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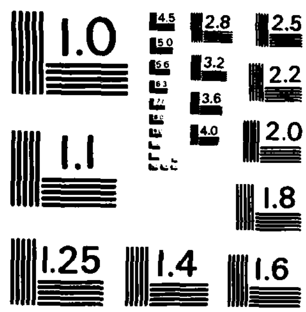
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16th ECLIM

(European Conference on Laser Interaction with Matter)

Book of Abstracts

IMPERIAL COLLEGE LONDON

26 - 30 September 1983

EOARD-TR-84-06

16th ECLIM

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IMPERIAL COLLEGE LONDON

26-30 September 1983

BOOK OF ABSTRACTS

as received by 3rd September 1983

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16th ECLIM

Scientific Programme

Monday, September 26th, 1983

Session A : 0900

Welcome

A1 - I* Laser matter interaction studies at GRECO
E. FABRE, Ecole Polytechnique, Palaiseau, France$_2$

A2 - I Implications of absorption and transport experiments with CO_2 lasers at Los Alamos
D.W. FORSLUND, Los Alamos National Laboratory, USA

A3 - C** Effect of coating material in 1.06 μm directly driven laser implosions
M. BERNARD, D. BILLON, J.L. BOCHER, P. COMBIS, D. JURASZEK, D. MEYNIAL, Centre d'Etudes de Limeil, France

A4 - C X-radiographic studies of ablatively imploded plastic shells
C.L.S. LEWIS, S. SAADAT, M.J. LAMB, P. McCAVANA, R. CORBETT, J. McGLINCHEY, The Queen's University of Belfast, and M.H. KEY, W.T. TONER, R. EASON, Rutherford Appleton Laboratory

A5 - C Emission diagnosis of 0.53 μm ablative implosions
B.J. MacGOWAN et al., Imperial College, M.H. KEY et al., Rutherford Appleton Laboratory, P. FEWS, D.L. HENSHAW, Bristol University

A6 - C Applications of ion emission measurements for estimates of the compression parameters of spherical plasmas
A.A. EROKHIM, A.S. SHIKANOV, G.V. SKLIZKOV, Yu.A. ZAKHARENKOV, Lebedev Institute, USSR, and S. DENUS, J. FARNY, W. MROZ, J. WOLOWSKI, Kaliski Institute, Poland

Session B : 1100 Posters

B1 - P*** Effects of self-induced magnetic field on Rayleigh-Taylor instability
Takashi YABE and Alio NISHIGUCHI, Osaka University, Japan

B2 - P Comparison of the properties of ablatively accelerated target between 1.06 μm and 0.26 μm laser light
B. FARAL, R. FABBRO, Ecole Polytechnique, Palaiseau, France
F. COTTET, J.P. ROMAIN, ENSMA Poitiers, France

*I - Invited paper - 30 minutes including questions
**C - Contributed paper - 15 minutes including questions
***P - Poster

B3 - P Spectroscopic studies of non-Debye discharge plasmas
K.G.H. BALDWIN and D.D. BURGESS, Imperial College,London

B4 - P Soft x-ray population inversion using resonant photo-excitation
J.G. LUNNEY, Trinity College, Dublin, M.J. LAMB,C.L.S. LEWIS, R. CORBETT, P. McCAVANA, Queen's University of Belfast, L.D. SHORROCK, Hull University, F. PINZONG, Rutherford Appleton Laboratory

B5[1]- P Experimental evidence for axial magnetic fields in plasma created by interaction of an intense laser pulse with a plane target
V. ADRIAN, J. BRIAND, M. EL TAMER, A. GOMES, Y. QUEMENER
Universite Paul Sabatier, France

B5[2]- P Axial magnetic field growth in laser-matter interaction plasma
V. ADRIAN, J. BRIAND, M. EL TAMER, A. GOMES, Y. QUEMENER
Universite Paul Sabatier, France

B6 - P Electron heat flow with inverse Bremmsstrahlung and ion motion
J.P. MATTE, T.W. JOHNSTON,Université du Quebec, J. DELETTREZ, R.L. McCRORY, LLE, Rochester, J. VIRMONT, Ecole Polytechnique, Palaiseau, France

B7 - P Ion fluctuations in stimulated Raman scattering
J.A. HEIKKINEN and S.J. KARTTUNEN, Technical Research Centre of Finland

B8 - P Validity of a few current temperature diagnostics in the critical density region
M. LAMOUREUX, C. MÖLLER and P. JAEGLÉ, Laboratoire de Spectroscopie Atomique et Ionique, France and Greco Interaction Laser Matière, Ecole Polytechnique, Palaiseau, France

B9 - P Resonant absorption in a steep density gradient
M. COLUNGA, P. MORA, R. PELLAT, Ecole Polytechnique, Palaiseau, France

B10 - P Electron density profiles of laser produced H_e plasma before and after shock wave reflection
A. GIULIETTI, M. VASELLI, Istituto di Fisica Atomica e Molecolare, CNR, Pisa, D. GIULIETTI, M. LUCCESI, Istituto di Fisica dell'Universita di Pisa, S. ATZENI, Laboratori Nazionali ENEA di Frascati, Italy

B11 - P Ripping in the critical surface of a laser produced laser in presence of anisotropic ion-acoustic turbulence
R. DRAGILA, Australian National University, Canberra

B12 - P Ion profiles of laser produced C plasmas
K. MANN, K. ROHR and H. WEBER, Universität Kaiserslautern,FRG

B13 - P Numerical methods for radiation transfer in lasing media
D.J. BOND, Imperial College, London

B14 - P Instability and chaos in laser plasma interaction
J.L. BOBIN, Université Pierre et Marie Curie. Paris, France

B15 - P Comparative measurements of plasma smoothing of laser beam modulations at 1.05 μm, 0.53 μm and 0.35 μm
A.J. RANKIN, J.D. KILKENNY, Imperial College, London
A.J. COLE, Rutherford Laboratory, UK

B16 - P Time resolved line broadening at 1.05 μm, 0.53 μm and 0.35 μm
S.D.TABATABAEI, J.D. KILKENNY, B.J. MacGOWAN, Imperial College, J.G. LUNNEY, Trinity College, Dublin, R.W. LEE, Lawrence Livermore National Lab, USA

Session C : 1345

C1 - I Review of suprathermal transport experiments at Los Alamos
P.D. GOLDTONE, M.M. MUELLER, K.B. MITCHELL, E. STOVER, M.A. YATES, R. KRISTAL, A. HAUER, Los Alamos National Lab. USA

C2 - C Suppression of preheat of targets at the CO_2 laser irradiation
H. NISHIMURA, T. YABE and C. YAMANAKA, Osaka University, Japan

C3 - C Transport experiments in spherical geometry with 1.05 μm and 0.53 μm irradiation
J.D. KILKENNY, D.K. BRADLEY, J.D. HARES, O.LANDEN, B.J. MacGOWAN, S.D. TABATABAEI and J.S. WARK, Imperial College
A. HAUER, W. MEAD, O. WILLI, Los Alamos National Laboratory,USA
C.J. HOOKER, R.W. EASON, Rutherford Laboratory, UK

C4 - C Electron transport experiments on spherical targets
D.C. SLATER, J.A. TARVIN, P.D. ROCKETT, G. CHARATIS, L.V. POWERS and W.B. FECHNER, KMS Fusion, USA

C5 - C Simulations and theoretical implications of KMS transport experiments for 1.05 μm and 0.53 μm laser irradiation
W.B. FECHNER, J.T. LARSEN, L.V. POWERS, KMS, USA

C6 - C Coronal expansion of laser-produced plasmas
R.F. STELLINGWERF, Mission Research Corporation, USA

Session C : 1600

D1 - I Strong density fluctuations in laser heated plasma
A.A. OFFENBERGER, University of Alberta, Canada

D2 - C Review of laser-plasma interaction studies at Darmstadt
P. MULSER, H.J. KULL, H. SCHNABL, W. SCHNEIDER, A. ZEIDLER Institut für Angewandte Physik-Theorie, Darmstadt,FRG

D3 - C Unresolved aspect of laser light scattering from solid target
G.P. BANFI, K. EIDMANN and R. SIGEL,Max-Planck Inst.Garching,FRG

D4 - C The nonlinear damping mechanism of SBS in an homogeneous plasma
B. GELLERT and B. KRONAST, Ruhr-Universität Bochum, FRG

D5 - C $3\omega_0/2$ harmonic emission from thin foils
V. ABOITES, E. McGOLDRICK, T.P. HUGHES and S.M.L. SIM, University of Essex, S. KARTTUNEN, Technical Research Centre of Finland, R.G. EVANS, Rutherford Appleton Laboratory

D6 - C Sunion - a numerical code for laser-plasma interaction
CH. SACK and H. SCHAMEL, Inst.für Theor.Phys.,Bochum,FRG

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Tuesday, September 27th, 1983

Session E : 0900

E1 - I Laser interaction experiments with double-shell targets
N.G. BASOV, A.A. EROKHIN, A.A. KOLOGRIVOV, A.A.RUPASOV, A.S.SHIKANOV, G.V.SKLIZKOV, YU.A.ZAKHARENKOV, N.N.ZOREV, P.N. Lebedev Physical Institute, USSR.
S. DENUS, J. FARNY, W.MROZ, J. WOLOWSKI, E. WORYNA, S. Kaliski Institute, Poland

E2 - I Review of the laser-plasma work at MPQ Garching, FRG
S. WITKOWSKI,Max-Planck-Institut für Quantenoptik,FRG

E3 - C Non-linear development of the Rayleigh-Taylor instability of a thin sheet in three dimensions
D. COLOMBANT, W. MANHEIMER and E. OTT, Naval Research Lab., Washington, D.C.,USA

E4 - C Measurement of areal mass variation in Rayleigh-Taylor unstable targets
J. GRUN, M.H.EMERY, M.J.HERBST, S.KACENJAR, E.A. McLEAN, S.P.OBENSCHAIN, B.H.RIPIN, Naval Research Lab., Washington DC,USA

E5 - C Measurements of the Rayleigh-Taylor instability in laser irradiated targets
A.J.COLE, M.H.KEY and P.T.RUMSBY,Rutherford Appleton Lab
J.D. KILKENNY and J.WARK, Imperial College, London

E6 - C Analytic results in linear Rayleigh-Taylor theory
D.H.MUNRO,Lawrence Livermore National Laboratory, USA

Session F : 1100 Posters

F1 - P Evaluation of lateral energy lost in laser-driven shock wave experiments
F.COTTET, R.FABBRO and J.P.ROMAIN, E.N.S.M.A. Poitiers and Ecole Polytechnique, Palaiseau, France

F2 - P The use of spatially-structured plane targets in laser plasma spectroscopy
Ph.ALATERRE, J.C.GAUTHIER, J.P.GEINDRE, K.NAJMABADI, C.POPOVICS, A.POQUERUSSE, Ecole Polytechnique, Palaiseau, France

F3 - P Absolutely unstable stimulated Brillouin scattering and two-plasmon decay
R.L.BERGER and L.V.POWERS, KMS Fusion Inc. USA

F4 - P Suprathermal electron transport in CO_2 laser plasma
J.C.KIEFFER, H.PEPIN, P.LAVIGNE, Univ. du Quebec, Varennes
F. AMIRANOFF, Ecole Polytechnique, Palaiseau, France

F5 - P Observation of bubble and spike formation in laser-accelerated foils
R.R.WHITLOCK, M.H.EMERY, J.A.STAMPER, E.A.McLEAN, J.A.SPRAGUE, S.P.OBENSCHAIN and M.C.PECKERAR

F6 - P Experimental results about 3/2 ω_o and 5/2 ω_o harmonic generation in plasmas created by interaction of intense neodynium laser pulse with a plane target
V.ADRIAN, J.BRIAND, M.EL TAMER, A.GOMES, Y.QUEMENER, Universite Paul Sabatier, France.

F7 - P Fast ion imaging of CO_2 laser ion plumes
D.R.BACH and D.W.FORSLUND, Los Alamos National Lab., USA

F8 - P Ablative flow from laser-irradiated pellets: a comparison of theory and experiments
J.SANZ, R.RAMIS and J.R.SANMARTIN, Univ. Politecnica de Madrid

F9 - P The accessibility of quasiplanar supercompression and gigagauss fields by coherent collisions in fragmented liner driven by the tunable lasers
V.A.BELOKOGNE, Moscow University, USSR

F10 - P Penumbral imaging of high energy x-ray emission from laser produced plasmas
K.A.NUGENT, A.PERRY, B.LUTHER-DAVIES, M.D.J.BURGESS, Australian National University, Canberra

F11 - P An electrodynamical coaxial spectrometer for multichannel plasma pulse analysis
J.EICHER, K.ROHR and H.WEBER, Universität Kaiserslautern, FRG

F12 - P Mathematical and numerical aspects of the theory of heat transport in a steep temperature gradient
J-F LUCIANI, P.MORA, R.PELLAT, Ecole Polytechnique, Palaiseau, France

F13 - P Particle trapping and acceleration by electron plasma waves
W.SCHNEIDER, Inst.für Angewandte Physik-Theorie, Darmstadt, FRG

F14 - P Analysis of back reflected light from homogeneous plasmas
C.GARBAN-LABAUNE, E.FABRE, A.MICHARD, Ecole Polytechnique, Palaiseau, France

F15 - P X-ray line self absorption and electron density determination in a laser created plasma
P.COMBIS, M.LOUIS-JACQUET, Centre d'Etudes de Limeil, France

F16 - P Simulation and evaluation of radiative processes in high-parameter plasmas
L.DRSKA, P.BITZAN, V.KASPAR, J.NEUBERG, G.SIMONI, J.VONDRASEK Technical Univ. of Prague, Czechoslovakia

Session G : 1345

G1 - I Laser fusion experiments and theory at the laboratory for laser energetics
R.L. McCRORY, Laboratory for Laser Energetics, USA

G2 - C Lateral energy smoothing in layered targets irradiated with 0.35 μm laser wavelength
B.MEYER, J.L.BOCHER, M.DECROISETTE, P.A.HOLSTEIN, M.LOUIS-JACQUET, A.SALERES, G.THIELL, Centre d'Etudes de Limeil, France

G3 - C Acceleration of thin plastic foils at λ = 1.3 μm and 0.44 μm
A.G.M.MAASWINKEL, K.EIDMANN, E.FILL, R.SIGEL, G.D.TSAKIRIS, S.WITKOWSKI, Max-Planck-Inst.für Quantenoptik,Garching,FRG

G4 - C Non uniform illumination of laser targets
R.G.EVANS, Rutherford Appleton Laboratory, UK

G5 - C 1-D simulation of laser foil experiments and foil collisions
R.F.SCHMALZ, P.HERRMANN, J.MEYER-TER-VEHN, Max-Planck-Inst. für Quantenoptik, Garching, FRG

Session H : 1600

H1 - I X-ray spectroscopy of laser produced plasmas
R.W.LEE, Lawrence Livermore National Laboratory, USA

H2 - C A comparison of laser irradiated target emissions at 1.06 μm, 0.53 μm and 0.27 μm
Ph.ALATERRE, B.D'ETAT, J.C.GAUTHIER, J.P.GEINDRE, J.GRUNBERG, K.NAJMABADI, H.NGUYEN, C.POPOVICS, A.POQUERUSSE, Ecole Polytechnique, Palaiseau, France

H3 - C The K absorption edge as a preheat diagnostic
J.D.HARES, D.K.BRADLEY, J.D. KILKENNY, A.J.RANKIN,Imp.Coll.,UK

H4 - C Analyses of experiments on x-ray emission from laser-irradiated targets
D.BABONNEAU, JL.BOCHER, G.DI BONA and X.FORTIN, Centre d'Etudes de Limeil, France

H5 - C X-ray emission in the sub-KeV range from laser irradiated thin plane targets
J.L.BOCHER, G.THIELL, D.BABONNEAU, G.DI BONA, X.FORTIN
Centre d'Etudes de Limeil, France

H6 - C X-ray diagnostic from short pulse 1.05 μm laser plasma
A.P.SCHWARZENBACH, W.LAMPART, P.LADRACH, and J.E.BALMER, University of Berne, Switzerland

Wednesday, 28th September, 1983

Session I : 0900

I1 - I Hydrodynamic studies in laser plasma experiments performed at Centre d'Etudes de Limeil
R. DAUTRAY et al., Centre d'Etudes Limeil, France

I2 - I Study of laser-produced plasmas and their applications at the SERC Central Laser Facility
M. H. KEY, Rutherford Appleton Laboratory, UK

I3 - C Spatial structure of expanding plasma in experiments of spherical laser-driven compression of microspheres
S. DENUS, H. FIEDOROWICZ, S. NAGRABA, W. PAWLOWICZ, L. SULWINSKI, A. WILCZYNSKI, J. WOLOWSKI, Kaliski Institute, Poland

I4 - C Electron density profiles and second harmonic emission from picosecond Nd laser-produced plasmas
B. LUTHER-DAVIES, M. D. J. BURGESS, R. DRAGILA, Australian National University, Australia

I5 - C New CuI-like lines of Cd XX and In XXI in laser-produced plasma
Y. GAZIT, N. SPECTOR, Soreq Research Centre, Israel

Session J : 1045 Posters

J1 - P Optical measurement of thin foil acceleration
E. FABRE, C. GARBAN LABAUNE, A. MICHARD, Ecole Polytechnique, France

J2 - P Use of holographic gratings for the investigation of scattered laser light at frequencies ω_0 and $2\omega_0$ in the laser installation "Delphin 1"
N. G. BASOV et al., Lebedev Physical Institute, USSR
K. JUNG et al., Institute of Optics and Spectroscopy, GDR

J3 - P Craterisation process by laser shock and simulation of hypervelocity impacts
M. HALLOUIN, F. COTTET, J. P. ROMAIN, ENSMA, France

J4 - P Laser pulse width and wavelength-dependent ion emission from laser-produced high-Z plasmas
R. DINGER, K. ROHR, H. WEBER, Universität Kaiserslautern, FRG

J5 - P Fine structure of the second harmonic radiation generated during the interaction of an intense neodymium laser pulse with a plane target
Y. ADRIAN, J. BRIAND, M. EL TAMER, A. GOMES, Y. QUEMENER, Université Paul Sabatier, France

J6 - P Spectroscopic emissions of multilayered targets using 1D Lagrangian simulations
Ph. ALATERRE, J. C. GAUTHIER, J. P. GEINDRE, C. POPOVICS, A. POQUERUSSE, Ecole Polytechnique, France

J7 - P Radiation codes using an average ion model approach
L. DRSKA, V. KASPAR, I. STOLL, Technical University of Prague, Czechoslovakia

J8 - P Stabilisation of the Rayleigh-Taylor instability by a shaped ion beam
M. SAPIR, D. HAVAZALET, Negev, Israel

J9 - P Soft X-ray refractometry of laser heated plasmas
R. BENATTAR, Ecole Polytechnique, France

J10 - P X-ray emission model for laser produced plasma
P. LADRACH, W. LAMPART, A. P. SCHWARZENBACH, J. E. BALMER, University of Bern, Switzerland

J11 - P Radiation transport in laser driven microballoon implosions
S. J. ROSE, B. J. MacGOWAN, R. G. EVANS, Rutherford Appleton Laboratory, UK

J12 - P Ablative flow from laser irradiated slabs: a comparison of theory and experiments
J. L. MONTANES, J. R. SANMARTIN, R. RAMIS, ETSI, Spain

J13 - P Spectral analysis of $3\omega_0/2$ emission in laser plasmas
S. J. KARTUNNEN, Technical Research Centre, Finland
T. P. HUGHES, E. McGOLDRICK, S. M. L. SIM, University of Essex, UK

J14 - P Inverse resonance absorption in a magnetised plasma
R. RANKIN, G. A. GARDNER, H. C. BARR, T. J. M. BOYD, University College of North Wales, Gwynedd

J15 - P X-ray and harmonic imaging studies of illumination uniformity for 0.53 μm ablative compressions
J. S. WARK, J. D. KILKENNY, B. J. MacGOWAN, Imperial College, UK
V. ABOITES, E. McGOLDRICK, S. M. L. SIM, University of Essex, UK
D. J. BASSETT, A. R. BELL, I. N. ROSS, Rutherford Appleton Laboratory, UK

J16 - P Large electrostatic fields and double layers in laser produced plasmas
P. LALOUSIS, H. HORA, University of New South Wales, Australia

J17 - P Shock propagation experiments in single and multilayer target foils at 1.06 and 0.53 μm
A. J. RANKIN, Imperial College, UK

J18 - P Thermonuclear spectroscopy with CR-39 track detectors
A. P. FEWS, D. L. HENSHAW, Bristol University, UK
W. T. TONER, Rutherford Appleton Laboratory, UK

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Thursday, 29th September, 1983

Session K : 0900

K1 - I Laser fusion research at NRL
S. BODNER et al., Naval Research Laboratory, USA

K2 - I Short wavelength experiments on Novette
R. L. KAUFMANN, Lawrence Livermore National Laboratory, USA

K3 - C Properties of ablatively accelerated planar target in 0.26 μm laser experiments
R. FABBRO, B. FARAL, Ecole Polytechnique, France
F. COTTET, J. P. ROMAIN, ENSMA, France

K4 - C Fast ion generation and transport in CO_2 laser irradiated ICF targets
C. W. BARNES, Los Alamos National Laboratory, USA

K5 - C Computational results of target compression
N. G. BASOV, P. P. VOLOSEVICH, E. G. GAMALY, Lebedev Institute, USSR

K6 - C Investigation of heating and compression of high aspect ratio targets at Delphin I installation
N. G. BASOV, G. V. SLIZKOV, Lebedev Institute, USSR

Session L : 1100 Posters and tradeshow

L1 - P Laser plasma diagnostics on HELEN
A. J. SUMMERS, M. HUBBARD, R. ALLISON, Atomic Weapons Research Establishment, UK

L2 - P The Novette laser
K R MANES, T. S. HILDUM, J. B. RICHARDS, D. R. SPECK, M. SUMMERS, Lawrence Livermore National Laboratory, USA

L3 - P Picosecond X-ray pulses from laser plasma mirror
M. KALAL, G. LONCAR, L. PINA, M. VRBOVA, Czech Technical University, Czechoslovakia

L4 - P Broad-band soft X-ray diagnostic instruments at the LLNL Novette laser facility
K. G. TIRSELL, P. H. Y. LEE, P. G. NILSON, H. MEDECKI, Lawrence Livermore National Laboratory, USA

L5 - P Subnanosecond X-ray framing camera
N. FINN, T. A. HALL, E. McGOLDRICK, University of Essex, UK

L6 - P A gated X-ray intensifier with a resolution of 50 psec
A. K. L. DYMOKE-BRADSHAW, J. D. HARES, J. D. KILKENNY, J. WESTLAKE, Imperial College, UK

L7 - P X-ray spectroscopy of a laser plasma created by NIXE
W. BRUNNER, M. DICK, S. I. FEDOTOV, E. FORSTER, A. GOTSCH, F. GOTZ, H. GUNKEL, A. MAKSIMTSCHUK, P. V. NICKLES, K. SCHAFER, G. V. SKLIZKOV, I. WILL, W. D. ZIMMER, Central Institute for Optics and Spectroscopy, GDR

L8 - P UV laser-etching of polymer laser targets
P. T. RUMSBY, C. BROWN, K. HOLLINGWORTH, M. DAVIES, Rutherford Appleton Laboratory, UK

Session M : 1345

M1 - I Improvement of compression in new types of targets
T. YABE, C. YAMANAKA, Osaka University, Japan

M2 - C Applications of laser produced plasmas
J. M. SOURES, J. M. FORSYTH, R. FRANKEL, M. C. RICHARDSON, B. YAAKOBI, University of Rochester, USA

M3 - C Laser-exafs studies of heated and unheated aluminium foils
D. K. BRADLEY, J. D. KILKENNY, Imperial College, UK
R. W. EASON, Rutherford Appleton Laboratory, UK
N. GREAVES, Daresbury Laboratory, UK

M4 - C Use of induced spatial incoherence for uniform illumination of laser fusion targets
R. H. LEHMBERG, S. P. OBENSCHAIN, A. J. SCHMITT, B. H. RIPPIN, S. E. BODNER, Naval Research Laboratory, USA

M5 - C Analytical inversion and gain calculations in laser produced hydrogen-like carbon plasmas
W. BRUNNER, Th. SCHLEGER, G. WALLIS, Central Institute for Optics and Spectroscopy, GDR

M6 - C Gain measurements at 182 Å from laser heated carbon fibres
G. PERT, L. D. SHORROCK, Hull University, UK
C. L. S. LEWIS, E. R. MAHONEY, M. J. LAMB, Queen's University, Belfast, UK
M. H. KEY, R. W. EASON, W. T. TONER, Rutherford Appleton Laboratory, UK

Session N : 1600

N1 - I Generation and focusing of light ion beams for fusion
W. SCHMIDT, Karlsruhe Nuclear Research Centre, FRG

N2 - C Status of light ion beam fusion at Sandia National Laboratories
M. M. WIDNER, Sandia National Laboratories. USA

N3 - C Ion beam-plasma interaction and radiation transport simulation in ICF targets: analysis and numerical calculations
G. VELARDE et al., ETSIIM, Spain

N4 - C ICF target physics with heavy ion beams
R. ARNOLD, J. MEYER-TER-VEHN, Max-Planck Institut für Quantenoptik, FRG

N5 - C Measurement of the energy loss of α-particles in hot dense plasma
A. P. FEWS, D. L. HENSHAW, Bristol University, UK
C. J. HOOKER, D. A. PEPLER, S. J. ROSE, W. T. TONER, Rutherford Appleton Laboratory, UK

N6 - C Ion beam interactions in dense plasmas
T. D. BEYNON, University of Birmingham, UK

* * *

Friday, 30th September, 1983

Session O : 0900

O1 - I	Inertial fusion: strategy and potential J. H. NUCKOLLS, Lawrence Livermore National Laboratory, USA
O2 - I	Light matter experiments in Frascati A. CARUSO, ENEA, Italy
O3 - C	Theoretical framework and numerical studies for modelling laser plasma interaction P. L. MASCHERONI, M. A. MAHAFFY, Los Alamos National Laboratory, USA
O4 - C	Nonlinear heat flow in a steadily ablating plasma T. H. KHO, Imperial College, UK

Session P : 1100

P1 - C	Heat flux down steep temperature gradients J. F. LUCIANI, P. MORA, J. VIRMONT, Ecole Polytechnique, France
P2 - C	Non local contribution to thermal transport D. SHVARTS, T. BAR NOY, Nuclear Research Centre - Negev, Israel
P3 - C	Kinetic treatment of heat flow instabilities in laser produced plasmas E. M. EPPERLEIN, M. G. HAINES, Imperial College, UK
P4 - C	Solution of the time independent Vlasov-Fokker-Planck equation for a laser-produced ablating plasma A. R. BELL, Rutherford Appleton Laboratory, UK
P5 - C	Applications of incomplete factorial designs to ICF modelling and experimental design L. SUTER, Lawrence Livermore National Laboratory, USA

* * *

Laser matter interaction studies at GRECO Interaction Laser Mattiere Palaiseau

E. Fabre,
Ecole Polytechnique, 91128 Palaiseau, Cedex, France.

The experimental studies carried on at the GILM are presented.

On interaction, spectral analysis of backscattered light and harmonics generation are analysed to study parametric instabilities in homogeneous plasmas and also linear conversion by mode coupling.

Transport studies concerning fast electron transport, ablation velocity and efficiency measurements on laser accelerated thin foils and also shock studies are presented.

X ray spectroscopy experiments are developed dealing with temperature and density measurements, Stark broadening and ionic species population distributions.

Finally two beam irradiation experiments at short wavelength 0.26 μm, of glass microballoons will be described.

A 2

Implications of Absorption and Transport Experiments With CO_2 Lasers at Los Alamos

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Recent experiments at Los Alamos have shown enhanced absorption at high intensity,[1] evidence for electron transport strongly modified by self-generated magnetic fields,[2] and moderately well collimated ion emission from flat or spherical targets.[3,4] Theoretical modeling with the WAVE and VENUS particle-in-cell simulation codes have reproduced all of these effects. The theory and experimental data are compared and the impact of these results on the inertial fusion program is discussed.

1 D. R. Bach, et al, Phys. Rev. Lett. 50, 2082 (1983).
2 M. Yates, et al, Phys. Rev. Lett. 49, 1702 (1982).
3 T. H. Tan and A. H. Williams, LA-UR-83-1577 (1983) 1983 Anomalous Absorption Conference.
4 D. R. Bach and D. W. Forslund, 16th ECLIM, 1983.

This work performed under the auspices of the U.S. Department of Energy.

A 3

16th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER

"16TH ECLIM"

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EFFECT OF COATING MATERIAL IN 1.06 µm DIRECTLY DRIVEN LASER IMPLOSIONS

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Abstract :

Directly driven laser implosions have been performed at C.E.L. with the 8 beams Nd-glass facility OCTAL, delivering 1.06 µm - 280 ps pulses at the power level ≈ 1 TW on target.

Targets were glass microballoons 120 µm diameter coated with Aℓ, Cu or Au. The irradiation geometry - two f/1 clusters of 4 beams -, allowed high irradiances (local value 10^{16} W.cm^{-2} for an average value ≈ 3.10^{15} W.cm^{-2}) so that interaction was dominated by suprathermal electrons generation. Diagnostics mainly concerned X-ray emission (pinhole and streaked cameras, K-edge filtered X-ray diodes, crystal spectrograph with 1 D spatial resolution) and neutrons.

Experimental evidence was given of an enhanced neutron yield when Z and density of the coating material are increased, for a given target mass. Several effects can be invoqued to give account of this result : more efficient suprathermal electrons generation or (and) deposition ; X-ray preheat ; 2 D effects ...

Experimental results are compared to 1 D numerical simulations carried out with the lagrangian FCI1 code in which suprathermal electrons and X-ray transport processes are simulated by multigroups diffusion methods.

X-RADIOGRAPHIC STUDIES OF ABLATIVELY IMPLODED PLASTIC SHELLS

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Two sets of experiments have been carried out to study the performance of ablatively imploded polystyrene shell targets under conditions attempting to minimise preheating and Rayleigh-Taylor effects and to maximise thermal smoothing and illumination uniformity effects. Typically targets with $\phi \approx 120 - 150\ \mu m$ and $r/\Delta r \approx 5 - 7$ have been irradiated with six $\lambda = 0.53\ \mu m$ beams at irradiance levels $I \approx 0.4 - 4 \times 10^{14}\ W\ cm^{-2}$ with drive laser pulse lengths $\tau \approx 1 - 1.3$ nsec. Pulsed X-ray radiography of imploding shells using an auxillary flash X-ray laser plasma source has been the primary diagnostic. Imaging was by the pinhole camera method but using active X-ray image recorders viz an X-ray streak camera in focus mode and a P11 phosphor plate fibre optically coupled to an image intensifier. The latter system was used at x 47 magnification giving a spatial resolution in the target plane of $\approx 10\ \mu m$ and a frame time of ≈ 100 psec.

Radiographs were taken early in the implosion history using ≈ 1.5 keV probe energy to map the structure of the shell outer boundary. These show pronounced hexagonal structure reflecting the target illumination non-uniformities arising from six overlapping beams and also show non-uniformities in drive pressure associated with the presence of the target support stalk. Radiographs taken near peak compression time using ≈ 2.5 keV probe energy show, to within the resolution limits, well-defined spherical core geometry. Abel inversion of the absorption features indicate core densities of the shell material of up to $10\ g\ cm^{-3}$ at stagnation. Analysis of ≈ 40 data shots and comparison with Medusa simulations indicate that these low aspect ratio targets performed as well as expected i.e. the targets had adequate preheat supression and thermal smoothing to implode as predicted by a code assuming only shock preheating and uniform illumination. Preliminary results will be presented extending pulsed X-radiographic techniques to using quasi monochromatic ($\Delta E/E \approx 5\%$) probe radiation in conjunction with projection from a quasi-point X-ray source ($\approx 10\ \mu m$).

A 5

Emission Diagnosis of 0.53 μm Ablative Implosions

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Recent experiments at Rutherford Appleton Laboratory have used up to 350 J of $\lambda = 0.53$ μm light in ½ nanosecond to implode microshells. Targets were designed such that sufficient kinetic energy was given to the pusher to produce hot compressed cores. Results of emission diagnosis using X-rays and nuclear particles will be described.

APPLICATIONS OF ION EMISSION MEASUREMENTS FOR ESTIMATES OF THE COMPRESSION PARAMETERS OF SPHERICAL PLASMAS

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The set of ion diagnostics used on the nine-channel laser system Kalmar (λ = 1,06 μm, $E_L \leqslant 200$ J, τ_L= 1,5 ns) consisted of ion collectors, electrostatic ion analyser and Thomson parabola ion analyzer, made possible for experimental measurements of the mass ablation rate and electron temperature for glass - SiO_2 microspheres of a diameter 2 $R_o \sim (140\div30)$ μm and a wall thickness 0,7÷5 μm irradiated at $\sim 10^{13}$ W/cm^2. We obtained $\dot{m}\left[g\ cm^{-2}\ s^{-1}\right] = 9{,}80\ 10^4 \cdot \left(q_{abs}/10^{13}\ W\ cm^{-2}\right)^{0,85}$ and $Te\left[eV\right] = 625\left(q_{abs}/10^{13}\ W\ cm^{-2}\right)^{0,17}$. Rightness of formula on the maximum implosion velocity $V_{imp\ max} = C_s \ln\left(m_o/m_o - m_{abl}\right)$ [where: C_s- isotheremal sound velocity, m_o- initial mass of the target, m_{abl}- ablated mas] was confirmed in the double shells experiment. Most favourable wall thickness of SiO_2 microspheres [for maximum hydrodynamic efficiency] was found: $\Delta r\left[\mu m\right] = 0{,}78\left(q_{abs}/10^{13}\ W\ cm^{-2}\right)^{0,84}$. Mean implosion velocity for such microspheres is:
$\overline{V}_{imp}\left[cm \cdot s^{-1}\right] \cong 0{,}6\ C_s \cong 1{,}0\ 10^7\left(q_{abs}/10^{13}\ W\ cm^{-2}\right)^{0,09}$.
Ablation pressure inferred from measurements of mass ablation is $P_{abl} = 2{,}23\left(q_{abs}/10^{13}\ W\ cm^{-2}\right)^{0,94}$. Relative position of the critical density for $q_{abs} \approx 10^{13}$ W cm^{-2} was estimated by R_{cr}/R_o= 1 3 and the thermal smothing 2÷7 according to the used model.

B 1

Effects of self-induced magnetic field on Rayleigh-Taylor Instability

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In the analysis of the Rayleigh-Taylor instability, the effect of self-induced magnetic field has not been included. Here, we re-examine the magnitude of the self-induced magnetic field in the R-T instability previously studied[1] and derive the scaling law of its amplitude.

The scaling law shows that the magnetic field amplitude becomes large enough to influence electron transport from absorption region to ablation front. A newly developed 2-D fluid particle code[2] is used to check the scaling law and to examine the consequence of electron transport affected by the self-induced magnetic field. The thermal energy preferentially flow through the magnetic neutral sheet and hence the mode is converted into higher mode[3] even at a small amplitude a, e.i. $ak<1$, k being the wavenumber.

1) T.Yabe and K.Niu : J. Phys. Soc. Japan 40(1976) 1221.
2) A.Nishiguchi and T.Yabe : J. Comp. Phys. 47(1982) 297 ; A.Nishiguchi and T.Yabe : J. Comp. Phys. (1983) in print.
3) A.Nishiguchi and T.Yabe : Research Rep. ILE, Osaka Univ., ILE-8307P, June (1983).

COMPARISON OF THE PROPERTIES OF ABLATIVELY ACCELERATED TARGET BEETWEEN 1.06 μm AND 0.26 μm LASER LIGHT

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The properties of ablatively accelerated Aluminium target to high velocity (- 10^6 - 10^7 cm/s) have been studied in experiments using 1.06 μm or 0.26 μm laser light. By measuring the spatial and temporal evolution of different parameters such as target velocity or target preheating (with double-foil technique and optical pyrometry) we can specify the effect of several processes of transport of energy in these experiments : shock wave, thermal and suprathermal electronic conduction, X ray radiation.

B 3

SPECTROSCOPIC STUDIES OF NON-DEBYE DISCHARGE PLASMAS

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A cold, dense Ar/H z-pinch plasma source with few particles per Debye sphere was developed as part of a continuing study of the spectroscopy of strongly coupled plasmas in this laboratory. Previous experiments here have been performed on similar z-pinch plasmas with densities of n_e=1-3X$10^{24}m^{-3}$ and T_e=20,000-30,000 K. In the present work, densities of 1-9X$10^{24}m^{-3}$ were measured interferometrically and temperatures of 2-3.5±0.5eV were deduced from the relative abundance of Ar ion lines.

Lyman-α emission profiles were measured to investigate the occurence of satellite features caused by extrema in the H/Ar ion interaction potential. Although such satellites were observed in the previous z-pinch experiments, no satellites were found at comparable plasma conditions in the present experiment. The satellites may thus have been simply due to impurity lines, or possibly due to regions of hydrogen emission outside the pinch core which were not present in the current experiment due to the higher filling gas pressures used. Some structure in the Lyman-α wing at ~ +8Å was however observed at a higher density condition (n_e=8X$10^{24}m^{-3}$, T_e=3eV) in the present experiment. The structure was still evident in the red wing when the continuum emission level was subtracted, thereby indicating that the feature was due to H/perturber interactions. Some asymmetry was also observed in the Lyman-α profiles and was found to increase with increasing density, possibly due to the greater contribution of higher order terms in the multipole expansion of the emitter-perturber interaction.

Future experiments will study the Lyman-α profiles in absorption using frequency upconversion techniques at the Rutherford UV Radiation Facility. Thomson scattering in the UV will also be attempted to further extend the range of diagnostics, and to alter the non-Debye plasma behavior by laser heating.

B 4

SOFT X-RAY POPULATION INVERSION USING RESONANT PHOTO-EXCITATION

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Experiments have been carried out to investigate the feasibility of obtaining soft X-ray laser action using resonant photo-excitation in laser produced plasmas. In one scheme the Na X $1s^2\ ^1S - 1s2p\ ^1P$ line at 11.00 Å from one plasma is used to pump the Ne IX $1s^2\ ^1S - 1s4p\ ^1P$ transition, and so produce population inversion between the n = 4,3 and n = 2 levels of helium-like neon in a nearby plasma. The laser target was constructed by ion-implanting neon into one side of a thin aluminium foil and depositing a thin layer of sodium fluoride on the other side. The neon side was first irradiated with a 100 ps laser pulse at $\sim 3 \times 10^{13}$ W cm^{-2}. About 300 ps later the neon-containing plasma has reached the appropriate conditions and then the sodium fluoride side of the target is irradiated. Space resolved X-ray spectroscopy was used to investigate the state of ionisation of the neon plasma. The effect of the pumping radiation on the neon plasma was investigated by recording the neon spectrum with and without the pumping radiation. Time-resolved X-ray spectroscopy was also used to measure the time history of the pumping pulse. In a second scheme, the F IX Lyman-α was used to photo-pump a dielectronic satellite transition in lithium-like fluorine. Here the laser target was made by depositing magnesium fluoride on both sides of a thin aluminium foil. The X-ray emission spectra of the pumped and pumping plasmas were recorded. Measurements were also made using X-ray spectral absorption as a signature of photo-pumping.

EXPERIMENTAL EVIDENCE FOR AXIAL MAGNETIC FIELDS IN PLASMA CREATED BY INTERACTION OF AN INTENSE LASER PULSE WITH A PLANE TARGET

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Evidence of axial magnetic fields in laser-matter interaction phenomena have been obtained from Faraday's effect measurement performed on backscattered radiation.More precisely,the experimental device was the following.The source was the C.N.R.S.'1,064 μm neodynium laser,located in the Ecole Polytechnique on Palaiseau,converted to 0,532 μm by a KDP crystal,giving pulses of 600 ps. with energy ranging from 1 to 8 Joules.Part of the incident radiation was sent onto the slit of a streak camera by means of a prismatic slide and a delay line.The plasma's backscattered radiation was send toward the same streak camera through a lens imaging the plasma onto the slit.Attenuators and a 0,532 μm interference filter were located just in front of the slit which was divided into two parts allowing the passage of radiation's carrying orthogonal polarization,the other half (P) corresponded to the orthogonal polarization.

If there is no axial magnetic field,not any radiation can go through (P),except the one occuring from a part of the principal backscattered radiation which is slightly depolarized (~10%).The Faraday's rotation study was done by rotating (P). One experimentally verify that a great part (about 30%) of the backscattered radiation have changed his polarization.This part is the smaller for a (P)'s few degrees rotation,corresponding to axial magnetic fields of about one megagauss.

B 5

AXIAL MAGNETIC FIELD GROWTH IN LASER-MATTER INTERACTION PLASMA

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For several years there have been many theorical and experimental articles published about toroidal magnetic fields appearing in plasmas created by interaction of an intense laser pulse with a plane target.These fields are given various sources,the most commonly accepted being the ($\vec{\nabla} n \wedge \vec{\nabla} T$) one.The corresponding theory is generally driven from electrons and ions fluid equations.

Another way is to carry it from magnetohydrodynamics equations.Then one can show that the electromotive fields E,arising from plasma's displacement across a magnetic field,can give rise to axial magnetic fields obeying the following equation:

$$(\partial_t + \vec{v}.\vec{\nabla})\vec{B} = (\vec{B}.\vec{\nabla})\vec{v} - (\vec{\nabla}.\vec{v})\vec{B} + \vec{\nabla}^2 B \quad , \sigma$$

where $\vec{v}$ = plasma's velocity

σ = electrical plasma's conductivity for B=0.

This equation have been established under the following assumptions:

* Magnetic Reynolds' number>1 (which is commonly the case for such plasmas)

* limitative effects arising from Laplace's force and Hall effects have been neglected

* colinear temperature and density gradients.

Analytical study has been carried along for simple cases corresponding to plane targets and cylindrical geometry.It leads to axial magnetic field's values of about 4 Megagauss.

ABSTRACT 16th E.C.L.I.M.

Electron Heat Flow with Inverse Bremmsstrahlung and Ion Motion

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Our Fokker-Planck code[1] (1-D in space, axisymmetric 2-D in velocity) has been modified to include inverse Bremsstrahlung heating[2] and self-consistent ion motion. Simulations run with $\lambda = 1\ \mu$, $I = 3 \times 10^{14}$ W/cm^2, $Z = 4$ gave coronal temperatures of order 2.5 keV, absorption of 30% and heat fluxes of 10-15% of the free streaming value, near the critical surface. The peak of $Fe(V_x)$ is displaced from the ion fluid velocity by several times (up to 5 C_s) the ion sound speed, which suggests that the system is ion accoustic unstable. We will report results for other values of Z and I.

1 J.P. Matte and J. Virmont, Phys. Rev. Lett. 49, 1936 (1982).
2 A.B. Langdon, Phys. Rev. Lett. 44, 575 (1980).

B 7

ION FLUCTUATIONS IN STIMULATED RAMAN SCATTERING

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Temporal behaviour of stimulated Raman scattering (SRS) in inhomogeneous plasma is investigated. WKB-model includes the parametric decay of the SRS-excited plasma wave $E_1(k_1,\omega_1)$ into an ion acoustic mode $E_s(2k_1,\omega_s)$ and another plasma wave $E_2(-k_1,\omega_1-\omega_s)$. The ensuing five-wave system is solved numerically in time and space assuming a relatively long gradient scalelength of few hundred laser wavelengths. The interaction region turns out to be very small $L_{int} \sim \sqrt{6}\lambda_D(k_1L_n)^{\frac{1}{2}}$ due to a large wavenumber mismatch.

With parameters $v_0/v_e = 1$, $v_e/c = 0.042$, $k_0L_n = 3750$, $(m_e/m_i)^{\frac{1}{2}} = 0.015$, $\Gamma_1/\omega_1 = 0.02$ and $\Gamma_s/\omega_s = 0.06$ the SRS-reflectivity oscillates between 1.7 % and zero with a period $\omega_0 t = 1.8\times10^4$ (10 ps for 1.06 μm light). Low peak reflectivities show that the nonlinear damping due to plasma wave decay dominates the primary SRS-process. In the limit $\Gamma_s/\omega_s \to 0$ the Raman scattering is completely quenched at $\omega_0 t \approx 3.6\times10^4$ (~ 20 ps) and another SRS-burst appears about 25 ps later corresponding roughly to the ion acoustic transit time. Considerably higher SRS-reflectivities are obtained when the linear damping of ion waves is increased. In this limit the secondary plasma wave decay is not able to prevent the Raman growth and also the time structure disappears.

Further cascading of plasma waves modifies the results only slightly. This indicates that the nonlinear damping in SRS-process is determined mainly by the secondary plasma wave decay.

B 8

VALIDITY OF A FEW CURRENT TEMPERATURE DIAGNOSTICS IN THE CRITICAL DENSITY REGION.

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Current electron temperature diagnostics based on the continuous spectrum are revised for plasmas strongly out of LTE. We study as an example a Nd laser produced aluminium plasma at the critical density of $10^{21} e^-/cc$, considering the equilibrium (electron distribution function of the form $e^{-(v/v_\circ)^5}$ reached when inverse Bremsstrahlung is the dominant heating process(1). The choice of the atomic physics approximation used to determine the radiative power losses $P(h\nu)$, either for Bremsstrahlung(2) or for radiative recombination. has little influence on the temperature T_e given by the current diagnostic $d \log P(h\nu)/d(h\nu) = 1/kT_e$. On the contrary, substituting the non LTE distribution to the Maxwellian one leads to a strong modification of the above slope. Therefore, when the discussed diagnostic is uncarefully applied to the non LTE plasma, it leads to large systematic errors in the evaluation of the temperatures.

(1) A.B. Langdon, Phys. Rev. Lett. 44, 575 (1980).

(2) M. Lamoureux, C. Möller and P. Jaeglé, Physics Letters, Vol 95 A, n°6, p 297 (1983).

B 9

RESONANT ABSORPTION IN A STEEP DENSITY GRADIENT

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We use the capacitor model to study the resonant absorption in a hot, unmagnetised, maxwellien, inhomogeneous plasma. We integrate the linearised Vlasov equation to get a nonlocal dispersion relation for the Fourier transform of the electric field. We solve this dispersion relation analytically for $L \gtrsim 600\,\lambda_D$, and numerically for $10\,\lambda_D \lesssim L \lesssim 600\,\lambda_D$, where L is the density scale length. The solution is given by an Airy-type function damped by the Landau effect. We also study the effect of a finite electron-ion collision rate on the electric field structure.

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ELECTRON DENSITY PROFILES OF LASER PRODUCED H_e PLASMA BEFORE AND AFTER SHOCK WAVE REFLECTION

Recent experimental results are reported concerning the action of a convergent shock wave on a plasma of intermediate density. The plasma was produced by focusing 1 GW,20 ns laser pulse in H_e at 1100 torr initial pressure. A strong shock wave propagated in the gas, and was reflected at R = 0.5 cm from the centre by two concentric spherical bowls. For absorbed laser energy of 8 j, the wave reached the reflecting surface with M $\sim$ 6.5 Mach number. As a consequence a convergent shock was produced, moving towards the centre.

Electron density distribution for different times up to 1200 ns is given by Abel inversion of holographic interferential patterns. n_e distribution during the converging shock is compared with n_e distribution in a free expansion experiment for the same time and absorbed energy. A net increase of n_e (a factor $\gtrsim$ 10) is apparent close to the centre when the converging shock reaches its maximum effect.

No analytical model is possible for such a motion. One-dimensional numerical simulation is reported, showing some features of hydrodynamics in spherical geometry.

B11

RIPPING IN THE CRITICAL SURFACE OF A LASER PRODUCED LASER

IN PRESENCE OF ANISOTROPIC ION-ACOUSTIC TURBULENCE

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ABSTRACT

The critical surface can be unstable to coherent rippling perturbations due to the action of negative pressure induced by the random magnetic field associated with ion-acoustic turbulence. The negative magnetic pressure occurs if there exists a preferential orientation of the random magnetic field (anisotropy of the ion-acoustic turbulence) when the non-potential component of the magnetic pressure more than compensate the potential part.

B12

Ion profiles of laser produced C plasmas

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The ion expansion structure of a C plasma produced by a Nd-YAG laser pulse (20 ns) at low energies (below 0.1 J) has been investigated in the asymptotic range. Using the combined time-of-flight retarding potential method, energy spectra are resolved for the charge states (C^+, C^{2+}, C^{3+}) produced.

It is found that for an obliquely incident laser pulse the expansion directions of the ions strongly depend both on their charge and on the laser energy. It seems, that the results are influenced essentially by ionisation and recombination effects during the expansion in the interaction volume with the laser. No recombination effects could be observed at larger distances from the focus (0.3 m to 2 m) in the present experiment.

B13

Numerical Methods for Radiation Transfer in Lasing Media

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A simulation of the performance of an x-radiation laser involves many complex aspects. In this paper one problem is examined: the solution of the coupled radiative transfer - atomic rate equations for a lasing media. Both time dependent and time-independent problems have been investigated.

Two problems must be considered. Firstly the formal (emissivity and opacity known) solution of the radiation transfer equation. Secondly the iterative solution of non-LTE problem must be investigated.

The former is treated by numerical integration (using finite differences) *along the characteristics of the transfer equation*. The Feautrier (U-V) variables are unsuitable even for time independent problems.

Non-LTE problems have been solved using the equivalent two level atom approach. The source function is not a useful concept for inverted transitions so we have solved the problems using either partial linearisation or Λ iteration for these transitions. The former has similar convergence properties to solutions based on iterating for the source function if the transition is not inverted.

B 14

Instability and Chaos in Laser Plasma Interaction

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Informal Abstract

Three and four wave couplings lead to chaotic states. The theory is applied to filamentation and self focusing.

B15

COMPARATIVE MEASUREMENTS OF PLASMA SMOOTHING OF LASER BEAM MODULATION AT 1.05, 0.53 AND 0.35 μm.

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Foil targets have been irradiated with spatially modulated laser beams at 1.05, 0.53 and 0.35 μm. X-ray shadowgraphy and optical streak photography have been used to measure the degree of smoothing of the imposed beam modulations. The results are interpreted as evidence of lateral diffusion of energy in the region between the critical density and ablation front. The x-ray studies have shown the smoothing to scale as $(I\lambda^2)^{1.5}$, while the optical streak approach has probed earlier in time (on a sub-nsec scale) where hydrodynamic effects may not significantly contribute to the amount of smoothing observed.

TIME RESOLVED LINE BROADENING AT 1.05 μm, 0.53 μm and 0.35 μm

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An X-ray streak camera in conjunction with a Bragg diffracting crystal has been used to time resolve the Hydrogen-like np - ls transitions of Aluminium. The electron density of the emitting plasma is estimated from the spectral line widths and shown to vary from $\sim 5 \times 10^{21}$ cm^{-3} for $\lambda = 1.054$ μm to $\sim 2 \times 10^{22}$ cm^{-3} for $\lambda = 0.35$ μm light.

Review of Suprathermal Transport Experiments at Los Alamos

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Laser-target interactions at 10 μm are dominated by the production and transport of suprathermal electrons. Experiments have been performed at Los Alamos using planar and spherical targets to characterize and understand both axial (radial) electron transport (to determine preheat) and lateral transport (which affects symmetry of deposition). We have used bremsstrahlung and K_α radiation as indicators of electron deposition in specific regions of the target and the bremsstrahlung spectrum to define hot-electron temperature. Nonuniform illumination of planar or spherical targets causes intense self-generated fields which transport $\gtrsim$ 2/3 the total deposited energy to large distances at velocities $\gtrsim 10^9$ cm/s. Spherical experiments with nearly uniform illumination show good agreement between measurements of radial electron penetration deduced from K_α or bremsstrahlung yield. The transport is characteristic of electron temperatures close to the experimentally determined bremsstrahlung slope. LASNEX calculations cannot accurately predict both the transport and the bremsstrahlung spectrum simultaneously. From this data we can empirically determine the ablator thickness required to produce 1% preheat levels in direct-drive targets at 10^{15} W/cm^2.

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

C 2

Suppression of Preheat of Targets at the CO_2 Laser Irradiation

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Abstract

A novel method aiming suppression of the target preheat by hot electrons is investigated under 10.6μm laser irradiation. A thick plate is set in front of the target so as to modify the formation of the electrostatic and magnetic fields, consequently truncate the spectra of hot electrons which are preferentially accelerated tward the underdense region via resonantly pumped plasma waves. Experimental results show remarcable reduction of the high energy particles in the target rear side in comparison with a conventional single foil target. We will discuss a simple model where the energetic hot electrons can be insulated from the target rear side by the cooperation of double foil effects and relevant magnetic field effects.

C 3

TRANSPORT EXPERIMENTS IN SPHERICAL GEOMETRY WITH 1.05 μm AND 0.53 μm IRRADIATION

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Experiments with six beam spherical irradiation of layered targets at 0.53 μm and 1.05 μm are reviewed. New results of a set of experiments at 1.05 μm with incident irradiances up to 10^{15} W cm^{2} in the case of uniform emission are presented. Faraday rotation and interferometric measurements show the $\nabla n \times \nabla T$ magnetic field disappearing as the focusing conditions are changed from a centre focus to focusing beyond the sphere's centre. Density profiles are measured up to critical density at various times during the ablation. Mass ablation rates are measured by time resolved X-ray spectroscopy. A timing fiducial is provided by for absolute timing by short pulse laser irradiating a separate target. Simultaneous measurements of Si, Mg, Na and Ca X-ray emission from the underlying glass show no significant difference in the emission time of the range of elements, indicating a steep temperature wave.

C 4

KMSF U-1386

Electron Transport Experiments on Spherical Targets

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The transport of suprathermal electrons has been studied experimentally using layered spherical targets uniformly irradiated at high intensity (> 4×10^{15} W/cm^2)) by 1.05 μm light from the CHROMA laser. Penetration of suprathermal electrons into the target was determined from the yield of Kα x-rays from thin titanium and vanadium layers, measured with two crystal spectrographs. A 3 μm thick outer parylene layer prevented heating of the metallic layers by thermal electrons. Other instruments recording data on these shots included plasma calorimeters for absorbed energy, x-ray diodes and scintillators for hard x-ray continuum spectra, and charge collectors for fast ions.

For these experimental conditions, resonance absorption dominates, so the total energy in fast electrons can be taken to be the measured absorbed energy. The temperature characterizing their distribution is deduced from the x-ray bremsstrahlung spectrum. Using these values to specify the suprathermal source distribution, we estimated the fast-electron energy distribution and the Kα emission in two ways - from the Harrach and Kidder analytical model and from a one-dimensional fluid hydrodynamics simulation that treats suprathermal electrons by multigroup diffusion. Both methods predict Kα yields approximately 20 times the measured value. By imposing an arbitrary group-by-group flux limit on the suprathermal electrons, the multigroup simulation could be made to agree with the measured Kα yield from the outer (titanium) layer, but could not simultaneously match the yield from the inner (vanadium) layer.

C5

Simulations and Theoretical Implications of KMS Transport Experiments for 1.05 μm and 0.53 μm Laser Irradiation

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ABSTRACT

Recent experiments at KMS Fusion, Inc. probed the transport properties of layered spherical targets with plastic ablators and high-z substrates. Two wavelengths were used (1.05 μm and 0.53 μm). Some experiments (10^{14} W/cm^2 < I_L < 10^{15} W/cm^2) were designed to study thermal transport (electron conduction) by looking at plasma density profiles, critical surface trajectories and ablation rates. Other experiments (I_L = 5×10^{15} W/cm^2) specifically measured the penetration rate of suprathermal electrons by looking at K_α emission from several substrate layers. Both sets of experiments have been analyzed with a one-dimensional simulation code. One conclusion from the simulations is that energy transport via electron conduction is inhibited relative to classical values, especially for λ_L 1.05 μm. A more surprising conclusion is that suprathermal electron penetration must be inhibited as well, relative to the predictions of standard multigroup diffusion models. The effects of slightly modified diffusion models, based on simple Fokker-Planck considerations, are discussed.

C 6

Coronal Expansion of Laser - Produced Plasmas

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Informal Abstract

Structure and time evolution of the coronal expansion of a laser plasma have been studied for a range of laser wavelengths and intensities including multi - ion effects and hot electrons in steady flow, self similar expansion and fast ion regimes.

D1

Strong Density Fluctuations in Laser Heated Plasma

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Abstract

A variety of processes, including electron-ion streaming and parametric decays, can lead to strongly enhanced electron and ion density fluctuations. Highly non-equilibrium plasma conditions may result which can modify transport behavior. Such conditions are readily achieved in the interaction of a strong electromagnetic wave with plasma, where even below threshold for exciting parametric instability, the presence of a strong pump wave can lead to enhanced fluctuations and increased electron collisionality. In addition, parametric instabilities such as stimulated Brillouin and Raman scattering, two-plasmon and electron-ion decay, and filamentation and modulational instability can drive up large density fluctuations. It is interesting that comparable fluctuation levels ($\gtrsim$ 10%) can be generated by these very different mechanisms, perhaps reflecting the saturating characteristic at such high amplitudes.
In this talk, I shall summarize experimental results of measured fluctuation levels accompanying various decays, including a first-time determination of the ion turbulence spectrum S(k) generated in the plane of the electric field of a strong pump wave when high intensity CO_2 laser radiation interacts with plasma, as well as discuss theoretical questions which we are pursuing.

Review of Laser-Plasma Interaction Studies at Darmstadt

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The main effort of theoretical laser-plasma interaction studies is concentrated on the investigation of

a) excitation of parametric effects in laser plasmas;
b) high amplitude electron plasma waves and wave breaking due to resonance absorption;
c) particle trapping and acceleration by electron plasma waves;
d) stability of imploding fusion pellets.

In an unmagnetized plasma all waves under consideration can be characterized by their electric fields and currents. By making use of this concept a general nonlinear wave equation is derived which describes the whole variety of parametric wave-wave interactions under arbitrary angles in a laser plasma. The equation represents a generalisation of the well-known Rosenbluth-Sagdeev envelope relation. We show further that by performing a suitable Lorentz transformation inelastic scattering of waves (e.g. Raman scattering) is reduced to elastic scattering (reflection). With the help of the ponderomotive force a simple physical interpretation of the equation is given and its extension to higher amplitudes is discussed.
Results will be presented on the shape of a high amplitude electron plasma wave in resonance absorption and other aspects (e.g. wavebreaking) of such highly nonlinear waves will be discussed. With particular attention particle trapping and acceleration by a high amplitude wave are studied (poster).
Several expressions for the ponderomotive force of time dependent electromagnetic field amplitudes are known from the literature which differ from each other. We have investigated this problem and present our formula; the reason for the differences will be indicated.
The nonlinear regime of Rayleigh-Taylor instability is investigated by studying bubble motion in terms of a Fourier series expansion. Consistent predictions for bubble velocities and curvature are obtained.

UNRESOLVED ASPECT OF LASER LIGHT SCATTERING FROM SOLID TARGET

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In the wavelenght region 0.4-0.5 μm, total reflectivity and amount of backscattering have been measured both for low and high Z target, at different intensities and pulse durations.

Spectra of the light scattered in different directions have been taken. Common features are: an unshifted specular reflection (observed with tilted target); a red component in backscattering that moves toward IR with increasing target tilt and, for low Z target, the appearance of an extended blue component (at irradiation above a few 10^{14} Wcm^{-2}) which can be detected only backwards.

The general features observed are not in contradiction with the usually accepted picture that scattering of radiation takes place through a reflection at the turning point and through SBS. However we find difficulties in comparing some of the results with the predictions of the theory. At low intensities there are conditions in which the expected gain for SBS appears too low to justify the observed backscattering, while on the contrary, at higher intensity, there is a tendency of the reflectivity to saturate already at a few per cent. At normal incidence the peak of the dominant IR component of backscattering occurs at a wavelenght that does not change with irradiance. If this reflection is ascribed to SBS, its IR shift suggests always $M \ll 1$, a condition difficult to understand at high fluxes. Furthermore, with short pulses, the expansion of the plasma is expected to increase the frequency of the scattered light. Beside shifting also the SBS spectra somewhat toward blue, this effect should contribute to give a definitely blue spectrum for the light specularly reflected. However in the specular reflection no blue component has been observed.

D 4

The Nonlinear Damping Mechanism of SBS in an Homogeneous Plasma.

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The spatial and temporal development of the SBS ion wave energy density was determined by using ruby laser light scattering techniques combined with a picosecond streak camera. By comparing the various experimental results with solutions of theoretical treatments it was found that harmonic damping of the ion wave represents the nonlinear mechanism causing the pronounced bend in the backscatter level plotted versus power density. In spite of this damping the Manley-Rowe limit is reached, nonetheless.

D 5

$3\omega_o/2$ HARMONIC EMISSION FROM THIN FOILS

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New experimental observations of temporally and spectrally resolved $3\omega_o/2$ harmonic emission from 1.05 μm laser irradiated thin foils are presented. A single beam of the Rutherford Appleton Laboratory Nd glass laser system with energies on target of up to 100 J in 500 ps was focussed onto the thin foils with an f/1 aspheric doublet lens. The foils of various atomic number materials (aluminium, polystyrene and mylar) were chosen for thicknesses which would result in their becoming underdense close to the peak of the laser pulse. A range of irradiances on target between 4×10^{14} W cm^{-2} and 2×10^{16} W cm^{-2} was obtained by varying the focal spot size between 30-250 μm diameter. The time the laser took to burn through the foil was estimated from temporally resolved observations of the transmitted and incident laser light.

The evolution and spectral features of the backscattered and forwardscattered harmonic light are discussed with the aid of various models of $3\omega_o/2$ harmonic generation.

D 6

SUNION

- A Numerical Code for Laser-Plasma Interaction

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Abstract

SUNION solves the combined problem of ion expansion and of resonance absorption of p-polarized electromagnetic radiation. The basic equations are the Lagrangian equations of motion for the (cold) ions, the two-component Schrödinger-type wave equation for the radiation field and Poisson's equation for the ambipolar electrostatic field. Well-posed initial and boundary conditions are derived within the ponderomotive approximation. Efficiency and accuracy of the code are checked by reproducing known results found in literature for various simplifications. The first time-derivative in the complex wave equation is found to be useful for an effective solution method (CRANK-NICHOLSON-scheme) avoiding iterative schemes. The absorption ceofficient turns out to depend on the scale length near critical density, reflecting profile steepening which occurs within the first twenty ion periods.

Furthermore, a new type of numerical instability is found. It originates from charge separation and is correlated with a new kind of singularity in the plasma flow.

[1]

LASER INTERACTION EXPERIMENTS WITH DOUBLE-SHELL TARGETS

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S.Denus, J.Farny, W.Mroz, J.Wolowski, E.Woryna
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Experiments with glass laser system "Kalmar" using double-shell targets were conducted in a regime of ablative acceleration of the outer shell. The laser energy was 200 J in 1.5FWHM pulse. Target dynamics and plasma corona parameters were investigated with X-ray, optical, spectroscopic and ion diagnostics. X-ray pin-hole plasma images gave evidence of spherical symmetry of the inner shell heating upon collision with the outer one.

Volume compression of the inner shell was about 150. Space-and-time-resolved measurements of the plasma second harmonic emission gave the estimation of the outer shell velocity (about 10^7 cm/s) before collision. Thomson ion analyser and time-of-flight ion collector array were used for measuring the evaporated target mass. Data obtained with this method gave estimation of hydrodynamic efficiency of shell accelerattion.

E 2

Review of the Laser-Plasma Work at MPQ Garching, FRG

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Our main tool for laser-plasma experiments is the ASTERIX III iodine laser. Recently $KD^{+}P$ cristals have been introduced to produce the second and third harmonic of the 1.3 µm laser light with maximum efficiencies of 63% and 44%, respectively. Further increase of these values will be achieved by introducing a telescope to reduce the divergence of the beam. With this facility several physical problems have been investigated at different wavelengths and in a wide range of intensities.

Our previous studies of lateral fast electron transport at 1.3 µm/~6.10^{15}W cm^{-2} experiments have been complemented by irradiation of free falling spherical targets. Fast electron transport around spheres is in agreement with the expectations derived from plane target experiments. The release mechanism developped for these experiments is now available for implosion experiments with unsupported targets.

A comparative study of thin foil acceleration has been performed at λ = 1.3 µm and 0.44 µm using a newly developped ps-framing photograph system. At the shorter wavelength the lack of lateral smoothing in the presence of an inherently poorer beam quality degrade the state of the accelerated material.

Our 1-D LAPLAS code has been further developped by introducing a more realistic EOS and is now capable of simulating colliding foil experiments. Besides lasers, also energetic heavy ion beams are potential reactor drivers. Studies have been undertaken that show the possibility of doing relevant target experiments already with the heavy ion accelerators presently planned for nuclear physics research.

E 3

Non-Linear Development of the Rayleigh-Taylor Instability of a Thin Sheet in Three Dimensions*

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Abstract

All non-linear developments of the Rayleigh-Taylor instability of an ablatively accelerated plasma have been obtained so far in two dimensions. A crucial issue then is whether three dimensional effects are important. In order to address this problem, we extend the analytical model for the Rayleigh-Taylor instability of a thin sheet[1] in two dimensions which compares well with 2D simulations[2]. The 3D extension of the model of Ref. 1 can be solved numerically. We calculate the rate of burn-through of the bubble (non-singular) region in two and three dimensions. We also show the development of spikes in three dimensions and the velocity field associated with them. We finally present the ratio of the mass density which remains in the bubble vs. the total mass density of the sheet.

* Work supported by DOE.

** University of Maryland, College Park, MD 20742.

1. E. Ott, Phys. Rev. Lett. 29, 1429 (1972).
2. C. P. Verdon, et al., Phys. Fluids 25, 1653 (1982).

E 4

16th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER

Imperial College, London

26-30 September 1983

Measurement of Areal Mass Variation in Rayleigh-Taylor Unstable Targets[a]

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E.A. McLean, S.P. Obenschain, B.H. Ripin

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The Rayleigh-Taylor (R-T) instability by its very nature redistributes mass from the "rising" to the "falling" part of the target. Variation of areal mass across the target surface is, therefore, directly related to the instability growth rate.

In our experiment[1] planar targets with an initial periodic perturbation[2] of their areal-mass density (λ = 10-100 μm, $\frac{\Delta\rho r}{\langle\rho r\rangle} = 0 - \frac{2}{3}$) are used to model R-T unstable fusion pellet shells in the early implosion phase. These targets are ablatively accelerated to 100 Km/sec by a 5 nsec FWHM, 1.06 μm, 10^{13} W/cm^2 laser beam providing conditions for up to 23 classical R-T e-foldings, depending on the imposed perturbation wavelength.

Using a novel face-on x-ray backlighting method,[1] we have measured the redistribution of mass in such targets and inferred instability growth rates. A comparison with simple R-T theory indicates that the growth rates are reduced from classical by ~ 2. Comparisons with the FAST2D hydrodynamic code[3] will also be presented.

a Sponsored by the U.S. Dept. of Energy and the Office of Naval Research.

b Mission Research Corporation, Alexandria, VA.

1) J. Grun et al., presented at the 13th Annual Anomalous Absorption Conf. at Banff, Canada, June 5-10, 1983; J. Grun, et al., Naval Research Laboratory Memo Report 4896 (1983) and references therein.

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

3) M.H. Emery et al., Naval Research Laboratory Memo Report 4500 (1981).

E5

Measurements of the Rayleigh - Taylor Instability in Laser Irradiated Targets

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The absolute value of the growth rate of a Rayleigh - Taylor type, hydrodynamic instability may be of crucial importance in determining the core parameters in a laser - driven implosion experiment.

Recent numerical simulations (1) and experimental measurements (2) in planar geometry have indicated a reduction in the growth rate to approximately one third of the classical value.

We present here, new experimental measurements of R-T growth in spherical geometry. Micro-balloon targets with a periodic mass perturbation were fabricated using a novel laser etching technique. Short pulse X-ray backlighting was employed to radiograph the targets as they were ablatively accelerated by 0.53 μm laser light at absorbed irradiances in the range $1 \times 10^{13} - 5 \times 10^{13}$ Wcm^{-2}.

The results show R-T spike amplitudes greater than can be explained by purely secular growth, but less than would be expected for a classically growing mode.

(1) M. H. Emery, J. H. Gardner and J. P. Boris, Phys. Rev. Lett 48 677 (1982)

(2) A. J. Cole, J. D. Kilkenny, P. T. Rumsby, R. G. Evans, C. J. Hooker and M. H. Key
Nature 299 329 (1982)

E 6

Analytic Results in Linear Rayleigh-Taylor Theory. D. H. Munro, Lawrence Livermore National Laboratory, Livermore, CA.--Graded density layers have been discussed as a possible way to lessen the growth of the Rayleigh-Taylor instability at a material interface. Using variational calculus, it is possible to analytically determine the optimum density profile for such a layer in several interesting cases.

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

EVALUATION OF LATERAL ENERGY LOST IN LASER-DRIVEN SHOCK WAVE EXPERIMENTS

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We present measurements of transit time of laser-induced shock waves through aluminum foils of thickness between 11.5 μm and 26.5 μm irradiated by laser pulses of about 1.5 10^{14} W/cm^2 intensity in 0.6 ns at full width at half maximum. The 1.06 μm Neodymium laser beam was focused onto the target with a spot diameter of 270 μm. A fast streak camera is used for recording the visible light associated with the shock emergence at the rear face of the foil.

An hydrodynamic model of laser shock wave propagation in a solid target, developed before, is used for analysing the experimental results. The variation of the applied pressure at the ablation surface is modelised by either a gaussian pulse reproducing the laser pulse, or by a square pulse with the same maximum pressure and the same width at half maximum. A correct fit of experimental results leads to determine a peak driving pressure in the range of 0.2 to 0.4 TPa for both pulse shapes.

This estimated maximum shock pressure, compared with theoretical values deduced from scalling laws at the same absorbed intensity, indicates an energy lost of about 75 % for the irradiation conditions used in these experiments. This energy lost is attributed to two dimensional effects of lateral energy transport, related to the finite spot size.

F 2

THE USE OF SPATIALLY-STRUCTURED PLANE TARGETS IN LASER PLASMA SPECTROSCOPY

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Band-shaped aluminum implants on plane carbon targets and multi-layered targets of various materials (Al/Si, Al/C) were irradiated at $0.1-2 \times 10^{15}$ $W.cm^{-2}$ by 600 ps laser pulses of 1.05, 0.26, 0.53 μm wavelength. The resulting blowoff plasmas were diagnosed by X-spectroscopy using entrance slits of various dimensions and orientations with respect to the target plane and adding a knife edge near the plasma. We studied the longitudinal and radial variations of line intensities and Stark widths of He-like and H-like Rydberg series. The effect of time integration was also qualitatively studied by varying implant thickness. Results showed a tenfold decrease of instrumental broadening due to the small lateral expansion of the plasma eliminating radial spatial deconvolution and minimizing opacity effects. The use of the knife edge gave a 2 to 3 μm spatial resolution on the spectral emissions. The spatial evolution of Stark broadening in the density gradient was pointed out.

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F3

Absolutely Unstable Stimulated Brillouin Scattering and Two-Plasmon Decay

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ABSTRACT

We have found the conditions for which stimulated Brillouin scattering (SBS) and two-plasmon decay are absolutely unstable. For the former instability, laser light incident obliquely at an angle θ_0 to the density gradient in a flowing plasma is unstable to a scattered light wave propagating at $2\pi - \theta_0$. In addition, in a supersonically flowing plasma, SBS is absolutely unstable for scattering angles such that $K' \equiv dK/dx|_0 = 0$ where $K(o) = (k_{ox} - k_{sx} - k_{ax})_{x=0} = 0$. Here k denotes the wavenumber and the subscripts o, s, a denote the laser, scattered light wave, and acoustic wave, respectively.

The two-plasmon instability we have analyzed in real rather than Fourier space and found that the instability is absolute because the spatial variation of the coupling (the homogeneous plasma spatial growth rate) is important. The instability is easier to analyze in x-space and makes the effect of adding dissipation easier to understand. We have found reasonably good agreement of the threshold and growth rate of two plasmon calculated in real space with those previously calculated in Fourier transform space.[1]

1. Liu and Rosenbluth, Phys. Fluids 19, 967 (1976) and Langdon and Lasinski, Lawrence Livermore National Laboratory Annual Report, UCRL-50021-77, 4-49 (1977)

F 4

ABSTRACT 16th E.C.L.I.M.

Suprathermal Electron Transport in CO_2 Laser Plasma

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Axial and lateral hot electron energy deposition profiles are inferred from continuum and characteristic X-ray emission for laser irradiances between 10^{13} and 10^{14} W/cm^2. Continuum X-ray emission is recorded with nine K edge filter detectors covering the 1-70 keV range. K_α emission is recorded with a multiple pinhole X-ray camera and PIN diodes filtered such that the difference between two images or signals gives the K_α emission of the target material. Spatial resolution of continuum and K_α emission is obtained directly from pinhole images and by using targets composed of an X-ray emitter disc of various diameter on an infinite substrate and covered by plastic layer of various thicknesses. Quantitative results obtained from continuum and K_α are compared and discussed. Measurements show that within a 1 mm diameter zone the hot electrons penetrate the target at near normal incidence, are less energetic than far from the focal spot and transport less than 10% of the total deposited energy (9% of the laser energy). Away from the focal spot the hot electrons are increasingly energetic and incident at oblique angles. The energy deposition geometry given by pinhole pictures at various depth inside the target is also presented and analysed. The physics of hot electron transport is discussed.

F 5

ABSTRACT FOR 16th EUROPEAN CONFERENCE
ON LASER INTERACTION WITH MATTER (ECLIM)
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<u>Observation of Bubble and Spike Formation in Laser-Accelerated Foils</u>

R.R. Whitlock, M.H. Emery, J.A. Stamper, E.A. McLean,
J.A. Sprague, S.P. Obenschain, and M.C. Peckerar

Laser-accelerated targets may be subject to the Rayleigh-Taylor (RT) instability when the target is not sufficiently uniform. We have enhanced the instability with mass thickness variations in foil targets.[1] A high-resolution transmission electron imaging technique for characterizing the foil thickness variations has been developed.[2] Targets were accelerated by the Pharos II laser operating at 1.05 micron wavelength, $0.5\text{-}1.8\times10^{13}$ W/cm^2, with pulse lengths of 4-5 nsec. Rear surface temperatures of the accelerated foils were measured. Side-on flash x radiography, conducted with a separate backlighting source,[3] has revealed structures such as those anticipated from numerical simulations[4] of the advanced development of the RT instability. Experimental and numerical results will be compared.

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

See also a related paper by J. Grun, et alii, to be presented at this Conference.

1. B.H. Ripin, S.P. Obenschain, J. Grun, M.J. Herbst, E.A. McLean, J.A. Stamper, R.R. Whitlock, J.M. McMahon, and S.E. Bodner, Bull Amer. Phys. Soc. <u>25</u>, 946 (1980).

2. R.R.Whitlock and J.A. Sprague, Procedings of the 40th Annual Meeting of the Electron Microscopy Society of America, 9-13 Aug., 1982, Washington, D.C.

3. R.R. Whitlock, S.P. Obenschain, and J. Grun, Appl. Phys. Lett.<u>41</u>, 429 (1982).

4. M.H. Emery, J.H. Gardner, and J.P. Boris, Phys. Rev. Lett. <u>48</u>, 667 (1982).

EXPERIMENTAL RESULTS ABOUT 3/2 W_0 AND 5/2 W_0 HARMONIC GENERATION IN PLASMAS CREATED BY INTERACTION OF INTENSE NEODYNIUM LASER PULSE WITH A PLANE TARGET F 6

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The experimental lay out is the same as the one described in the second harmonic observation (t=600 ps.,0<E<90J.,I=10e(15,16) W/cm2,high spectral and spatial resolution spectrograph).

* The 5/2 W_0 harmonic has been observed for energies >70J.,corresponding to intensities of about 10e(16)W/cm2.The observed spectral structure is mainly a double line (D1) centered on 421,1nm.,the two maxima's separation being of 2,5nm..As for the 3/2 W_0 harmonic,the "blue" component is much less intense and so exhibits a 1,5 nm. half height width instead of 2,5 nm. for the "red" component.Using the Wollaston's prism we observe the double line (D1)for a polarization // to that of the incident radiation,but for the orthogonal direction of polarization there is also a much larger line which seems to exhibit also a double structure(D2).(D1) may have his origin in the coalescence of ($2W_0$) with (Wp/2) radiations,the last one corresponding to two plasmons instabilities;(D2) may be think of as the coalescence of (2Wp) with (Wp/2) radiations.

* Observation of 3/2 W_0,without hight resolution presents also a double structure (D1) centered on 702,0 nm. with a 5,0 nm.(resp. 3,0 nm.) maxima's separation for right angle (resp. 45°) observation.(D1) corresponds to the coalescence of (W_0) with (Wp/2) radiations.The coalescence of (Wp/2 + Wp/2 + Wp/2) radiations may explain the spectral width of (D1).

With a good spectral resolution each line of (D1) appear to have a multiple structure,the origin of which may be either coalescences ($2W_0$ - Wp/2) or (2Wp - Wp/2) either Zeeman effect.

F 7

Fast Ion Imaging of CO_2 Laser Ion Plumes*

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ABSTRACT

Recent high intensity CO_2 laser experiments have shown emission of fast ions from an extended region well beyond the orig'nal target, with ions traveling in a direction nearly perpendicular to that of the normal ion flow from the target. We believe these ions are due to an ion-ion instability[1] in the plume leaving the target surface.

The ion images were obtained using standard x-ray pinhole cameras with CR-39 as a track etch detector and filtered to provide a proton cutoff below 0.3 MeV. Distortion of the images due to space charge effects in the pinholes was not believed to be a difficulty. This was verified experimentally by the maintenance of image properties in photos obtained from cameras looking at the targets from three perpendicular angles. Direction of ion flow from the targets was well correlated with data obtained using a multiple ion calorimeter array and is consistent with the magnetic field acceleration model.[2]

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

1. D. W. Forslund and C. R. Shonk, Phys. Rev. Lett. 25, 1675 (1982) and D. W. Forslund, J. M. Kindel, K. Lee, and E. L. Lindman, BAPS 20, 1377 (1975).
2. D. W. Forslund and J. U. Brackbill, Phys. Rev. Lett. 48, 1614 (1982).

ABLATIVE FLOW FROM LASER-IRRADIATED PELLETS: A COMPARISON OF THEORY AND EXPERIMENTS.

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ABSTRACT

Theoretical[1-3] and experimental[4] results on the corona of plasma ablated from a pellet by a laser pulse, are compared. The theoretical model includes Spitzer's heat conductivity ($\bar{K}T^{5/2}$), heat -flux saturation, ion-electron relaxation, absorption both by inverse Bremmstrahlung and anomalous at the critical density n_c, and hot-electron generation and transport; the corona is assumed to be quasisteady and spherically symetric. The results can be parametrized by the dimensionless quantities Z_i (mean ion charge number), f (flux-limit factor), $W_L/r_a^2 n_c \bar{m} V^3$, and $\bar{m}V/m_e c$, where $V \equiv (r_a n_c/\bar{m}^{5/2}\bar{K})^{1/4}$ is a speed, c is the speed of light, m_e is the electron mass, and $\bar{m}$ the ion mass per unit charge; r_a and W_L are the instantaneous pellet radius and incident laser power. Ablation pressure, mass ablation rate, ion exhaust velocity, and maximum electron temperature are discussed.

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2 J.R.Sanmartín, R.Ramis, J.L.Montañés, and J.Sanz, submitted to Nuclear Fusion.

3 J.A.Nicolas and J.R.Sanmartín, 11th European Conference on Controlled Fusion and Plasma Physics, Aachen (Federal Republic of Germany) Septembre 1983.

4 T.J.Goldsack, J.D.Kilkeny, J.MacGowan, P.F.Cunningham, C.L.S. Lewis, M.H.Key, and P.T.Rumsby, Phys. Fluids 25, 1634(1982).

THE ACCESSIBILITY OF QUASIPLANAR SUPERCOMPRESSION AND GIGAGAUSS FIELDS BY COHERENT COLLISIONS IN FRAGMENTED LINER DRIVEN BY THE TUNABLE LASERS

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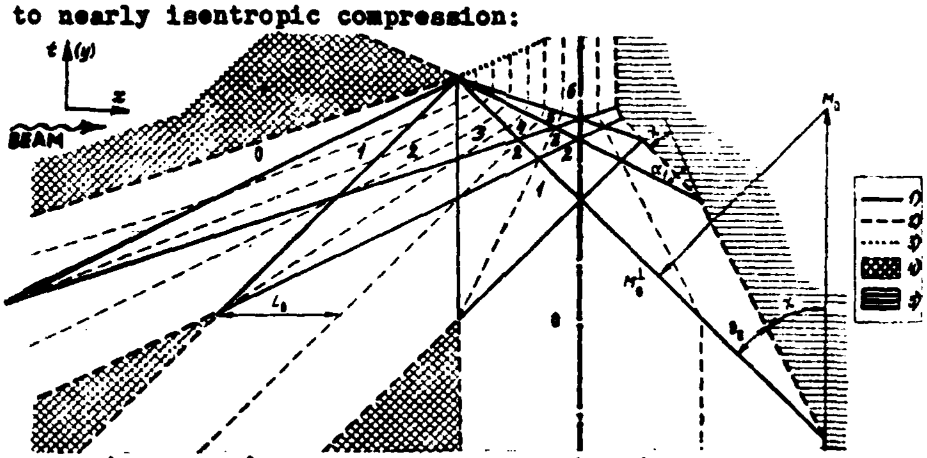
Coherent collisions -impact assembly of liner's fragments , speeded up by such accelerator as tunable FEL with narrow beam ($I \lesssim 10^{13}$ W/cm^2) giving linear space distribution of the fragments velocities (up to $U_{max} \cong 10^{7\div8}$ cm/sec before simultaneous mutual impacts) opens a new fundamental method for optimal (let only rational) accession of compressions to $\gtrsim 10^{4\div5}$ g/cm^3 with fields of $\gtrsim 10^{4\div5}$ T (plane or cylindrical) if initial intensity is $\approx 10^{1\div2}$ T. The general theory is published in /[1]/.

In such fragmented impactly assembled liners the plasma undergoes multiply shocks reflections with the quick transition to nearly isentropic compression:



here 1)shocks;2)particles of plasma ($c_p/c_v=3$ with magnetic field); 3) front of rarefaction; 4) vacuum; 5) wall (of piston etc)

The given maximum density of liner,energy of compression is lower with better space-time resolution of registered devices.

[1] V.A.Belokogne: Sov.Phys.Doklady v.222n3(1975);v.268n1(1983); INTERNATIONAL JOURNAL of FUSION ENERGY v.2 n 3 pp 25-41(1980).

F10

PENUMBRAL IMAGING OF HIGH ENERGY X-RAY EMISSION FROM LASER PRODUCED PLASMAS

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ABSTRACT

In this poster we will describe a simple technique allowing very high collection efficiency and high resolution imaging of the x-ray emission from a laser produced plasma. The technique, penumbral imaging, is simply an extension of the pinhole camera such that the 'pinhole' is now larger than the object being imaged. This does not reduce the high spatial frequency information content of the exposure and increases the device sensitivity to broad (low spatial frequency) features, though this is at the cost of having to do some simple computer processing to recover the image. We have applied this technique to image 20 keV x-rays with about 20 micron resolution in an experiment with only 2 Joules of laser energy. These images will be shown.

The same method may also be applied to image neutron emission from an imploding laser fusion pellet. We will show here that penumbral imaging should allow good quality neutron images to be obtained (with better than 10 micron resolution) in conditions such as those anticipated in experiments with NOVA.

An electrodynamical coaxial spectrometer for multichannel plasma pulse analysis

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Construction and operation of a dynamical particle spectrometer is described, which allows complete and simultaneous analysis of ion energy and charge distributions of laser produced plasma pulses.

The system uses a combined time-of-flight arrangement with a coaxial capacitor, whose potential is varied as $1/(\text{time})^2$. Ions with the same mass to charge ratio are independently of their velocity deflected to concentric collecting electrodes, where the spectra are analyzed with fast time resolving detectors.

Compared with a parallel plate geometry, the cylindrical symmetry offers substantial advantages both in principle and in practical application. The performance of the instrument is tested using laser produced C plasma pulses.

F 12

MATHEMATICAL AND NUMERICAL ASPECTS OF THE THEORY OF HEAT TRANSPORT IN A STEEP TEMPERATURE GRADIENT.

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We present some new results concerning the mathematical properties of the Fokker-Planck equation describing the electron distribution function. We discuss the validity of the approximations obtained by using a finite number of Legendre polynomials to describe the electron distribution function. We show that, due to the Landau form of the e.i. collision operator, it is sufficient to use 2 or 3 Legendre polynomials in problems of interest. We apply our theory to the classical albedo problem as a test. We also apply the theory to determine the distribution and the heat flow in a heat front typical of laser plasma experiments. We show that the heat flux can be expressed as a sort of a convolution of the Spitzer Harm heat flux by a delocalization function[1].

1 This last point is developped in the oral paper presented by J. Virmont, (J.F. Luciani, P. Mora, J. Virmont, heat flux down steep temperature gradients, this conference).

F13

Particle Trapping and Acceleration by Electron Plasma Waves

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In laser produced plasmas electrons are accelerated to energies of several hundred keV due to their interaction with electron plasma waves, which are produced either by resonant absorption or by parametric instabilities. Another possible acceleration mechanism may be the collapse of Langmuir solitons.
An analytic model is presented which explains some of the main features of the velocity distribution of accelerated electrons. The distribution is calculated for an electron plasma wave with a space dependent stationary amplitude.

A strong dependence on the shape of the amplitude function is pointed out:
In the case of a slowly varying field amplitude $\hat{E}$, i.e. $|\lambda\, d\hat{E}/dx| << \hat{E}$, where λ is the wavelength, it is shown that particle trapping can occur only for those particles entering the field region with velocities exceeding 30% of the wave phase velocity v_{ph}. Thus only a few electrons from the tail of the initial distribution are accelerated in this case. The velocity of the fastest electrons is approximately 1.7 v_{ph}.

In the case of an amplitude profile which rises steeply to its maximum and then decays slowly in the direction of wave propagation no such limitations exist. Electrons with low initial velocities are trapped and accelerated as well. The maximum electron velocity depends on the field amplitude.
It is shown that the analytic model agrees well with results obtained from numerical solutions of the particle equation of motion. Velocity distributions of the accelerated electrons were calculated for different kinds of accelerating fields.

F14

Analysis of back reflected light from homogeneous plasmas.

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J. Briand,
CPA, Toulouse, France.

Homogeneous plasmas are generated by laser irradiation of thin plastic foils at 1.06 μm, and 0.53 μm laser wavelengths. Irradiation of the plasma is made by a probe beam at 0.53 μm for intensities ranging up to 10^{15} W cm^{-2}. Time resolved backscattered light spectrum, and 3/2 ω harmonic for 0.53 μm light have been detected and analysed.

In some experiments the back reflectivities could be attributed to Brillouin back scattering in an underdense plasma, at a rather moderate level.

16th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER F15

"16TH ECLIM"

LONDRES, september 26-30, 1983

X-RAY LINE SELF ABSORPTION AND ELECTRON DENSITY DETERMINATION IN A LASER CREATED PLASMA

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Abstract :

Hot and dense laser created plasma cannot be considered as optically thin, and the knowledge of line self absorption is needed for a proper interpretation of X-ray spectra. We report an experiment in which the target geometry allows to measure opacities, and to infer optical depths and even electron densities.

Experiments have been performed with a Nd-glass laser delivering 50 J in 800 ps onto a thick extensive plane silica target in which a small bar of aluminum had been embedded. During the plasma expansion, the aluminum remains confined within silica. The X-ray emission is analysed in the two mains directions of the Al bar. Resonance lines are clearly self absorbed in the longitudinal direction. Experimental results are compared with theoretical evaluations based on the solution of radiation transfer equation and considering line profiles as a convolution of gaussian and holtzmarkian profiles. Variations of optical depth along the direction of the plasma expansion are inferred, as well as the electron density profiles.

F16

SIMULATION AND EVALUATION OF RADIATIVE PROCESSES IN HIGH-PARAMETER PLASMAS

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A computer simulation program RACHEL has been developed for laser/ion beam produced plasmas which consist of material with a high Z. The code is 1D, Lagrangian; the structure of the program is based on the OLYMPUS system. Emphasis is given on the ionization and radiation processes involved. Atomic collision physics is threated in reduced DCA approximation . A special fast algorithm for the solution of rate equations has been developed. Detailed time-dependent calculations for a planar, laser-irradiated aluminum target have been carried out.

Several numerical techniques for the calculations of radiative transfer in high-Z plasma systems have been analyzed. They include multifrequency-grey method for solving the time-dependent radiation transport equation and simple implicit algorithm for the solution of radiation hydrodynamics problems. Various approaches for the opacity calculations (including AIM) have been adopted. The techniques have been incorporated in the 1D codes FOIL1 and FOIL2 and some test problems have been calculated.

A program package DAISY for the evaluation of the x-ray and particle diagnostics of high-parameter laser/ion beam produced plasmas has been elaborated. Emphasis is imparted on the x-ray spectral and imaging methods. The programs of the package enable to design effectively x-ray filters, to evaluate foil measurements and to analyze dielectronic satellite spectra as well. Pinhole camera and coded aperture imaging could be evaluated, some techniques for the 2D digital signal processing are available.

LASER FUSION EXPERIMENTS AND THEORY AT THE LABORATORY FOR LASER ENERGETICS*

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Experiments at LLE during the past year, with both the 24-beam 1054 nm OMEGA facility and the single beam 351 nm GDL system have concentrated on defining the uniformity and the physics of coronal coupling and energy transport in spherical geometry for short wavelength direct-drive laser fusion. Irradiation uniformity is estimated from known beam irradiance profiles; at present on OMEGA these estimates give r.m.s. values of ~6% for nonuniformities in low-order spherical harmonic modes. Beam profile improvements demonstrated on GDL, together with a reduction of the OMEGA beam energy variance, will yield irradiation nonuniformities a factor of three lower. The resulting irradiation symmetry is close to that required for high-gain target implosions. Wavelength, intensity, and geometry scaling studies of parametric processes capable of generating *suprathermal* electrons have been peformed with GDL and OMEGA. Delineations between SRS and the $2\omega_{pe}$ instabilities has been made with 351 nm radiation in planar geometry. The $2\omega_{pe}$ instability, along with resonance absorption, have been identified as the principal generators of hot electrons in 1054 nm experiments in spherical geometry. These results lead to the expectation that spherically irradiated targets at 351 nm will experience minimal electron preheat. Thermal transport measurements in spherical geometry at 1054 nm have exposed the inadequacy of a simple flux-limited electron energy transport model. X-ray signatures indicate penetration of the ionization front to greater depths than previously measured in experiments at all wavelengths, prompting a reassessment of the diagnosis and interpretation of energy transport. In preparation for 351 nm spherical implosion experiments a number of new diagnostic techniques have been developed. These include time resolved x-ray image photography and shadowgraphy, high energy x-ray investigations incorporating Von Hamos and Laue spectroscopic techniques, and the progressive implementation of a high fluence, short pulse x-ray flash capability. Latest results will be discussed.

*This work was partially supported by the U.S. Department of Energy Inertial Fusion Project under contract No. DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

G 2

16th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER

"16TH ECLIM"

LONDRES, september 26-30, 1983

LATERAL ENERGY SMOOTHING IN LAYERED TARGETS IRRADIATED WITH 0.35 μm LASER WAVELENGTH

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M. LOUIS-JACQUET, A. SALERES, G. THIELL

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Abstract :

The effect of laser beam modulations on planar accelerated targets has been analysed as a function of spatial scale length of the non-uniformities by means of space resolved X-ray shadowgraphy.

For 25 μm thick aluminum targets, the results are consistent with lateral thermal conduction and laser wavelength scaling. The use of gold-aluminum layered targets allows to clearly improve the lateral smoothing. The results are tentatively interpreted in terms of X-ray radiative transfer from the gold layer to the aluminum target.

Acceleration of thin plastic foils at λ = 1.3 μm and 0.44 μm

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The acceleration of thin plastic foils has been investigated with the iodine laser at λ = 1.3 μm and 0.44 μm (third harmonic). The experimental conditions ($\phi_{inc} \leq 10^{14}$ W/cm^2, focal spot diameter 400 μm, pulse duration 350 ps) provided a geometry very close to planar, which is important for comparison of the experiment with our 1-D Lagrangian computer code LAPLAS. 4π reflectivity at λ = 1.3 μm and 0.44 μm were measured with the Ulbricht sphere. Plasma evolution and hydrodynamic response of the foils were visualized with a novel photographic diagnostic (λ = 580 nm) with which a sequence of 6 frames (either shadowgrams or interferograms) is obtained in a single iodine shot. Exposure time of this diagnostic is 3 ps, time delay between the frames is ≥ 370 ps. The rear side velocities were obtained from single foil (giving a low density velocity) and double foil (dense mass velocity) experiments. Whereas both methods give comparable velocities at 1.3 μm, at 0.44 μm the low density velocity is up to a factor three larger than the dense mass velocity. It is suggested that the poorer beam quality and lack of lateral smoothing at 0.44 μm are detrimental for the accelerating foil. Calculated ablation pressures scale as $P_{abl} \propto \phi_{abs}^{0.6} \lambda^{-0.4}$.

G 4

Non Uniform Illumination of Laser Targets

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Abstract

The effects of non uniform illumination on the hydrodynamic behaviour of laser accelerated targets is discussed under two headings.

1) Thermal smoothing: A dispersion relation is given for harmonically limited heat flux. In the limit $Q = Q_s$ the result of Skupsky[1)] is obtained but, hydro code simulations do not support Skupsky's conclusion that inhibited heat flow gives greater smoothing.

2) Hydrodynamic response: Hydro code simulations show transverse sound wave generation as predicted by Manheimer et al[2)] and also coupling into Rayleigh Taylor modes.

1) S. Skupsky University of Rochester Report No 131, May 1982

2) W.M. Manheimer, D.G.Colombant, J.H.Gardner
Phys Fluids 25, 9, 1644 (1982)

G 5

1-D Simulation of Laser Foil Experiments and Foil Collisions

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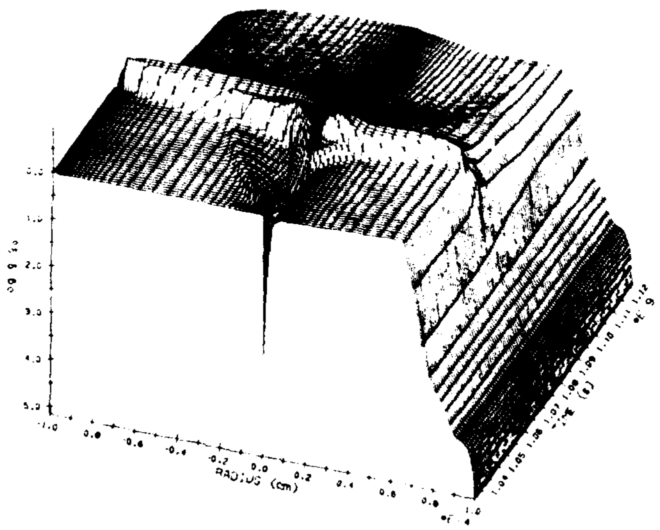
We study laser acceleration of plane foils and foil collisions numerically with emphasis on equation-of-state effects. Results of space and time evolution are presented in form of 3-D plots.

The simulations are carried out with the 1-D Lagrange code Laplas /1/. In its latest version, the tabulated SESAME equation-of-state is used /2/. Thermodynamic state as well as hydrodynamics of accelerated foils are discussed and compared with corresponding ideal gas EOS calculations. In foil collisions, pressures in the range of 100 - 1000 Mbar are obtained, provided that hot electron preheat of the projectile foil is low. An example is shown in the figure, where a 1µm aluminum foil accelerated with 2×10^{14} W/cm^2 to $v = 1.4 \times 10^7$ cm/sec hits a stopper foil at rest. A maximum pressure of 300 Mbar is reached over 10 psec. The plot starts at collision time; the density (in units of the solid density) versus Lagrangean coordinate and time is shown.



/1/ Schmalz, R.F. et al., MPQ report 75 (1983)
/2/ Bennett, B.I. et al., Los Alamos report UC-34 (1978)

X-RAY SPECTROSCOPY OF LASER PRODUCED PLASMAS

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A review of recent results from planar target ablation and implosion plasma will be presented. The techniques of X-ray spectroscopy developed over the past few years will be discussed. These include the use of line width diagnostics to predict densities, line intensity ratios to predict temperatures and density and recombination slope measurement to infer temperature. The importance of time and space resolution, and opacity will be discussed.

Specifically, results will be presented from experiments performed at the National User Laser Facility at LLE illustrating implosion diagnostics, experiments at the Central Laser Facility at Rutherford Appleton Laboratory together with experiments at the Phoenix Research Laser at LLNL studying spectroscopy of ablation plasmas, and experiments from the Novette laser at LLNL on the recombination emission from O VIII Balmer α transitions.

A COMPARISON OF LASER IRRADIATED TARGET EMISSIONS AT 1.06 μm, 0.53 μm and 0.27 μm

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The laser wavelength dependance of the spectroscopic features of X ray emission in a plane target laser interaction is investigated. The driving laser is a Neodymium glass laser, used at its first, second and fourth harmonic. The laser intensity ranges from 10^{14} to 10^{15} W/cm^2 and laser pulse duration is about 600 ps. We use Fluorine targets, spatially structured targets (Aluminum dots on Carbon substrates) as well as laser drilled spot-like targets in order to improve the spectral resolution. Three micrometers resolution is achieved using a wide slit (300 μm) or a knife edge in front of the spectrograph and by processing the digitized spectral data by numerical deconvolution.

Electron temperatures and densities are determined by standard diagnostic techniques involving continuum slopes, Stark broadening and satellite line intensities.

Variations of the conduction zone extent and density gradient scale lengths with the laser frequency are clearly exhibited. They are in good agreement with the predictions of corresponding hydrodynamic Lagrangian simulations.

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H 3

THE K ABSORPTION EDGE AS A PREHEAT DIAGNOSTIC

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Time resolved X-ray absorption spectroscopy ahs been used to investigate the K absorption edge structure of solid density matter subjected to preheating by a laser produced plasma. The K absorption edge of material buried in plane laser irradiated targets is shon to broaden in response to radiative preheat.

The preheating in relatively deeply buried layers, principally due to $h\nu > 2$ keV X-rays, is inferred from an absolute measure of the X-ray flux in this range and also from the photoionisation induced Kα fluorescence in the buried layer.

A simple model to predict the broadening for these measured energy depositions is proposed and is in resonable agreement with the observed broadening in such deeply buried layers.

The broadening in layers near to the surface is much greater and is attributed to preheating by soft X-rays which have a reduced range in the target. The model and experimental results are extrapolated to the observed degree of K edge broadening in near surface layers (~ 30 eV) to give an inferred soft X-ray preheat level of ~ 150 eV/atom

H 4

ANALYSES OF EXPERIMENTS ON X-RAY EMISSION FROM LASER-IRRADIATED TARGETS

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Abstract

We analyse the recent experiments performed at Limeil on X-ray emission from laser irradiated high-Z targets, through three techniques :

- The Limeil one - dimensional, hydrodynamic FCI.1 code, with multi-group radiative transfer and LTE ionisation.

- A model for emission and radiation transfer in a laser - irradiated target, using stationary temperature and density profiles and LTE atomic physics (averaged atom - like) connected with a coronal model, in order to get X-ray spectrum.

- Analytical expressions to explain qualitatively the experimental results about X-ray conversion rates and their evolution in function of the different parameters of the interaction.

H 5

16th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER

"16TH ECLIM"

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X-RAY EMISSION IN THE SUB-KEV RANGE FROM LASER IRRADIATED THIN PLANE TARGETS

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Abstract :

X-ray emission from gold and aluminum thin plane targets have been experimentally and theoretically studied for two laser wavelengths, λ = 1.06 and 0.35 μm.

Experiments have been performed with 1 ns pulses in the range of irradiance I : 3.10^{13} - 3.10^{14} Wcm^{-2}. Influences of the main parameters : λ,I, atomic number, laser prepulse and target thickness , are presented and discussed.

Results are compared with numerical simulations carried both with the 1 D hydrodynamic lagrangian code FCI1 in which radiative transfer is treated by a multigroup method (X-ray lines not taken in account) and a model for X-ray radiation transfer taking account of lines, which is elsewhere presented in the same conference.

H 6

X-RAY DIAGNOSTIC FROM SHORT PULSE 1,05 μm LASER PLASMA

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A low-Z plasma is produced on plane perspex slab targets ($C_5H_8O_2$) by a short pulse from a Nd: glass laser system (80 psec, up to 10 GW). In order to determine the electron temperature, the x-ray emission from the plasma is measured simultaneously by six x-ray PIN diodes through different absorber foils. The long duration of the recorded signal (up to 10 nsec) implies that the Bremsstrahlung emission is followed by a substantial amount of recombination radiation. This is confirmed by time-integrated x-ray pinhole photography. A time-dependent numerical code, including ionization and recombination rate equations further corroborates the observation: Bremsstrahlung is restricted mainly to the 80 psec duration of laser irradiation, whereas recombination radiation remains at an appreciable level for several nanoseconds. Its influence on temperature measurements by the absorber-foil method is discussed.

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16 th EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER

"16TH ECLIM"

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HYDRODYNAMIC STUDIES IN LASER PLASMA EXPERIMENTS PERFORMED AT CENTRE D'ETUDES DE LIMEIL

AUTHORS : E. BERTHIER, G. BOSCA, E. BURESI, A. COUDEVILLE, J. COUTANT, R. DAUTRAY, M. DECROISETTE, C. DELMARE, B. DUBORGEL, P. GUILLANEUX, P. NELSON, JM REISSE, B. SITT, JP WATTEAU.

Interaction and implosion studies have been carried out at C.E.L. with the two main Nd-glass laser facilities : P 102, delivering currently on target 20 J at λ = 0.35 μm after frequency tripling and OCTAL, the power of which has been recently increased ($\simeq$ 0,5 kJ in 280 ps, $\simeq$ 2 kJ in 1ns).

Plane target experiments mainly concerned the behaviour of thin accelerated targets. X-ray conversion rates have been studied versus laser wavelength, irradiance, atomic number and thickness of the target. A particular attention was paid to the effect of beam modulation on target acceleration, and the use of gold-aluminum targets clearly evidenced a lateral smoothing. Besides, the optical depth of a laser plasma could be measured using convenient target geometry.

Spherical implosions of coated glass microballoons evidenced an enhanced neutron yield when Z and density of the coating material was increased, attributed to a more important preheat.

Concerning theoretical work, special attention has been given to transport :

- A Fokker-Planck code is under writing. The Landau collision terms are discretized with enough exact conservation properties, so that few velocity points are needed.

- A two-fluid transport model for suprathermal and thermal electrons, taking into account the self-consistant electric field has been studied numerically. Suprathermal transport is made in total energy space and electric field is calculated from neutrality violation charge in each cell. Significant results are obtained, showing a good coupled diffusion of the two populations and strong electric fields in the corona, up to 10^8 V m^{-1}.

I 2

STUDY OF LASER PRODUCED PLASMAS AND THEIR APPLICATIONS AT THE SERC CENTRAL LASER FACILITY

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A brief summary will be given of the principal facilities and University research programmes at the SERC Central Laser Facility. Emphasis will be placed on discussion of directly driven laser compression. Recent results of background studies of ablation, thermal smoothing, hydrodynamic stability and preheat will be used to define constraints for compression experiments, and recent compression results using six beam irradiation of spherical shell targets will be presented. The limits of present achievements and future prospects will be reviewed.

SPATIAL STRUCTURE OF EXPANDING PLASMA IN EXPERIMENTS OF SPHERICAL LASER-DRIVEN COMPRESSION OF MICROSPHERES

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Results of investigations of expanding plasma generated in result of glass microsphere spherical irradiation with high power laser pulses, carried out with optical and X-ray diagnostics, are presented in this paper.

Plasma investigations were carried out with use of our four beam experimental facility. Glass microspheres of 100-140 μm diameter and of 1 - 1,2 μm wall - thickness, filled with deuterium, were used as targets.

The plasma was created in result of target irradiation with the focused laser pulses of several joules total energy and 1,5 ns pulse duration. The target was irradiated by means of a lens focusing system according to a tetrahedral geometry. To make shade photographs of the laser - produced plasma we used the laser radiation beam produced in result of conversion of a part of the main laser beam into the second harmonic.

On shade photographs made in time - delay of 5 ns after the laser heating pulse and for 1,5 ns exposure time, the plasma area is asymmetrical (shape of the shade corresponds to the tetrahedral geometry of irradiation) and shade area are smooth.

The estimated velocity of shade area expansion is , $1,1 - 1,4 \times 10^6$ cm/S according to the expansion direction.

On shade photographs made 15 ns after the laser heating pulse (for the exposure time t_{exp}= 1,5 ns as well as for t_{exp}= 7 ns) the filamentary or jet shaped can be seen. These structures tend to increase with the rise time and maintain their shape dirung plasma expansion process.

I 4

ELECTRON DENSITY PROFILES AND SECOND HARMONIC EMISSION FROM PICOSECOND Nd LASER-PRODUCED PLASMAS

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ABSTRACT

We have studied the electron density profile and second harmonic emission from plasmas generated by short, high intensity Neodymium laser pulses on various targets. We observe profile modification in the vicinity of the critical density surface and strongly red-shifted, highly structured second harmonic spectra. Such spectra indicate the presence of ion acoustic waves in the critical region which can provide rippling of the critical density surface. This is central to the model used to explain the measured density profile, which is based upon a self-consistent treatment of profile modification due to resonance fields with the surface rippling being used to explain why resonance absorption should be dominant even for nominally normally incident light. The model correctly predicts the intensity scaling of both the observed profiles and the superthermal electron temperature when the empirically determined intensity scaling of the plasma thermal temperature is included.

The second harmonic spectra are explained by the operation of a decay instability of resonance absorption in the presence of ion waves with a strongly peaked distribution of wave vectors which produces side bands upon the central red-shifted spectral peak produced by the decay instability. The spectral features are shown to be consistent with the model of profile modification by resonance absorption with the background ion waves generated by return current driven ion acoustic turbulence.

New Cu I-like lines of Cd XX and InXXI in laser produced plasma

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Informal Abstract

Seven new lines designated as 4s $^2S_{\frac{1}{2}}$ - 5p $^2P_{\frac{1}{2},3/2}$ and 5s $^2S_{\frac{1}{2}}$ - 4p $^2P_{\frac{1}{2},3/2}$ of Cd^{19+} and In^{20+} in laser produced plasma have been observed around 50 A.

Optical measurement of thin foil acceleration

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The velocity of thin plastic foils accelerated by laser ablation at 0.53 μm has been measured from Doppler shift observed on the back reflected laser light by time resolved spectroscopy. Velocities ranging from 3.10^6 cm sec^{-1} to 2.10^7 cm sec^{-1} are determined for the motion of the critical region away from the laser. Experimental results obtained for different foil thickness and laser intensity are compared with numerical simulations, and give smaller shifts than expected at high intensities, indicating probable effects of lateral transport.

Use of holographic gratings for the investigation of scattered laser light at frequencies ω_c and $2\omega_c$ in the laser installation "Delphin 1"

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Requirements on holographic gratings are analysed to get a high spectral and spatial resolution for laser light scattered by plasma in laser fusion experiments.

Intensities at frequencies ω_c and $2\omega_c$ are registered with the help of holographic gratings. The plasma is imaged by an aspheric objective with an aperture f/2. In the spectrographs holographic concave gratings were used of a dimension 50 x 50 mm^2 and an aperture f/2. The experimental results show an anomalous scattering of light at frequencies ω_c and $2\omega_c$ in a range, in which the density is much lower than the critical one. It is found, that the range in which scattering is produced has a size 4 times larger than the diameter of the not irradiated target and a sharp bound. A theoretical interpretation of the experimental results is given in the paper. The observed phenomenon is explained as formation of instabilities in the corona. As a result of this, magnetic fields are produced of about $H \triangleq 10^5$ Gs.

CRATERISATION PROCESS BY LASER SHOCK AND SIMULATION OF HYPERVELOCITY IMPACTS

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Hypervelocity impacts are simulated with a 1.06 μm Neodymium pulsed laser, producing a maximum energy of 100 J in a few ns. The simulated projectiles have a velocity in the range of 5 km/s - 45 km/s and a mass in the range of 0.1 μg - 2 μg. The mass loss ratio is measured for Aluminum targets of different hardness.

Experiments were performed on multilayered Cu/Ni target. Nickel markers deflections in copper target impacted by laser beam show the two process of crater formation : ejected matter and material displacement at increasing distance in the target.

Laser Pulse Width and Wavelength Dependent Ion Emission from Laser Produced High-Z-Plasmas

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Ion emission generated by Nd-YAG laserpulses has been investigated using the time-of-flight and retarding field method. The targets under study are Ni, Mo, Ta, W, and Au.

Ion energy spectra have been obtained for the different charge states for laser pulse widths of 35 ps and 20 ns and of about the same pulse energy. The residual gas pressure in the vacuum chamber has been below 10^{-7} mbar.

It is found that in the case of short pulses the emission spectra, for all target materials investigated, are influenced by additional admixtures of H, C and O ions. This general behaviour is not dependent on the laser intensity (up to 10^{14} W/cm^2). It is shown that these impurities can be removed by a prepulse which impinges on the target in a time as short as 50 ms before the main pulse.

In contrast to the experiments with λ = 1,06 μm a frequency doubled laser pulse results in an enhanced absorption and higher kinetic energies of the ions are observed.

FINE STRUCTURE OF THE SECOND HARMONIC RADIATION GENERATED DURING THE INTERACTION OF AN INTENSE NEODYNIUM LASER PULSE WITH A PLANE TARGET

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Experiments were performed with the C.N.R.S.'1,053 μm neodynium laser,located at the Ecole Polytechnique in Palaiseau, delivering pulses of t=600 ps. and energy 0<E<90 J. allowing intensities of 10e(15-16) W/cm2.Plane iron targets were used. The direction of observation was at right angle with the incident radiation's axis.We used a great numerial aperture (0,3) objective imaging the plasma onto the slit (broadness < 50 μm) of a spectrograph.The spatial resolution on the slit was ~ 1 μm and the spectral resolution was 1/500 nm.Then,the slit was imaged either on the slit of a streak camera,either on a fast camera's photocathode,thus eliminating radiations emitted after a few nanoseconds.The experimental device was completed by a Wollaston's prism.

The plasma's second harmonic emission has been studied. It exhibits a triple structure corresponding to the three following processes (t = photon ; l = plasmon):

* (t+t) : resonant absorption.It is a very narrow line (0,2 nm.) of weak intensity owing to the right angle observation.It is blue shifted of about 0,5 nm.,which corresponds to a plasma velocity expansion of 2.e(5) m/s

* (t+l) : parametric instability.A quite narrow line (1 nm.) separated from the preceding by 0,4 nm. and corresponding to an electronic temperature of 1,5 kev.

* (l+l) : parametric instability. A quite large,red shifted (mainly on the plasma's axe) line.Its maximum intensity is situated about 1,5 nm. from the (t+t) line.The total spectrum width being of 5 nm.

The spectral line's streak camera analysis exhibits a spatio-temporal structure with particularly a temporal periodicity of 300 ps. and a spectral periodicity shifting toward the red as time goes on.

SPECTROSCOPIC EMISSIONS OF MULTILAYERED TARGETS USING 1D LAGRANGIAN SIMULATIONS

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We have used a 1D Lagrangian code coupled to a detailed atomic physics model to predict line and continuous emissions of multilayered plane targets irradiated by a 1.06 μm, 0.53 μm or 0.27 μm laser pulse. Several materials in the $Z \leq 20$ range can be simulated in the calculations. An implicit algorithm solves the coupled equations governing the plasma ionic composition and the electron energy balance. This allows to use a large time step without energy coupling instabilities. Fractional populations of selected excited levels are computed in a post processor under the quasistatic approximation. Continuum and line emissions are deduced. Reabsorption of the lines is calculated but no self-consistant account of the effect of the photon pumping on the excited levels is included.

We have mainly studied aluminum layers of various thickness in the micrometer range, deposited on silicon substrates. Ablation depths and spatial extensions of aluminum and silicon coronal emissions are compared to experimental results obtained at the GRECO ILM laser facility using a 600 ps, 25 J, 0.53 μm laser pulse. Although the comparison with experiments is rather preliminary, a good overall agreement with the simulations is obtained. The use of various layers thicknesses to achieve temporal resolution is investigated by computing the line emissions with the same spatial resolution as in our experiments. These experiments allow us to compare this method for temporal resolution to streak camera recording which have a poor spatial discrimination.

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RADIATION CODES USING AN AVERAGE ION MODEL APPROACH

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There exist several ways to calculate internal state of plasma particles and radiative properties of hot dense matter (i.e. method of detailed configuration accounting - DCA,cluster band model etc.). With respect to the demand of universality and input unnecessity a method of Average Ion Model (AIM) has been chosen. Versatile computer programs incorporating this approach have been developed. The program DITRA1 makes possible to obtain numerical data for a single element LTE/NLTE plasma, the code DITRA3 can be used for multicomponent plasmas.

The programs have been used to the calculations of group emissivities and opacities of several types of plasmas (i.e. Al, Au, SiO_2 etc.). A comparison of the LTE opacity results has been made with those obtained by using different approaches (including DCA). For the low-Z and medium-Z materials the values are in reasonable agreement. For the high-Z elements the programs are applicable for determination of the qualitative course and for the order-of-magnitude estimations of absorption characteristics.

The programs have been also employed to investigate the radiation and absorption characteristics of NLTE plasmas. The NLTE plasma state is defined in the ad-hoc way. A large difference between the equilibrium and non-equilibrium data can be achieved.

J 8

STABILIZATION OF THE RAYLEIGH-TAYLOR INSTABILITY BY A SHAPED ION BEAM

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Ion beam targets are vulnerable to Rayleigh-Taylor (R-T) instability at the ablation front during the acceleration stage as well as at the gas-pusher interface during the deceleration of the pusher.

We suggest that stabilization of the ablation front might be achieved by appropriately shaping the ion beam voltage. The idea is to raise the voltage so that the deposition front is just behind the density peak. Consequently the highest pressures are generated almost at the density peak leaving little room for R-T instability.

To study the idea detailed 1-D computer simulations were performed (ref. 1). In conjunction with the simulation, the perturbation growth rate was calculated. The target which was examined is simply a gold shell of inner and outer radii of 0.5 and 0.72 mm, containing 50 μg D-T (ref. 1). The shaped voltage was also taken from ref. (1) since it had been programed there according to the same principle.

The calculations indicate that perturbations throughout the gold layer (apart from a small region near the gas interface) grew by a factor less than ten. At the same time comparision calculations for a constant 10Mev proton beam indicated a growth factor of several thousands.

The situation is improved also at the pusher-gas interface. It turned out that in the shaped case, fusion had been completed before the 'free fall' to the center. This is not the case for the constant voltage alternative. This behaviour is the consequence of the much higher densities achieved in the pusher and especially in the fuel in the shaped case.

(1)
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AD A138 316 EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER (16TH ECLIM) IMPERIA..(U) EUROPEAN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT FPO NEW.. 30 SEP 83 2/2

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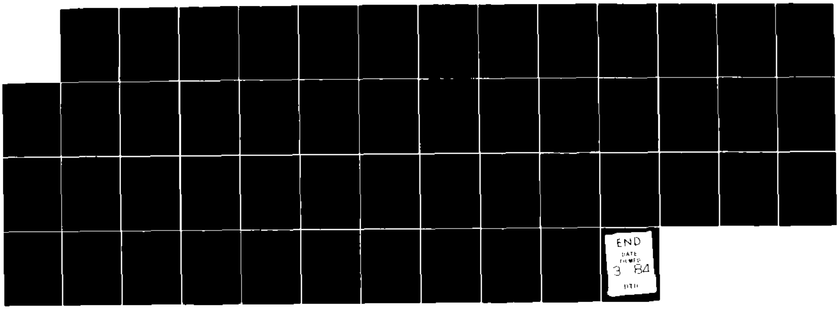

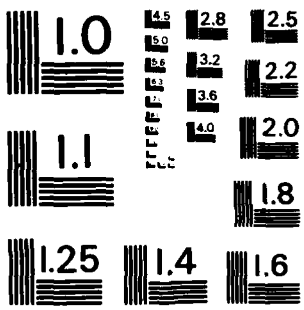

MICROCOPY RESOLUTION TEST CHART
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SOFT X RAY REFRACTOMETRY OF LASER HEATED PLASMAS

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To know or to determine the density profile in the high density region of laser produced plasmas (i.e. the critical density of a 4 ω created plasma or the over critical density region of other laser plasmas) a possibility is to illuminate the plasma with a short wavelength radiation (X UV or X ray range). But interferometry and imaging of plasmas are very difficult or impossible to achieve. The refraction by the plasma of such a probe radiation is another approach.

We propose a new diagnostic of refraction of a probe beam which does not imply an imaging system . First we discuss about the more appropriate wavelength to probe the high density region of a laser created plasma by refractometry. After, we show two possibilities, using a X-ray point source as a probe, of determination of the $\alpha(p)$ law (angle of refraction versus impact parameter) :

- The measurement of the spatial distribution of the intensity of the refracted rays by the plasma which is proportional to the derivative $dp/d\alpha$.
- The perturbation by the refracted light of a micromesh put between the refracting plasma and the recording film which lead to the knowledge of the angles of refraction.

In conclusion we give first results of refraction of soft X-ray radiation coming from a copper or an aluminium laser produced plasma through a CH spherical plasma.

J10

X-RAY EMISSION MODEL FOR LASER PRODUCED PLASMA

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We consider the atomic physics of a perspex ($C_5H_8O_2$) plasma. The ionization states of the atomic species carbon and oxygen are calculated within the framework of a time dependent corona model. The equation for the rate of change for the population density of an ion of charge Z may be written:

$$\frac{dn_Z}{dt} = n_e \left[n_{Z-1}S_Z - n_Z S_{Z+1} - n_Z a_Z + n_{Z+1}a_{Z+1}\right]$$

The collisional ionization rates, S, and the radiative recombination rates, a, are both dependent on the ionization energies, E_Z, of the corresponding species and the plasma temperature, T_e:

$$S_Z(T_e,E_Z) = 1.1\times10^{-5}(T_e/E_Z)^{1/2}\,\frac{\exp(-E_Z/T_e)}{(6 + T_e/E_Z)}\,E_Z^{-3/2}$$

$$a_Z(T_e,E_Z) = 2.6\times10^{-14}Z(E_Z/T_e)^{1/2}[0.86+\ln(E_Z/T_e)+0.94(E_Z/T_e)^{-1/3}]$$

Assuming the composition of a plasma obtained from these equations, we further calculate the free-free bremsstrahlung emission, I^{ff}, and the recombination radiation, I^{fb}, (neglecting line radiation) using the following formulae:

$$I^{ff} \sim n_e(E_H/T_e)^{1/2}\int\sum_Z Z^2\, n_Z\, \exp(-\frac{h\nu}{T_e})\, d\nu$$

$$I^{fb} \sim n_e(E_H/T_e)^{3/2}\int\sum_Z n_Z\, (E_Z/E_H)^2\, \exp(E_Z-\frac{h\nu}{T_e})\, d\nu$$

Simulation runs for a laser pulse duration of 80 ps and plasma temperatures of several hundred eV show, that bremsstrahlung only contributes at most 30% of the whole X-ray emission. Bremsstrahlung is emitted mainly during the laser pulse duration, whereas recombination radiation remains at an appreciable level for several nanoseconds.

J11

Radiation transport in laser-driven microballoon implosions

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Abstract

The transport of energy by X-ray photons has been included in the 1D Lagrangian hydrodynamics code, MEDUSA, and a comparison is made between experimentally measured X-ray spectra and calculated values. Calculations of the implosion by 0.53 μm laser irradiation of plastic and glass microballoons of current interest at the Central Laser Facility show that radiation preheats the fill gas and a significantly lower maximum temperature is obtained. This results for the example of a DT gas fill in a greatly reduced neutron yield. Radiation transfer also alters the temperature and density profile of the shell during implosion which may have implications for the interpretation of backlighting experiments.

ABLATIVE FLOW FROM LASER-IRRADIATED SLABS: A COMPARISON OF THEORY AND EXPERIMENTS.

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ABSTRACT

Theoretical[1-3] and experimental[4-7] results on the corona of plasma ablated from a slab by a laser pulse, are compared. The theoretical model includes Spitzer's heat conductivity ($\bar{K}T^{5/2}$), heat-flux saturation, ion-electron energy relaxation, and absorption both by inverse Bremmstrahlung and anomalous at the critical density n_c; the laser irradiance is assumed to be $I(t)=I_0(t/\tau)^p$, p=1 or 3/2, in order to conveniently model the rising-half of a gaussian pulse of peak *irradiance* I_0 and full width at half-maximun τ. The results can be parametrized by the dimensionless quantities Z_i (mean ion charge number), f (flux-limit factor), $I_0/n_c\bar{m}U^3$, and $\bar{m}U/m_ec$, Where $U\equiv(\tau n_c/\bar{m}^{5/2}\bar{K})^{1/3}$ is a speed, c is the speed of light, m_e is the electron mass, and $\bar{m}$ the ion mass per unit charge. Ablation pressure, mass ablation rate, ion exhaust velocity, and hydrodynamic efficiency are discussed.

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SPECTRAL ANALYSIS OF $3\omega_0/2$-EMISSION IN LASER-PLASMAS

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Near one quarter critical density the incident or back-reflected photon can couple with plasmons from two-plasmon decay (TPD) to generate $3\omega_0/2$-light. In a homogeneous plasma the matching conditions of TPD and 3/2-generation give a red-shift from the nominal $3\omega_0/2$-frequency for the backscattered $3\omega_0/2$-light and a blue-shift for the forward scatter [1]. In an inhomogeneous plasma the wavenumber of plasmons changes during the propagation of the wave. Thus short wavelength TPD-plasmons ($k \gg k_0$) propagating up to density gradient may interact resonantly with photons ($k \sim k_0$) to generate $3\omega_0/2$-radiation. The photons can couple also with reflected plasmons.

The density gradient modifies strongly the results of the homogeneous case increasing possible coupling configurations. The blue-shift in forward $3\omega_0/2$-emission can be considerably larger than predicted by the homogeneous model. The coupling between the incident photon and the reflected plasmon gives a large blue-shift for the backscattered $3\omega_0/2$-photon. In certain conditions also a large red-shift from $3\omega_0/2$-frequency may appear in the forward scatter.

The applicability of the present model to the recent $3\omega_0/2$-experiments at the Rutherford Appleton Laboratory will be discussed.

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J14

Inverse Resonance Absorption in Magnetized Plasmas

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The linear mode conversion of a light wave to a plasma wave is well understood as resonance absorption. However, little attention has been paid to the reverse process. Both can, for example, significantly alter the spectrum, level and threshold of Raman emission from the quarter critical density surface of laser produced plasma. Efficient conversion requires the close proximity of resonance points of the two waves and a finite electric field in the density gradient direction. This, in turn, requires waves propagating obliquely to the density gradient - a two dimensional problem. Alternatively, a DC magnetic field allows coupling in one dimension[1]. Thus, we have studied, using a fluid model and by particle simulation, the linear mode conversion of an upper hybrid wave to an extraordinary wave (and vice-versa).

The wave equation was solved with boundary conditions chosen to simulate an incident upper hybrid wave propagating in to its cut-off from which the conversion efficiency into an extraordinary wave can be computed. In the particle simulations, an upper hybrid wave was artificially stimulated near its cut-off (no incident laser light was present) and the emission emerging from the plasma measured. Both demonstrate the expected scaling with $\tau = (k_0L)^{1/3} (\omega_c/\omega_0)^{1/2}$ (ω_0, k_0, emitted light wave frequency and wave number in vacuo, L is the plasma scale length and ω_c the cyclotron frequency) with maximum conversion efficiencies of 30-50% around $\tau \simeq 0.8$.

In $1\frac{1}{2}$D simulations of stimulated Raman scatter the DC magnetic field reduces emission levels and can even switch off the instability. This is due to the mode conversion of the scattered extraordinary wave to an upper hybrid wave, resulting in an effective increase in the scattered wave damping. Thus growth is reduced and the threshold increased.

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X-RAY AND HARMONIC IMAGING STUDIES OF ILLUMINATION UNIFORMITY FOR 0.53 μm ABLATIVE COMPRESSIONS

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The first 2 ω_0 and $^3/_2$ ω_0 harmonic emission images with high spatial resolution from 0.53 μm laser irradiated microspheres have been obtained using a f/10 spherical reflecting system. The 2 ω_0 images show significant smoothing of the critical density surface for a defocus of greater than 4.5 target radii. The effects of the microsphere stalk on the uniformity of expansion of the quarter critical density surface are apparent in the $^3/_2$ ω_0 images.

The uniformity of X-ray pictures from two orthogonal pin-hole cameras shows strongest energy deposition at the positions where three of the six irradiating beams overlap for a defocus of 4.5 radii, this is in good agreement with computer simulations.

J16

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LARGE ELECTROSTATIC FIELDS AND DOUBLE LAYERS IN LASER PRODUCED PLASMAS

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The hydro-codes for electrons and ions with collisions and time dependent Poisson coupling for very small time steps, arrives at the fact that all real inhomogeneous plasmas have strong electrostatic fields. Their value and collisional damping from the codes can be explained analytically. The generation of 10^9 V/cm fields in the plasma cavitons from 10^{16} W/cm² neodymium glass laser irradiation shows oscillations and wide spread double layers.

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SHOCK PROPAGATION EXPERIMENTS IN SINGLE AND MULTILAYER TARGET FOILS AT 1.06 AND 0.53 μm

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Single and multilayer target foils of different materials have been irradiated with 1.06 μm and 0.53 μm laser beams. Optical streak photography of the rear surface of these targets has recorded the thermal emission from the propagating shockfront. Multilayer targets consisting of layers of low opacity material have revealed the spatial shape and position of the shockfront as it crosses different acoustic impedance boundaries. Shock velocities and inferred pressures have been obtained at different times during the laser pulse. Stepped Al. targets have also been irradiated, giving shock velocities and pressure as a function of irradiance. A two-channel blackbody temperature diagnostic has been used to measure temperatures of a few eV in 5-15 μm Al. foils with 1.06 μm radiation.

Thermonuclear spectroscopy with CR-39 track detectors

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and

W T Toner (R A L)

Detailed analysis of alpha particle and proton tracks in CR-39 prepared and etched under carefully controlled conditions enables the energy of the particles to be determined with a precision approaching the straggling limit.[1] This technique has been applied to ablatively driven implosions of D-T filled glass-walled microballoons at the C.L.F. With thin walled balloons ($t < 1.5$ μm) both α - particles and protons penetrated the stagnated shell material to be registered in this detector. Proton tracks have been recorded for implosions with balloon wall thickness of up to 3.3 μm.

The technique for preparing and analysing the CR-39 will be described and results for the $\rho\Delta r$ of the compressed shells will be presented.

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16th ECLIM, Imperial College, London, 26-30 September 1983

Laser Fusion Research at NRL

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Until recently the NRL laser fusion program has emphasized near-infrared lasers in order to provide enough thermal smoothing of laser nonuniformities, plus broad bandwidth to control the plasma instabilities. Unfortunately, near infrared lasers nave a marginal overall coupling efficiency of the laser energy to the imploding pellet. Near ultraviolet lasers can provide a better overall efficiency (up to a factor of four), but then the smoothing of laser nonuniformities is rather questionable.

Two recently invented concepts[1] now offer the potential of producing ultra-uniform laser illumination starting with realistic laser beam quality. As a result, the NRL program is shifting its emphasis to shorter laser wavelengths, and we are placing extensive effort on upgrading and modifying our facility to test these ideas.

Recent NRL research also includes: (1) Rayleigh-Taylor experiments;[2] (2) a three-dimensional Rayleigh-Taylor theory, and an analytic theory that fits the growth rate found in simulations; (3) long scalelength experiments on backscatter and filamentation with a controlled and variable plasma scalelength; (4) coupling experiments with a variable laser bandwidth; and (5) parameter studies of hydrodynamic efficiency.

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2. J. Grun et al. and R. Whitlock et al., this conference.

K2

Short Wavelength Experiments on NOVETTE

R L Kaufmann

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No Abstract Available

PROPERTIES OF ABLATIVELY ACCELERATED PLANAR TARGET IN 0.26 μm LASER EXPERIMENTS

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Experiments at a wavelength of 0.26 μm, and an intensity range of 10^{13}-10^{14} W/cm^2 have been done in order to study the main parameters characterizing an accelerated thin target : target velocity, uniformity of acceleration and target preheating. The diagnostics used the double-foil technique and optical pyrometry. Different Parameters have been varied, such as the target thickness, the Z of the material and the laser intensity.

K 4

Fast Ion Generation and Transport in CO_2 Laser Irradiated ICF Targets

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No Abstract Available

K5

Computational Results of Target Compression

N G Basov, P P Volosevich, E G Gamaly et.al.

P N Lebedev Physical Institute, Moscow, USSR.

Informal Abstract

Recent results of 1 D and 2 D computations of high aspect ratio targets are presented.

K 6

Investigation of Heating and Compression of High Aspect Ratio Targets at Delphin 1 Installation

N G Basov, G V Sklizkov

Lebedev Physical Institute, Moscow, USSR.

Informal Abstract

Recent experimental results on high aspect ratio targets heating and compression are presented.

L1

Laser Plasma Diagnostics on HELEN

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The HELEN laser system at AWRE is a two beam Nd-glass laser delivering 1 TW per beam at pulse widths ~120 ps. The laser, designed at AWRE, is based upon technology developed at LLNL. The experimental programme is directed towards studying plasma phenomena that occur in very hot dense matter and diagnostics capable of high spectral, temporal and spatial resolution are required.

Fast X-ray diodes (~120 ps), PIN diodes, filter fluorescers and crystal spectrographs are used to record the X-ray spectrum. X-ray streak cameras also provide temporal information.

X-ray backlighting plays a major role in experiments and 4-channel Kirkpatrick Baez X-ray microscopes record the radiographs. Grazing incidence pinhole cameras are used for imaging in regions <500 eV.

Other diagnostics are available including various calorimeters for measurement of target absorption and scatter, streaked optical spectrographs, neutron and α-particle detectors.

New diagnostics under development are high magnification large aperture Wolter X-ray microscopes, Kirkpatrick Baez X-ray microscopes with multilayer coatings for imaging at X-ray energies >4 keV and a streaked X-ray crystal spectrograph for operation in a hard X-ray environment.

L2

The Novette Laser

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The performance of the Novette multi-terrawatt frequency converted glass laser is compared to simulation calculations.

PICOSECOND X-RAY PULSES FROM LASER PLASMA MIRROR

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The dynamics of superradiantly triggered Nd:glass laser system with a target plasma mirror is studied. The system basically consists of four amplifiers (max. rod diameter 45 mm and total optical energy stored up to 560 J), a highly reflecting rear mirror, a focusing lens and a tilted planar target placed inside a vacuum chamber.

The laser action is triggered by the plasma creation on the surface of the carbon target when the superradiance density exceeds a treshold level. The nonlinear reflectivity of the plasma mirror causes the system mode-locking and Q-switching. In one of three observed regimes trains of ultra-short pulses with modulated envelop (approx. 4 pulses on FWHM) due to the system Q-switching have been generated. Mode-locked pulse duration is about 20 ps and pulse separation determined by the system round trip time is 94 ns.

Simultaneously done optical and X-ray diagnostics gave the optical energy density at the surface of the target about 1 kJ/cm^2 (focal spot diameter cca 300 um) and X-ray conversion efficiency $\sim 10^{-6}$ for energies above 1 keV. The electron plasma temperature about 300 eV has been measured using two-foil technique.

The system is considered as a promising source of intense picosecond X-ray pulses and as a new experimental technique of high power large aperture laser system mode-locking.

L 4

Broad-band Soft X-ray Diagnostic Instruments at the LLNL Novette Laser Facility*

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Abstract

Complementary broad-band instruments have been developed to measure time dependent, absolute soft x-ray spectra at the LLNL Nd glass laser irradiation facilities. Absolute flux measurements of x-rays emitted from laser-produced plasmas are important for understanding laser absorption and energy transport. For a number of years, arrays of filtered x-ray diodes, some with grazing incidence mirrors, have been used as primary instruments because they are reliable and can be accurately calibrated. We will describe two new ten-channel XRD systems that have been installed at the LLNL Novette facility for use in the 0.15 to 1.5 keV range. Since XRD channel time response is limited by available oscilloscope performance to 120 ps, a soft x-ray streak camera has been developed for better time resolution (20 ps) and greater dynamic range ($\sim 10^3$) in the same x-ray energy region. Using suitable filters, grazing incidence mirrors, and a gold or cesium-iodide transmission cathode, this instrument has been installed at Novette to provide one broad and four relatively narrow channels. It can also be used in a single channel, spatially discriminating mode by means of pinhole imaging. The complementary nature of these instruments has been enhanced by locating them in close proximity and matching their channel energy responses. As an example of the use of these instruments, we present results from Novette 2ω(0.53 μm) gold disk irradiations at 1 ns and 10^{14} to 10^{15} W/cm^2.

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

L5

SUBNANOSECOND X-RAY FRAMING CAMERA

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In a recent experiment at the Rutherford Laboratory Laser Facility a subnanosecond X-ray framing camera was used as a diagnostic for the first time. Framing speeds of 500 ps were easily obtained, and it is hoped that this will be shortened to $\sim$ 200 ps in future experiments.

The camera was a travelling wave deflection structure driven by a fast risetime staircase waveform. This staircase was produced by a silicon photo-conducting switch illuminated by a series of very short laser pulses, which individually cannot drive the switch into saturation but which increase the switch conductivity in a series of steps thus forming a fast risetime staircase waveform. The laser pulse train was produced by means of a Fabry Perot, which determined the interpulse time.

In this case the interframe time was limited to 500 ps due to the laser probe pulse width of $\sim$ 150 ps. However, for shorter pulses < 100 ps, the effect of the risetime of the camera deflection system would have to be taken into account.

L 6

A GATED X-RAY INTENSIFIER WITH A RESOLUTION OF 50 PSEC

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The design of a gated X-ray intensifier with a resolution of 50 psec is described. A gating pulse derived from a photo conductive switch is used to gate the photo-cathode which is designed as a matched transmission line.

Simple magnetic focussing system allows the gated signal to be differentiated from the hard X-ray signal transmitted through the cathode.

Results from laser produced plasma experiments show gating times of less than 100 psec.

X-Ray Spectroscopy of a Laser Plasma Created by "NIXE"

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The paper deals with the high power Nd^{3+} laser facility "NIXE" built up in cooperation between ZOS of Academy of Sciences of GDR and the Lebedev Physical Institute, Moscov, USSR, and the spectroscopic investigations of the laser created plasma in the x-ray region.

The high power laser facility consists of an electro-optically switched YAG-generator, working in the TEM 00-Mode regime and rod-shaped Nd^{3+} glass amplifiers with 45 mm diameter. At present pulses with a pulse length of 25 ns and a maximal energy of 40 Ws are generated, corresponding to a total amplification of $4 \cdot 10^3$. The beam divergence is $7 \cdot 10^{-4}$ rad. The intensity distribution is slightly hypergaussian shaped and has a half width of 2 w - 30 mm. The linear polarized radiation produced from the YAG-generator is conserved essentially in the whole laser system.

The laser beams have a high degree of coherence according to the single mode regime.
For laser-plasma interaction experiments the radiation of the laser can be focused with the aspherical lens of f/2 aperture into the spherical target chamber.

Investigations of the X-ray spectrum of high Z-plasma were performed by using a three channel X-ray crystal spectrometer in the wave length rang of 0.1 - 1.0 nm and an X-ray microscope with spherically curved crystals. Spectrums were recorded on a UF-VR-film. The results will be discussed.

UV Laser Etching of Polymer Laser Targets

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A novel technique has been developed for structuring polymer laser targets on scale lengths of a few microns. The process involves the removal of material from the surface of the target by UV photo-ablative etching. ArF (193 nm) and KrF (248 nm) lasers have been used to apply modulations to the surface of microdisc and balloon targets by contact lithography methods using this process. Details of the method are presented and examples of targets are shown.

Improvement of compression in new types of targets

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Various targets are designed for GEKKO XII(20KJ,40TW) experiment coming this December. Cannonball target[1] is an example. Recently, preliminary experiments have been done by GEKKO MII(4TW) laser. The experiments have demonstrated *uniformity improvement* and high efficiency of the target and also shown the importance of the x-ray effect.

The soft x-ray driven scheme have also been investigated[2] by GEKKO IV laser and the ablation pressure produced by x-ray heat deposition agrees well with the theoretical prediction[3].

Here, we review recent works on these compression experiments and computer simulations of a new types of targets at ILE Osaka University.

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M2

APPLICATIONS OF LASER PRODUCED PLASMAS*

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When high-power laser radiation is focused onto a solid target, temperatures in excess of several hundred electron volts at plasma densities near that of the solid material can be produced. In this high-energy-density environment, a large fraction of the deposited laser energy may be re-radiated as x-ray radiation. The spectral characteristics of the x-ray emission are dependent on the target and laser parameters. In a series of experiments performed at LLE, we have used the x-ray emission from laser-produced plasmas in a variety of applications including dynamic x-ray diffraction and x-ray lithography. In addition, we are investigating the laser-produced plasma as a medium for achieving soft x-ray amplification. The dynamic diffraction measurements are being conducted with quasi-monochromatic ($\frac{\Delta\lambda}{\lambda} \sim 10^{-2}$) x-ray radiation produced by the radiation of chlorine doped targets. In excess of 1% of the incident 351 nm laser radiation is converted to helium-like chlorine emission at 4.45 Å. A small fraction of this radiation is focused by means of a toroidal x-ray mirror onto a hydrated sample of purple membrane of the Halobacterium halobium. A synchronized visible laser stimulus is applied to this sample in order to study the structural evolution of this protein. X-ray lithographic applications of laser produced plasmas have been demonstrated at LLE in single-shot, sub-micron resolution exposures of PBS and COP resists. The exposures required only 35 J of 351 nm laser energy on target. Finally, we will discuss the current status of x-ray laser development at LLE which includes studies of a recombination laser at 130 Å and a collaborative study with Lawrence Livermore National Laboratory, of a photoionization laser at 460 Å.

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

M3

LASER-EXAFS STUDIES OF HEATED AND UNHEATED ALUMINIUM FOILS

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Time integrated and time resolved extended X-ray absorption fine structure (EXAFS) spectra near the aluminium K edge have been taken, using a laser produced plasma as the X-ray source. The time integrated measurements of unheated aluminium are the clearest yet reported using a laser plasma source, and compare very favourably with data taken using a synchrotron source (ref. 1). Fourier transform analysis of data truncated at $\sim$280eV above the edge shows the positions of the first five coordination shells very clearly. The fit on the positions of the first three shells is to $\sim$1% of crystallographic data.

Time resolved measurements of heated aluminium have been taken, using an X-ray streak camera, the analysis of which will prove very useful for establishing the validity of EXAFS for transient strucutral phase change analysis.

References

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M 4

16th ECLIM, Imperial College, London, 26-30 September 1983

Use of Induced Spatial Incoherence for
Uniform Illumination of Laser Fusion Targets.*

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Earlier studies[1] have shown that the spherical illumination uniformity required for direct drive laser fusion can be achieved by overlapping a limited number ($\gtrsim 20$) of beams, provided that each individual beam profile is smooth and reproducible. Previous efforts to obtain such profiles have been frustrated by the inherent imperfections in high power multistage lasers, which tend to produce random nonuniformities in the output intensity profile. These nonuniformities can only be partially controlled by using ultrahigh quality optics and extensive beam relaying. A recent technique called induced spatial incoherence (ISI)[2] may achieve smooth illumination profiles at the target with modest quality laser beams. The spatial incoherence is created by imposing different optical delays upon different transverse sections of the output beam from a broadband laser, and choosing the delay increments somewhat larger than the optical coherence time $t_c = 1/\Delta\nu$. If t_c is much smaller than the pulsewidth, then a wide aperture beam is broken up into a large number of independent beamlets, each of which focuses to the same smooth and reproducible profile. For times long compared with t_c but short compared to hydrodynamic response times, the interference among the beamlets averages out, leaving only a superposition of the individual profiles. Here, we report the results of preliminary experiments, theory and numerical modeling of this technique. The physics issues include (i) limitations on illumination uniformity of spherical targets, (ii) laser bandwidth requirements and harmonic conversion of broadband laser light, and (iii) filamentation and other instabilities in the underdense plasma.

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

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[2] R.H. Lehmberg and S.P. Obenschain, Optics Commun. 46, 27 (1983).

Analytical inversion and gain calculations in laser-produced hydrogen-like carbon plasmas

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Recombining laser-produced plasmas have been described as attractive sources of strong x-ray emission. Furthermore, under appropriate conditions the origin of population inversions becomes possible and an amplification of x-rays by stimulated emission can be expected /1 - 3/. The purpose here is to calculate analytically population inversion densities and gain in dependence of system parameters.

We start the investigation from a set of rate equations for level population densities in hydrogenic carbon ions. Our model contains radiation reabsorption and stimulated emission in the 2 - 1 Lyman-α line as well as a transition rate to the He-like stage of ionization. In our estimate we take advantage of a 4-level quantum system, where all levels with quantum numbers $q \geq 4$ are connected to an effective pump level.

Population density of the 3 - 2 transition is calculated for the quasi stationary state with electron temperatures between o.5 eV and 50 eV and electron densities $N_e < 10^{18}$ cm^{-3} in collisional-radiative equilibrium.

Following results are obtained:
An inversion of population densities pertaining to levels 2, 3 appears at given temperature only below a determined ion density N_c, whereas N_c decreases with reduced temperature. Taking into account resonance absorption in the H(L_α) line density limit N_c is shifted by about a magnitude toward less values at a plasma length L = 1 mm.

In connection with relatively small allowed population densities, as a result of the 3$\leftrightarrow$2 collisional - radiative conditions and of limitations by radiation trapping, small gain factors will be expected too.
The highest value attainable makes up $G \lesssim 0.6\ cm^{-1}$.

The results will be discussed.

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/2/ A.M. Malvezzi et al., J. Phys. B12, 1437 (1979)

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GAIN MEASUREMENTS AT 182 Å FROM LASER HEATED CARBON FIBRES

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C L S Lewis, E R Mahoney, M J Lamb - The Queen's University of Belfast

M H Key, R Eason, W T Toner - Rutherford Appleton Laboratory

Recombination kinetics in adiabatically expanding laser produced plasmas has been a much discussed mechanism for generating population inversion on soft X-ray transitions within an ion species. We present here conclusions drawn from experimental observations and numerical simulations of gain in the specific recombination scheme leading to lasing action on the 182 Å Balmer Alpha transition of hydrogenic carbon.

Carbon fibres of ≈ 5 μm diameter were irradiated with four cylindrically focussed and symmetrically arranged laser beams at λ = 0.53 μm with an energy of ≤ 10 J per beam in a 200 psec pulse preceded by a 20% prepulse. Energy coupling monitors showed the fibres to be heated over 1.8 mm length with specific absorbed energies in the range 0-2 J/mm. Two cross-calibrated grazing incidence spectrographs recorded time integrated spectral emissions from the plasma in directions axial and transverse to the fibre. Anomalous line intensity ratios on the 182 Å H_α line are interpretated as evidence of gain-length products up to values of about unity (i.e. $\alpha \leq 5\ cm^{-1}$) and this is regarded as a lower limit due to the transient nature of the gain phase.

Numerical simulations using the 2-D hydro code Pollux and the ionisation code GAIN indicate broad agreement with experimental observations but also indicate that the fibres used were not optimally matched to the laser energy available for producing maximum gain. The results obtained in this experiment at the Central Laser Facility will be discussed in the context of earlier results obtained for one sided fibre illumination at Hull University (Ref 1).

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N 1

GENERATION AND FOCUSING OF LIGHT ION BEAMS FOR FUSION

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KARLSRUHE NUCLEAR RESEARCH CENTER, POB 3640,D-7500 KARLSRUHE 1

THE KARLSRUHE NUCLEAR RESEARCH CENTER (KFK) STARTED WORK ON THE PRODUCTION AND FOCUSING OF PULSED LIGHT ION BEAMS IN 1980. THE PURPOSE OF THE PROGRAM IS TO ACHIEVE AND STUDY THOSE EXTREME STATES OF MATTER BEING NECESSARY FOR CONTROLLED INERTIAL CONFINEMT FUSION. FIRST RESULTS IN PARTICULAR WITH THE KFK PULSED POWER GENERATORS WILL BE REPORTED. THE STATE AND CONCEPT OF THE PROGRAM WILL BE OUTLINED.

FIRST EXPERIMENTS ON APPLYING THE PINCH REFLEX DIODE TO THE 2 TW GENERATOR KALIF WILL BE SHOWN. THE CONCEPT OF AN ION DIODE USING SELF-ENFORCED MAGNETIC INSULATION OF THE ELECTRON CURRENT AND FIRST RESULTS ON A 0.1 TW GENERATOR WILL BE REPORTED. FEASIBILITIES STUDIES OF AN ION DIODE OPERATED IN A PARTICULAR GAS DISCHARGE (PSEUDOSPARK)MODE ARE PRESENTED. TECHNICAL DEVELOPMENTS ON INDUCTIVE STORAGE AND OTHER COMPONENTS OF PULSED POWER TECHNIQUE ARE DISCUSSED AS WELL AS RESULTS FROM TARGET CALCULATIONS AND SYSTEM STUDIES.

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x) University of Karlsruhe

xx) University of Braunschweig

N 2

STATUS OF LIGHT ION BEAM FUSION AT SANDIA NATIONAL LABORATORIES

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ABSTRACT

During the past year three diodes have been tested on the PBFA-I accelerator and on several smaller accelerators at Sandia National Laboratories. These tests have pointed out the significance of anode plasma properties. The microscopic divergence of proton beams was measured to be in the range of 1-2 degrees, however, beam deflection has prevented tight focusing on PBFA I. This deflection, thought to be largely because of nonuniform plasma properties, is correctable as evidenced by smaller experiments on PROTO I and Hydramite. Additional experiments on large area diodes and research on plasma sources are continuing. Ion beams were also found to contain several ion species including H, various charge states of C, and other elements. Theoretical modeling predicts the beam composition and points out the need for development of pure, dense, and uniform plasma sources that is currently underway. Progress in the above areas, and plans for higher voltage, nonprotonic ions, and shorter pulses with higher power will be reviewed. Incorporation of these elements and the availability of more energy should lead to the high beam intensity needed for inertial fusion target ignition studies on PBFA II in the late 1980's.

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II 3

ION BEAM-PLASMA INTERACTION AND RADIATION TRANSPORT SIMULATION IN ICF TARGETS: ANALYSIS AND NUMERICAL CALCULATIONS.

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Several physical features are presented in this paper which are needed to check the evolution of targets in ICF, independent of the driver used.

Some of them are related to the hydrodynamic evolution and others to the fusion reactions and alpha and neutron transport.

For the hydrodynamic analysis the mass, momentum and energy conservation equations are solved for each of the two species considered: ions and electrons, in the 2T procedure. In this scheme, the electrons are assumed to be in a state of local thermodynamic equilibrium (LTE) with the radiation field.

The radiation flux is carried out in a monoenergetic diffusion scheme, using an analytical expression for the Roseland opacities that includes bound-free and free-free absorption coefficients, corrected by the stimulated emission, and the Thompson scattering. Because of the several inconsistencies that may appear in the evaluation of the thermal and radiation fluxes when very strong temperature gradients are present, a flux limiter technique is used for the electron and radiation species.

The neutron and alpha particles are considered in a transport scheme calculation, using S_N and a finite element method for the coupling energy--space.

These physical features have been incorporated in our NORCLA modular code, and numerical results for a target of 2 mg of DT, 15 mg of lead, 115 mg of alumina and 100 mg of lead are presented and discussed.

An ion beam profile made up of bismuth ions of 10 GeV is used. After the energy of the ions is deposited in the pellet (STOP rutine), a comparison between the use of 1T and 2T is presented in different time steps.

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IMPERICAL COLLEGE. London

N 4

ICF Target Physics with Heavy Ion Beams

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Possibilities to study ICF target physics relevant to heavy ion fusion with a heavy ion synchrotron are discussed[1). The advantage of using high energy heavy ions (ion energies of some 100 MeV/amu) for producing hot, dense matter is that such beams have low emittance and can be focussed on small spots. Scaling relations for spot size, energy deposition and hydrodynamic response of the heated, needle-like target cylinders are derived. Also, 1D and 2D simulations are shown. Structured targets including different materials and also hollow cylinders leading to cylindrical implosions are discussed.

The heavy ion synchrotron SIS, proposed to be built at GSI/Darmstadt[2) for basic atomic and nuclear research, is taken as a reference case to investigate the limits of target deposition powers and average temperatures to be reached under various circumstances.

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N 5

MEASUREMENTS OF THE ENERGY LOSS OF α-PARTICLES IN HOT, DENSE, PLASMA

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A thin foil heated by two laser beams incident from opposite sides is backlit by α-particles from a nearby exploding pusher driven by four laser beams. The α-particles are registered in CR-39 where their energies can be determined from the etch pit dimensions with a precision approaching the straggling limit.[1] α-particles which have traversed the central heated region of the foil are spatially resolved from those which have traversed the unheated periphery so that the difference in energy loss due to heating can be determined. In a first experiment with a mylar foil the stopping power of the hot region (at a temperature of ~ 150 eV) was a factor of $1.33^{+0.16}_{-0.08}$ greater than that of the cold material, in good agreement with theory. Preliminary results of further experiments will also be discussed.

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N 6

ION BEAM INTERACTIONS IN DENSE PLASMAS

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A unified model is presented for the slowing down of ions in both solid and dense plasmas. The model therefore allows existing data on dE/dx and ion-range measurements made in solids to be extrapolated to the plasma case. Particular examples are given which illustrate both range-shortening and range-lengthening in plasma regimes appropriate to ICF.

Inertial Fusion: Strategy and Potential*

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Inertial fusion must demonstrate that the high target gains required for practical fusion energy can be achieved with driver energies not larger than a few megajoules. Before a multi-megajoule scale driver is constructed, inertial fusion must provide convincing experimental evidence that the required high target gains are feasible. This will be the principal objective of the NOVA laser experiments. Implosions will be conducted with scaled targets which are nearly *"hydrodynamically equivalent" to the high gain target* implosions.

Experiments which demonstrate high target gains will be conducted in the early nineties when multi-megajoule drivers become available. Efficient drivers will also be demonstrated by this time period. Magnetic fusion may demonstrate high Q at about the same time as inertial fusion demonstrates high gain.

Beyond demonstration of high performance fusion, economic considerations will predominate. Fusion energy will achieve full commercial success when it becomes cheaper than fission and coal. Analysis of the ultimate economic potential of inertial fusion suggests its costs may be reduced to half of those of fission and coal. Relative cost escalation would increase this advantage. Fusions potential economic advantage derives from two fundamental properties: negligible fuel costs and high quality energy (which makes possible more efficient generation of electricity).

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

Light Matter Experiments in Frascati

A Caruso

E N E A, Frascati, ITALY

Abstract Not Available

Theoretical Framework and Numerical Studies for Modeling Laser Plasma Interaction

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ABSTRACT

We discuss the theoretical framework used to model the interaction of a focused CO_2 laser on a spherical target. In order to model the self-consistent generation of fast electrons, we include the absorption and hot electron spectrum as calculated by WAVE, in a self-consistent fashion, in the multi-fluid code LASNEX. For numerical studies, the intensity pattern on a target has been chosen to mock-up the experimental pattern.

Because the physics is at least 2D, the effect of self-generated magnetic fields must be taken into account due to the fact that they inhibit the electron transport producing sharper pressure profiles, and hence, fast ions, etc. Detailed comparison between theory and CO_2 experimental data in which no "fudge" parameters (i.e., flux limitor, etc.) are used, for a given shot is presented.

If time allows, we will discuss similar experiments done with different laser wave lengths (e.g., 1. μm, .5 μm, .25 μm).

04

Nonlinear heat flow in a steadily ablating plasma

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Abstract

A simple method of solving the electron transport equation in the presence of a steadily ablating plasma is described. The electric field, ion motion and density gradients are considered self-consistently. The numerical method involves decomposing the electron distribution function into discrete trajectories of the collisionless electrons. The results show that the presence of a steady state ablation tends to reduce the electric field in the direction of the heat flow (compared to a plasma with no ion motion). No indication that ion motion can result in further 'flux inhibition' is seen.

Heat Flux Down Steep Temperature Gradients

J F Luciani, P Mora, J Virmont

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Informal Abstract

Results from fully kinetic Fokker-planck simulations are presented. A simple non-local expression of the heat flux is proposed and compared to the simulation results.

NON LOCAL CONTRIBUTION TO THERMAL TRANSPORT

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In typical laser-plasma interaction experiments the temperature gradient at the heat front is steep enough to cause significant non local energy transport.

In order to study the effects of such non local energy transport on the temperature profile at the heat front we have used the hybrid model[(1)] which describes both the fastest electrons of the thermal distribution (above $\sim 4kT_e$) and the suprathermal electrons via a multi-group treatment.

Simulations of 1μm laser experiments show a large broadening of the temperature profile at the base of the heat front, compared to simulations using an effective flux limiter. Low temperature contours (such as 200 ev) penetrate deeply into the target while the penetration of higher temperature contours (such as 800ev), which better represent the position of the main heat front, is comparable to that described by a flux limiter of 0.06.

(1)
D. Shvarts, J.A. Delettrez and R.L. McCrory, in workshop on "The flux limiter and heat flow instabilities in laser fusion plasma", Orsay, September 1981.

Kinetic Treatment of Heat Flow Instabilities in Laser-Produced Plasmas

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Abstract

A new kinetic model appropriate to thermomagnetic instabilities of collisional, high Z, plasmas has been developed. The theory corrects and extends the earlier fluid results to where the perturbation wavelength is less than 10^3 times the electron mean-free-path. A greatly increased growth rate for the instability is predicted for regions where the density and temperature gradients are anti-parallel. Improved fluid results are also presented, based on correction of Braginskii coefficients.

Solution of the time-independent Vlasov-Fokker-Planck equation for a laser-produced ablating plasma

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Electron energy transport in a laser-produced ablating plasma is examined by self-consistent solution of the Vlasov-Fokker-Planck equation for electrons and the fluid equations for cold ions. Approximations are introduced which allow the equations to be placed in a form which provides for much faster solution on a computer than was previously possible. It is found that the spatial profiles for temperature and density in planar geometry differ very little from those calculated from the Spitzer conductivity. At high irradiances, the effects of spherical geometry are important, the scalelength of the temperature profile is shorter, and the Spitzer conductivity is not valid.

Applications of Incomplete-Factorial-Design to ICF Modeling and Experimental Design.* L. Suter, Lawrence Livermore National Laboratory, Livermore, CA.--Many industrial processes are similar to ICF in that they're characterized by a large number of free parameters whose effects are poorly understood. To minimize the number of experiments needed to understand these processes, industry uses a systematic technique of parameter variation called "incomplete factorial design." We'll apply incomplete factorial design to the LASNEX modeling of disc experiments. This case study will show how you can use this technique to understand the main effects of physics-model parameters. We'll also show how you might use incomplete factorial design to experimentally understand the effect of hard to calculate parameters such as aspect ratio, convergence, surface finish and symmetry on capsule performance.

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

16th European Conference on Laser Interaction with Matter

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