Murdoch
Imperial College, London University

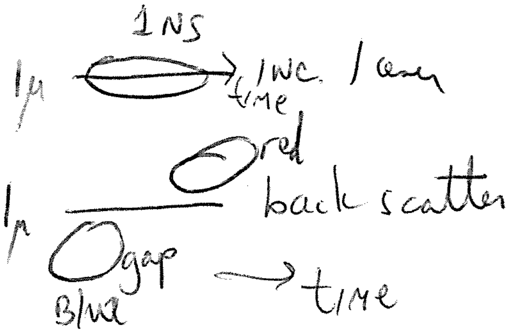
R G Evans
Rutherford Laboratory

In laser fusion experiments the study of the plasma instabilities excited by the interaction of intense laser light with plasma is of interest. Some of these enhance absorption, for example the parametric decay instability near the critical density surface and the two plasmon decay instability which occurs near the quarter critical density layer. Others such as the Brillouin and Raman scattering instabilities which both occur in the underdense plasma, enhance the light reflection. Evidence for the presence of these instabilities and their importance have been sought in the observations of scattered light near the fundamental frequency and its harmonics.

This paper presents time resolved measurements of the backscattered emission through the f/1 focussing lens, from plane targets irradiated by the Nd/glass laser at the SRC Laser Facility, Rutherford Laboratory, both at 1.052μm and 0.526μm. Laser energies of $\lesssim$ 125J and pulse lengths of 1.3 - 2.0 ns FWHM were used, resulting in irradiances on target of $\lesssim 6 \times 10^{15}$ W cm^{-2} at 1.052μm and $\lesssim 3 \times 10^{15}$ W cm^{-2} at 0.526μm. A range of data was obtained by varying the target material Z, from plastic to gold, and for two target orientations: both at normal and 45^{o} incidence to the laser beam.

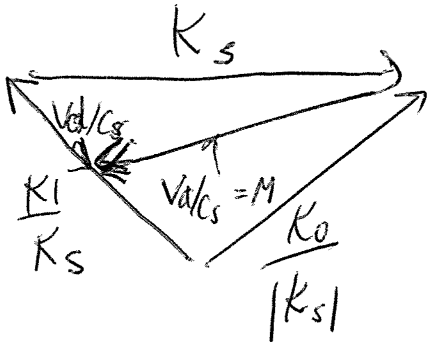
Of chief interest are the time resolved spectra near the fundamental frequency in each case, which display the characteristic red shift of stimulated Brillouin scattering. Time resolved backscatter studies of the 2 ω_o and 3/2 ω_o harmonic spectra were also obtained (for laser wavelength of 1.052μm only) and these exhibit behaviour strongly dependent on threshold. This is explained by the onset of plasma instabilities.

Calorimetry measurements show that the backscatter energies were reduced for the frequency doubled studies, in agreement with wavelength scaling theories.



$\underline{K_0} = \underline{K_\perp} + K_s$

$V_g = \vec{K}_{c_s} + \vec{V_d}$



Abstract of presentation for the 10th Anomalous Absorption Conference
San Francisco, May 28-30 1980

Brillouin Scattering at Arbitrary Angles
in Drifting Plasma: Application to experiment

G. Mitchel, T.W. Johnston, B. Grek, H. Pépin, F. Martin
INRS-Energie, Université du Québec
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The laboratory anisotropy of the sound waves in a drifting plasma means that the possibilities for absolute stimulated Brillouin scatter (SBS) instability requiring coupled waves with apposing group velocities[1] exist at angles other than 180^{o} backscatter. Indeed, at drift velocity Mach numbers between 0.5 and 1.0 two other possibilities exist which are favored, even for light directly opposed to the flow. Furthermore, absolute SBS from reflected light travelling with the out going flow are favored over incoming light of the same intensity. Some implications of this analysis for experiments will be discussed.

1. A. Bers F.W. Chambers MIT Quarterly Prog. Rep. 113 pp 112-116 April 15, 1974.

non linearity in Amplitude & frequency shift could quickly saturate things.

Abstract

NEW RESULTS ON BRILLOUIN SCATTERING

Francis F. Chen
University of California, Los Angeles CA 90024

sees only 5% SBS & then saturates

Progress has been made both experimentally and theoretically in the understanding of stimulated Brillouin scattering. The dependence on f-number is a complicated function of the focal depth, plasma creation and heating, and the range of angles of the incident rays. It is commonly thought that more scattering is observed with tighter focus, but in a controlled experiment we find less SBS at f/2 than at f/7.5. Holographic probing of the density contours is used to help explain the result. The dependence on ionic charge Z is also complicated because Z affects both Landau damping and plasma heating. In different experiments we have observed both larger and smaller scattering in A and He than in H_2. To understand the Z dependence, spectroscopic measurements of T_e and interferometric measurements of n_e have been made to document the plasma conditions in each case. Theoretical understanding of the saturation level has relied mainly on ion trapping and ion heating. We find that the simple waterbag treatment of ion trapping is insufficient to explain experimental results. We have investigated in more detail what happens when ions are trapped; for instance, whether nonlinear frequency shifts or harmonic generation can explain observations. Regardless of the ion wave saturation, saturation of the scattering ultimately depends on the scale length L. Experiments in which L has been measured are compared to see whether a consistent picture emerges.

$R \sim F^2$ $\quad F = f\#$ of lens

$$Q \sim \left(e^s/s\right)^{3/2} \qquad s = 1 + \frac{ZT_e}{3T_i}$$

$$s - 1 = \frac{3\cdot 10^7}{n_e \tau}\left(\frac{M}{M_H}\right) T_{eV}^{3/2}$$

Seed a gas with H_2 & SBS goes down due to killing ion Landau Damping

PLASMA FLOW EFFECTS ON LANGMUIR AND ION ACOUSTIC WAVES*

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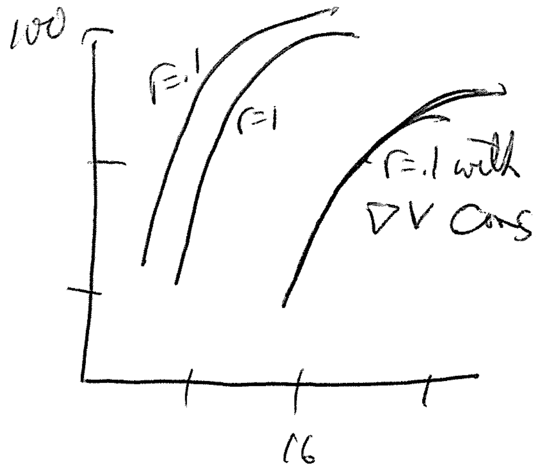
ABSTRACT

In laser-plasma interactions, Langmuir and ion acoustic waves can be driven by parametric instabilities near the critical density layer. Usually the pump is large enough so that the excited longitudinal waves are highly nonlinear and interact strongly with the particles. Circumstances exist for strong turbulent states and sometimes more coherent localized excitations. We investigated the effect of plasma flow on the spectra and the nonlinear levels of the waves, which are essential in the problem of electron heating and heat transport. A moving solitary wave, which can be viewed as stationary in the flowing plasma, has long been considered critical. We find that the Langmuir solitons are more subsonic, whereas the ion acoustic solitons (modified with the associated high frequency plasma waves) are more supersonic. The frequency shift due to the flow is essential in determining the prominent modes in the turbulent waves. Analytical and particle simulation results will be presented.

*Supported by the Lawrence Livermore Laboratory under Intramural Order #6407609.

$L = 30\mu \quad T_e = 10\,keV \qquad \Gamma = \frac{T_i}{Z T_e}$



SBS depends strongly on $\frac{\nabla V_\phi}{T_e}$

FLUID SIMULATION OF STIMULATED BRILLOUIN BACKSCATTER IN LASER-PRODUCED PLASMAS

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Stimulated Brillouin backscatter is an important physical process in limiting the coupling of laser light to material targets. Most analysis has been applied to homogeneous plasmas. In this numerical one-dimensional study, emphasis is placed on inhomogeneous plasmas.

Equations are solved for the pump, reflected and ion-acoustic wave simultaneously. Several ion acoustic waves can also be integrated at the same time, thus allowing the study of the effects of finite bandwidth on SBS. However, the present emphasis has been on the effects of density gradients, velocity gradients, temperature ratios and magnitudes. The study of these effects is important in order to understand how the anomalous reflectivity scales with physical parameters.

All the fluid variables profiles can be varied arbitrarily. In this work, exponential profiles have been assumed for the density and linear profiles for the fluid velocity (from a rarefaction wave). The temperature profiles have been assumed constant. It is found that

- A detailed knowledge of the electron blow-off temperature is as important for determining the levels of reflectivity as is ion heating.

- Velocity gradients can change the SBS threshold by more than an order of magnitude.

Non-linear effects like limitation of the amplitude of the ion acoustic wave are also presently investigated.

$$Q \sim \frac{L}{\lambda}\left(\frac{n}{n_c}\right)\left(\frac{V_0}{V_e}\right)^2$$

claim: Q ind. of λ

r_c moves out faster in time for red than for green.

My way

$$T_e \sim (I Z \tau)^{.4}$$

$$V_0^2 \sim I\lambda^2$$

$$\frac{n}{n_c} \approx 1$$

$$\frac{L}{\lambda} \approx \frac{1}{\lambda}$$

$$\therefore Q \sim \lambda$$

Their way: as λ↓ $I\lambda^2$↓ P.M. forces ↓

∴ $\frac{n}{n_c}$↑ (lower shelf rise)

& L↑

$$V_0^2 \sim \lambda^2$$

$$\frac{n}{n_c} \sim \left(\frac{1}{\lambda}\right)^{\alpha}$$

$$\left(\frac{L}{\lambda}\right) \sim \frac{1}{\lambda}\left(\frac{1}{\lambda}\right)^{\beta}$$

$$Q \sim \lambda^{1-(\alpha+\beta)}$$

Wavelength Scaling of Brillouin Scattering and Profile Modification by Fluid Simulation*

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ABSTRACT

A spherically symmetric Lagrangian hydrodynamic fluid simulation is used to study the interaction of Stimulated Brillouin Scattering (SBS) and profile modification by ponderomotive force and by heat flux inhibition. The results are compared to the KMS experiments on infrared and green light illumination of spherical targets for both short and long pulses. The amount of Brillouin scattering is calculated by solving coupled nonlinear equations for incident and reflected light waves when the ion acoustic wave is heavily damped. The reflected light grows from plasma noise or from light reflected from the critical surface(1). The effects of plasma inhomogeneity and laser bandwidth on the growth rate of SBS and the heating of the plasma by the driven (but heavily damped) ion acoustic waves are included. Density profile modification requires the resolution of steep gradients in the critically dense region through which Lagrangian zones are moving. This is accomplished by use of an automatic fine zoning technique(2). The profile modification is very important to include as it significantly reduces both the Brillouin scattering and the inverse Bremsstrahlung absorption (simulations without fine zoning over estimate the effects of these latter processes).

References

1. C. Randall, J. J. Thomson, K. Estabrook, PRL 43, 924 (1979).
2. D. Tanner, L. V. Powers, R. A. Grandey, Bull. Am. Phys. Soc. 24, 1105 (1979).

*This work prepared for the Department of Energy under Contract No. DE-AC08-78DP40030.

Effects of Secondary Brillouin Scattering*

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ABSTRACT

Stimulated Brillouin Scattering in which the scattered light wave also undergoes scattering is investigated. Rescattering is found to be ineffective in reducing the net reflection coefficient if ion wave damping is isotropic except when the background noise level of the rescattered wave is artificially enhanced. A modest level of anisotropy is shown to significantly reduce the reflection coefficient although the rescattered light intensity remains small compared with the incident light intensity. These results suggest that appreciable cascading to higher order modes requires both anisotropy and reflection from the critical surface in laser produced plasma.

*This work was supported under the United States Department of Energy Contract DE-AC08-78DP40030.

SBS IN A MICROWAVE - PLASMA INTERACTION: THRESHOLD AND GROWTH RATE

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and
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We report here observations of SBS which is initiated from density perturbations by the ponderomotive force of a partially standing wave in the plasma. We find good agreement with classical calculations of growth rate after an initial fast growth due to the ponderomotive force driven density fluctuations.

The microwave pump ($\omega_0/2\pi$ = 3.3 GHz, $P_0 \lesssim$ 1 MW, and pulse width τ_p = 0.1 ~ 20 μsec) is incident upon a 2m - long unmagnetized plasma ($\bar{n}_0 \simeq 0.1\, n_{crit}$, H, He, or Ar ion species, $T_e \simeq 2$eV). The resultant density fluctuations are detected by movable Langmuir probes. The incident and reflected waves are separated by a directional coupler and monitored with a square law detector.

In our experiment, a small amount of light ($\simeq$1%) is scattered from the back walls of the vacuum chamber. This small reflectivity produces significant ripples in the standing wave power resulting in a spatially dependent ponderomotive force term which drives ion waves. The fluctuating ion density is given by;

$$\tilde{n}/n_0 = r^{1/2}(v_0/v_{te})^2\ (1-\cos\omega_s t) \qquad (1)$$

where r is the reflectivity, v_0 (v_{te}) is the oscillating (electron thermal) velocity, and $\omega_s/2\pi$ is the ion wave frequency. Experimental results were consistent with Eq. (1).

The standing ponderomotive force generated density fluctuations can scatter the incident wave via ordinary Thomson scattering. The scattered wave may therefore act as an enhanced noise level for the initiation of SBS. Experimentally, at high power levels, an increase in the level of the reflected wave is observed ≃ 5 μsec after initiation of the incident pulse. This is to be compared with the calculated temporal growth rate for SBS (1)

$$\gamma = \sqrt{2}\ \frac{v_0}{c}\ \omega_{pi} \sqrt{\frac{\omega_0}{\omega_s}\ \frac{c_s}{c}}\ , \qquad (2)$$

which yields $\gamma \simeq 10^5$ sec^{-1} for our experiment. Moreover, we observe the enhancement of the red shifted component of the scattered wave as expected for SBS.

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(1) D.W. Forslund, J.M. Kindel and E.L. Lindman; Phys. Fluids 18, 1002 (1975).

*Work supported in part by DOE-OLF Contract DE-AS03-76SF00034, U.S. AFOSR Contract F48620-76-C-0012 and DOE Contract DE-AC08079DP40116.

ABSTRACT SUBMITTED TO 10TH ANNUAL ANOMALOUS ABSORPTION CONFERENCE

SBS STUDY IN MICROWAVE - PLASMA INTERACTION: SATURATION AND CONTROL

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SBS poses severe problems for the long laser pulses and associated density gradient scalelengths envisioned for the next generation of laser fusion targets. Here, we report on the study of the saturation mechanism and control of SBS in a microwave experiment. In summary, we have: (1) observed a saturation of the reflectivity at 5 - 10% and associated ion density fluctuations $(\tilde{n}/n_o)_{max} \simeq 5\%$, (2) tentatively identified the saturation mechanism as a frequency shift of the ion waves due to ion trapping, and (3) demonstrated that finite bandwith comb type (multiline gas laser) or random noise type (glass laser) pumps can eliminate SBS.

Microwave radiation ($\omega_o/2\pi$ = 3.3 GHz, $P_o \lesssim 1$ MW and pulse width τ_p = 0.1 - 20 μsec) is launched from a gridded horn (aperture = 2 - 10 λ_o where λ_o is the incident wavelength) along the axis of unmagnetized plasmas (75 cm diameter, 2m length, $n_o = 0.1\ n_{crit}$, H, He, Ne or Ar ion species, and $T_e \simeq 2$ eV). The density gradient scalelength $L_n = 8 - 40\ \lambda_o$ and $\omega_s\ \tau_p \gtrsim 30$, where $\omega_s/2\pi$ is the ion wave frequency. In this experiment, SBS seems to occur through two main processes. Initially, ion waves are excited due to the spatially dependent pondermotive force ($k = 2k_o$) produced by the partially standing wave formed by the incident microwave field and the wave reflected by an imperfect absorbing boundary. After the ion waves produced by the standing wave field build up, they scatter the incident wave as in ordinary Thomson scattering. This portion of the scattered wave acts as an enhanced noise level for the initiation of SBS. Saturation of both the ion density fluctuations and the reflectivity are observed with $(\tilde{n}/n_o)_{max} \simeq$ 5% and $R \simeq 5$ - 10%. Since more than 40 μsec pulse width is required for appreciable ion heating, ion Landau damping is not expected to be a saturation mechanism. Experimental measurements indicate that ion trapping appears to be the dominant saturation mechanism. The trapped ions produce a sufficiently large frequency shift to move the ion waves out of the resonance width for SBS.

We have also worked on the study of the effectiveness of finite bandwidth pumps in controlling SBS. We find that for $\Delta\omega/\omega_o \simeq 0.03$, the reflectivity decreases by almost two orders of magnitude for both comb type and random noise type pumps. The ion density fluctuations exhibit a corresponding reduction with increased pump bandwidth decreasing from 4% for the narrowband pump to $\simeq 0.3\%$ for $\Delta\omega/\omega_o \simeq 3\%$.

This work is supported in part by DOE OLF Contract No. DE-AS03-76-SF00034, AFOSR Contract No. F490620-76-0012 and DOE Contract DE-AC08079DP40116.

LASTEST RESULTS OF LASNEX AND KINETIC SIMULATIONS OF BRILLOUIN AND RAMAN SCATTERING*

Kent Estabrook, Judith Harte, and W. L. Kruer

What Knobs?
3/10^13 abs at μ?

Lawrence Livermore Laboratory
University of California
Livermore, California 94550

2NS?

Abstract

The Brillouin model in Lasnex now includes a self consistent model for the ion density heated by Brillouin with collisional relaxation to the thermal ions. The heated ion density is used to figure the ion Landau damping. It now includes density and velocity gradient damping, an accurate treatment of reflection at low intensities, and a better treatment of ion wave saturation. We can match experimental data to within 10% over a fairly wide range of intensity and laser wavelengths on gold. We extrapolate our model to short wavelength lasers for a variety of intensities and find that the Brillouin loss is small for $I < 3 \times 10^{15}$, $\lambda_0 = .27\,\mu$, and for $I < 5 \times 10^{14}$, λ_0 $.53\,\mu$ (experimentally confirmed). See paper by V. Rupert, M. Campbell, D. Philion, and F. Ze for experiments.

We have also done 1-D kinetic simulations on the effect of bandwidth on Raman. We find that if the Raman is near its density gradient threshold, sufficient bandwidth can drive Raman below its density gradient threshold.

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

Limitations on Brillouin Scattering by Inverse Bremstrahlung and ion heating

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Laser Division
Rutherford Laboratory
Chilton
Didcot
Oxon

Abstract

Two limitations on the level of Stimulated Brillouin Scattering (SBS) are considered which are important respectively for short wavelength and long wavelength lasers. At short wavelengths and particularly for high Z targets inverse bremstrahlung can force the SBS to larger radii and lower densities where the irradiance can drop below the SBS threshold. Heating of the plasma ions is an effective mechanism for reducing SBS at wavelengths greater than ∿3μm and a simple self consistent ion heating model gives good agreement with experimental data at 10.6μm.

CO_2 $4\,10^{14}$ W/cm^2 $T_H \approx 20$ keV

$T_C \approx 1$ keV

Raman produced $T_1 = 87$ $T_2 = 145$ $n_{Raman} \approx .15\, n_{crit}$

Nonlinear Behavior of Stimulated Scattering, Self-Focussing and Bubble Formation*

J. M. Kindel, C. H. Aldrich and D. W. Forslund,
Los Alamos Scientific Laboratory, Los Alamos, NM 87545

Two Dimensional simulations with WAVE have been carried out to examine the interplay between stimulated Brillouin scatter (SBS), stimulated Raman Scatter[1] (SRS), self-focussing and bubble formation.[2] Both focussed and unfocussed laser beams have been considered at intensities such that $V_0 \sim 0\,(V_{HOT})$, where V_{HOT} is the hot electron thermal velocity. For example, we consider a case where the underdense plasma is taken to be uniform and composed entirely of hot electrons at .5 n_{crit}. Some of our preliminary results are as follows: For the case of $T_e/T_i \gg 1$ and SBS, ion waves break reducing $\Delta n/n$ from a 70% backscattering level to 30% - 40% diffuse scatter at late times. Profile steepening occurs, but does not reduce backscatter and can enhance oblique scatter. Bubbles form in two dimensions due to Raman ponderomotive effects at quarter critical and tend to produce a two temperature superhot electron distribution. Warm ions reduce backscatter relative to oblique scatter and for the case of a focussed beam greatly enhance self-focussing.

*This work was performed under the auspices of the USDOE.

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

[2] Kent Estabrook, Phys. Fluids 19, 1733 (1976).

Bubbles taken off ion

SESSION F

FRIDAY, MAY 30

2:00 P.M. - 5:30 P.M.

POSTER SESSION

Absorption Experiments on CO_2 Laser Produced Plasmas*

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ABSTRACT

Experiments have recently begun on the measurement of the absorption of CO_2 laser light. They concentrate primarily on observation of light scattered from the target. In one experiment, an integrating sphere is used to collect diffusely scattered light, giving data on total (time and angle) integrated reflection. The technique is being used initially with one beam of the LASL two-beam system at energies up to ∿ 200 J (intensity ∿ 10^{16} W/cm^2). A second experiment is in progress on time resolved absorption at low energies (intensity ∿ 10^{13} W/cm^2). Pulse shape measurements show a general shortening of the backscatter pulse with respect to the incident pulse. For both aluminum and tungsten slabs, the backscatter pulse peaks some 400 ps before the incident pulse (1.1 ns FWHM). This may be evidence of early saturation of SBS. Significant structure is also observed for lower atomic number targets.

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

STIMULATED BACKSCATTER AND ANOMALOUS ABSORPTION OF CO_2 LASER RADIATION IN GAS TARGETS

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University of Alberta
Edmonton, Canada

Efficient absorption of long pulse CO_2 laser radiation following a transient phase of stimulated backscatter has been experimentally observed in a supersonic laminar jet oxygen gas target. The maximum total power reflectivity was ≃ 30% for an incident intensity of 5 x 10^{12} watt/cm^2 ($V_o^2/V_e^2 \simeq 1$) which decreased to ≃18% at 10^{13} watt/cm^2, roughly divided between specular and stimulated backscatter. Significantly, the duration was found to be short-lived compared to the laser pulse length, unlike earlier results on strictly underdense plasma where scattering occured throughout the laser pulse. In a time interval of ~ 10 nsec following backscatter nearly complete absorption occurs after which target burn-through and refraction dominate. Little energy is scattered sideways. Classical inverse bremsstrahlung is inadequate to account for the high absorption in the critical density plasma with scale length ≤ 100 μm at early time, or subsequently underdense plasma at later time. Resonance absorption does not appear to be important in this experiment. In addition, strong flux inhibition is inferred from ion velocity measurements. Saturation mechanisms for the observed backscatter and the postulated ion turbulence which appears to account for the absorption and reduction in transport will be discussed.

EFFICIENT SATURATION OF PARAMETRIC INSTABILITIES BY THE SECONDARY DECAY OF ELECTROSTATIC WAVES

S.J. Karttunen*, A. Ng and A.A. Offenberger

University of Alberta, Edmonton, Canada

Secondary decay of the electrostatic daughter wave is shown to provide an efficient saturation mehanism for stimulated Brillouin (SBS) and Raman (SRS) scattering and for two-plasmon decay (TPD). In the case of SBS[1] the secondary ion wave decay into two new ion waves is possible in the linear region of the dispersion relation ($k_s\lambda_D<<1$), where both phase matching conditions for the secondary decay can be satisfied. For weak ion wave damping ($\Gamma_s/\omega_s \lesssim 0.35\ (v_o/c)(k_s\lambda_D)^{-1}$) SBS saturates to very small values below quarter critical density. Large reflectivities (>50%) are predicted for $n>0.5n_c$ but other effects such as profile steepening are expected to inhibit SBS in this high density region.

Ion dynamics dominate the behaviour of SRS[1] and TPD which are basically high frequency phenomena. Langmuir waves excited by SRS or TPD can decay further into another Langmuir mode and ion acoustic wave. Saturated reflectivity due to SRS is $r_\infty \simeq 10(v_e/c)^4$. Correspondingly, the coversion ratio of TPD saturates to the value $r_c \simeq \alpha\ (v_e/c)^2$, where $\alpha \sim \mathcal{O}(1)$ depends on the TPD-geometry. Relatively large ion fluctuation levels are expected at the saturated stage of SRS and TPD.

1. S.J. Karttunen, Plasma Phys. 22, 151 (1980).

*Permanent address: Technical Research Centre of Finland, Helsinki, Finland.

Abstract of presentation for the 10th Anomalous Absorption Conference
San Francisco, May 28-30 1980

Brillouin Scattering at Arbitrary Angles
in Drifting Plasma: Application to experiment

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The laboratory anisotropy of the sound waves in a drifting plasma means that the possibilities for absolute stimulated Brillouin scatter (SBS) instability requiring coupled waves with apposing group velocities[1] exist at angles other than 180^{o} backscatter. Indeed, at drift velocity Mach numbers between 0.5 and 1.0 two other possibilities exist which are favored, even for light directly opposed to the flow. Furthermore, absolute SBS from reflected light travelling with the out going flow are favored over incoming light of the same intensity. Some implications of this analysis for experiments will be discussed.

1. A. Bers F.W. Chambers MIT Quarterly Prog. Rep. 113 pp 112-116 April 15, 1974.

Backscatter of CO_2 Laser Light from an Overdense Z pinch Plasma

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The first results of an experimental study involving the interaction of a mode-locked CO_2 laser with an overdense helium Z pinch plasma will be presented. The laser is incident radially upon the plasma. It produces pulses $\sim$2.5 nsec long with $\sim$15 nsec between pulses. When focussed by an F/5 KCl lens, the maximum intensity (in vacuum) is $\sim 2 \times 10^{12}$ Wcm^{-2} over a 700 μm diameter focal shot. The Z pinch at the time of peak compression provides a target $\sim$ 2-3 mm in diameter with $n_e \sim 5n_{cr}$, and density scale lengths of several hundred microns.

The single-pulse intensity of light backscattered through the F/5 lens shows an approximately exponential growth rate with incident laser power. The reflectivity is $\sim$4% at I(vacuum) $\sim 2 \times 10^{12}$ W cm^{-2} and shows some signs of saturating. These results, and measurements of the shift in the backscattered light from ω_o, will be presented and discussed.

Nonlinear Scattering of Electromagnetic Waves in a Magnetized Plasma

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and

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ABSTRACT

We have explained the experimental results of Smith, Radebaugh and Scharer[1] on the parametric decay of a whistler wave into an upperside band whistler and a low frequency long wavelength wave. The low frequency wave is a negative energy mode, driven by the parallel ponderomotive force on the electrons due to the pump and the side band. The threshold power and the spectrum of the instability are in good agreement with the observed ones.

The present analysis gives an insight into the interaction of high power radiation with the negative energy and unstable modes. We have discussed the influence of laser radiation on the Weibel instability.

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1. D.K.Smith, J.C.Radebaugh and J.E.Scharer, Plasma Physics 21, 643 (1979).

STIMULATED BRILLOUIN BACKSCATTER BEHAVIOR NEAR THRESHOLD

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Stimulated Brillouin backscattering was studied using the Vlasov equation with ponderomotive force term included. The well-known dispersion equation is solved numerically for both the temporal and the spatial problems in the case of a bounded homogeneous plasma. Improved analytic solutions are also obtained for plasmas with $z_i T_e / T_i$ large compared to unity. From these solutions it is found for example that the frequency shift of the scattered radiation can be quite large compared to the ion acoustic frequency when the electron thermal speed is of the same order as the quiver velocity.

THEORY AND SIMULATIONS OF CRITICAL SURFACE DOMINATED STIMULATED BRILLOUIN SCATTER *

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Abstract

It has been shown that when the light reflected from the critical surface is considered, the boundary conditions for stimulated Brillouin scattering (SBS) are greatly modified.[1] The noise source for the scattered light, in the steady convective growth regime is no longer α the thermal level, but instead f the fractional reflectivity of the critical surface. In general $f \gg \alpha$, yielding a great enhancement of SBS. In this paper we extend our analysis of critical surface dominated SBS to include arbitrary gradients of density temperature and velocity. We find excellent agreement between this theory and numerical simulations of high Z disk experiments using the wave optics–hydro code AURUS.

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

[1] C. J. Randall, J. J. Thomson, and K. G. Estabrook, Phys. Rev. Lett. 43, 924 (1979).

Abstract Submitted
For the Tenth
Annual Anomalous
Absorption Conference
May 28 - 30, 1980

Stimulated Brillouin Scattering in Underdense Plasmas.*
R. A. JAMES, K. MIZUNO, and J. S. DeGROOT, Dept. of App. Sci., Univ. of Calif., Davis. -- We are investigating stimulated Brillouin scattering of microwaves in the CERBERUS V device. This system is designed to model stimulated Brillouin scattering in laser driven pellets. A variable diameter ($D/\lambda_o \leq 7$), parallel beam of microwaves (frequency = 5.4 GHz) is incident on a variable length underdense plasma ($L/\lambda_o \lesssim 50$) with or without a critical surface. The flow velocity is variable ($V/C_s \lesssim 1$). The incident microwave power is 600 kW ($v_{os}/v_{eo} \lesssim 1$) with a pulse length of $\tau_p \lesssim 20$ μsec ($k_o C_s \tau_p \lesssim 5$). A pulsed LaB_6 source is used for plasma production. Measurements to be made include scattering as a function of azimuth and elevation using high gain antennas, backscatter power into the lens which produces the microwave beam, and ion wave spectrum using probes.

*Work supported by Lawrence Livermore Laboratory under Intramural Order 6407609.

HARMONIC GENERATION BY LARGE AMPLITUDE ION ACOUSTIC WAVES *

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Livermore, California 94550

Abstract

An interesting characteristic of a long wavelength ion accoustic wave is its tendency to steepen; i.e. to generate harmonics. We here examine harmonic generation by an ion accoustic wave driven by a ponderomotive force. Our preliminary results show that this harmonic generation can act like an enhanced damping and significantly reduce the amplitude to which a long wavelength ion wave can be driven.

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

FILAMENTATTION IN COLLISIONAL ICF PLASMAS*

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Abstract

Characteristics of the development of filaments in large collisional plasmas of ICF interest will be compared to the collisionless situation.

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

ACCELERATION OF LASER IRRADIATED THIN FOIL TARGETS

Gaston Thiell
C.E.A. - C.E.L.
B.P. 27
Villeneuve-St-Georges, France

Energy Transport and Rear Surface Temperature Evolution in Laser-Accelerated Foils.* S.H. Gold**, E.A. McLean, J.A. Stamper, H.R. Griem***, R.R. Whitlock, S.P. Obenschain, B.H. Ripin, and M.J. Herbst****, Naval Research Laboratory, Washington, D.C. 20375.

To achieve the long-term goals of laser fusion, it is necessary to compress fuel to very high densities. This high density compression requires that the fuel be accelerated inward near-isentropically. By diagnosing the rear surface temperature of the cold fuel, one can judge the extent of fuel preheat. At NRL, we are studying the ablative acceleration of thin planar targets to velocities sufficient for pellet shell implosion.[1] Planar targets permit optical diagnosis of the rear surface conditions which correspond to those of the inaccessible inner pellet shell surface.[2]

These experiments have been performed at irradiances of up to 5×10^{12} W/cm^2 at 1.05 μm using the NRL Pharos II Nd-glass laser system with up to 200 J on target in a 4-nsec-duration pulse. Time-resolved rear surface temperature measurements were made for a variety of CH, C, and Al foil targets ranging from 2.5 to 30 μm thick. We demonstrate that the rear surface radiates approximately as a blackbody by measuring the emission at several wavelengths in the continuum, as well as the wavelengths where line emission should stand out from the continuum if the surface does not radiate as blackbody. Then, using blackbody assumptions, the complete time history of the rear surface temperature is inferred from absolutely calibrated measurements of the continuum emission at a single wavelength. This was done using two stigmatic, 3/4-meter monochromators equipped with fast (1-nsec) photomultipliers, and was supplemented by streak camera studies of the rear surface luminosity. To the overall accuracy ($\sim$a factor of 2) of the luminosity measurements the measured "brightness temperatures" at various wavelengths between 4300 Å and 5700 Å agree, as does the "color temperature".

This paper will discuss the effect of varying target thickness, incident irradiance, and focal spot size on the development of the rear surface temperature. We relate the measured emission to interferometric measurements of electron densities on the rear of the target. Finally, we will discuss the contributions of x-ray and fast electron preheat, shock effects, and thermal transport through the target, and will comment on the inappropriateness of possible "cookie-cutter" models that would permit the rear surface to heat by means of front surface plasma flow around the edges of the accelerated region of the target. A companion paper[3] will discuss x-ray measurements related to this study.

*Work supported by the U.S. Department of Energy.
**NRC/NRL Resident Research Associate.
***Also of the University of Maryland, College Park, MD.
****Mission Research Corporation, Alexandria, VA.

[1] B.H.Ripin, et al., Phys. Fluids, May 1980.

[2] E.A. McLean, et al., Bull. APS 24, 1075 (1979), and S.H. Gold, et al., ibid.

[3] R.R. Whitlock, et al., paper presented at this conference.

X-RAY ENERGY DEPOSITION AT THE REAR SURFACE OF LASER-ACCELERATED FOILS*

R.R. Whitlock, S.H. Gold**, M.J. Herbst***,
F.C. Young, E.A. McLean and J.H. Stamper

Naval Research Laboratory, Washington, D.C. 20375

Preheating of the fuel in a laser fusion pellet can decrease compression efficiencies. Measurements of rear surface temperatures on ablatively accelerated thin (3-30 micron) Al and CH foil targets, which simulate a small section of a spherical pellet, have been made[1]. Temperatures of up to several electron volts have been observed during the 4 nsec, 100-200 J, 1.054 micron laser pulse. A number of mechanisms, including thermal conduction, shocks, fast particles, direct x-ray deposition and x-ray deposition followed by thermal conduction, might contribute to this transport of energy to the rear surface of the target.

The fraction of the rear surface heating due to the absorption of x-rays from the front surface plasma will be estimated from our x-ray measurements which have been recently performed. These measurements include absolute x-ray spectra (above 1 keV) of the front side plasma and spatially resolved x-ray images taken from the target rear with Al and CH targets.

The results of calculations of the x-ray spectral deposition within and on the back surface of foil targets will be presented. These results will be compared with the observed x-ray images and with the temperature measurements of the rear surface of the foil.

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

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Reference

1. E.A. McLean, et al., BAPS 24, 1075 (1979) and S.H. Gold, et al., paper presented at this conference.

PLASMA FLOW EFFECTS ON LANGMUIR AND ION ACOUSTIC WAVES*

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ABSTRACT

In laser-plasma interactions, Langmuir and ion acoustic waves can be driven by parametric instabilities near the critical density layer. Usually the pump is large enough so that the excited longitudinal waves are highly nonlinear and interact strongly with the particles. Circumstances exist for strong turbulent states and sometimes more coherent localized excitations. We investigated the effect of plasma flow on the spectra and the nonlinear levels of the waves, which are essential in the problem of electron heating and heat transport. A moving solitary wave, which can be viewed as stationary in the flowing plasma, has long been considered critical. We find that the Langmuir solitons are more subsonic, whereas the ion acoustic solitons (modified with the associated high frequency plasma waves) are more supersonic. The frequency shift due to the flow is essential in determining the prominent modes in the turbulent waves. Analytical and particle simulation results will be presented.

*Supported by the Lawrence Livermore Laboratory under Intramural Order #6407609.

10th ANNUAL CONFERENCE

ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

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