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9th Annual Conference on Anomalous Absorption of Electromagnetic Waves

May 15-18, 1979

Laboratory for Laser Energetics

University of Rochester
College of Engineering and Applied Science

9th Annual Conference on Anomalous Absorption of Electromagnetic Waves

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The University of Rochester
Rochester, New York

May 15-18, 1979

ORGANIZING COMMITTEE

R. McCrory, co-chairman	University of Rochester
E. Williams, co-chairman	University of Rochester
R. Berger	KMS Fusion
D. Forslund	Los Alamos Scientific Laboratory
M. Lubin	University of Rochester
K. Matzen	Sandia Laboratories
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R. Morse	University of Arizona
J. Pearlman	U. S. Department of Energy
B. Ripin	Naval Research Laboratory

9th Annual Conference on Anomalous Absorption of Electromagnetic Waves

SESSION SCHEDULE

A. Backscatter (Wednesday, May 16, 8:30 a.m.—12:30 p.m.)
Chairman: M. J. Lubin, University of Rochester

B. Transport Phenomena (Wednesday, May 16, 2:00 p.m.—5:00 p.m.)
Chairman: M. Bruce Langdon, Lawrence Livermore Laboratory

C. Hot Electrons and Resonance Absorption (Thursday, May 17, 8:30 a.m.—12:30 p.m.)
Chairman: M. Keith Matzen, Sandia Laboratories

D. Filamentation and Ponderomotive Effects (Thursday, May 17, 7:30 p.m.—9:45 p.m.)
Chairman: R. Evans, Rutherford Laboratories

E. Hydrodynamics (Friday, May 18, 8:30 a.m.—12:00 noon)
Chairman: D. W. Forslund, Los Alamos Scientific Laboratory

Ninth Annual Conference on

ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

May 15-18, 1979

CONFERENCE TIME TABLE

TUESDAY, May 15

8:00 p.m. - 10:00 p.m.	Registration/Cocktail Party Sheraton-Inn (Airport) - Grand Salon

All Conference sessions will be conducted in Hubbell Auditorium of Hutchison Hall at the University of Rochester.

WEDNESDAY, May 16

8:00 a.m. Bus leaves from Sheraton-Inn for Hubbell Auditorium
8:30 a.m. Late registration and sign-up for Institute of Optics tour

Session A -- Backscatter - M. J. Lubin, Chairman

8:30 a.m. - 8:45 a.m.		Welcome, M. J. Lubin
8:45 a.m. - 9:00 a.m.	A-1.	"Wavelength Scaling in Laser Fusion from a Plasma Physics Point of View," C. Max, K. Estabrook, C. F. McKee, and W. Kruer.
9:00 a.m. - 9:15 a.m.	A-2.	"The Absence of Significant Stimulated Brillouin in CO_2 Laser-Produced Plasmas," D. W. Forslund.
9:15 a.m. - 9:30 a.m.	A-3.	"Latest Results on Brillouin Studies," K. Estabrook and J. Harte.
9:30 a.m. - 9:45 a.m.	A-4.	"Brillouin Backscatter Experiments on a Flowing Gas Target," F. J. Mayer, G. E. Busch, C. M. Kinzer and K. Estabrook.
9:45 a.m. - 10:00 a.m.	A-5.	"Improved Absorption Using a Plasma Spatial Filter," D. C. Slater and D. J. Tanner.
10:00 a.m. - 10:15 a.m.	A-6.	"Doppler Shift of Laser Light Reflected from Expanding Plasmas," T. Dewandre, J. R. Albritton, and E. A. Williams.
10:15 a.m. - 10:30 a.m.		COFFEE BREAK

10:30 a.m. - 10:45 a.m. A-7. "Enhancement of Stimulated Brillouin Scatter Due to Reflection of Light from Plasma Critical Surface," C. Randall, J. J. Thomson and K. Estabrook.

10:45 a.m. - 11:00 a.m. A-8. "Time Resolved Observations of Brillouin Backscatter from Variable Z Targets," D. Gray, J. D. Murdoch, S. M. L. Sim, A. Cole, R. G. Evans, and W. T. Toner.

11:00 a.m. - 11:15 a.m. A-9. "Saturated Backscatter and Corresponding Sidescatter from an Underdense Plasma," M. J. Herbst, C. E. Clayton, and F. F. Chen.

11:15 a.m. - 11:30 a.m. A-10. "Scale Length Dependence of Stimulated Brillouin Scattering," R. Turner and L. Goldman.

11:30 a.m. - 11:45 a.m. A-11. "Microwave Experimental Studies of Stimulated Brillouin Scattering," H. E. Huey, A. Mase and N. C. Luhmann, Jr.

11:45 a.m. - 12:00 noon A-12. "Observations of Spectral Shape and Saturation of Stimulated Raman Scattering in Underdense Hydrogen Plasma," R. G. Watt and Z. A. Pietrzyk.

12:00 noon - 12:15 p.m. A-13. "Optical Ray Retracing and Pump Depletion Effects on Brillouin Backscatter in a Non-Isothermal Plasma, $T_e >> T_i$," V. K. Tripathi and C. S. Liu.

12:45 p.m. - 2:00 p.m. LUNCH - Hollister Hall

Session B -- Transport Phenomena - M. Bruce Langdon, Chairman

2:00 p.m. - 2:15 p.m. B-1. "Saturation Levels of Heat Flux Driven Ion Acoustic Wave Turbulence," H. C. Barr and T. J. M. Boyd.

2:15 p.m. - 2:30 p.m. B-2. "Hot Electron Heat Flux Inhibition Due to Anomalous DC Resistivity," C. L. Yee, J. S. DeGroot, and W. Woo.

2:30 p.m. - 2:45 p.m. B-3. "Excitation of Ion Acoustice Turbulence by Heat Flux in an Inhomogeneous Plasma," J. C. Adam.

2:45 p.m. - 3:00 p.m. B-4. "Ponderomotive Potential Effects on Transport," R. L. Berger, L. V. Powers, and B. K. Berger.

3:00 p.m. - 3:15 p.m. B-5. "Experimental and Numerical Energy Transport Studies with 80 ps, 1.06 μm Laser Pulses," J. C. Couturaud, P. A. Holstein, M. Louis-Jacquet, B. Meyer and G. Thiell.

3:15 p.m. - 3:30 p.m. B-6. Vortex Formation in Laser-Pellet Interaction," A. Hasegawa, M. Y. Yu, P. K. Shukla and K. H. Spatschek.

3:30 p.m. - 3:45 p.m.	B-7.	"Simple Models of Stimulated Scattering," W. L. Kruer.
3:45 p.m. - 4:00 p.m.	B-8.	"Heat Conduction and Magnetic Field Induction in the Presence of Cold and Hot Electron Maxwellian Distributions," I. P. Shkarofsky.
4:00 p.m. 4:15 p.m.		COFFEE BREAK
4:15 p.m. - 4:30 p.m.	B-9.	"Electron Transport in Laser Produced Plasmas," R. J. Mason.
4:30 p.m. 4:45 p.m.	B-10.	"The Effect of Thermal Transport on Ion Dynamics," W. Woo and J. S. DeGroot.
4:45 p.m. 5:00 p.m.	B-11.	"Resonance Absorption Produced Quasi-Static Magnetic Fields," M. Rhodes, A. Y. Lee, N. C. Luhmann, Jr., Y. Nishida and S. P. Obenschain.

THURSDAY, May 17

Session C -- Hot Electrons and Resonance Absorption - M. Keith Matzen, Chairman

8:30 a.m. - 8:45 a.m.	C-1.	"Interaction of CO_2-Laser Radiation with a Z-Pinch Plasma," J. Meyer.
8:45 a.m. - 9:00 a.m.	C-2.	"Effect of a Noisy Pump on Resonantly Driven Plasma Oscillations," E. A. Williams and J. R. Albritton.
9:00 a.m. - 9:15 a.m.	C-3.	"Wavebreaking with a Multiple Frequency Driver," T. Speziale.
9:15 a.m. - 9:30 a.m.	C-4.	"Observation of Electron Heating and Ion Acceleration in Microwave Plasma Interactions," W. F. DiVergilio and A. Y. Wong.
9:30 a.m. - 9:45 a.m.	C-5.	"The Effect of Resonant Absorption and Non-Linear Processes on Momentum Measurements in Laser Produced Plasmas," B. Arad, S. Eliezer, S. Jackel, A. D. Krumbein H. M. Loebenstein, I. Pelah, A. Zigler, H. Zmora and S. Zweigenbaum.
9:45 a.m. - 10:00 a.m.	C-6.	"Suprathermal Electrons and Strongly Heated Thermal Electrons Due to Resonant Absorption," K. Mizuno, R. B. Spielman and J. S. DeGroot.
10:00 a.m. - 10:15 a.m.	C-7.	"Plasma Density Profiles and Resonant Absorption," R. B. Spielman, K. Mizuno, W. Woo and J. S. DeGroot.
10:15 a.m. - 10:30 a.m.		COFFEE BREAK

10:30 a.m. - 10:45 a.m.	C-8.	"Analysis of the Z Dependence of Laser Generated Suprathermal Electron Temperature," M. D. Rosen and K. G. Estabrook.
10:45 a.m. - 11:00 a.m.	C-9.	"Variation of Hot Electron Temperature with Target Material for Nanosecond Pulses," C. E. Max.
11:00 a.m. - 11:15 a.m.	C-10.	"Reheating of Hot Electrons in Laser-Fusion Plasmas," J. R. Albritton and E. A. Williams.
11:15 a.m. - 11:30 a.m.	C-11.	"Resonant Absorption - Model Fields and Electron Heating," B. Bezzerides, D. W. Forslund and S. J. Gitamer.
11:30 a.m. - 11:45 a.m.	C-12.	"Nonlinear Inverse Bremstrahlung and Heated Electron Distributions," A. B. Langdon.
11:45 a.m. - 12:00 noon	C-13.	"Reduction of Resonant Absorption by Non-Linear Effects on Plasma Waves," J. C. Adam, A. G. Serveniere and G. Laval.
12:00 noon - 12:15 p.m.	C-14.	"Nonlinear Resonant Absorption," J. F. McGrath, L. V. Powers and R. L. Berger.
12:15 p.m. - 12:30 p.m.	C-15.	"Fast-Ion Measurement and Hot-Electron Temperature," T. H. Tan and G. H. McCall.
12:30 p.m. - 1:45 p.m.		LUNCH - Hollister Hall
1:45 p.m. - 2:00 p.m.		BUS from Rush Rhees Library to Laboratory for Laser Energetics
2:00 p.m. - 4:15 p.m.		TOUR - Laboratory for Laser Energetics
4:30 p.m.		BUS to Sheraton-Inn or transportation to Institute of Optics for those who have registered for tour.
5:30 p.m.		Transportation of Institute of Optics tour group back to Sheraton-Inn.
7:00 p.m.		BUS from Sheraton-Inn to Hubbell Auditorium.

Session D -- Filamentation and Ponderomotive Effects - R. Evans, Chairman

7:30 p.m. - 7:45 p.m.	D-1.	"A Reconsideration of Decay Instabilities for Infinite Media with Coherent Non-Uniform Phase Mismatch," T. W. Johnston, J. P. Matte, V. Fuchs and M. Shoucri.
7:45 p.m. - 8:00 p.m.	D-2.	"Evidence of Ponderomotive Effects from Analysis of Infrared and X-Ray Emission in CO_2 Laser Produced Plasmas," H. Pepin, G. Mitchel, F. Martin, B. Grek, T. W. Johnston and J. C. Kieffer.

8:00 p.m. - 8:15 p.m.	D-3.	"Spatial Structure of Filamented Laser Light," B. F. Lasinski, A. B. Langdon and J. J. Thomson.
8:15 p.m. - 8:30 p.m.	D-4.	"Experimental Observation of Filamentation in a CO_2 Laser Produced Plasma," A. Ng, D. Salzmann and A. A. Offenberger.
8:30 p.m. - 8:45 p.m.	D-5.	"Nonlinear Development of an Electromagnetic Filamentation Instability," D. Montgomery and C. S. Liu.
8:45 p.m. - 9:00 p.m.	D-6.	"Supercritical Density Profile Measurements of CO_2 Laser-Irradiated Glass Microballoons," R. Fedosejevs, M. D. J. Burgess, G. D. Enright and M. C. Richardson.
9:00 p.m. - 9:15 p.m.	D-7.	"Experimental Observation of Nonlinear Effects in a Laser Created Plasma with S or P Polarisation," C. Gouedard and A. Saleres.
9:15 p.m. - 9:30 p.m.	D-8.	"Self-Consistent Profile Modification in the Underdense Region of Laser-Produced Plasmas," J. R. Sanmartin and J. L. Montanes.
9:30 p.m. - 9:45 p.m.	D-9.	"Surface Wave Propagation and Solitons," J. Kupersztych and S. Azra.

FRIDAY, May 18

Session E -- Hydrodynamics - D. W. Forslund, Chairman

8:30 a.m. - 8:45 a.m.	E-1.	"Fluid Simulation of Absorption, Backscatter and Flux Inhibition in Laser-Produced Plasmas," D. G. Colombant and W. M. Manheimer.
8:45 a.m. - 9:00 a.m.	E-2.	"Measurements and Simulations of the Plasma Expansion from Ablatively-Driven Thin Al Foils," M. K. Matzen, J. P. Anthes, R. L. Morse and C. P. Verdon.
9:00 a.m. - 9:15 a.m.	E-3.	"Two-Dimensional Simulation of Growth and Saturation of an Ablation-Driven Rayleigh-Taylor Instability," R. McCrory R. L. Morse and C. P. Verdon.
9:15 a.m. - 9:30 a.m.	E-4.	"Analysis of Ablation Driven Taylor Instability by the Steady Flow Model," F. Cochran, L. Montierth and R. Morse.
9:30 a.m. - 9:45 a.m.	E-5.	"Is there an Exploding Pusher Target for $\lambda = 1/4\ \mu$?" J. T. Larsen.
9:45 a.m. - 10:00 a.m.	E-6.	"Overview of 6 Beam (ZETA) Exploding Pusher Target Experiments at Rochester," T. C. Bristow, J. Delettrez, A. Entenberg, W. Friedman, Y. Gazit, S. Letzring, J. McAdoo, W. Seka, J. Soures, E. Thorsos, B. Yaakobi.

10:00 a.m. - 10:15 a.m.	E-7.	"X-Ray Imaging of 6 Beam (ZETA) Implosion Experiments at Rochester," E. Thorsos, T. C. Bristow and J. Delettrez.
10:15 a.m. - 10:30 a.m.		COFFEE BREAK
10:30 a.m. - 10:45 a.m.	E-8.	"Effect of Electrostatic Fields on Charged Reaction Products in 6 Beam (ZETA) Implosion Experiments," Y. Gazit, J. Delettrez, A. Entenberg, T. C. Bristow, S. Kacenjar and S. Skupsky.
10:45 a.m. - 11:00 a.m.	E-9.	"Long Pulse Low Intensity Laser-Plasma Interaction and Hydrodynamic Physics," R. Decost, B. H. Ripin, S. P. Obenschain, S. E. Bodner, E. A. McLean, R. R. Whitlock, F. C. Young, J. A. Stamper, J. Grun and S. H. Gold.
11:00 a.m. - 11:15 a.m.	E-10.	"Rarefaction Driven Collisionless Ion Shocks," M. A. True, J. R. Albritton and E. A. Williams.
11:15 a.m. - 11:30 a.m.	E-11.	"Implosion Dynamics of Asymmetrically Illuminated Radiationally Cooled Targets," R. S. Craxton and R. L. McCrory.
11:30 a.m. - 11:45 a.m.	E-12.	"Boltzmann Equilibrium and Energy Conservation in the Self-Similar Expansion of a Plasma into a Vacuum," P. Mora and R. Pellat.
11:45 a.m. - 12:00 noon	E-13.	"Expansion of a Strongly Magnetised Plasma," L. M. Wickens and J. E. Allen.

SESSION A

Wednesday, May 16
8:30 a.m. - 12:15 p.m.

M. J. Lubin, Chairman
University of Rochester

Abstract Submitted
for the

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Wavelength Scaling in Laser Fusion from a Plasma Physics Point of View*

Claire Max, Kent Estabrook, C. F. McKee, and W. Kruer

University of California, Lawrence Livermore Laboratory
Livermore, California 94550

ABSTRACT

The scaling with laser wavelength of plasma physics processes important to laser fusion is examined. Application to physical conditions typical of eventual reactors is emphasized: The spherical targets are large (d = 1mm-1 cm), laser pulse lengths are long (5-20 nsec) and intensities are low by present-day standards (10^{13}-10^{15} W/cm^2). We discuss hot electron generation, stimulated Brillouin scattering and filamentation, transport inhibition mechanisms, and implosion efficiencies.

Past studies of wavelength scaling have heavily emphasized hot electron generation. The main point we wish to make is that there are important plasma processes other than hot electron generation which show considerable sensitivity to laser wavelength. Moreover, in the cases we discuss here short-wavelength lasers are strongly favored, for wavelengths below a few microns. Our results thus emphasize the potential benefits of lasers with wavelength considerably shorter than 1 μm. The target conditions produced by CO_2 lasers (wavelength 10 μm) are sufficiently unique that scaling arguments different from those relevant to shorter laser wavelengths have been developed.

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

THE ABSENCE OF SIGNIFICANT STIMULATED BRILLOUIN IN CO_2 LASER-PRODUCED PLASMAS

by

D. W. Forslund
Laser Division
Los Alamos Scientific Laboratory

A number of laser interaction experiments with nanosecond pulses have shown that stimulated Brillouin scattering (SBS) appears to be significant at 1 μm wavelengths but negligibly small at 10 μm wavelengths. We present here an explanation for this behavior in terms of the saturation of the induced Brillouin ion waves.

Since the ion waves are limited to an amplitude $\delta n/n \lesssim 1$, we show that the scattering scales as $1/\lambda$ and is essentially independent of intensity for sufficently intense light in contrast to the $I\lambda$ scaling at lower intensities. SBS may begin to be a problem at 10 μm for greater than 10 nanosecond pulses and should be a severe problem at 1 μm for 10 nanosecond pulses. Whether inverse bremsstrahlung reduces SBS at shorter wavelengths depends on the incident power level.

Abtract Submitted
for the

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Latest Results on Brillouin Studies*

Kent Estabrook and Judith Harte

University of California, Lawrence Livermore Laboratory
Livermore, California 94550

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

Brillouin Backscatter Experiments on a Flowing Gas Target*

F.J. Mayer, G.E. Busch, C.M. Kinzer and K. Estabrook
KMS Fusion, Inc. Lawrence Livermore Laboratory

We report preliminary measurements of spectral shape and magnitude of laser energy backscattered from a flowing gas target. The experiments are similar to those reported by Offenberger, et. al. [1,2] but at the 1 μm wavelength. We have made use of a puffed nitrogen gas flowing through a 100 μm diameter pinhole which provides a target with a long (∿50 μm) density gradient scale length, and irradiated this profile with a narrow (∿1 A°) and 1.06 μm laser pulse of short duration (∿100 psec.). This target has been employed to optimize and isolate Brillouin backscattering[3,4] in a parameter range of interest in larger target, higher power implosion experiments. For our short pulse length and estimated plasma temperature, no significant hydro motion of the interaction region is expected (nor was any observed as a Doppler blue shift). The intensity range investigated was 7×10^{13} W/cm^2 $\leq I \leq 7 \times 10^{14}$ W/cm^2 at the focal plane of the f/3.5 optics.

The spectrum of backscattered energy was measured with a grating spectrograph having 1 A° wavelength resolution.

Measurements of the energy backscattered into the focussing lens were made with calibrated photodiodes. Backscattered energies up to 50% were observed at the highest intensities.

At the lower powers, a clear indication of the Brillouin mechanism was observed as a well defined red shift of the backscattered energy. The spectral width was small compared to the shift, indicating weak damping. At the higher powers, a fraction of the backscattered energy was observed at ω_o, and the Brillouin shifted component became broader. The measured phase velocity gave,

$$ZT_e + 3T_i \approx 1 \text{ keV}$$

At the highest powers used, the spectrum was found to extend further into the red, and to exhibit roughly periodic structure. This structure has been observed in particle simulation[5] and may be explained as multiple Brillouin scattering during the pulse; the frequency being shifted by the acoustic frequency for each scattering. Finally, we compare our reflectivity data with a simple Brillouin model where,

$$R = 1 - \exp -0.1 \left(\frac{V_{os}}{V_{th}}\right)^2 \frac{n}{n_{cr}} \frac{L}{\lambda_o}$$

References

(1) A.A. Offenberger, M.R. Cervenau, A.M. Yam, A.W. Pasternak, J.A.P., 47, 1451, (1976).

(2) A. Ng, L. Pitt, P. Salzmann, A.A. Offenberger, Phys. Fluids, 42, 307, (1979).

(3) B.H. Ripin, F.C. Young, J.A. Stamper, C.M. Armstrong, R. Decoste, E.A. McLean, S.E. Bodner, Phys. Rev. Lett. 39, 611 (1977).

(4) D.W. Phillion, W.L. Kruer, V.C. Rupert, Phys. Rev. Lett. 39, 1529, (1977).

(5) K. Estabrook, Bull. Am. Phys. Soc. 21, 1067, (1976).

*This work was supported by the U.S. Department of Energy: KMS Fusion under Contract No. ED-78-C-08-1598 and Lawrence Livermore Laboratory under Contract No. W-7405-ENG-48.

A-5

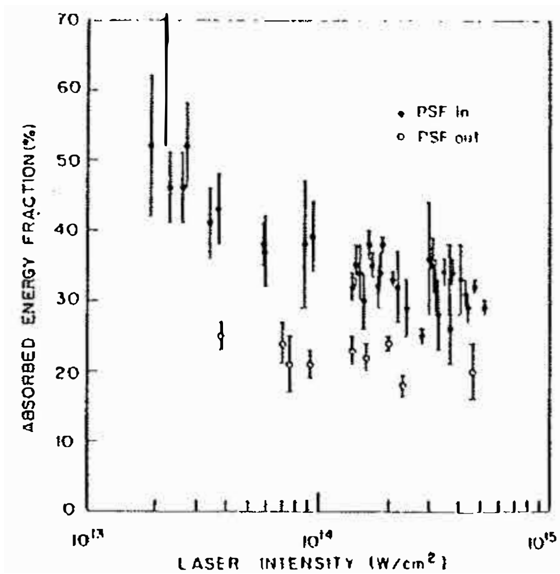
IMPROVED ABSORPTION USING A PLASMA SPATIAL FILTER*

D.C. Slater and D.J. Tanner

KMS Fusion, Inc.
Ann Arbor, Michigan 48104

Spherical glass shell targets ranging in diameter from 109 to 290 μm and in wall thickness from 0.8 to 2.5 μm were irradiated with 1.06 μm laser light at 2×10^{14} W/cm^2 in pulses of approximately 1ns.

The energy absorbed by each target was measured with two thermopile differential calorimeters which sample the plasma blowoff energy. Two uncovered TLD chips at a third location provided an additional measurement which in a few cases indicated an asymmetric energy expansion pattern. The measured energy absorption fractions are plotted against irradiance below. Each point represents one target shot. The error bars are the standard deviation of a weighted average of the three measurements.



The solid-circle data were taken with the plasma spatial filter (PSF)[1] installed in the laser system. The open-circle data, taken with the PSF removed, show lower absorption at all irradiances. The PSF device changes the character of the laser beam by smoothing the time-integrated spatial intensity pattern, by broadening the laser bandwidth to approximately 30 Å, and by slightly degrading the beam focussability.

We believe the increase in laser bandwidth is the most likely reason for the improved absorption when the PSF was installed, because a sufficiently broad bandwidth can reduce the level of stimulated Brillouin scattering which would otherwise prevent some portion of the laser energy from reaching the critical density surface.[2]

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[1]N.K. Moncur, Appl. Opt. 16, 1449 (1977).

[2]Kent Estabrook, Lawrence Livermore Laboratory Report UCRL-81017 (1978).

*This work was supported by the Department of Energy under Contract No. ED-78-C-08-1598.

DOPPLER SHIFT OF LASER LIGHT REFLECTED FROM EXPANDING PLASMAS

T. Dewandre, J. R. Albritton, and E. A. Williams
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University of Rochester
Rochester, New York 14623

The frequency shift of the laser light reflected from an expanding plasma is analyzed. A linear theory is constructed for a s-polarized wave incident obliquely on an inhomogeneous, time-varying plasma. The frequency shift is shown to be due partly to the motion of the reflecting surface, and partly to the plasma flow through that surface. Both contributions are typically comparable in laser fusion applications, being of order $\delta\omega \sim \omega_L \, c_S/c$, where c_S is the sound speed in the underdense plasma. However, these two shifts vary differently with the angle of incidence of the laser light. In general, the frequency shift is shown to vary also in time, inducing a bandwidth of the reflected wave.

Abstract Submitted
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Enhancement of Stimulated Brillouin Scatter due to Reflection of Light from Plasma Critical Surface*

C. Randall, J. J. Thomson and Kent Estabrook

University of California, Lawrence Livermore Laboratory
Livermore, California 94550

ABSTRACT

Previous analyses of stimulated Brillouin scattering (SBS) have found that the instability exponentiates in space from some small noise level, α , usually taken to be in the range 10^{-4} -10^{-2}. Thus, the interaction length must be much larger that a growth length for significant scatter to occur, i.e., $Q = l/l_g \gg 1$. However, for an expanding plasma with a critical surface there will be a certan Mach number at which the light reflected from the critical surface is correctly Doppler shifted to act as the noise source for SBS exponentiation. At this Mach number, given by $M = M_C + \sqrt{\varepsilon}$, where M_C is the critical surface Mach number and ε is the plasma dielectric constant, the effective noise level is much enhanced: $\alpha \sim fT$ where f is the fractional reflectivity of the critical surface and T is the fraction of light transmitted to the critical surface. In the limit $f \sim 1$ we find that $T = (1 + Q)^{-1}$. Thus for a Q of only 1, one may obtain 50% scattering. We present theoretical calculations and fluid and particle simulations which exhibit this significantly enhanced level of scattering

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

Time Resolved Observations of Brillouin Backscatter from Variable Z Targets

D Gray
J D Murdoch — Imperial College London

S M L Sim — Royal Holloway College London

A Cole
R G Evans
W T Toner — Laser Division, Rutherford Laboratory

Time resolved spectra have been obtained of the ω_o and 2 ω_o backscatter from spherical targets of 70 m to 240 μm diameter, ranging in Z from plastic to Uranium, irradiated by up to 100J of laser energy in a 1.6 ns pulse at 1.06 μm. Simultaneous calorimetry of the backscatter radiation showed significantly less backscatter with high Z targets at constant irradiance.

The 2 ω_o spectrum shows significant changes with irradiance which are interpreted as due to ion turbulence, probably driven by the fast electron return current. The 2ω emission is pulsed on a picosecond time scale and possible reasons for this are discussed.

Saturated Backscatter and Corresponding Sidescatter from an Underdense Plasma*

M. J. Herbst, C. E. Clayton, and F. F. Chen
University of California Los Angeles

Previously reported observations of red-shifted backscatter and sidescatter from an underdense plasma[1] are extended to higher intensity levels. At lower intensities, both prompt and late scattering are observed from plasmas created by a 30J CO_2 laser in 15 Torr of hydrogen preionized by an arc discharge. The level of preionization is found to determine whether prompt or late scattering is observed. Interferometric measurements show that preionization-dependent axial growth rates for the laser-induced ionization wave explain the appearance of prompt and late features, at least in the sidescatter direction. Only tentative explanations may be offered, however, for the observed lack of dependence of sidescatter level on incident polarization. With increased intensity, prompt backscatter is observed to saturate at 4-6% of incident power. Increased prompt sidescattered power is also observed. The possibility that red-shifted backscatter observed in this experiment and in a number of similar experiments could be explained by ordinary dielectric reflection processes as well as by Stimulated Brillouin Scattering will be discussed.

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[1]Bulletin of the APS, 23, 767 (1978)

*Work supported by Los Alamos Scientific Laboratory PO #X49-0027K; U.S. DOE, EY-76-S-0034, PA236; and by NSF ENG -75-16610 and 77-17861.

SCALE LENGTH DEPENDENCE OF STIMULATED BRILLOUIN SCATTERING

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Interferometrically measured electron density profiles of prepulse created plasmas are presented, along with the time integrated backscatter energy and spectrum. Glass microballoon targets were irradiated with Rochester's Glass Development Laser (GDL) at intensities up to 10^{16} w/cm^2. A synchronous 4th harmonic (2635Å) probe, used in a double pulse holographic interferometer, measured densities over a range of 0.1 to 1.2 x 10^{21} cm^{-3}. Measurements were taken at various times with respect to the main laser pulse. The preliminary data show the axial density scale length created by the prepulse to be well correlated with the amount of backscattered energy.

Abstract Submitted to the Conference on Anomalous Absorption of Electromagnetic Waves
Rochester, New York May 16-18, 1979

Microwave Experimental Studies of Stimulated Brillouin Scattering*

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University of California, Los Angeles 90024

We report here on what we believe to be the first conclusive identification of Stimulated Brillouin Scattering of microwave radiation in an underdense laboratory plasma.

Pulsed microwave radiation ($\omega_o/2\pi$ = 3.4 ~ 16 GHz, P_o = 150 kW,~1 MW, and τ_p=0.1 ~ 10μsec) is launched along the axis of a large (0.75 m diam. and 2 m - length) unmagnetized quiescent plasma produced by a multi-filament discharge with surface multipole magnetic confinement. Typical operating parameters are: pressure P = (3 ~ 6) × 10^{-4} Torr, electron density $n_{eo} \simeq 10^{10} \sim 10^{11}$ cm^{-3}, electron temperature $T_e \simeq 2$ eV and $T_e/T_i \simeq 10$-12. The ion waves associated with SBS are detected using movable coaxial Langmuir probes and 40 GHz microwave scattering. The SBS identification is aided by observing that the ion wave frequency ω and ion wave number k for various values of ω_o and ion species (H, He, Ne, Ar and Kr) satisfy the energy and momentum selection rules ($\omega_o = \omega + \omega_s$ $\underset{\sim}{k}_o = \underset{\sim}{k} + \underset{\sim}{k}_s$). Associated with the appearance of ion waves of the appropriate frequency and wavelength is an increase in the reflected rf power. This increased reflectivity appears to scale with $\left(\frac{\tilde{n}}{n_o}\right)^2$ For $\omega_o/2\pi$ = 8.6 GHz and $n \simeq 0.1\, n_{crit}$, we find that both the reflected rf power and the ion fluctuation level appear to saturate at an input power of 300 kW which corresponds to a mean intensity of $\simeq 1.5$ kW/cm^2. At this field strength $E^2/8\pi nKT_e \simeq 2$ and $v_o/v_{te} \simeq 0.5$ where v_o $eE/m\omega_o$ and $v_{te} = (KT_e/m_e)^{\frac{1}{2}}$. The measured density fluctuation level $\tilde{n}/n_o$ at the saturation point is ≃ 3.6%. An investigation of the saturation mechanism(s) are now underway. We note that the threshold power appear to be in agreement with the homogenenous interaction length theory(1); if we take the interaction length to be the ≃ 100 cm long region over which we can detect the ion waves. Complimentary rf intensity measurements are being made.

(1) D. Pesme, G. Laval and R. Pellat, Phys. Lett. 31, 203 (1973).

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

A-12

OBSERVATIONS OF SPECTRAL SHAPE AND SATURATION OF STIMULATED RAMAN SCATTERING IN UNDERDENSE HYDROGEN PLASMA

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The stimulated Raman scattering instability has been studied in the University of Washington theta pinch and in the U.W. fast solenoid. These devices have plasma of 2×10^{16} cm^{-3}, 15 ev and 3.5×10^{17} cm^{-3} 30 ev respectively and are heated using 10.6μ CO_2 laser radiation. The backscattered radiation has been studied both spectrally and in terms of reflectivity vs. incident intensity. It is found that the wavelength shifts of the backscattered radiation agree quite well with those predicted ($\Delta\omega \approx \omega_{pe}$) over almost two decades in density. The spectral shapes frequently show multiple peaks (rather than the single resonance predicted for a homogeneous plasma).[1] A recent theory[2] of the instability in the presence of a density gradient, which predicts the onset of higher order, frequency shifted modes, offers one possible explanation of these multiple peaks. The intensity scales exponentially with incident intensity as expected but an apparent saturation sets in for intensities of order 10^{11} w/cm^2 in the fast solenoid experiment. Several possible causes of this apparent saturation seem plausible but the exact cause has not been determined.

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1. J.F. Drake, P.K. Kaw, Y.C. Lee, G. Schmidt, C.S. Lieu, M.N. Rosenbluth, Phys. Fluids 17, 778 (1974)
2. V. Fuchs, Phys. Fluids 22, (1979), to be published June 1979.

OPTICAL RAY RETRACING AND PUMP DEPLETION EFFECTS ON BRILLOUIN BACKSCATTER IN A NON-ISOTHERMAL PLASMA, $T_e \gg T_i$

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

We have studied the optical ray retracing[1] of stimulated Brillouin backscatter in a typical laser-pallet fusion plasma when $T_e \gg T_i$, i.e., the acoustic wave is weakly damped; T_e and T_i are the electron and ion temperatures. The WKB approximation is used for the acoustic and scattered waves to account for convection losses[2] due to plasma inhomogeneity. Pump depletion effects have also been included. It is seen that on account of the active grating structures formed by the overlapping of different parts of the beam (propagating at different angles), the scattered radiation has the same transverse spatial structure as the pump, i.e., the rays are retraced.

Work supported by Department of Energy and Office of Naval Research.

1. R. H. Lehmburg, Phys. Rev. Lett. 41, 863 (1978).
2. C. S. Liu, Adv. Plasma Phys. 6, 121 (1976).

SESSION B

Wednesday, May 16
2:00 p.m. - 5:00 p.m.

M. Bruce Langdon, Chairman
Lawrence Livermore Laboratory

Saturation Levels of Heat Flux Driven Ion Acoustic Wave Turbulence

H.C. BARR and T.J.M. BOYD

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR, WALES.

Suprathermal electrons produced by absorption processes in laser plasma interactions are a dominant feature in the energetics of solid target compression studies. At the same time, the heat flux is estimated at a small fraction of its free streaming value. Ion acoustic wave turbulence, generated by the return current set up to maintain charge neutrality with the hot electrons has been suggested as a flux limitation mechanism. Growth is limited by ion "trapping". Simple trapping arguments are widely used to predict saturation levels which we believe are considerable overestimates.

We present results of a calculation to predict the saturation level of ion acoustic waves as a function of the heat flux using various models to simulate the electron distribution function. Our approach, now a familiar one, is to derive a nonlinear dispersion relation incorporating turbulently broadened resonance functions. The ion resonance broadens into the ion distribution which becomes an efficient sink for the wave energy. Using marginal stability we obtain a measure of the saturation level for ion acoustic waves. For parameters appropriate to experiments at the S.R.C. Rutherford Laboratory we find that even under optimum conditions $e\phi/T_e < 1\%$. This is to be compared with the simple trapping picture where $e\phi/T_e \sim 10\%$.

HOT ELECTRON HEAT FLUX INHIBITION DUE TO ANOMALOUS DC RESISTIVITY

by

Charles L. Yee, J. S. DeGroot, and Wee Woo
Department of Applied Science
University of California, Davis
Davis, California 95616

We have developed a simple model to investigate the energy transport of the laser heated electrons into the overdense region. Anomalous dc resistivity due to ion acoustic turbulence induces a dc electric field which impedes the inward flow of the hot electrons into the overdense region. We model in spherical geometry and calculate the hot electron heat flux inhibition due to electron trapping in the potential well as a function of the density scale length, $L = n_c (\frac{dn}{dr})_c^{-1}$, and critical radius, R_c ($R_c \to \infty$ corresponding to slab geometry). Preliminary calculations show that for typical plasma parameters, $n_c = 1.8 \times 10^{10}$ cm^{-3}, $T_h = 24$ eV, $T_e = 4$ eV, $L = 10^2 \lambda_D$, and $R_c \simeq 5 - 10$ cm, the dc potential ($\Delta(e\phi) \simeq .3\ T_h$) is insufficient in strongly reducing the heat flow. The flux reduction factor, $f_t = R_{MAX}^2 H(R_{MAX})/R_c^2 H(R_c) \simeq .70$, which is in rough agreement with experiments.

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 2435809.

B-3

Excitation of Ion Acoustic Turbulence by Heat Flux in an Inhomogeneous Plasma

by

J. C. Adam
Ecole Polytechnique
France

B-4

PONDEROMOTIVE POTENTIAL EFFECTS ON TRANSPORT*

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KMS Fusion, Inc.
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Ann Arbor, MI 48106

and

B. K. Berger

Oakland University
Rochester, MI

ABSTRACT

The Boltzmann equation (time averaged over the high frequency time scale of the laser) has, in addition to the usual terms, a ponderomotive force term. This force is proportional to the gradient of the electric field intensity. The electric field intensity is largest near the critical density and, here, is modelled by a single maximum in that region. Low velocity electrons are reflected by the potential barrier set up by the large field intensity. As a result the current and the heat flow resulting from thermal electrons is reduced.

In this paper, we solve the Boltzmann equation in the limit that the electron-ion scattering mean free path $\lambda_{ei} < \lambda$ the gradient length of the ponderomotive potential and that the laser light is normally incident on the critical density surface. We find the current and heat flow resulting from both reflected and transmitted electrons. Assuming the low velocity electrons have a Maxwellian velocity distribution we find the modification of the electrical conductivity and the thermal conductivity.

In the limit $L \simeq \lambda < \lambda_{ei}$, the dominant terms in the Boltzmann equation involve the collisionless motion of the electron in the self consistent fields and the subdominant term involves the electron-ion collisions. Solutions are found in both limits and must be matched on a boundary layer where the overlap of the two regions of validity occurs.

Inclusion of these kinetic effects produces a picture of profile modification that differs significantly from the picture obtained from the fluid description especially when the high velocity electrons are characterized by a different temperature than the low velocity ones.

*The work was supported by the Department of Energy under Contract No. ED-78-C-08-1598.

9th Annual Conference on Anomalous Absorption
of Electromagnetic Waved
Rochester, New York
May 15-18/1979

EXPERIMENTAL AND NUMERICAL ENERGY TRANSPORT STUDIES WITH 80 ps, 1.06 μm LASER PULSES

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B. MEYER, G. THIELL

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Layered plane targets have been irradiated with 80 ps, 1.06 μm laser pulses at intensities between 5 10^{14} and 5 10^{15} W cm^{-2}.

Spatially resolved X-ray lines intensities and ratios were studied versus the aluminum coating and silicon target thickness between 3000 A and 2 mm. Results are compared to numerical computation using a simple monodimensionnal lagrangian code, including preheating, flux limitation, X-ray lines emission and opacity.

The plasma expansion was observed with a double pulse technique ; the pulse-to-pulse timing was varied from 0.5 nsec to 2 nsec. The spatial shape of X-ray lines clearly shows the features of the preheating by suprathermal electrons.

VORTEX FORMATION IN LASER-PELLET INTERACTION

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4630 Bochum, West-Germany

and

K. H. Spatschek
Fachbereich Physik
Universität Essen
4300 Essen, West-Germany

ABSTRACT

In laser-pellet interactions, a baroclinic vector, $\nabla n \times \nabla p$, can be generated. A well-known consequence of this situation is a production of a magnetic field in the pellet. We show here that the baroclinic vector also generates ion vortices which may produce potential effects in the pellet dynamics. We present an example of such a vortex in a simple cylindrical geometry.[1] A significant ($\sim$60%) density depletion in the vortex core with a radius of c/ω_{pi} appears with the ion kinetic energy exceeding the magnetic field energy by an order of magnitude.

REFERENCE

1. A. Hasegawa, M. Y. Yu, P. K. Shukla and K. H. Spatscheck, Phys. Rev. Lett. 41, 1656 (1978) and 42, 412 (1979).

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for the

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Simple Models of Stimulated Scattering*

William L. Kruer

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Livermore, California 94550

ABSTRACT

Simple theoretical models have played a useful role in helping the community understand the importance of stimulated scattering in laser plasma experiments. These nonlinear estimates emphasize the importance of distinguishing experiments on the basis of the size of the underdense plasma (which is a function of both the pulse length and the size of a prepulse), the ratio of the light pressure to the plasma pressure, and the time scale for such effects as significant ion heating. We briefly review these models and discuss some of the recent refinements. We show how experimental results have tended to corroborate the qualitative features predicted. Lastly we speculate on the role of filamentation and show how this effect could lead to the appearance of a characteristic heated electron temperature of about 60 KeV.

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

HEAT CONDUCTION AND MAGNETIC FIELD INDUCTION IN THE PRESENCE OF COLD AND HOT ELECTRON MAXWELLIAN DISTRIBUTIONS *

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MPB Technologies Inc., P.O. Box 160, Ste. Anne de Bellevue, Quebec, H9X 3L5.

ABSTRACT

Using a two-temperature Maxwellian velocity distribution with cold and hot electrons, we show that the electron heat conductivity associated with the cold component (∇T_c) decreases greatly and changes sign when $n_c T_c^{5/2} \lesssim n_h T_h^{5/2}$. This is so in a weak magnetic field or parallel to a strong magnetic field. The heat conductivity transverse to a strong magnetic field and to ∇T_c changes sign when $n_c T_c \lesssim n_h T_h$ but that parallel to ∇T_c never changes sign. Even when the above coefficient changes sign, the total heat flow retains its proper sign due to new contributions from ∇n_c and possibly ∇T_h. The influence of the hot electrons on various transport properties and on the self-generated magnetic field is also analyzed.

* This work was supported by the National Research Council, Ottawa, Canada, under Contract No. 17SQ.31155-7-4306, Serial No. 0SQ77-00134.

ELECTRON TRANSPORT EFFECTS IN LASER PRODUCED PLASMAS*

by

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A 1-d Monte-Carlo hybrid model has been developed for the study of electron transport effects in laser produced plasmas. The suprathermal electrons are treated as weighted PIC particles. They are Coulomb scattered according to Jackson's Gaussian distribution of deflection angles, and undergo Coulomb drag decelerations. The cold electrons are represented as a fluid obeying donor-cell, collisional hydrodynamics. Both species move in a self-consistent E field. The E field is calculated by means of either: a) a "Debye length stretching" technique or, b) an advanced-time, quasi-neutral moment method. The efficacy of these techniques will be discussed in the context of application of the model to the study of transport inhibition by 1) the E field from cold resistivity with cold pressure gradients, and by 2) convective and thermoelectric effects induced by suprathermal currents.

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

THE EFFECT OF THERMAL TRANSPORT ON ION DYNAMICS*

by

Wee Woo and J. S. DeGroot
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University of California, Davis
Davis, California 95616

The density profile can be affected by the dc potential. This potential is generated by the return current which is driven by hot electron production due to resonant absorption. The three species (the ions, the thermal electrons, and the hot electrons) contribute an amount of charge separation which determines the potential, while the potential decelerates the ions and simultaneously accelerates the electrons. The net effect is that the ion density accumulates in the heating region due to the potential and also due to the ponderomotive force of the high frequency fields. The tunneling of the high frequency fields through the density accumulation, in which a trapped spikon is formed, depends on the parameters chosen. We can investigate ion dynamics on a long time scale without knowing the details of the ion turbulence by using the results from microwave experiments. Comparisons are made between experimental and theoretical results.

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 2435809.

Abstract submitted for the Conference on Anomalous Absorption of Electromagnetic Waves
Rochester, New York May 16-18, 1979

Resonance Absorption Produced Quasi-Static Magnetic Fields*

M. Rhodes, Ann Y. Lee, N. C. Luhmann, Jr., Y. Nishida** and S. P. Obenschain***
University of California, Los Angeles 90024

Quasi-static magnetic fields are expected to play an important role both in the absorption of intense laser radiation and in the resultant energy transport. Two important source mechanisms for magnetic field generation are the $\nabla n \times \nabla T$ electron pressure source term[1] and the currents associated with the resonance absorption process [2,3,4]. We will describe an experiment designed to investigate the resonance absorption source term in great detail. Microwave radiation ($\lambda_o \simeq 10$ cm) is launched by a gridded horn along the density gradient [$L_n/\lambda_o \simeq 5 - 15$] of an unmagnetized argon plasma [$T_e \simeq 2$ eV, $T_e/T_i \simeq 10$, $n_e \simeq 10^{11}$ cm^{-3}] produced by multi-filament discharges with surface multipole magnetic confinement.

Present magnetic field generation studies are restricted to relatively low power levels ($E_{vac}^2/8\pi nkT_e < 4 \times 10^{-4}$) in order to facilitate the conclusive identification of the resonance absorption source mechanism. We find that the initial magnetic field growth rates are in excellent quantitative agreement with theory [2] and exhibit the expected linear scaling with incident power. In addition, the field geometry appears to have the proper form. However, the saturation process is somewhat less clear. Specifically, at these low power levels, plasma wave convection should provide the saturation mechanism leading to a saturated field strength which also scales linearly with power. This is in fact the observed saturated field dependence. However, the saturation process is somewhat less clear Specifically, at these low power levels, plasma wave convection should provide the saturation mechanism. However, we find that both the saturation time and saturated field strength exceed the predicted values by a factor of 100. A possible explanation for these observations is that the small density profile modifications observed at these power levels have reduced the convective wave loss by trapping the electron plasma waves. Preliminary rf probe measurements in the vicinity of the critical layer verify the field trapping and also demonstrate that the rf field and magnetic field saturation times are coincident. Presently, efforts aimed at nonperturbing measurements (electron beam probing and laser scattering) of the trapped electron plasma waves are underway which may resolve the saturation time discrepancy.

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(2) T. Speziale and P. J. Catto, Phys. Fluids 21, (1978).
(3) J. J. Thomson, C. E. Max and K. Estabrook, Phys. Rev. Lett. 35, 663 (1975).
(4) B. Bezzerides, D. F. Dubois, D. W. Forslund and E. C. Lindman, Phys. Rev. Lett. 38, 495 (1975).

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**Naval Research Laboratory, Washington, D.C. 20375
***Utsunomiya University, Utsunomiya, Japan

SESSION C

Thursday, May 17
8:30 a.m. - 12:30 p.m.

M. Keith Matzen, Chairman
Sandia Laboratories

C-1

Interaction of CO_2-Laser Radiation with a Z-Pinch Plasma

by

J. Meyer
University of British Columbia
Canada

C-2

Effect of a Noisy Pump on Resonantly Driven Plasma Oscillations

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ABSTRACT

We investigate the effect of pump bandwidth on the breaking of plasma waves driven near the critical surface of an inhomogeneous plasma. We find that breaking occurs after a longer time but at a lower amplitude and that the resonant region is broadened. We apply the results to the resonant absorption of finite bandwidth laser pulses on laser fusion targets.

C-3

WAVEBREAKING WITH A MULTIPLE FREQUENCY DRIVER

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ABSTRACT

Breaking of large amplitude electron oscillations in a nonuniform plasma driven by a multiple frequency pump is investigated. The Lagrangian oscillator equation is solved and is examined in detail for the special case of a two component pump. Electron amplitudes and effective resonance widths at initial wavebreaking are estimated for arbitrary driver frequency separations. The role of the initial dephasing between the pump components is discussed.

Abstract of a paper to be presented at the 9th Annual
Conference on Anomalous Absorption of Electromagnetic
Waves, Rochester, NY May 15-18, 1979.

OBSERVATION OF ELECTRON HEATING AND ION ACCELERATION IN MICROWAVE PLASMA INTERACTIONS*

by

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TRW Systems Group, Redondo Beach, CA 90278

The interaction of an intense, pulsed microwave beam (λ = 10.6cm, pulse width = 10 μs, $E_0^2/8\pi nT \leq .4$) with an inhomogeneous plasma ($k_0L > 30$, $T_e < 2$ eV) is studied using a combination of probe and optical diagnostics. A hot electron tail ($T_h \doteq 20$ eV) is generated in the critical region and approximately equal transport of energetic electrons into the overdense and underdense regions is observed. The tail temperature is weakly dependent on power ($T_h \propto p^{1/4}$) for pump field strengths as low as $E_0^2/8\pi nT = .01$. The heated distribution is isotropized within one freespace wavelength of the critical density point, indicating a polarization independent enhanced scattering mechanism with $\nu_{eff} > 10^3 \nu_{ei}$. Outside of this region, transport is by free streaming.

Preliminary results obtained with a novel target plasma more closely simulating typical laser targets will be presented. A transient rf discharge in a pulsed magnetic field produces a field free plasma slab expanding into vacuum. Development of the ambipolar potential at the vacuum-plasma interface, due to electron heating, and the resultant ion acceleration are described.

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Abstract Submitted
to the 9th Annual Conference
on Anomalous Absorption of Electromagnetic Waves

The Effect of Resonant Absorption and Non-Linear Processes on Momentum Measurements in Laser Produced Plasmas. B. ARAD, S. ELIEZER, S. JACKEL, A. D. KRUMBEIN*, H. M. LOEBENSTEIN, I. PELAH, A. ZIGLER, H.ZMORA AND S. ZWEIGENBAUM Soreq Nucl. Res. Cent., Yavne, Israel.—The recoil momentum of a target irradiated by a high power Nd:glass laser was measured as a function of irradiation intensity and polarization. Momentum scaled linearly with intensity over the range $10^{14} \leq I \leq 5 \times 10^{15}$ watt/cm^2. Resonantly absorbed energy was found to couple from the coronal plasma to the dense target material, resulting in a 35% increase in the target momentum. Ponderomotive forces did not appear to contribute significantly to the target momentum. This implies large values for the effective collision frequency ($\nu/\omega \gtrsim 0.02$).
*At the University of Maryland, College Park, 1978-1979.

Submitted by:

A. D. Krumbein
Department of Physics & Astronomy
University of Maryland
College Park, Md. 20742

C-6

SUPRATHERMAL ELECTRONS AND STRONGLY HEATED THERMAL ELECTRONS DUE TO RESONANT ABSORPTION*

by

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University of California, Davis
Davis, California 95616

Very intense microwaves ($v_{os}/v_{eo} \lesssim 1$, $\omega_o/2\pi = 1.2$ GHz) are resonantly absorbed by an essentially collisionless, inhomogeneous plasma ($10^2 \lesssim L/\lambda_{Deo} \lesssim 10^3$) in the U. C. Davis PROMETHEUS I device. This machine models the oblique incidence of p-polarized light onto a spherical segment of a laser driven pellet. Suprathermal electrons are heated by the resonantly driven electrostatic fields to produce a hot Maxwellian. Most of these hot electrons flow through the overdense plasma. This hot current is unbalanced by a return current for a short time ($\lesssim 1$ μsec at high power) after the beginning of the microwave pulse. The resulting charge inbalance drives the plasma potential positive in the critical region. This dc electric field accelerates a return current of thermal electrons so that after a short time the return current equals the hot current. The return current drives ion acoustic waves ($T_{eo}/T_{io} \approx 10$) which propagate down the density gradient. The ion waves drive anomalous dc resistivity so that the thermal electrons in the critical region have a temperature of about the potential drop ($kT_e \lesssim e\Delta\phi$ and $T_e \lesssim 10T_{eo}$).

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 2435809.

C-7

PLASMA DENSITY PROFILES AND RESONANT ABSORPTION*

by

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Department of Applied Science
University of California, Davis
Davis, California 95616

Very intense microwaves ($v_{os}/v_{eo} \lesssim 1$, $\omega_o/2\pi = 1.2$ GHz) are resonantly absorbed by an inhomogeneous plasma ($10^2 \lesssim L/\lambda_{Deo} \lesssim 10^3$) in the U. C. Davis PROMETHEUS I device. The resonantly driven electrostatic fields strongly modify the plasma density profile near the critical density. The effects of the plasma density gradient scale length and flow velocity on microwave absorption, hot electron production and transport is measured. We find that at high power the density and temperature of the hot electrons are functions of the density gradient in the overdense region. However, the microwave absorption is essentially independent of the density gradient (over the range we have investigated, i.e., $10^2 \lesssim L/\lambda_{Deo} \lesssim 10^3$).

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 2435809.

Abstract Prepared for the
9th Annual Conference on Anomalous Absorption
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University of Rochester
Rochester, New York
May 15-18, 1979

Analysis of the Z Dependence of Laser Generated Suprathermal Electron Temperature*

M. D. Rosen and K. G. Estabrook

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ABSTRACT

Recent experiments with high Z disks on the Argus facility have extended our knowledge of the temperature (inferred from the slope of the hard x-ray spectrum) of laser generated suprathermal electrons, from the previous regime of $1 \leq Z \leq 30$ to the $Z \approx 80$ regime. The systematic rise of temperature with Z is theoretically analyzed. We believe that material albedoes (electron reflectivity) which increase with Z can account for this behavior, since electrons can make multiple passes through the region of resonant electric fields and are thus reheated. We treat this effect quantitatively and obtain reasonable agreement with experiment. The effects of magnetic fields and filamentation are also examined.

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

C-9

Profile Modification in Laser Plasmas Expanding with Uniform, Time-Dependent Temperature

J.R. Sanmartín and J.L. Montañes

Escuela Técnica Superior de Ingenieros Aeronáuticos, Universidad Politécnica de Madrid, Madrid, Spain.

Profile modification in both the transition layer around critical density, and the flow on the overdense side, is studied. A general proof is given that, for negligible absorption, no transition other than the know subsonic-supersonic one is possible. The overdense flow adjusts itself for the transition in a manner (formation of plateaus, shocks or cavities) critically dependent on how the (spatially uniform) temperature varies with time. Spherical effects and evidence for the results are considered.

Variation of Hot Electron Temperature with Target Material for Nanosecond Pulses

C. E. Max
Lawrence Livermore Laboratory
Livermore, California

Recent experiments for nanosecond pulses on various materials indicate a different (slower) scaling with target Z than previous short pulse results.

Scaling of θ_{hot} with Z and examples from very recent experiments will be presented.

C-10

Reheating of Hot Electrons in Laser-Fusion Plasmas

by

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Resonant Absorption - Model Fields and Electron Heating*

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Single test particle calculations of heating are performed in various localized, large amplitude, high frequency fields. These model fields are chosen to mimic the resonantly converted wave in the neighborhood of the critical density. We have explored the (1) warm, linear (2) cold, non-linear and (3) warm, non-linear, convectively stabilized limits. Although there have been several earlier attempts to explain the heating by simple field models, we find that detailed agreement with the self-consistent simulations is not possible without including subtle features of the time behavior of the critical fields.

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

Nonlinear Inverse Bremstrahlung and Heated Electron Distributions*

A. Bruce Langdon

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We reexamine the classical collisional absorption of intense laser light in a dense plasma, considering heating and diffusion of electrons of various energies, the evolution to a non-Maxwellian electron distribution when $Zv_0^2/v_e^2 \gtrsim 1$, and the resulting changes to transport and other properties. For example, the inverse Bremstrahlung absorption itself is reduced by a factor of two compared to the absorption in a Maxwellian plasma of the same thermal energy density. For materials with $Z >> 1$, this is significant at lower intensities than for the well-known nonlinearity for which the measure is v_0^2/v_e^2. (Here v_0 is the peak velocity of oscillation of the electrons in the high-frequency electric field, $v_e \equiv (T_e/m_e)^{1/2}$ is the electron thermal velocity, and Z is the ionization state.) Note also that enhanced isotropic ion fluctuations increase the scattering rate, as high Z does. The origin of this nonlinearity is that, when $Zv_0^2/v_e^2 \gtrsim 1$, electron-electron collisions are not rapid enough to Maxwellianize the flat-topped velocity distribution produced by inverse Bremstrahlung.

In the standard classical treatment, a Maxwellian electron distribution oscillates relative to the ions at frequency $\omega >> \tau_{ei}^{-1}$, where τ_{ei} is the electron-ion scattering time. For small v_0/v_e, the absorption is $\propto f_e(0)$, the distribution function evaluated at $v = 0$, so it seems that only the slowest electrons contribute to absorption. By an analysis which requires no $\omega\tau_{ei}$ ordering we show that the absorption is in fact proportional to f evaluated not at $v = 0$ but at the velocity for which $\omega\tau_{ei}(v) \lesssim 1$, i.e. the oscillation period and scattering times are matched.

The equation for evolution of $f_e(v,t)$, due to inverse Bremstrahlung and electron-electron collisions, is derived and integrated numerically. We consider first the effect of inverse Bremstrahlung alone. An initially monoenergetic distribution diffuses and slows in balance so that no net gain in kinetic energy results. When electrons reach slow velocities (such that $\omega\tau_{ei}(v) \lesssim 1$) their loss of energy is slowed while upward diffusion of faster particles continues. This is the meaning of the result that the absorption rate depends on f_e at low velocities. By the time the electrons have gained only 10% in energy, f_e is close to its late-time form, described by a similarity solution of the form $u^{-3}\exp(-v^5/5u^5)$, with $u^5 \propto t$. For this distribution, the absorption is only 45% of what it would be if electron-electron collisions enforced a Maxwellian distribution. Transport and atomic processes are also affected.

For moderate values of Zv_0^2/v_e^2, electron-electron collisions alter these results only slightly. For example, with $Zv_0^2/v_e^2 = 6$ the absorption is still only 49% of its Maxwellian value, and inverse Bremstrahlung contributes equally with electron-electron collisions to diffusion of superthermals into the "tail" of the distribution.

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

REDUCTION OF RESONANT ABSORPTION BY NON LINEAR EFFECTS ON PLASMA WAVES.

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We consider the resonant absorption of an electromagnetic wave in a collisionless inhomogeneous plasma. For a weak gradient, the absorption mechanism is known to be the excitation of Langmuir waves which propagate towards regions of lower density and eventually are damped by wave particle interactions. The ponderomotive force of these waves can lead to modifications of the density profile. The plasma wave propagation is then described by a non-linear Schrödinger equation with a source term. We show numerically that stationary solution exist even for strong non linearity. The non-linear term reduces the coupling between the electromagnetic wave and the electrostatic wave yielding a fast decrease of the absorption coefficient. Our results are quite different from previous published works and new features of the solution are found.

KMSF-U879

C-14

NONLINEAR RESONANT ABSORPTION*

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ABSTRACT

The fraction of light absorbed resonantly when light of one wavelength is incident on the critical surface depends on the angle of incidence, the plane of polarization, and the density scale length. The nonlinear effects on resonance absorption concern profile steepening and the electrostatic wave-particle interaction. Here we consider resonance absorption due to simultaneous illumination with the laser (ω) and its first harmonic (2ω). The beating of these two waves at the fundamental critical surface drives a large amplitude electron plasma wave. Under ideal conditions, twenty-five percent heating efficiency results. The process does not depend on angle of incidence or plane of polarization but does depend on the density scale length. Such experiments can be performed with the KMS optics system and theoretical results relevant to this system will be emphasized.

*The work was supported by the Department of Energy under Contract No. ED-78-C-08-1598.

FAST-ION MEASUREMENT AND HOT-ELECTRON TEMPERATURE

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ABSTRACT

Based on data collected over four decades in laser intensity, we have found that the hot-electron temperature for each laser target interaction can be uniquely determined from the fast-ion measurement. The relationship between the fastest ion velocity v_i and the laser flux on target ϕ_L is empirically established to be $v_i \propto \phi_L^{1/6}$. From the isothermal expansion model $v_i \propto C_s$, where C_s is the ion sound speed. The hot electron temperature T can then be related to ϕ_L as $T \propto \phi_L^{1/3}$. Data points from x-ray measurements at lower intensity appears to fall well within the established distribution. This temperature-laser flux relationship agrees with computer plasma simulation work which suggests the prominence of resonant absorption and strong density-profile steepening due to the pressure of the ponderomotive force. Since the simulation analysis assumes a constant absorption fraction, the agreement further suggests that the absorptance is the same at 10^{17} W/cm^2 as that measured at lower intensity for a 1 ns CO_2 laser pulse.

SESSION D

Thursday, May 17
7:30 p.m. - 9:45 p.m.

R. Evans, Chairman
Rutherford Laboratories

Abstract for the 9th Annual Conference on Anomalous Absorption of Electromagnetic Waves, May 15-18 1979, at the Laboratory for Laser Energetics, University of Rochester, New York

A Reconsideration of Decay Instabilities for Infinite Media with Coherent Non-Uniform Phase Mismatch

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V. Fuchs and M. Shoucri
Institut de Recherche de l'Hydro-Québec, Varennes

ABSTRACT

Earlier analysis[1] with δ-function initial perturbation, unbounded lossless media, opposed group velocities and quadratic spatial phase mismatch (phase ~ $K^1x^2/2$) showed limited amplification, an apparent contradiction with other results[2-4] demonstrating absolute instability for sufficiently large media and plausible boundary causal conditions on one or two finite boundaries. We have begun to look at this problem for other phase mismatch functions and for nonuniform coupling (to approach stealhily the boundary value problem). Computations using either or both of two rather different numerical codes show that eventually one has unlimited growth in most cases. A limit to growth occurs when the mismatch function F can be written as a sum of monotonic functions of each of the daughter wave characteristics ($\tau_\pm$) and monotonic functions of product (Note $\tau_\pm \sim (t \pm v_\pm x) > 0$). The amplitude approaching the growth limit can be well approximated by $d(\tau_+\tau_-)$. Quite small modifications, including non-uniform coupling, upset the conditions for this amplification limit, which we therefore conclude is a special feature of uniform media with quadratic mismatch. This is in accord with results[5] obtained with random modifications to F, and we therefore expect that in practice one is unlikely to find any linear amplification limitation.

[1] M.N. Rosenbluth, R.B. White, C.S. Liu, Phys. Rev. Lett. 31 (19) 1190-3 (1973).

[2] D.F. DuBois, D.W. Forslund, E.A. Williams, Phys. Rev. Lett., 33 (17) 1013-6 (1974).

[3] F.W. Chambers, A. Bers, Phys. Fluids 20 (3) 466-8 (1977).

[4] V. Fuchs, G. Beaudry, to appear in Phys. Fluids.

[5] D. Nicholson, A.N. Kaufman, Phys. Rev. Lett. 33 (20) 1207-10 (1974).

Evidence of ponderomotive effects from analysis of infrared and X-ray emission in CO_2 laser produced plasmas

H. Pépin, G. Mitchel, F. Martin, B. Grek, T.W. Johnston, J.C. Kieffer

INRS-Energie, Université du Québec, Varennes, JOL 2PO

ABSTRACT

CH_2, Al and Pb targets have been irridiated at a maximum flux of 3×10^{13} Wcm^{-2} with a focussed CO_2 laser in order to study the effects of non-linear processes on X-ray emission and back-scattered radiation. Above a critical flux of 6×10^{12} Wcm^{-2}, the results show: spatial inhomogeneity in re-imaged backscatter, a change in the slope of soft X-ray intensity versus laser flux, a change in the power law dependance of hot temperature versus flux, an anisotropy of soft X-ray emission, a strong production of energetic electrons. With increasing Z, there is no reduction of the effects of non-linear phenomena, which appeared stronger with Al. The comparison with experiments performed at 1.06μm suggests that the fraction of laser energy present in fast electrons scales as $\phi\lambda^2$.

Abstract Submitted
for the

Ninth Annual Conference on Anomalous Absorption
of Electromagnetic Waves

May 15-18, 1979
Rochester, New York

Spatial Structure of Filamented Laser Light*

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ABSTRACT

With the advent of long pulse length, high power lasers, laser-plasma experiments are entering the regime where self-focusing or filamentation is a dominant effect. We solve numerically the time independent Shroedinger equation in cylindrical geometry with an exponential non-linearity to investigate the spatial structure of filaments in underdense plasmas. Our results extend previous numerical work using another type of saturable non-linearity. We compare our results to previous theoretical work which assumes the beam remains close to Gaussian in shape.

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

D-4

EXPERIMENTAL OBSERVATION OF FILAMENTATION IN A CO_2 LASER PRODUCED PLASMA

A. Ng, D. Salzmann* and A.A. Offenberger

University of Alberta

Edmonton, Canada

Evidence for filamentation in underdense hydrogen plasma produced by CO_2 laser radiation has been obtained from X-ray emission measurements. The X-ray energy spectrum was determined using the absorption foil technique. For the long pulse irradiation ($\sim$ 40 nsec), a distinct non-thermal enhancement of X-ray emission is observed which is temporally superimposed on the normal bremsstrahlung radiation. From the ratio of non-thermal to thermal X-ray signal, we calculate the emitting region to have a dimension of $\sim$ 30 μm which is much less than the focal spot size. The measured non-thermal X-ray energy emitted as a function of incident laser power is found to saturate in a manner identical to that found in stimulated Brillouin backscatter. General features of filamentation, including results from this experiment will be discussed.

* On leave from the Soreq Nuclear Research Center, Israel.

D-5

NONLINEAR DEVELOPMENT OF AN ELECTROMAGNETIC FILAMENTATION INSTABILITY

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A simplified model of an electromagnetic filamentation instability that arises when two counterstreaming electron beams pass through a uniform ion background is treated by statistical mechanical techniques borrowed from fluid turbulence theory. Accumulation of magnetic energy at long wavelengths is predicted, as observed in the numerical simulations of Lee and Lampe.

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Supercritical Density Profile Measurements of CO_2 Laser-irradiated Glass Microballoons

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National Research Council of Canada
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Interferometric measurements have been made of the supercritical density profile of plasmas produced on glass microballoons by 10.6 μm laser radiation. In the intensity range of 3×10^{12} to 10^{14} W/cm^2 the density profile was measured from 0.4 n_c to 40 n_c. Steepening of the profile with scale lengths $\lesssim \lambda_0/2$ has been observed in the critical density region. In the supercritical density region an extended plateau at many times n was measured and in some cases a distinct overdense bump was seen. In addition, during and after the peak of the laser pulse the plasma on axis generally displayed an enhanced expansion towards the incoming radiation, giving a pointed structure to the leading edge of the profile.

Comparisons with theoretically predicted flow profiles indicate that a "shock plus D front" type of structure exists during some periods of the laser plasma interaction. However, more often this structure merges with the rising density profile to produce an extended plateau region. The excessive height of this density plateau coupled with its protrusion into the laser beam suggests that the flow structure is governed by more factors than radiation pressure effects alone.

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9th Annual Conference on Anomalous Absorption
of Electromagnetic Waved
Rochester, New York
May 15-18/1979

EXPERIMENTAL OBSERVATION OF NONLINEAR EFFECTS IN A LASER CREATED PLASMA WITH S OR P POLARISATION

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We report experimental results on ion acceleration in a plane solid deuterium Nd 80 psec irradiated target. Our investigations range from 5 10^{13} W/cm^2 up to 10^{16} W/cm^2 with S or P polarization. Absorption and scattering of light impinging obliquely the target have been studied using a spherical chamber consisting of 25 glass calorimeters all around the target. Spectral measurements of the scattered and the refracted light near the laser frequency as well as around the second harmonic has been investigated at the specular angle and through the solid angle of the lens using a high resolution spectrograph.

Self-Consistent Profile Modification in the Underdense Region of Laser-Produced Plasmas

by J.R. Sanmartín and J.L. Montañés

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Universidad Politécnica de Madrid, Spain

ABSTRACT

Profile modification in the underdense region of laser-plasmas with spatially uniform temperature T_e, is studied. A multiple scale method is used to describe self-consistently the plasma flow and the wave-field, in i) the scale of the field wavelength, and ii) the overall expansion scale. For $T_e \sim t^\alpha$ ordinary differential equations are obtained. The boundary conditions result from a previous analysis of how the overdense flow adjusts itself to enter the thin transition layer around critical density. For $\alpha=0$ and weak fields, we explicity solve the equations and relate the field in the critical layer to the incident field.

D-9

Surface Wave Propagation and Solitons

by

J. Kupersztych and S. Azra
Centre d'Etudes de Limeil
France

SESSION E

Friday, May 18
8:30 a.m. - 12:00 noon

D. W. Forslund, Chairman
Los Alamos Scientific Laboratory

Fluid Simulation of Absorption, Backscatter and Flux Inhibition In Laser-produced Plasmas

D. G. Colombant and W. M. Manheimer
Plasma Physics Division
Naval Research Laboratory

Extensive experimental data has been published on the absorption and backscattering of laser light by a plasma[1,2] at various laser irradiances. We present here results from a 1D numerical model of these phenomena based on a fluid description including collective effects. We consider three absorption mechanisms: inverse bremsstrahlung, resonant absorption and absorption by ion acoustic fluctuations. We have also included in our model Brillouin backscatter of the laser light with saturation due to ion trapping. The backscatter term is strongly coupled to the absorption processes in our treatment of the laser light wave equations. Transport coefficients are determined self-consistently from the processes included in our model. For example, ion acoustic fluctuations besides providing anomalous absorption, give rise to flux inhibition and anomalous electron-ion energy exchange. Results are presented for Nd and CO_2 laser light irradiances varying over several orders of magnitude, for short and long pulses. Comparisons are made with experiments and suggestions for some further experiments are presented.

[1] B. H. Ripin et al., Phys. Rev. Lett. 33, 634 (1974).

[2] D. W. Phillion, W. L. Kruer and V. C. Rupert, Phys. Rev. Lett. 39, 1529 (1977).

E-2

MEASUREMENTS AND SIMULATIONS OF THE PLASMA EXPANSION FROM ABLATIVELY-DRIVEN THIN Al FOILS

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ABSTRACT

We have characterized the expanding plasmas produced by focusing 8-nsec Nd:glass laser pulses onto thin Al foils. The power density was varied from 1.5×10^{13} to 7×10^{13} W/cm^2 on foil thicknesses from 1.5 to 12.5 m. The transition from ablative behavior to exploding pusher behavior was observed both as a function of target thickness at a specified power density and as a function of power density for a specified target thickness. Preliminary measurements indicate that the hydrodynamic conversion efficiency does not vary strongly with target thickness. Two-dimensional simulations of these laser-target interactions indicate that the critical surface is nearly planar. In turn, we find that one-dimensional planar simulations give good predictions of the velocity of the ablatively-driven rear surface but overpredict the hydrodynamic conversion efficiency.

TWO-DIMENSIONAL SIMULATION OF GROWTH AND SATURATION OF AN ABLATION-DRIVEN RAYLEIGH-TAYLOR INSTABILITY

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Various target designs for inertial confinement fusion require that small thin-walled shells be imploded over a distance large compared to their original thickness. We investigate the hydrodynamic stability of these systems in simulations using our two-dimensional Lagrangian hydrodynamics and heat flow code, DAISY, which uses triangular zoning. Representative calculations will be presented for an ablation-driven carbon shell irradiated with 5×10^{14}, and 10^{15} w/cm^2 of 1.06 μm light. We restrict ourselves to the ideal gas, one-temperature approximation, so that we may scale the results to other target materials at irradiances which preserve the hydrodynamic/heat flow similarity constraints.[1]

For initial perturbation amplitudes of order .1 of the perturbation wavelength, for wavelengths which are comparable to the shell thickness, results indicate substantial shell instability and growth of the perturbation by the time the shell accelerates through 10 times its original (compressed) thickness.

The nonlinear evolution for various wavelengths and irradiances will be discussed. Sample calculations of Taylor instabilities in the absence of heat flow will be presented for comparative purposes.

[1]R.L. McCrory and R.L. Morse, Phys. Rev. Lett. 38, 544 (1977).

E-4

Analysis of Ablation Driven Taylor Instability by the Steady Flow Model

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L. Montierth
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The form and growth rates of linearly unstable Taylor modes in ablation-driven shells have been calculated using the steady flow model with Spitzer conductivity to provide realistic zero order solutions. Results have been obtained for a number of steady flow solutions with different ratios of shell maximum density to sonic point density. The values of perturbed density, velocity, and temperature are highly peaked near the point of maximum gradient of zero order density in the ablation front, while the perturbed displacement reaches a maximum much further down stream. These results are in qualitative agreement with earlier linear stability analyses of time-dependent implosion solutions by the spherical harmonic method.*

The growth rates have a maximum at a value of k_y which depends on the zero order solution, i.e., the burn-through parameter, and can be of the order of the inverse of the shell thickness. In contrast with Taylor instability behavior, in the absence of heat flow, the growth rates decrease with increasing k_y beyond this maximum and fall to zero at a k_y which is about twice the value at which the maximum occurs. In all cases, the maximum growth rates are significantly less than would be given by the Atwood number equal to 1 approximation, $\sqrt{k_y g}$, in some cases as much as five times smaller. These growth rates are however still large enough to cause some concern about symmetrical implosion of large aspect ratio shells.

*G. Fraley, W. Gula, D. Henderson, R. McCrory, R. Malone, R. Mason, and R. Morse, "Implosion, Stability and Burn of Multilayer Laser Fusion Targets", Plasma Physics and Controlled Nuclear Fusion Research, /AEC-CN-33/F5-5. International Atomic Energy Agency, Vienna (1974).

E-5

Abstract Prepared for the
9th Annual Conference on Anomalous Absorption
of Electromagnetic Waves

University of Rochester
Rochester, New York
May 15-18, 1979

Is There an Exploding Pusher Target for $\lambda = 1/4\ \mu$? *

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ABSTRACT

With the growing interest and availability of short wavelength lasers for fusion research, many experiments are being proposed to investigate coupling and transport properties in fusion targets. We present results of numerical simulations on exploding pusher targets for $\lambda_L \approx 2500$ Å with attention directed toward the absorption and transport efficiencies. A comparison is made with glass microballoon exploding pushers at $\lambda_L = 1.06$ μm for which there is a large experimental and theoretical base. Specific differences in target performance resulting from the wavelength change are noted with an emphasis on effects which may be observed in the laboratory. For a certain range of target parameters it is shown the targets operate in a more ablative-like regime.

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

E-6

OVERVIEW OF 6 BEAM (ZETA) EXPLODING PUSHER TARGET EXPERIMENTS AT ROCHESTER

T. C. Bristow, J. Delettrez, A. Entenberg, W. Friedman, Y. Gazit, S. Letzring
J. McAdoo, W. Seka, J. Soures, E. Thorsos, and B. Yaakobi

This paper will report on six beam symmetrical laser-interaction experiments at power levels up to 3.2 TW. The experiments were conducted on explosive pusher targets ranging from 32 to 72 μm radius and 0.6 to 1.4 μm thick glass walls filled with 10-20 atm of DT or 50 atm DT plus 5 atm of neon. The ZETA system used for these experiments consists of 6 beams of 1.054 μm light symmetrically focused on target by f/1.2 lenses. Peak laser intensities on target ranged from 10^{15} - 10^{17} w/cm^2 with pulse widths between 40-80 psec and pre-pulse levels less than 10 μjoules. Diagnostics of the interaction experiments include absorption, x-ray imaging, neutron yield, x-ray continuum and line spectrum, and alpha and proton reaction product measurements.

The overview of experimental results will include the effects of symmetry and implosion from a variation of focusing conditions on target, electrostatic acceleration of alpha and proton reaction products, ion temperature, absorption measurements versus focusing conditions on target, x-ray spectrum and electron temperature measurements, and neutron yields.

E-7

X-RAY IMAGING OF 6 BEAM (ZETA) IMPLOSION EXPERIMENTS AT ROCHESTER

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Results from x-ray imaging of six beam exploding pusher target experiments on ZETA will be presented. Variations of implosion symmetry with focal position will be shown. In addition, implosions for a range of laser power levels will be discussed, and the symmetrizing effect of a prepulse will be indicated. Some preliminary comparisions with the implosion code LILAC will be made.

Effect of Electrostatic Fields on Charged Reaction Products in 6 Beam (ZETA) Implosion Experiments

Y. Gazit, J. Delettrez, A. Entenberg,
T. C. Bristow, S. Kacenjar and S. Skupsky

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The alpha particle and proton energy spectra were measured in exploding pusher experiments conducted on the six-beam ZETA laser system of the Laboratory for Laser Energetics at the University of Rochester. The alpha particle mean energy shifts and the estimated ion temperatures were compared to results from the code LILAC. Observation of alpha particle mean energy higher than 3.5 MeV indicates that electrostatic potentials are present. The magnitude of the shift due to the potentials was calculated from the alpha particle and proton mean energy. The presence of such potentials explains the observation of anomalously large thermal width.

LONG PULSE LOW INTENSITY LASER-PLASMA INTERACTION AND HYDRODYNAMIC PHYSICS*

R. Decoste[a], B.H. Ripin, S.P. Obenschain[a], S.E. Bodner, E.A. McLean, R.R. Whitlock, F.C. Young, J.A. Stamper, J. Grun[b] and S.H. Gold[c]

Naval Research Laboratory, Washington, D.C. 20375

Laser fusion involves imploding pellets through reaction to the thrust produced by laser induced ablation of the pellet surface. For the case of hollow pellets with moderate to large aspect ratios of pellet radius to thickness ($R/\Delta R > 10$), the required acceleration rate is relatively small and only modest laser intensities are required ($\sim 10^{14}$ W/cm^2) in multi-nanosecond pulses. Our experiments attempt to study this low intensity approach and to find out whether the pellet walls can be efficiently and stably accelerated to fusion velocities. This paper deals mostly with the interaction physics and the overall efficiency of the acceleration process.

Thin planar foils, rather than spherical pellets, are used in our experiments in order to have good access to the rear as well as to the laser side of accelerated foils. The laser intensity at 1.06μm is chosen below 10^{14} W/cm^2 to maximize the ablation efficiency and laser light absorption. Below 10^{14} W/cm^2, we demonstrate with 3-nsec laser pulses: efficient light absorption (80-90%) without significant Brillouin backscatter, energetic electrons and fast ions. The low velocity ablative ion blowoff is well suited for efficient momentum transfer to the target. At higher irradiance, undesirable effects such as Brillouin backscatter, energetic electrons and ions are more apparent.

The hydrodynamic behavior of the foil is found to be consistent with a simple analytical model which treats the ablative acceleration of the target analogously to that of a rocket. The "rocket" model does not contain any explicit assumption about heat transport or density and temperature profiles. This information is lumped into a knowledge of the ablation velocity which is determined experimentally for each laser irradiance. Experimentally, thin foil targets of different thickness are irradiated with several laser intensities and spot diameters. We demonstrate ablative acceleration of thin foils to near fusion velocities ($\sim 10^7$ cm/sec) with good hydrodynamic efficiency (~20%). Also, the structure and behavior of the rear target surface is studied with several optical diagnostics to confirm the acceleration and to provide information about spatial and velocity distributions across the accelerating target. Finally, axial and lateral heat transport are studied under different experimental conditions.

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*Work sponsored by the U.S. Dept. of Energy
[a]Sachs/Freeman Assoc., Bladensburg, MD.
[b]University of Maryland, College Park, MD
[c]National Research Council Resident Res. Assoc.

E-10

RAREFACTION DRIVEN COLLISIONLESS ION SHOCKS

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We investigate two-electron-temperature rarefactions in the presence of rapidly increasing hot electron number and temperature. We find that a shock is launched from the interior Debye sheath which separates hot and cold electrons; the shock propagates through the fast ion rarefaction. Density ripples on the high density side of the shock have wavelengths on the order of the local Debye length, which is characteristic of a collisionless ion shock. We speculate that "bumps" in fast ion detector signals could indicate time dependent hot electron behavior.

*On assignment from Exxon Research and Engineering Company, Linden, NJ 07036

E-11

IMPLOSION DYNAMICS OF ASYMMETRICALLY ILLUMINATED RADIATIONALLY COOLED TARGETS

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We present calculations from the two-dimensional hydrocode SAGE[1] which has been extended to include suprathermal electron transport in the multi-group, flux-limited, diffusion approximation.

The radiationally cooled target designs proposed for the six beam, 3 to 4 TW (1.054μm) Zeta experiments have been discussed previously.[2] Here we consider a representative design which consists of a 10μm thick-walled microballoon filled with neon. We analyze the degradation in achievable core density due to the two-dimensional effects arising from typical irradiation asymmetries, and discuss the effects of transport inhibition associated with self-generated magnetic fields on the implosion dynamics.

[1] R. S. Craxton and R. L. McCrory, BAPS 23, p. 750 (1978).
[2] R. L. McCrory, S. Skupsky, J. Delettrez and R. S. Craxton, XII ECLIM, Moscow, December 1978.

E-12

BOLTZMANN EQUILIBRIUM AND ENERGY CONSERVATION IN THE SELF-SIMILAR EXPANSION OF A PLASMA INTO A VACUUM

Patrick Mora

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René Pellat

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Ecole Polytechnique, 91128 Palaiseau Cedex, France

ABSTRACT

The Boltzmann equilibrium for electrons has been an ad-hoc assumption of previous work about self-similar plasma expansion in vacuum. Using the Boltzmann's relation, one finds as solution of the self-similar expansion a linear electrostatic potential. It is first shown that in such a potential, the electron behavior is exactly solvable. As a result one finds that the exact electron density differs substantially from the Boltzmann equilibrium for moderate value of the self-similar parameter. The complete calculations of the self similar expansion, without any assumption about the equation of state of the electrons, is presented. It is shown in particular that half the electron density depletion in logarithmic units is compensated by the self consistent modification of the electric potential. Finally, the effect is analysed in terms of energy exchange between the electrons and the ions in the expansion.

E-13

EXPANSION OF A STRONGLY MAGNETISED PLASMA

L.M. Wickens and J.E.Allen
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University of Oxford,U.K.

Recent measurements on planar target laser produced plasmas have confirmed that mega-gauss magnetic fields with a β of order unity can be obtained. These magnetic fields can inhibit the ablation of plasma from the target . A simplified analytic model for the hydrodynamics of the expansion of a strongly magnetised plasma shows that a wavefront develops which travels at twice the fast magneto-acoustic speed. This contrasts with the expansion of an unmagnetised plasma,where no similar wavefront exists.

9TH ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

List of Attendees

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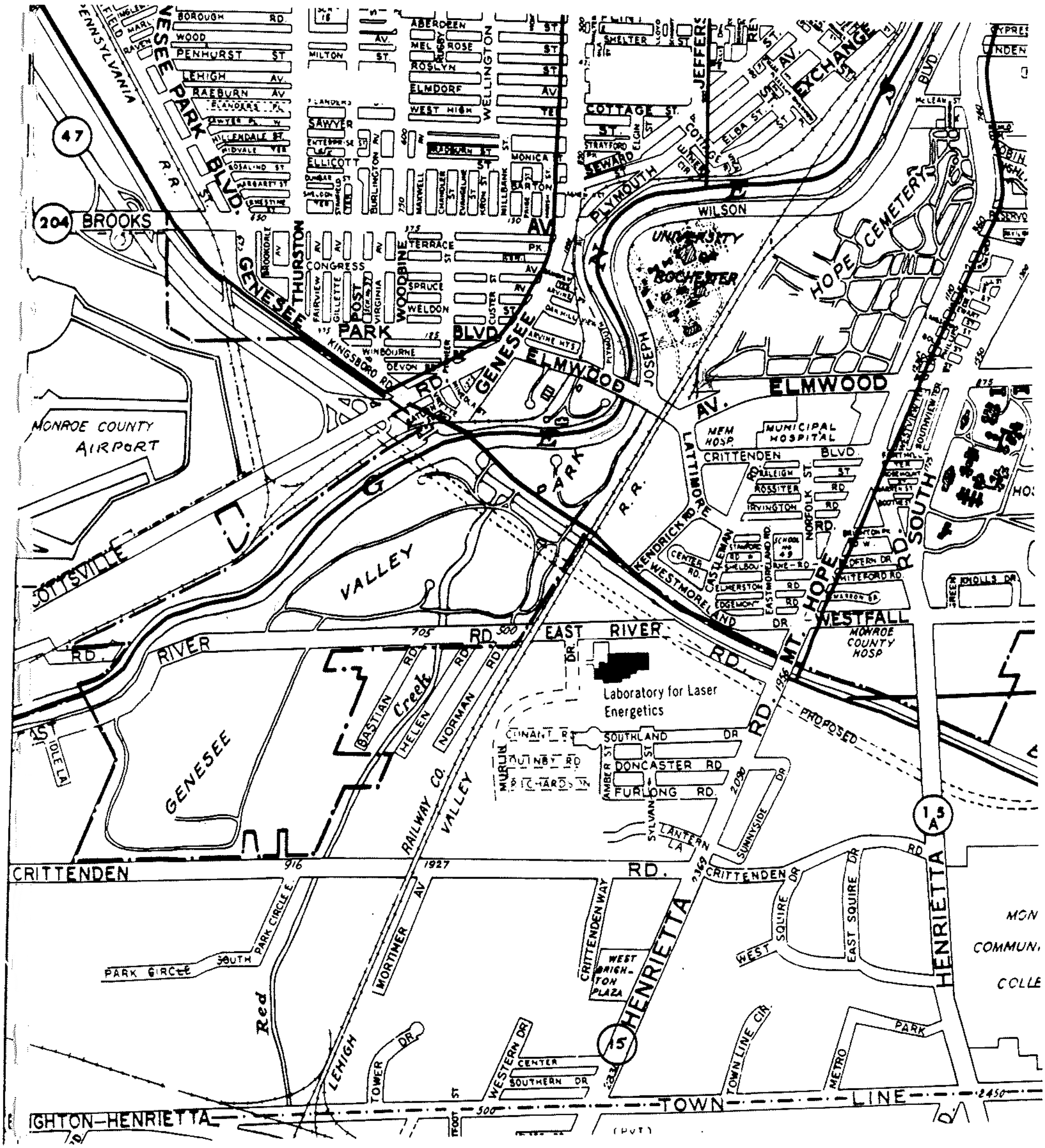

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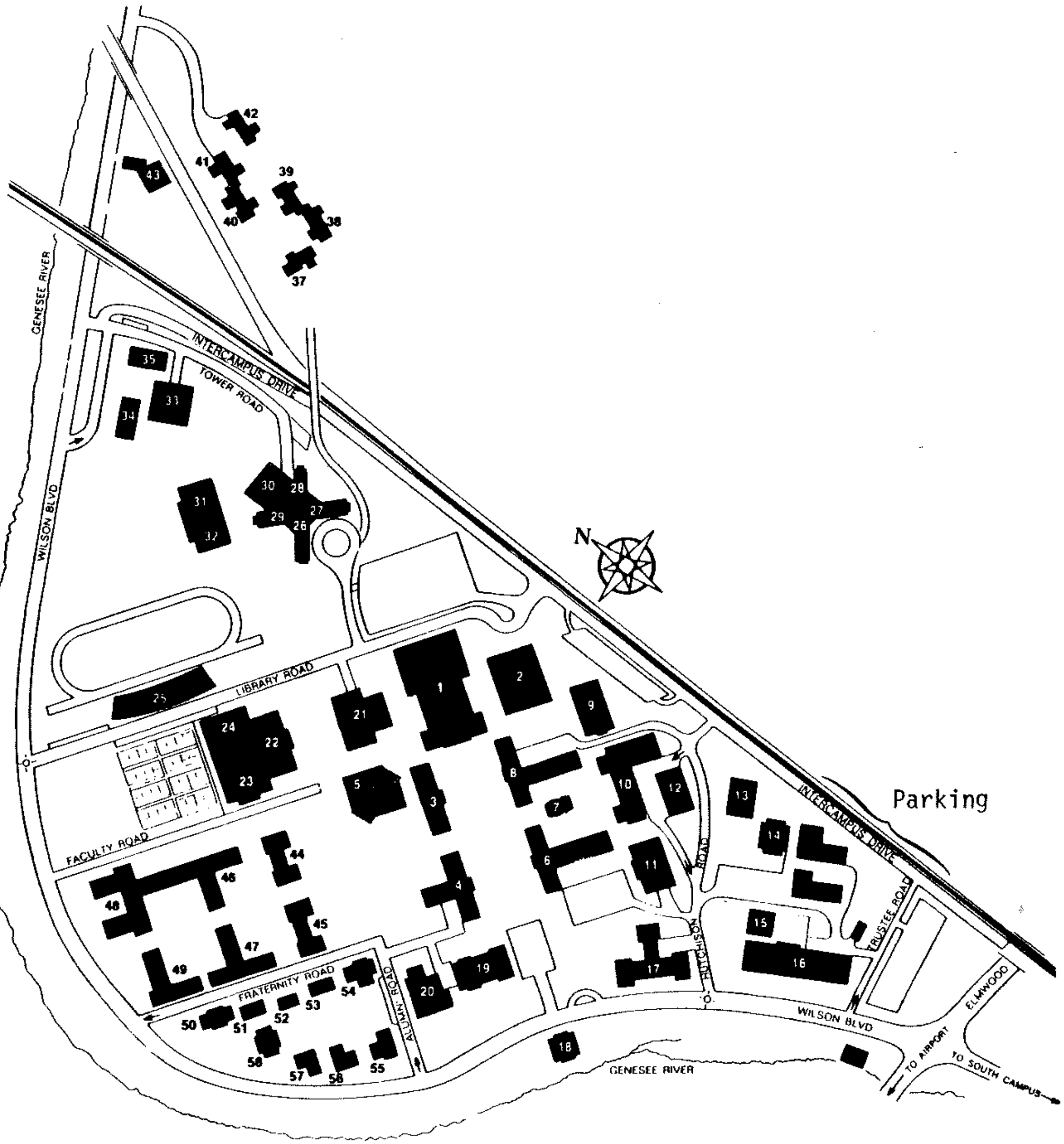

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