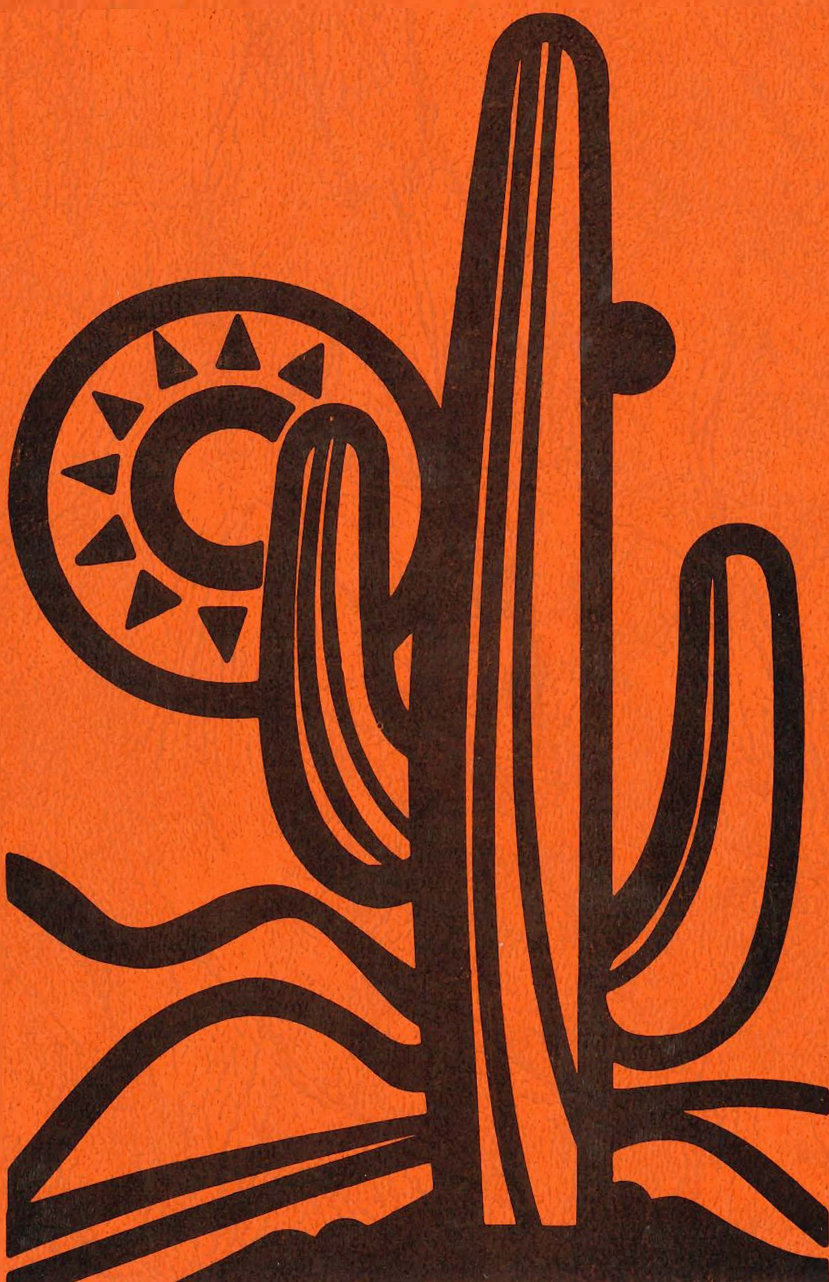
8TH ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

Sponsored by

The College of Engineering
The University of Arizona
Tucson, Arizona

April 19-21, 1978



THE EIGHTH ANNUAL CONFERENCE ON
ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

April 19-21, 1978

The University of Arizona
Tucson, Arizona

Organizing Committee:

S. Bodner, NRL
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J. Kindel, LASL
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R. McCrory, Univ. of Rochester
J. Pearlman, DOE
R. Morse, Univ. of Arizona

Eighth Annual Conference on

ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

April 19-21, 1978

CONFERENCE TIME TABLE

TUESDAY, APRIL 18

5:00 p.m. - 8:00 p.m.	Registration/Cocktail Party Plaza International Hotel

All Conference sessions will be conducted in the auditorium of the Optical Science Building at the University of Arizona.

WEDNESDAY, APRIL 19

8:00 a.m.	Registration Optical Sciences Center

Session A -- Absorption Phenomena and Diagnostics - J. Pearlman, Chairman

8:30 a.m. - 8:45 a.m.	A-1.	"Studies of Spontaneous Magnetic Fields in Laser-Produced Plasmas by Faraday Rotation", J. A. Stamper, E. A. McLean, and B. H. Ripin.
8:45 a.m. - 9:00 a.m.	A-2.	"Laser Fusion Research in Osaka", K. Mima, K. Nishihara, S. Nakai, T. Yamanaka, T. Sasaki, M. Matoba, and C. Yamanaka.
9:00 a.m. - 9:35 a.m.	A-3.	"Preliminary Shiva Laser/Target Experiments", K. R. Manes, H. G. Ahlstrom, J. A. Glaze, D. E. Campbell, F. Rienecker, and E. K. Storm.
9:35 a.m. - 9:50 a.m.	A-4.	"Absorption and X-Ray Characteristics of High Z Disks Irradiated with Nanosecond, 1.06 μm Laser Pulses", M. Boyle.
9:50 a.m. - 10:15 a.m.	COFFEE BREAK	
10:15 a.m. - 10:30 a.m.	A-5.	"Theoretical Interpretation of High-Z Discs Irradiated with 1.06 μ Laser Light", M. D. Rosen, W. C. Mead, J. J. Thomson, and W. L. Kruer.
10:30 a.m. - 10:45 a.m.	A-6.	"Absorption and Profile Modification on Spherical Targets for .25 $< \lambda <$ 2 microns", J. T. Larsen.

10:45 a.m. - 11:00 a.m.	A-7.	"Experimentally-Determined Absorption for Spherical-Shell Targets", S. B. Segall.
11:00 a.m. - 11:15 a.m.	A-8.	"Absorption of One Nanosecond CO_2 Laser Pulses by Plane Finite Targets", V. Codels, L. White, and A. Williams.

Session B -- CO_2 Experiments and Transport - C. E. Max, Chairman

11:15 a.m. - 11:30 a.m.	B-1.	"Superthermal X-Ray Emission Characteristics of CO_2 Laser Produced Plasmas", G. D. Enright.
11:30 a.m. - 1:30 p.m.	LUNCH	
1:30 p.m. - 1:45 p.m.	B-2.	"The Interaction of High Power CO_2 Laser Radiation with Solid Targets", M. Richardson.
1:45 p.m. - 2:00 p.m.	B-3.	"CO_2 Interactions at Quarter Critical", J. C. Samson.
2:00 p.m. - 2:15 p.m.	B-4.	"Two-Dimensional Resolution of CO_2 Profile Modification", M. A. Stroscio and D. B. Henderson.
2:15 p.m. - 2:30 p.m.	B-5.	"Two-Electron-Temperature Blow-Off Behavior in Spherical Geometry", D. Mitrovich.
2:30 p.m. - 2:45 p.m.	B-6.	"Transport of Long Mean Free Path Electrons, I", J. Albritton.
2:45 p.m. - 3:00 p.m.	COFFEE BREAK	
3:00 p.m. - 3:15 p.m.	B-7.	"Transport of Long Mean Path Electrons, II", E. Williams.
3:15 p.m. - 3:30 p.m.	B-8.	"Fast Ion Production by Suprathermal Electrons", M. True.
3:30 p.m. - 3:45 p.m.	B-9.	"Electron Transport Phenomena in Laser-Induced Fusion", R. A. Grandey.
3:45 p.m. - 4:00 p.m.	B-10.	"Observation of Enhanced Absorption and Reduced Thermal Conductivity in the Presence of Ion-Acoustic Instabilities Excited in an Underdense Plasma", E. J. Yadlowsky, R. C. Hazelton, P. W. Chan, and R. J. Churchill.
4:00 p.m. - 4:15 p.m.	B-11.	"Theory of Moments, Hydrodynamical Equations and the Flux Limit", A. Decoster.
4:15 p.m. - 4:30 p.m.	B-12.	"Resonant Absorption of Microwaves", J. S. DeGroot, R. B. Spielman, and K. Mizuno.

THURSDAY, APRIL 20, 1978

Session C -- Ablation and Hydrodynamic Expansion - R. Johnson

8:30 a.m. - 8:45 a.m.	C-1.	"Shock Wave Characteristics", J. Pearlman.
8:45 a.m. - 9:00 a.m.	C-2.	"Ablation Structure and Hot Electron Transport", K. Mima, K. Nishihara, and H. Takabe.
9:00 a.m. - 9:15 a.m.	C-3.	"Stationary Flow Model of Ablation", L. Montierth and R. Morse.
9:15 a.m. - 9:30 a.m.	C-4.	"Two Dimensional Numerical Simulation of Flat Target Experiments", R. McCrory, C. Verdon, and R. Morse.
9:30 a.m. - 9:45 a.m.	C-5.	"Structure and Observable Characteristics of Laser Driven Ablation", K. Matzen and R. Morse.
9:45 a.m. - 10:00 a.m.	C-6.	"Experimental Observation of Laser Driven Ablation", M. Gusinow, J. Anthes, and K. Matzen.
10:00 a.m. - 10:15 a.m.	COFFEE BREAK	
10:15 a.m. - 10:30 a.m.	C-7.	"Effect of Inhibited Transport on the Implosion Efficiency of a Spherical Laser Target", C. E. Max, C. F. McKee and W. C. Mead.
10:30 a.m. - 10:45 a.m.	C-8.	"Self-Similar Flows in Laser Irradiation of Plasmas", J. J. Thomson.
10:45 a.m. - 11:00 a.m.	C-9.	"Stability of Shells Accelerated by Ablation", L. Montierth, R. Morse, and T. Speziale.
11:00 a.m. - 11:15 a.m.	C-10.	"Stability of Steady-State Laser Irradiated Plasma Profiles", L. V. Powers, G. R. Montry, and R. L. Berger.
11:15 a.m. - 11:30 a.m.	C-11.	"Plasma Profile Modification Including Resonance Absorption", G. R. Montry and R. L. Berger.
11:30 a.m. - 5:00 p.m.	TOUR OF KITT PEAK NATIONAL OBSERVATORY. (Lunch will be served on the bus.)	

Session D -- Parametric Processes - S. Bodner, Chairman

6:30 p.m. - 6:45 p.m.	D-1.	"Stimulated Brillouin Scattering from an Underdense Laminar Gas Jet", J. C. Samson, H. A. Baldis, N. H. Burnett, and P. B. Corkum.
6:45 p.m. 7:00 p.m.	D-2.	"Brillouin Backscatter with Structured Laser Pulses", B. H. Ripin, E. A. McLean, J. A. Stamper, and R. H. Lehmberg.

7:00 p.m. - 7:15 p.m.	D-3.	"Where is Raman Scatter?", W. L. Kruer and K. G. Estabrook.
7:15 p.m. - 7:30 p.m.	D-4.	"Observations of Raman Backscatter Radiation from Underdense Plasma", A. Pietrzyk.
7:30 p.m. - 7:45 p.m.	D-5.	"Nonlinear Theory of Raman and Brillouin Scattering", C. S. Liu.
7:45 p.m. - 8:00 p.m.	D-6.	"Nonlinear Theory of Raman Backscatter with Soliton Formation in Laser Irradiated Plasmas", H. H. Chen.
8:00 p.m. - 8:15 p.m.	D-7.	"High Energy Electrons", B. F. Lasinski, A. B. Langdon, and W. L. Kruer.
8:15 p.m. - 8:30 p.m.	D-8.	"Some Remarks on Parametric Instabilities", A. B. Langdon.
8:30 p.m. - 8:45 p.m.	D-9.	"Parametric Instabilities in the Presence of Long Wavelength Langmuir Turbulence", F. Brunel and J. Teichmann.
8:45 p.m. - 9:00 p.m.	D-10.	"Effect of Magnetic Field on Parametric Instabilities", C. Grebogi and C. S. Liu.

FRIDAY, APRIL 21, 1978

Session E -- Harmonics, Resonant Absorption, and Other Electromagnetic Phenomena - K. Mima

8:30 a.m. - 8:50 a.m.	E-1.	"Harmonic Production in Inhomogeneous Plasmas", R. G. Evans.
8:50 a.m. - 9:10 a.m.	E-2.	"Microwave Experimental Investigations of Spontaneous Magnetic Field Generation", S. P. Obenschain and N. C. Luhmann, Jr.
9:10 a.m. - 9:30 a.m.	E-3.	"Abstract Complex Electron Density Structures in the Initial Stages of Laser-Plasma Interaction", B. Grek, F. Martin, H. Pepin, F. Rheault, and T. W. Johnston.
9:30 a.m. - 9:50 a.m.	E-4.	"Latest Results", K. Estabrook.
9:50 a.m. - 10:10 a.m.	E-5.	"Effect of Large Density Depressions on the Absorption of Focused Laser Beams", C. Randall and J. S. DeGroot.
10:10 a.m. - 10:25 a.m.	COFFEE BREAK	

10:25 a.m. - 10:45 a.m.	E-6.	"Relativistic Effects on Electromagnetic Wave Propagation in a Cold Electron Plasma: Travelling Wave, Standing Wave", A. Bourdier.
10:45 a.m. - 11:05 a.m.	E-7.	"Kinetic Theory of Magnetic Field Generation in Resonance Absorption of Light", P. Mora and R. Pellat.
11:05 a.m. - 11:30 a.m.	E-8.	"Resonant Absorption Induced by DC Magnetic Fields", W. Woo and J. S. DeGroot.
11:30 a.m. - 1:30 p.m.	LUNCH	

Session F -- Harmonics, Resonant Absorption, and Other Electromagnetic Phenomena (continued) - R. L. McCrory

1:30 p.m. - 1:45 p.m.	F-1.	"Magnetoplasma Absorption of Intense Electromagnetic Waves on Self-Consistent Plasma Parameters", A. L. Peratt.
1:45 p.m. - 2:00 p.m.	F-2.	"Resonant Absorption by Linear Wave Conversion in an Unmagnetized, Collisionless Plasma", T. W. Tang.
2:00 p.m. - 2:15 p.m.	F-3.	"Emission of Electromagnetic Radiation At and Near Critical Surfaces in Laser Plasmas", W. P. S. Tan.
2:15 p.m. - 2:30 p.m.	F-4.	"A Variational Approach to Perturbed Soliton Equations", D. Anderson, A. Bondeson, and M. Lisak.
2:30 p.m. - 2:45 p.m.	COFFEE BREAK	

POST DEADLINE PAPERS

3:00 p.m. TOUR OF ON CAMPUS OPTICAL SHOPS

APRIL 19

WEDNESDAY MORNING

8:30 A.M. - 11:15 A.M.

SESSION A

CHAIRMAN

J. PEARLMAN

U. S. DEPARTMENT OF ENERGY

STUDIES OF SPONTANEOUS MAGNETIC FIELDS IN LASER-PRODUCED PLASMAS BY FARADAY ROTATION*

J. A. Stamper, E. A. McLean, and B. H. Ripin
Naval Research Laboratory
Washington, D.C. 20375

ABSTRACT

A broad scale study has been made of the large magnetic fields produced in the focal region of a high irradiance Nd-laser incident on a solid target. The study utilized a Raman-shifted probing beam with a 3-channel Faraday rotation diagnostic system. Timing, target material and geometry, laser irradiance and polarization, focal position and prepulse was varied and the effect noted. Faraday rotation showed a maximum at about 50 psec after the peak of the main laser pulse. A pre-formed plasma due to a pre-pulse, increased both the observability and spatial extent of the rotation. All of the 72 data shots are consistent with an azimuthal magnetic field which is clockwise when looking in the direction of the main laser beam. A sample calculation (for shot 3662) shows that the magnitude of the sampled magnetic field is 0.6 ± 0.1 megagauss.

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*This work supported by the United States Department of Energy.

LASER FUSION RESEARCH IN OSAKA

K. Mima, K. Nishihara, S. Nakai, T. Yamanaka
T. Sasaki, M. Matoba, and C. Yamanaka
Institute of Laser Engineering
Osaka University
Osaka, JAPAN

ABSTRACT

Absorption processes of Nd glass and CO_2 laser radiations and the relations among a hydrodynamical power, a fast ion energy spectrum and an absorption rate have been investigated in both experimental and theoretical researches(1) in Osaka. One of the important recent results on the absorption processes is the measurements of the angular distribution of reflected radiations from a plane target and a spherical target. The angular distribution for a polyethylene plane target irradiated by the CO_2 laser radiation at a power 10^{12}w/cm^2 $\sim$ 10^{13}w/cm^2 shows that an intensity dip appears in the specular reflection cone for the P-polarization and the side band is produced outside the specular reflection cone for the S-polarization. The intensity dip is due to the resonance absorption under the steep density gradient and the side band is considered to be due to a critical surface rippling. A scattered angle of the side band reasonably agrees with a theoretical prediction. Angular distributions for a spherical target irradiated by Nd glass laser at a power $\sim 10^{16}$w/cm^2 also indicate that an incident laser radiation is absorbed by the resonance mode conversion.

In order to investigate the hydrodynamical power due to the reaction of the plasma expansion, backward velocities of a Al coated polypropylene target irradiated by CO_2 laser and fast ion energy spectra are measured simultaneously for various input powers. The power dependence of the target velocity is argued from the standpoint of the power dependence of an absorption rate and a fast ion energy ratio to an incident energy. The saturation of a target velocity increment can be explained by the enhancement of the total fast ion energy. The relations between the fast ion energy spectra and the hot electron energy density are also discussed by analyzing the hot electron transport and the ablation structure of plasmas with cold and hot electrons.

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(1) Annual Progress Report on Laser Fusion Program, Sept. 1976 $\sim$ Aug. 1977., Institute of Laser Engineering, Osaka University.

PRELIMINARY SHIVA LASER/TARGET EXPERIMENTS*

K. R. Manes, H. G. Ahlstrom, J. A. Glaze,
D. E. Campbell, F. Rienecker and E. K. Storm

Lawrence Livermore Laboratory
University of California
Livermore, California 94550

ABSTRACT

In the course of building the Shiva target irradiation facility, a number of opportunities were planned to test portions of the system with actual target shots. These target irradiations have provided operational tests of the numerous systems and subsystems which make up the Shiva facility.

Following Shiva's successful operation at an output energy of > 10 kJ in ∿ 1 nsec, the laser was reconfigured for 100 psec pulse duration. As the first propagation studies using one amplifier chain were completed, that chain was used to irradiate a target. Similarly a target shot followed the alignment of the first cluster of five beams. Such target studies were planned for each subsection of the laser to come into operation, culminating with twenty-beam shots. Besides imposing realistic spatial and temporal pulse quality constraints on the laser from the beginning, these target studies have tested Shiva's alignment systems, pulse simultaneity systems, laser diagnostics and target diagnostics.

The use of the Shiva facility for target experiments will be described and the results of these preliminary exploding pusher experiments will be presented in detail.

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

A-4

ABSORPTION AND X-RAY CHARACTERISTICS OF HIGH Z DISKS IRRADIATED WITH NANOSECOND, 1.06 μm LASER PULSES

M. Boyle
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Abstract Submitted
for the

Eighth Annual Conference on Anomalous Absorption
of Electromagnetic Waves

April 19-21, 1978
Tucson, Arizona

Theoretical Interpretation of High-Z Discs Irradiated with 1.06μ Laser Light*

M. D. Rosen, W. C. Mead, J. J. Thomson, and W. L. Kruer

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Livermore, California 94550

ABSTRACT

High Z discs have been irradiated with 1.06μ laser light at intensities between 7×10^{13} and 3×10^{15} W/cm^2, and pulse lengths between 200 and 1000 ps. Due to the high Z, inverse bremsstrahlung becomes an important absorption effect and competes strongly with resonance absorption and stimulated scattering. We find that inhibited electron thermal conduction and non-LTE ionization physics are important. Their inclusion in the LASNEX modelling results in steepened temperature and density profiles near critical, thus producing a several keV underdense corona. These conditions bring what would otherwise be 100% inverse bremsstrahlung absorption down to the experimentally observed values (50% at 10^{14} W/cm^2). The non-LTE physics is essential to correctly compute the level populations of the high Z atoms moving rapidly through a steep density gradient into the corona. This modelling also shows that x-rays are emitted in a thin overdense region, and on a time scale 50% longer than the laser pulse. Both of these effects are seen in the experiments.

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

Abstract Submitted
for the

Eighth Annual Conference on Anomalous Absorption
of Electromagnetic Waves

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Absorption and Profile Modification on Spherical Targets for .25 < λ < 2 microns*

Jon T. Larsen

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ABSTRACT

LASNEX calculations for focused laser beams on spherical targets have been performed for laser wavelengths of 0.25, 0.5, 1.0 and 2.0 microns. One-dimensional calculations, including the ponderomotive force, show a profile steepening that determines the fractional absorption by anomalous mechanisms. However, increased absorption occurs at the shorter wavelengths because of more efficient inverse bremsstrahlung absorption at the higher critical densities. In general, the absorption efficiency increases with shorter laser wavelength and decreases with increasing f-number of the illuminating optics for sufficiently long plasma scale lengths.

The effect of the absorption and laser wavelength on the thermal and superthermal electron physics will be discussed along with the combined effects on the implosion performance. Certain aspects of two-dimensional LASNEX calculations will be presented.

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

A-7

EXPERIMENTALLY-DETERMINED ABSORPTION FOR SPHERICAL-SHELL TARGETS

S. B. Segall
KMS Fusion, Inc.
Ann Arbor, Michigan 48106

ABSTRACT

Energy absorbed by spherical-shell targets irradiated using the KMSF ellipsoidal-mirror illumination system at powers on target of up to 0.5 TW has been measured using thermopile differential calorimeters. Data will be presented for 1.06 μm and 0.532 μm laser light, for glass and low atomic number PVA targets, and for laser configurations with and without a plasma spatial filter. The relative importance of different absorption mechanisms will be discussed.

A-8

ABSORPTION OF ONE NANOSECOND CO_2 LASER PULSES BY PLANE FINITE TARGETS

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P. O. Box 1663
Los Alamos, New Mexico 87545

APRIL 19

WEDNESDAY AFTERNOON

11:15 P.M. - 4:30 P.M.

SESSION B

CHAIRMAN

C. E. MAX

LAWRENCE LIVERMORE LABORATORY

X-RAY EMISSION CHARACTERISTICS OF CO_2 LASER-PRODUCED PLASMAS

G. D. Enright, M. C. Richardson, N. H. Burnett,
D. M. Villeneuve, and H. A. Baldis
National Research Council of Canada
Division of Physics
Ottawa, K1A 0R6, CANADA

ABSTRACT

The COCO-II laser system has been used to irradiate plane targets at intensities up to 2×10^{14} W cm^{-2}. A variety of diagnostic techniques have been employed to characterize the resulting plasmas. The superthermal portion of the x-ray emission spectrum yields information about the fast electrons. This spectrum can be characterized by a hot electron temperature T_H which we have found to be particularly sensitive to the focussing condition and somewhat less dependent on laser power, irradiance angle, and target composition. These results will be presented and compared with concurrent measurements of absorbed energy and backscattered harmonic emission levels. A comparison with other CO_2 laser-produced plasma measurements indicate that a scaling law of $T_H \sim I^{1/3}$ does describe the general trend of the intensity dependence of T_H. These results will be compared to similar data from 1.06 μm experiments.

FEATURES OF THE INTERACTION OF HIGH POWER CO_2 LASER RADIATION WITH SOLID TARGETS

M. C. Richardson, H. A. Baldis, N. H. Burnett, G. D. Enright,
R. Fedosejevs, P. Jaanimagi, and D. M. Villeneuve
National Research Council of Canada
Division of Physics
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ABSTRACT

Recent investigations of high power (10^{14} W cm^{-2}) short pulse (1 ns) CO_2 laser-produced plasmas have identified a number of distinct characteristics which have a direct bearing to laser fusion studies. The parametric dependence of the fractional absorption is compatible though not conclusive evidence of significant resonance absorption. This is further substantiated by the emission of an extended series of high harmonics from the plasma. In addition, picosecond interferometry has provided direct evidience of substantial profile modification due to radiation pressure effects at the critical surface. Recent results in a continuing study of these characteristics will be described and their implications discussed.

B-3

ENHANCED THOMSON SCATTERING FROM PLASMA FLUCTUATIONS EXCITED BY CO_2 LASER LIGHT

H. A. Baldis, J. C. Samson, and P. B. Corkum
National Research Council of Canada
Division of Physics
Ottawa, K1A 0R6, CANADA

ABSTRACT

Thomson scattering employing a 2 ns, 0.52 μm beam has been used to study the interaction of a short (5 ns) CO_2 laser pulse with plasmas at electron densities between critical (10^{19} electron/cm^3) and one tenth critical. The peak intensity of the focussed CO_2 radiation was approximately 5×10^{12} W/cm^2. Scattering has been performed at values of $(k\lambda_D)^{-1}$ near unity, to measure the plasma parameters and the level of thermal fluctuations; and, at large values of $(k\lambda_D)^{-1}$, approx. 8, where enhancement over the thermal spectra has been observed in three different electron density regions. Near the critical density, the scattering spectra show strong enhancements in both the ion and electron features (with $\Delta\omega \simeq \omega_{CO_2}$). At quarter critical density the enhancement spectra gives strong evidence for two-plasmon decay instability; enhancement observed only in the electron feature (now at $\Delta\omega \simeq \omega_{CO_2}/2$) and decreases markedly within 2-3 ns of the beginning of the CO_2 pulse. Below quarter critical density no enhancement is observed except near one tenth critical where enhancement is observed only in the ion feature, attributed to decay through Brillouin scattering.

B-4

TWO-DIMENSIONAL RESOLUTION OF CO_2 PROFILE MODIFICATION*

M. A. Stroscio and D. B. Henderson
University of California
Los Alamos Scientific Laboratory
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Los Alamos, New Mexico 87545

ABSTRACT

A two-dimensional simulation of the expansion of the laser-produced plasma is performed for a spherical microballoon irradiated by CO_2 laser light. Important implications of the results are discussed with regard to (a) absorption measurements, (b) unifying previous calculations, and (c) symmetry of implosions. In particular, it is demonstrated that the ponderomotive and superthermal effects greatly enhance spherical symmetry. Finally, we discuss the role of ponderomotive symmetry in laser fusion applications.

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

B-5

TWO-ELECTRON-TEMPERATURE BLOW-OFF BEHAVIOR IN SPHERICAL GEOMETRY*

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ABSTRACT

Resonance absorption and other processes that produce anomalously hot electrons can create a two-electron-temperature coronal plasma. The resulting radial electric field distinguishes two regions in the plasma: an inner low temperature one, and an outer high temperature one. Lindman has shown that in planar geometry, when the temperature ratio is large enough the regions are connected by a rarefaction shock. A spherically symmetric hydrodynamic code has been adopted to calculate blow-off behavior for two-electron-temperature conditions. Rarefaction shocks are seen for temperature ratios exceeding ~ 10. The energy flow from resonance absorption to hydrodynamic work (giving rise to fast ions) and to heating the cold electrons is computed for various conditions.

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*This work was supported by the United States Department of Energy under Contract No. ES-77-C-02-4149.

B-6

TRANSPORT OF LONG MEAN FREE PATH ELECTRONS, I

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B-7

TRANSPORT OF LONG MEAN PATH ELECTRONS, II

E. Williams
University of Rochester
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B-8

FAST ION PRODUCTION BY SUPRATHERMAL ELECTRONS

M. True
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ELECTRON TRANSPORT PHENOMENA IN LASER-INDUCED FUSION*

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ABSTRACT

The two dominant electron collisional processes are electron-ion scattering and electron-electron energy exchange. The respective mean free masses for an electron with energy E_e keV large compared to the local thermal energy are

$$\rho\lambda_{ei} \approx 3 \times 10^{-6} E_e^2/Z \ \mathrm{gm/cm^2}$$

$$\rho\lambda_{ee} \approx 3 \times 10^{-6} E_e^2 \ \ \mathrm{gm/cm^2}$$

where Z is the atomic number. The mass per unit area of the (glass) shells used in current experiments is of order 2×10^{-4} gm/cm^2, accordingly, electrons with energy $\lesssim$ 6 keV diffuse and thermalize within typical scale lengths, electrons above ~ 25 keV transport freely, losing energy by collisions slowly, and electrons with energies 6 keV $\lesssim E_e \lesssim$ 25 keV more or less diffuse in space while losing energy.

In the corona, when the product of absorbed energy flux, ϕ_L (W/cm^2), and the square of the laser wavelength, λ(μm), exceeds a few times 10^{14} W μm^2/cm^2, the rates of energy deposition and PdV work (via the induced electric field) are both larger than electron-electron collision rates with the result that the entire coronal electron distribution is grossly non-Maxwellian. This directly affects all of the classical transfer coefficients such as electron conductivity.

Calculations give a reduction in electron energy transfer into the ablation region of two orders of magnitude for an absorbed flux of 10^{15} W/cm^2, as a result of these classical corrections. As a consequence of this reduction, the coronal electron temperature approaches 10 keV at this level. The transporting tail of this electron distribution can produce preheating of order 100 eV in the imploding shell and fuel under these conditions.

Calculations also show that the X-ray spectrum in the region from 10 keV to 50 keV is strongly modified by transport of electrons from the fuel through the tamper and that care must be taken in inferring a coronal electron temperature from X-ray spectral data in experiments exhibiting strong spherical convergence.

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*This work was supported by the United States Department of Energy under Contract No. ES-77-C-02-4149.

B-10

OBSERVATION OF ENHANCED ABSORPTION AND REDUCED THERMAL CONDUCTIVITY IN THE PRESENCE OF ION-ACOUSTIC INSTABILITIES EXCITED IN AN UNDERDENSE PLASMA

E. J. Yadlowsky, R. C. Hazelton, P. W. Chan and R. J. Churchill
Colorado State University
Fort Collins, CO 80523

The relative importance of ion-wave instabilities, resonant absorption, and self-generated magnetic fields in laser-plasma absorption and thermal conductivity must be determined in order to establish a basis for theoretical models which predict fusion operating conditions. Although enhanced laser-plasma absorption and reduced thermal conductivity have been observed in laser fusion experiments, the physical mechanism responsible for these effects has not been identified precisely. To alleviate this situation an experimental program has been established in this laboratory wherein the effect of ion-acoustic instabilities in laser-generated plasmas is examined by means of laser Thomson scattering and other supporting diagnostic techniques.

This paper reports the measurements of the spatial and temporal frequency spectra of 0.6943 μm ruby radiation scattered from an underdense plasma produced by a pulsed CO_2 laser in deuterium at 300 Torr. From the frequency spectrum of scattered radiation, the level of ion-density fluctuations and the plasma electron temperature can be determined. Further, on the assumption of total absorption of CO_2 laser radiation by the plasma, the measurements enable the calculation of the laser absorption length and the plasma thermal conductivity. An analysis of the experimental results leads to the observation of enhanced ion-density fluctuations accompanied by enhanced laser absorption and reduced thermal conductivity in a thin region of the underdense plasma for laser power levels below 6×10^7 Watts/cm^2.

The principal observations in this work are of significance because they add support to the theoretical analyses of Malone et. al. [Phys. Rev. Letters 34, 721 (1975)] and Manheimer [Phys. of Fluids 20, 265 (1977)] who predict reduced thermal conductivity resulting from ion-acoustic fluctuations. The experimental results also point out the importance of ion-acoustic fluctuations relative to resonant absorption and self-generated magnetic field phenomena in underdense plasmas. The extent to which the observations in this work will have broader application to the overall problems of laser-induced fusion will be explored in the paper.

B-11

THEORY OF MOMENTS, HYDRODYNAMICAL EQUATIONS AND THE FLUX LIMIT

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ABSTRACT

The Fourier law of thermal conduction (as well as the Navier-Stokes law of viscosity) finds its justification in the Chapman-Enskog scheme, which assumes near-equilibrium. Recent computations suggest that the use of more flexible sets of hydrodynamical equations, such as Grad's 13 moments equations, could improve the description of heat transfer without ad-hoc flux-limiting. Since even Grad's method makes heavy reference to the Maxwellian equilibrium, more general principles must be used to set up hydrodynamical equations for non-equilibrium flows.

The mathematical theory of moments gives conditions on a set of quantities for them to be the moments of an everywhere non-negative distribution. New results are found for the set n, $\vec{u}$, $\overline{\overline{P}}$, $\vec{q}$ and R (scalar fourth moment), namely:

$$n \geq 0, \ \overline{\overline{P}} \geq 0, \ R - 4\vec{q} \cdot \overline{\overline{P}}^{\,-1} \cdot \vec{q} - \frac{(\mathrm{Tr}\ \overline{\overline{P}})^2}{mn} \geq 0.$$

Grad's method is found valid only for heat fluxes lower than the classical "flux limit". Some ways to close the hierarchy of hydrodynamical equations in accordance with the conditions of the theory of moments are discussed. In particular, a set of 14 equations (a) makes no reference to Maxwellian equilibrium, but describes situations ranging from collisional (near-equilibrium) to adiabatic (b) is always hyperbolic (Grad's equations can be elliptic).

RESONANT ABSORPTION OF MICROWAVES*

by

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High power ($v_o/v_e \lesssim 0.5$) microwaves (f = 1.2 GHz) propagating in a cylindrical waveguide in the TM_{01} mode are resonantly absorbed by an inhomogeneous plasma. If the ion drift velocity in the critical region is subsonic, strongly steepened density profiles are observed. At low powers, the density scale length near the critical surface decreases with power, but in the range $0.1 \lesssim v_o/v_e \lesssim 0.5$, the density scale length <u>increases</u> with power. If the ion drift velocity is supersonic, a quite different density profile is observed. In addition, high levels of ion turbulence are observed in this case. At low powers, primarily suprathermal electrons are heated, and they have a Maxwellian distribution, but at high powers essentially all the electrons are heated. A large fraction of this heating occurs before the electrons moving toward the critical surface reach the critical surface. These electrons are drifting at high enough velocity so that ion waves are strongly driven. The resulting anomalous dc resistivity strongly heats the electrons.

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 7314503.

APRIL 20

THURSDAY MORNING

8:30 A.M. - 11:30 A.M.

SESSION C

CHAIRMAN

R. JOHNSON

KMS FUSION

C-1

SHOCK WAVE CHARACTERISTICS

J. S. Pearlman
United States Department of Energy
Washington, D.C. 20545

C-2

ABLATION STRUCTURE AND HOT ELECTRON TRANSPORT

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Osaka University
Osaka, JAPAN

ABSTRACT

The ablation structure strongly depends on the density ratio between hot electrons and cold electrons. Therefore, it is important to determine the density ratio for investigating the fast ion energy spectra. In order to analyze the hot electron dynamics, a simple theoretical model is investigated. The collisionless Vlasov equation for the hot electron and the fluid equation with the classical and the anomalous drug forces for the cold electron are used. Under the stationary production of the hot electron, it is found that a large electrostaic potential, say, $\left|\frac{e\Phi}{T_h}\right| \simeq 2 \sim 3$ is built up when the ion acoustic turbulence is generated and the critical density region is then thermally insulated. For a given input power, a density ratio between the hot electrons and the cold electrons is determined. When the density ratio is given, ablation structures are investigated and the fast ion velocity distribution is found to become two components, say $\frac{1}{N}\frac{dN}{dv} = \sqrt{\frac{T_c}{M}}$ and $\sqrt{\frac{T_h}{M}}$. Finally, input power dependence of the total fast ion energy is considered.

C-3

STATIONARY FLOW MODEL OF ABLATIVELY IMPLODED SPHERICAL SHELLS

L. Montierth and R. Morse
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ABSTRACT

The stationary flow model of spherical ablation[1] is extended to shells, solutions with a density discontinuity at the critical surface and charged particle beam driven ablation. Parameter studies of the shell solutions show the relationship between shell aspect ratio, relative ablative mass removal or burn thru, laser power, and shell material type. The discontinuous solutions are shown to occur when the critical surface and sonic surface co-allesce. The relationship of these solutions to particular physical situations is shown to be ambiguous in a way that must be resolved by microscopic transport calculations. Charged particle driven ablative implosion processes are shown to resemble laser driven ablation. However, qualitatively different ablation processes occur in different regimes of the power and range of the incident beam. Procedures are described by which stationary solutions can be used to interpret and predict the results of experiments and numerical simulations.

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[1] S. J. Gitomer, R. L. Morse, and B. S. Newberger, Phys. Fluids 20, 238 (Feb. 1977).

Two Dimensional Numerical Simulation of Flat Target Experiments

by
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University of Rochester
Rochester, New York

R. Morse and C. Verdon
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University of Arizona
Tucson, Arizona

Numerical simulations of flat target experiments have been done with DAISY, a two dimensional triangular zone, Lagrangian hydrodynamics and heat flow code. A number of cases have been run with different laser spot spatial profiles, a mean spot diameter of 100 μm., and different absorbed power densities in the range from 3×10^{13} to 3×10^{14}. The plasma spot expands by less than its original radius in 1 ns. Because of the finite width of the laser spot, the expanding plasma flow diverges. This divergence makes possible a quasi-stationary flow with a subsonic to supersonic transition. The simulations show that quasi-stationary flow does develop and is approximately spherically diverging with a center of curvature at a distance of approximately twice the spot radius behind the target surface. The expansion velocity profiles and exhaust velocity are found to be in reasonable agreement with solutions of the stationary flow model of spherical ablation when the radius of curvature is chosen by this perscription.

STRUCTURE AND OBSERVABLE CHARACTERISTICS OF LASER DRIVEN ABLATION*

M. Keith Matzen
Laser Theory Division
Sandia Laboratories
Albuquerque, New Mexico 87185

and

Richard L. Morse
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University of Arizona
Tucson, Arizona 85721

ABSTRACT

Numerical hydrodynamic simulations of spherical ablation have been done with sufficient spatial resolution to show the details of the ablation front structure. These simulations show a continuous qualitative change in the ion velocity spectrum with increasing pulse length. Short pulses give an approximately isothermal spectrum. Longer pulses an ion spectrum with a "fast" peak, a characteristic of ablation which is experimentally observable. The longer pulse cases are in good agreement with the stationary flow model of ablation. Flat target experiments are modeled by using a spherical expansion to approximate the expansion from the finite spot size. Good agreement is obtained with recent Ni flat target experiments at Sandia Laboratories.

*This work supported by the United States Department of Energy.

EXPERIMENTAL OBSERVATION OF LASER DRIVEN ABLATION*

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ABSTRACT

The Sandia Nd:glass laser system has been used to study the expanding plasma produced from a wide range of thick target materials. Laser energies from 5 to 50 J in an 8 ns pulse were focused to approximately 100 μm on targets ranging from Be to U. Thomson parabolas and Faraday cups were used to diagnose the expanding plasma. A prominent feature of the parabola traces for nearly all of the target materials is a well-defined group of ions with a constant velocity. This ablation velocity has been characterized for a wide range of target materials. This velocity has also been determined as a function of laser energy for selected materials and for two different angles from the target surface. Detailed comparisons are made between the experimental results and a 1-D hydrodynamic simulation.

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*This work supported by the United States Department of Energy.

Abstract Submitted for the
Eighth Annual Symposium on the
Anomalous Absorption of Electromagnetic Waves

April 18 - 21, 1978
Tucson, Arizona

Effect of Inhibited Transport on the Implosion Efficiency of a Spherical Laser Target*

C.E. Max, C.F. McKee†, and W.C. Mead

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ABSTRACT

Using our previous analytical model for laser driven ablation including the effects of inhibited electron thermal conduction,[1] we derive scaling laws for the implosion efficiency and radius versus time history of a spherical laser target. The maximum efficiency is given as a function of the laser parameters, the degree of transport inhibition, and the initial target size. Our results are not restricted to the case when only a small fraction of the pellet mass is ablated away.

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

†Permanent addresss: Physics Department, University of California, Berkeley, CA 94720.

1. C.E. Max, C.F. McKee, and W.C. Mead, "Plasma Flows in the Conduction Region of a Spherical Laser Target", University of California Report UCRL-78458, 1976, and paper presented at last year's Anomalous Absorption Conference.

Abstract Submitted for the
Eighth Annual Symposium on the
Anomalous Absorption of Electromagnetic Waves

April 18 - 21, 1978
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Self-Similar Flows in Laser Irradiation of Plasmas*

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ABSTRACT

A self-similar solution of the continuity, momentum and energy equations is one in which the fluid properties are a function of a single parameter $\zeta = X/R(t)$. A familiar example is isothermal flow, where $R(t) = C_s t$, C_s being the sound speed. Self-similar solutions are very useful for finding scaling laws for pressure, density and flow speed. Here we find one-dimensional self-similar solutions for two cases: 1) inverse bremsstrahlung heating and 2) light pressure and local heating at the critical density. The former case is useful for low intensity light on high Z targets; the latter case holds for higher light intensities and collective heating at critical density.

For very efficient inverse bremsstrahlung heating, we find the formation of a sharp density drop at critical, concomitant with a sharp temperature rise. The resulting density profile, consisting primarily of very hot, very underdense matter, is less efficient at collisional absorption than might be naively thought. The temperature in the underdense region scales as $(It)^{2/5}$, where I is the light intensity and t is the laser pulse time, in agreement with LASNEX calculations.

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

C-9

STABILITY OF SHELLS ACCELERATED BY ABLATION

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ABSTRACT

Preliminary results of a perturbation analysis of imploding shell stability are presented. The evolution of localized small amplitude disturbances in an accelerating plasma shell is examined. The method employed consists of direct integration of the linearized equations in the presence of arbitrary steady flow parameters. The method is applied to an idealized density profile which permits the effects of plasma correction through the unstable region to be isolated. Zero order mass and heat flow are seen to have a substantial stabilizing effect.

C-10

STABILITY OF STEADY-STATE LASER IRRADIATED PLASMA PROFILES*

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ABSTRACT

Solutions of the steady-state hydrodynamic equations for a normally incident laser wave predict, in spherical geometry, the formation of subcritical plateaus[(1)] when the flow into the critical density is supersonic and density steps when this flow is subsonic. Hydrodynamic simulations of pellet implosions that include radiation pressure[(2)] do not show the appearance of such plateaus but rather produce supercritical bumps near the critical density. We have investigated the stability of the steady-state plateau solutions imposing an initial perturbation on this steady-state solution and following its subsequent time evolution. Supercritical bumps are produced outside the critical surface and propagate down the density gradient once the field intensity exceeds a threshold value. We also investigated the stability of steady-state profiles produced when resonance absorption fields are included for oblique incidence.

---

*This work was supported by the United States Department of Energy under contract No. ES-77-C-02-4149.

(1) P. Mulser and C. Van Kessel, Phys. Rev. Lett. 38, 902 (1977).

(2) J. Virmont, et. al., "Density Profile Modification by Light Pressure in Spherical Geometry", submitted to Phys. Fluids.

PLASMA PROFILE MODIFICATION INCLUDING RESONANCE ABSORPTION*

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ABSTRACT

Solutions of the steady-state hydrodynamic equations are found for an isothermal plasma in the vicinity of the critical surface in one dimension and in spherical geometry. The electrostatic fields due to resonance absorption are included in the hydrodynamic equations for a fixed angle of incidence. These fields are computed from coupled second order differential equations including electron temperature and phenomenological damping.(1) The resonance absorption field qualitatively modifies the profile significantly, especially in the case of supersonic flow into the critical density. Instead of a subcritical density plateau(2), a supercritical density plateau is produced. The transition to subcritical density occurs via a density step as in subsonic flow. The scale length that determines the resonance absorption fraction is reduced from the value obtained for the same incident laser intensity without inclusion of the resonance absorption field pressure.

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*This work was supported by the United States Department of Energy under Contract No. ES-77-C-02-4149.

(1) D. W. Forslund, et. al., Physical Review A, 11, 679 (1975).

(2) P. Mulser and C. Van Kessel, Phys. Rev. Lett., 38, 902 (1977).

APRIL 20

THURSDAY EVENING

6:30 P.M. - 9:00 P.M.

SESSION D

CHAIRMAN

S. BODNER

NAVAL RESEARCH LABORATORY

STIMULATED BRILLOUIN SCATTERING FROM AN UNDERDENSE LAMINAR GAS JET

by

J.C. SAMSON, H.A. BALDIS, N.H. BURNETT and P.B. CORKUM

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A laminar molecular gas jet has been developed as a target to study radiative instabilities in homogeneous underdense plasmas. A stable two-dimensional laminar flow is obtained by discharging high pressure nitrogen through a convergent-divergent (supersonic) nozzle into ambient He at a pressure of $\lesssim 2$ Torr. The ~ 1 mm thick, 1 cm wide jet is illuminated transversely with a train of 2 ns 10.6 μm pulses from a high power mode-locked CO_2 oscillator. With a molecular nitrogen density of $1.5 \times 10^{17} cm^{-3}$ (available electron density $\lesssim 0.2\ n_c$) it is observed that the breakdown threshold in the jet is $\sim 5 \times 10^{12} W/cm^2$ for 2 ns pulses and that with suitable preionization, single pulse reflectivities through the Brillouin instability can approach 100% into the f/10 focussing optics. Plasma diagnostic studies and 2D numerical simulation of the resulting plasma will be described.

D-2

BRILLOUIN BACKSCATTER WITH STRUCTURED LASER PULSES*

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ABSTRACT

It has been shown recently that the presence of a preformed plasma greatly enhances the backscatter of high irradiance (> 10^{15} W/cm^2) Nd-laser light from target plasmas.[1,2] This enhanced backscatter, and subsequent reduction in absorption, exhibits many of the properties of the Brillouin backscatter instability. These properties include optic ray retracing, occurrence in the very underdense region of the plasma, insensitivity to the tilt of the target, backscattered spectra near the laser frequency, and increasing backscatter with both prepulse level and incident irradiance.

The dependence of the backscatter process has been experimentally studied as a function of several parameters which further elucidate its properties. Enhanced backscatter has occurred eventhough the target material has been varied from CH to Au, the target geometry has been changed from planar to spherical, the focal position of the lens has been varied and the prepulse-to-main pulse timing was varied from 0.5 nsec to 8 nsec. The dependence of the backscatter process will be correlated to the density scale length in the underdense region obtained interferometrically. These results will be compared with theory.

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*This work supported by the U.S. Department of Energy.

[1] B. H. Ripin, et al., Phys. Rev. Lett. 39, 611 (1977).

[2] B. H. Ripin, NRL Memo Rept. No. 3684 (1977).

Abstract Submitted for the
Eighth Annual Symposium on the
Anomalous Absorption of Electromagnetic Waves

April 18 - 21, 1978
Tucson, Arizona

Where is Raman Scatter?*

W.L. Kruer and K.G. Estabrook , Langdon, Lasinski

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ABSTRACT

Many plasma physics effects predicted by the community have been confirmed in numerous experiments. These effects include profile steepening, resonance absorption, hot electrons, Brillouin scatter, and the $2\omega_{pe}$ instability. In contrast, very little experimental information on Raman scatter in laser plasma has been obtained. In the light of our current understanding of the conditions in the underdense plasma, we reexamine the Raman instability and its nonlinear effects. We try to sketch out experiments in which this instability may surface as a significant effect.

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

D-4

OBSERVATIONS OF RAMAN BACKSCATTER RADIATION FROM UNDERDENSE PLASMA

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Seattle, Washington 98195

D-5

NONLINEAR THEORY OF RAMAN AND BRILLOUIN SCATTERING

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Department of Physics and Astronomy
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NONLINEAR THEORY OF RAMAN BACKSCATTERING WITH SOLITON FORMATION IN LASER-IRRADIATED PLASMAS*

H. H. Chen and C. S. Liu
University of Maryland

ABSTRACT

Nonlinear evolution of Raman backscattering at the quarter-critical point is important in determining the amount of laser light that can reach the critical density region and get absorbed there. We propose here a mechanism of saturation by soliton formation. Due to the absolute nature of the instability localized at the quarter-critical region, the scattered light wave and the plasma wave grow locally to large amplitude. These waves exert a ponderomotive force that drives plasma out of the resonance region thus creating a density cavity that traps more waves. On the other hand, the local plasma wave frequency is shifted by an amount proportional to the density change. When this frequency shift is large enough, it detunes the resonance condition and stops the instability. The saturation level is then found to be

$$\frac{|E_s|^2}{8\pi nT} \sim \frac{\gamma_0}{\omega_p} \sim \frac{2v_0}{c}$$

where E_s is the scattered wave amplitude, n the density of the plasma, γ_0 the linear growth rate, ω_p the plasma frequency and v_0 the electron oscillation velocity in the incident wave field. The reflection coefficient is given by

$$R \equiv \frac{|E_s|^2}{|E_0|^2} \sim \frac{v_e^2}{v_0 c}$$

where v_e is the electron thermal speed.

---

*Research supported by DOE.

D-7

Abstract Submitted for the
Eighth Annual Symposium on the
Anomalous Absorption of Electromagnetic Waves

April 18 - 21, 1978
Tucson, Arizona

High Energy Electrons*

B.F. Lasinski, A.B. Langdon, and W.L. Kruer

ABSTRACT

The high frequency instabilities which occur at or below quarter-critical are thought to be responsible for a flux of high energy ($\gtrsim$ 100 keV) electrons. The most plausible candidate is the $2\omega_{pe}$ instability, the decay of the incident light wave into two electron plasma waves. Our ZOHAR simulations confirm that the $2\omega_{pe}$ instability is effective in producing these hot electrons for a wide range of experimental conditions. The role of the Raman instability, the decay of the incident light into an electromagnetic wave and an electron plasma wave, will also be considered.

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

D-8

SOME REMARKS ON PARAMETRIC INSTABILITIES

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D-9

PARAMETRIC INSTABILITIES IN THE PRESENCE OF LONG WAVELENGTH LANGMUIR TURBULENCE*

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ABSTRACT

A general formalism which describes parametric instabilities in a hot homogeneous plasma penetrated by turbulence is derived. A kinetic description of the turbulence is used[1] and the pump is assumed to be dipolar and monochromatic. The influence of the turbulent field on several decay parametric instabilities is studied in the regime of stationary turbulence. The long wavelength Langmuir turbulence strongly affects the ion sound phase velocity and consequently the evolution of decay parametric modes. In the case when the turbulent spectrum is situated in the domain of wavelengths much larger than the wavelength of the excited parametric mode, the growth rate of the instability is largely reduced for a weak pump.

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*Work supported in part by NRC.

(1)Tsytovich, V. N., Sov. Phys. JETP 30, 183 (1970).

D-10

EFFECT OF MAGNETIC FIELD ON PARAMETRIC INSTABILITIES*

C. Grebogi and C. S. Liu
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ABSTRACT

The effects of self-generated magnetic field in laser-produced plasmas on the parametric decay of laser radiation in the underdense region are studied. The dispersion relation of the decay into two upper hybrid plasmons is derived for arbitrary magnetic field intensity and arbitrary ratio k/k_0, and the growth rate is evaluated. Due to the presence of magnetic field, the linear Landau damping is greatly reduced and the spectrum is significantly modified for $k\lambda_D \gtrsim 0.2$. In the stimulated Brillouin scattering process, the low frequency waves is a lower hybrid wave but the growth rate is unchanged by the presence of magnetic field and the threshold reduced. For Raman backscattering we find growth even for large $k\lambda_D$ when, in the case of unmagnetized plasma, Compton scattering should be the prevailing process in that region.

---

*Work supported by NSF, DOE, and CNPq.

APRIL 21

FRIDAY MORNING

8:30 A.M. - 11:30 A.M.

SESSION E

CHAIRMAN

K. MIMA

INSTITUTE OF LASER ENGINEERING, OSAKA

E-1

HARMONIC PRODUCTION IN INHOMOGENEOUS PLASMAS

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ABSTRACT

The density scale length in plasmas generated by intense laser beams ($I \gtrsim 3.10^{15} Wcm^{-2}$) is largely determined by the ponderomotive pressure of the laser beam. This spatial structure limits the modes of turbulence which can develop in the plasma near critical density and ablation of the plasma across this density structure can result in a well defined frequency of ion turbulence being dominant. This monochromatic ion wave may be responsible for the spectral structure observed in $2\omega_0$ emission from the plasma.

The plasma turbulence will strongly limit the thermal conductivity of the plasma near critical density as deduced from "burn through" experiments. In the presence of the ponderomotive pressure of the laser beam the observed expansion of the plasma critical density surface at a velocity of $\sim 10^5 m\ s^{-1}$ agrees with a 1-D fluid simulation only if the thermal conductivity is strongly inhibited.

E-2

MICROWAVE EXPERIMENTAL INVESTIGATIONS OF SPONTANEOUS MAGNETIC FIELD GENERATION*

S. P. Obenschain and N. C. Luhmann, Jr.
University of California
Los Angeles, California 90024

ABSTRACT

The source mechanisms, growth and saturation of spontaneously generated quasi-static magnetic fields in laser pellet experiments are studied in a microwave simulation. Here intense 3-10cm wavelength microwave radiation is incident upon an inhomogeneous near critical density unmagnetized argon plasma produced by filament discharge. These spontaneously generated fields were investigated over five orders of magnitude variation in incident power. In these studies $10^{-5} \lesssim 1$ where $\eta_{vac} = E_{vac}{}^2/8\pi nKT_e$. The magnetic field was found to saturate with increasing pump power well below $\eta_{vac} = 1$. The use of microwave pumps with finite bandwidth allowed additional investigations to be made into the mechanisms responsible for magnetic field generation and means for controlling the fields. Pumps whose bandwidth was due to random phase or amplitude modulation were found to produce significantly attenuated magnetic fields. In a simulation of multi-line, multi-band CO_2 lasers multiple current sheets were observed at the respective critical density layers.

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*Work supported by US DOE DLF Contract E(04-3)-34, PA 236 and US AFOSR Contract F49620-76-C-0012.

E-3

~~ABSTRACT~~ COMPLEX ELECTRON DENSITY STRUCTURES IN THE INITIAL STAGES OF LASER-PLASMA INTERACTION

B. Grek, F. Martin, H. Pépin
F. Rheault, and T. W. Johnston
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ABSTRACT

Interferometry and Schlieren have been done using a synchronized short pulse (20 psec) ruby laser on the plasma created by a short CO_2 laser pulse (12J, 1.7 nsec) incident on polyethylene slab. The results indicate clearly the formation of remarkable density structures in the (CO_2) overdense plasma ($n_e > 10^{19}$ cm^{-3}) during the first few tenths of nanoseconds, smoothing out at later times. Since Abel inversion is manifestly inapplicable and ruby ray bending important, we have resorted to inventing plausible plasma models with a complete ray tracing program -- including the optical system -- to simulate results, to be relaxed to the observations by adjusting the plasma model parameters. The raw results and their interpretation will be discussed.

E-4

LATEST RESULTS

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E-5

Abstract Submitted for the
Eighth Annual Symposium on the
Anomalous Absorption of Electromagnetic Waves

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Effect of Large Density Depressions on the Absorption of Focused Laser Beams*

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ABSTRACT

We have developed a computational model to describe the absorption of a focused beam of circularly polarized laser light including the ponderomotive force. We find, in agreement with recent experiments, that at high intensity large density depressions can form due to the variation of the ponderomotive force across the focal region. The critical surface becomes concave and the walls of the cavity refract some of the incident light so that resonant absorption can be greatly enhanced.

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

†Permanent address: University of California, Department of Applied Science, Davis, California.

E-6

"RELATIVISTIC EFFECTS" ON ELECTROMAGNETIC WAVE PROPAGATION IN A COLD ELECTRON PLASMA: TRAVELLING WAVE, STANDING WAVE

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ABSTRACT

We study the propagation of a linearly polarized travelling wave in a cold electron plasma with the following form[1]:

$$E_i = F_i(z)\ f_i(\theta) \qquad (\theta = \omega t - \psi(z);\ i - x,\ z)$$

We use an iterative method and perform expansions in powers of the strength parameter. According to the parameter order, we find the different results respectively for the homogeneous and inhomogeneous plasma cases. We only detail on results in the inhomogeneous plasma case when "relativistic effects" are taken into consideration.

The values of $F_x^2(z)$ we obtain for different laser intensities are weakened by the "relativistic effects" which allow propagation in the overdense plasma.

In the same way we study the form of a standing wave[2]. We obtain the same kind of results as in the previous case. However, for one laser intensity the "relativistic effects" are more important than in that case as the reflected wave comes to the assistance of the incident one to produce "relativistic effects".

---

(1) A. Bourdier, D. Babonneau, G. DiBona, and X. Fortin, Phys. Lett. A <u>64,</u> 292 (1977)

(2) A. Bourdier, X. Fortin, Submitted to Phys. Lett. A

E-7

KINETIC THEORY OF MAGNETIC FIELD GENERATION IN RESONANCE ABSORPTION OF LIGHT

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Cedex, FRANCE

ABSTRACT

A kinetic theory is built to study magnetic field generation in resonance absorption of light. Previous results are recovered in the purely collisionless regime, while a collisional and an intermediate regime are shown to give rise to new behaviours: Scaling laws are set up in those regimes.

RESONANT ABSORPTION INDUCED BY DC MAGNETIC FIELDS*

by

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Resonant absorption is investigated for a plane wave incident obliquely onto a magnetized plasma with the density varying in one direction. Fully three dimensional geometry is treated. For the dc magnetic field perpendicular to the density gradient, the maximum absorption is highest (~99%) for p-polarization and lowest for s-polarization (~60%) and is optimized if the field is perpendicular to the polarization of the light. A dc magnetic field parallel to the density gradient results in a driver for the usual resonant absorption even in the s-polarization case. To model the geometry of many laser experiments, the dc magnetic field is assumed to point in the azimuthal direction with the direction of the density gradient as an axis. Averaging over the azimuthal direction, we find that the absorption curve for p-polarization is lower and flatter and that for s-polarization peaks at normal incidence.

* This work was supported by the Lawrence Livermore Laboratory under Intramural Order 7314503.

APRIL 21

FRIDAY AFTERNOON

1:30 P.M. - 2:30 P.M.

SESSION F

CHAIRMAN

R. L. MCCRORY

UNIVERSITY OF ROCHESTER

MAGNETOPLASMA ABSORPTION OF INTENSE ELECTROMAGNETIC WAVES ON SELF-CONSISTENT PLASMA PARAMETERS*

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ABSTRACT

QUELLE[1], a full-wave analytical/numerical code utilizing a kinetically derived current density, used to investigate the reflection, conversion, and absorption of electromagnetic fields incident upon nonuniform plasma with and without the presence of magnetic fields has been expanded to include a ponderomotive force description as well as resonant electron heating. The evolution of electron flow, density profile, DC magnetic field generation, and the kinetic energy gained by electrons from the intense field for angles of wave incidence varying from -60° to +60° are presented in graphical form, where selected "snap-shots" are directly compared to simulation code predictions in 5 KeV plasma at 1.06 um. The asymmetrical behaviour of the absorptivity and reflectivity evolution earlier formulated analytically[1] is illustrated.

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*Part of this work was done at the Max-Planck Institut fur Plasmaphysik, Garching under terms of agreement on association with Euratom and part was performed under the auspices of the U. S. Energy Research and Development Administration.

[1]A. L. Peratt and H. H. Kuehl, Radio Sci. 7 309 (1972).

Resonant Absorption by Linear Wave Conversion in an Unmagnetized, Collisionless Plasma*

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There have been several analytical and numerical calculations[1-4] for the absorption coefficient of an electromagnetic wave obliquely incident upon a non-uniform plasma. After tunneling through to the critical surface where the local plasma frequency equals the wave frequency, the incident wave undergoes a linear wave conversion at the critical surface if the electric field has a component along the density gradient. The absorption coefficient associated with this resonance absorption is generally expressed as a function of a parameter, $q = (k_0L)^{2/3}\sin^2\theta_0$.

In this paper, we present an analytical solution to the problem of linear wave conversion in a cold, unmagnetized, collisionless plasma when the value of q is neither too large nor too small ($q = 0.5 \sim 2.0$). Instead of solving the original exact equation, a set of substitute equations in two separate regions are solved and these two solutions are matched together in the vicinity of the critical surface. The result obtained for the absorption coefficient is in good agreement with that of large q approximation,[2] small q expansion,[3] and numerical solution.[4]

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*This work was supported in part by the National Science Foundation Research Grant ENG 76-15623.

[1] V. L. Ginzburg, Propagation of Electromagnetic Wave in Plasmas, (Pergamon, New York, 1970), p. 260.

[2] T. Tang, Radio Sci., 5, 111 (1970).

[3] T. Speziale and P. J. Catto, Phys. Fluids, 20, 990 (1977).

[4] D. W. Forslund, J. M. Kindel, K. Lee, E. L. Lindman, and R. L. Morse, Phys. Rev., A11, 679 (1975).

EMISSION OF ELECTROMAGNETIC RADIATION AT AND NEAR CRITICAL SURFACES IN LASER PLASMAS

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ABSTRACT

Recent laser plasma simulations indicate a hump electron density profile along the target surface normal in the initial stages of heating. Thus there are front and back critical surfaces delimiting a thin overdense region, the back surfaces being critical with respect to emitted electromagnetic radiation frequencies. Plasma oscillations, set up in the overdense region near the front critical surface by for example laser induced oscillating two stream instabilities, when carried by the hot electron flow to and beyond the back critical surface interact linearly with the density and temperature gradients to produce electromagnetic waves.

Perturbation analysis of the electron fluid whose equilibrium is characterized by a balance between a steady electric field and the pressure gradient leads to a dispersion relation for the hybrid electromagnetic/plasma waves. This relation indicates that the critical surface in the direction along the gradients two purely growing modes are produced whose amplitudes have e-folding lengths of the order of the density gradient scale length. Away from the critical surfaces in the underdense region the roots indicate a growing propagating plasma wave and a very slightly damped electromagnetic wave for gradient scale lengths much larger than the Debye lengths. This may be a new mechanism for core pre-heat. Transverse to the gradient there is no emission at the critical surface but in the underdense region the roots of the dispersion relation are purely real and purely imaginary. The real roots are vanishingly small and appear to be trivial. The imaginary roots represent one damped and one growing mode and remain so as the density and temperature decrease, for gradient scale lengths much greater than the Debye lengths. For these reasons direct observations of such radiation may prove difficult.

A VARIATIONAL APPROACH TO PERTURBED SOLITON EQUATIONS

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ABSTRACT

By rewriting a perturbed soliton equation in terms of an approximate variational principle, equations are derived for the adiabatic time evolution of characteristic soliton parameters. These evolution equations generalize the results of previous treatments, while avoiding the complicated algebra associated with standard perturbation schemes. The method is applied to the Korteweg-de Vries and non-linear Schrodinger equations modified by various dissipative perturbation terms.

EIGHTH ANNUAL CONFERENCE ON ANOMALOUS ABSORPTION OF ELECTROMAGNETIC WAVES

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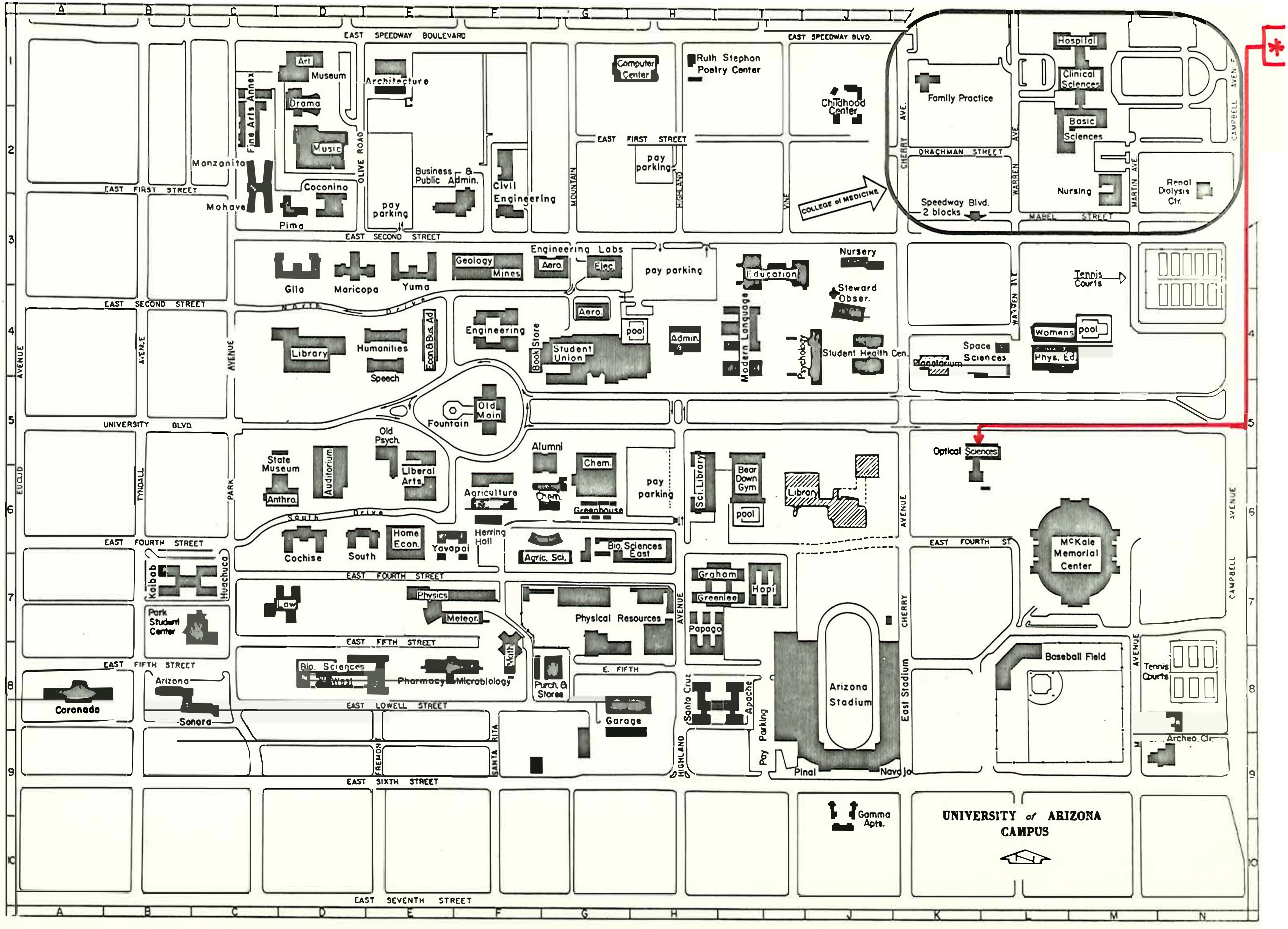

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