16th Anomalous Absorption Conference

Lake Luzerne, N.Y.

July 13-18, 1986

Hosted By:

Laboratory for Laser Energetics
University of Rochester

Conference Chairman: Wolf Seka
Conference Coordinator: Linda Cicero

AGENDA

16th ANOMALOUS ABSORPTION CONFERENCE

LAKE LUZERNE, N.Y. -- JULY 13-18, 1986

Sunday: 6:00-8:00 PM Dinner

8:00-10:00 PM Registration and Reception

Meals served as follows:

Breakfast	7:30 - 8:30 AM
Lunch	12:00 - 1:00 PM
Dinner	6:00 - 7:00 PM

			Category	Chairman
Monday:				
A	8:30 AM	Oral	Laser-Plasma Interactions	H.A. Baldis (NRC)
B	7:30 PM	Review	Laser-Plasma Interactions - Where do we stand? E.M. Campbell (LLNL)	R.L. McCrory (LLE)
C	8:30 PM	Poster	Hydrodynamics, Transport, Diagnostics	
Tuesday:				
D	8:30 AM	Oral	Hydrodynamics, Transport, Uniformity	R. R. Johnson (KMS)
E	7:30 PM	Review	TITLE: Summary of Experiments on Delfin-1 O. Krokhin (USSR)	D. W. Forslund (LANL)
F	8:30 PM	Poster	Interaction Physics	

Wednesday:

G	8:30 AM	Oral	**Parametric Instabilities in the Corona**	W. L. Kruer (LLNL)
H	7:30 PM	Review	**Nonlinear Processes in Ionspheric Plasma** A. Wong (UCLA)	T.J.M. Boyd (U of N. Wales)
I	8:30 PM	Poster	**X Rays, Beat Waves**	

Thursday:

J	8:30 AM	Oral	**ICF Experiments and Theory**	A.A. Offenberger (U of Alberta)
	6:00 PM	BBQ		
K	8:00 PM	Review	**Symmetry and Stability Issues in Direct Drive Laser Fusion,** S. E. Bodner (NRL)	E. Fabre (Ecole Polytechnique)
	9:00 PM	**Business Meeting**		W. Seka (LLE)

Friday:

L	8:30 AM	Oral	**Beat Wave Accelerators, X-Ray Generation and Transport**	J. Grun (NRL)

Monday 8:30 AM

Laser-Plasma Interactions (Oral) Chairman: H.A. Baldis (NRC)

8:30 Introductory Remarks

8:45 A1 **Second Harmonic Emission from an Underdense CO_2-Laser Produced Plasma and Filamentation,** J. Meyer and Y. Zhu (UBC)

9:00 A2 **Frequency Shift of Plasma Waves Driven by Absolute SRS,** D. M. Villeneuve, H. A. Baldis, and J. E. Bernard (NRC of Canada)

9:15 A3 **Observation of Enhanced Short Wavelength Ion-Acoustic Fluctuations in a CO_2 Laser-Plasma Interaction,** J. E. Bernard, H. A. Baldis, and D. M. Villeneuve (NRC of Canada)

9:30 A4 **Observation of Forward SRS from Thin-Foil Targets,** R. E. Turner, K. Estabrook, R. P. Drake, H. Kornblum, and E. A. Williams (LLNL)

9:45 A5 **Effect of Angle of Incidence on Scattered Light in Nova Experiments,** R. P. Drake, D. Montgomery, R. E. Turner, and P. W. Phillion (LLNL)

10:00 A6 **Frequency Modulation of Laser Radiation Reflected from an Expanding Laser Produced Plasma,** R. Dragila, A. Maddevar, B. Luther-Davies (Australian National University)

10:15 Coffee Break

10:45 A7 **Raman Scattering Via Enhanced Thomson; Further Studies,** A. Simon, R.W. Short, K. Swartz, and W. Seka (LLE)

11:00 A8 **Raman Scattering from Inhomogeneous Plasmas,** S.H. Batha, W. Seka, and A. Simon (LLE)

11:15 A9 **Simulations of Enhanced Thomson Scattering,** T. J. M. Boyd and G. A. Gardner (University of Wales)

11:30 A10 **Stimulated Raman Scattering in the Presence of Filamentation,** H. C. Barr, T. J. M. Boyd, and G. A. Coutts (University of Wales)

11:45 A11 **Stimulated Raman Scattering in Filaments,** R. W. Short (LLE)

12:00 A12 **Raman Scattering Driven by Multiple Pumps in Laser Fusion Plasmas,** K. Swartz, R. W. Short, and A. Simon (LLE)

Monday 7:30 PM

B Review and Discussion Chairman: R.L. McCrory (LLE)

Laser Plasma Interactions - Where do we stand?
E.M. Campbell (LLNL)

Monday 8:30 PM

C Hydrodynamics, Transport, Diagnostics (Poster)

C1 **The Generation and Transport of Hot Electrons in CO_2 Laser-Target Interactions at Intensities up to 5 x 10^{15} W/cm^2,**
G. D. Enright and N. H. Burnett (NRC of Canada)

C2 **Time Resolved Thomson Scattering Measurements of the Electron and Ion Temperatures in a CO_2 Laser-Plasma Interaction,** J.E. Bernard, H. A. Baldis, and D. M. Villeneuve (NRC of Canada)

C3 **Measurements of Scattered Light and Absorption Processes in Cavity Structured Targets,** K.A. Tanaka, T. Boehly, T. Mochizuki, K. Nishihara, M. Mineo, M. Murakami, Y. Sakawa, K. Sakurai and C. Yamanaka (Osaka University)

C4 **Compression Measurements from X-Ray Backlighting of Cryogenic Implosion Experiments,** C.L. Shepard, R.R. Johnson, G. Charatis, B.H. Failor, E.F. Gabl, J.T. Larsen, L.V. Powers and P.D. Rockett (KMS Fusion)

C5 **Time-Resolved Absorption Measurements on OMEGA,** P. A. Jaanimagi, L. DaSilva, J. Delettrez, G. G. Gregory, and M. C. Richardson (LLE)

C6 **Space Resolved X-Ray Spectra of Imploding Laser Fusion Targets,** P. Audebert, O. Barnouin, J. Delettrez, F. J. Marshall, and B. Yaakobi (LLE)

C7 **Alpha Particle Imaging of High-Yield Implosions,** J. S. Wark, J. Delettrez, S. Letzring, F. J. Marshall, R. L. McCrory, M.C. Richardson, J.M. Soures, and C.P. Verdon (LLE)

C8 **Simulation and Optimization of a Penumbral Neutron Imaging Camera,** K.A. Nugent and B. Luther-Davies (Australian National University)

Monday 8:30 PM

C9 **"Modulated Interferometry" for Fully Automated Analysis of Magnetic Field Measurements in Laser-Produced Plasmas,** M. Kalal, K.A. Nugent and B. Luther-Davies (Australian National University)

C10 **Generation of Axial Magnetic Fields in a Laser-Produced Plasma by a Turbulent Dynamo,** R. Dragila (Australian National University)

C11 **Smoothing of Non-Uniform Illumination of Laser Target,** J. Sanz, J.R. Sanmartín, and J.A. Nicolás (Universidad Politecnica de Madrid)

C12 **Stability of Deflagration Layer in a Laser-Produced Plasma,** J.R. Sanmartín, J.A. Nicolás, and J. Sanz (Universidad Politecnica de Madrid)

C13 **Evaporation of a Cold, Dense, Hydrogen Sphere in a Hot Plasma: The Evolution to Steady State,** M.J. Dunning, F.J. Mayer, and S.B. Wineberg (KMS Fusion)

C14 **Generation of Ultra-High Pressures Obtained by Collision of a Foil Accelerated by a 0.26 μm Wavelength Laser. Experimental and Numerical Results Evidencing Two-Dimensional Effects,** R. Fabbro, B. Faral, J. Virmont (Ecole Polytechnique), F. Cottet, and J.P. Romain (ENSMA, France), H. Pépin (INRS Energie)

C15 **Hydrodynamic Aspects of Pharos III X-Ray Laser Target Designs,** J.P. Dahlburg, J.H. Gardner, M.H. Emery, and J.P. Boris (NRL)

C16 **An Examination of Experimentally Measured Plasma Density Distributions Produced Between Two Exploding Foils,** B. H. Failor, C. L. Shepard, E. F. Gabl, and G. Charatis (KMS Fusion)

C17 **Lagrangian Simulation of Laser Heated Thin Foil Planar Targets,** D. Havazelet, C.E. Capjack, C.R. James, and R. Marchand (University of Alberta)

C18 **Simulations of Reduced Burn Through Times During Long Scalelength Plasma Formation by CO_2 Lasers,** R. Rankin, C. E. Capjack, and J. Meyer (University of Alberta)

C19 **Fokker Planck Modelling of Laser Plasma Interactions,** L. Wood (St. Andrews University)

C20 **Time-Resolved Ablation Measurements of Imploding Targets,** L. DaSilva (UBC), J. Delettrez, R. Epstein, G.G. Gregory, P.A. Jaanimagi, and M.C. Richardson (LLE)

C21 **Study of the Existence Conditions of the Dynamo Effect in Laser Matter Interaction,** J. Briand, M. El Tamer, J. C. Kieffer, A. Gomes, Y. Quemener, C. Arnas, J. P. Dinguirard, M. Armengaud, L. Berge (U of Sabatier and Ecole Polytechnique, France)

<u>Tuesday</u> 8:30 AM

D <u>Hydrodynamics, Transport, Fillamentation (Oral)</u>

Chairman: R. Johnson (KMS)

8:30 D1 **Dynamics of Laser-Driven Shock Waves,** A. Ng, P. Celliers, and D. Parfeniuk (UBC)

8:45 D2 **Measurements of Mass Ablation Rate and Pressure in Planar Targets Irradiated by 0.27 μm Laser Light,** T. Boehly, K. A. Tanaka, T.Mochizuki, K. Nishihara, and C. Yamanaka (Osaka University)

9:00 D3 **Energy Transport in High-Z Plasma Produced by a KrF Laser,** P. D. Gupta, Y. Y. Tsui, R. Popil, R. Fedosejevs, and A. A. Offenberger (University of Alberta)

9:15 D4 **Thermal Energy Transport in Spherical Geometry,** D. Bassett, D. K. Bradley, A. Cole, A. Hauer, J. D. Kilkenny, S.D. Tabatabaei, and O. Willi (Imperial College of Science and Technology)

9:30 D5 **Effects of Ilumination Non-Uniformities on the Interpretation of Spherical Transport Experiments,** J. Delettrez, R. Epstein, P. Jaanimagi, T. Kessler, M. Richardson, W. Seka, and S. Skupsky

9:45 D6 **Thermal Smoothing and Filamentation in Laser Irradiated Targets,** R. J. Mason and J. M. Wallace (LANL)

10:00 Coffee Break

10:30 D7 **LASNEX Laser Plasma Simulations Employing Nonlocal Electron Heat Transport,** R. A. Sacks, B. F. Lasinski, J. R. Albritton, and E.A. Williams (LLNL)

10:45 D8 **Electro-Sound Solitary Wave in Rarefied Nonisothermic Plasma,** O.N.Krokhin (USSR Academy of Science)

11:00 D9 **Delocalisation of Heat Flux,** Pierre-André Holstein (CEA)

11:15 D10 **Rayleigh Taylor Instability and Implosion Uniformity,** K. Mima, H. Takabe, F. Hattori, H. Nishimura, Y. Izawa, S. Nakai, and C. Yamanaka (Osaka University)

11:30 D11 **The Rayleigh-Taylor Instability with 1, 1/2 and 1/4 μm Laser Light,** M. H. Emery, J. P. Dahlburg, and J. H. Gardner (NRL)

Tuesday 7:30 PM

E Review and Discussion Chairman: D. Forslund (LANL)

Summary of Experiments on Delfin-1, O.N. Krokhin (USSR Academy of Science)

Tuesday 8:30 PM

F Parametric Instabilities in the Corona (Poster)

F1 **Raman Studies in a Long Homogeneous Plasma,** F. Amiranoff, C. Labaune, E. Fabre, and C. Stenz (Ecole Polytechnique) G. Matthieussent (Université Paris), M. Hagenauer and E. Parey (Ecole Polytechnique)

F2 **On the Stimulated Raman Scattering Threshold,** H. C. Barr, T. J. M. Boyd, and G. A. Couttes (U of N. Wales)

F3 **Stimulated Raman Scattering from Hot Underdense Plasmas at 10.6 μm,** S. Aithal, M. Chaker, P. Lavigne, H. Pépin, and T. W. Johnston (INRS-Enérgie)

F4 **Temporal Behavior of Stimulated Raman Scattering in a CO_2-Laser Produced Plasma,** J. Meyer, G. McIntosh, and Y. Zhang (UBC)

F5 **Observation of $(3/2)\omega_0$ EM Radiation from the Resonant Layer in an Inhomogeneous Plasma,** T. Tanikawa and A. Y. Wong (Univ. of CA)

F6 **Heating of Electrons by the Langmuir Waves Produced in Stimulated Raman Scattering,** W. Rozmus, R. P. Sharma, J. Samson, W. Tighe, and A. A. Offenberger (University of Alberta)

F7 **Nonlinear Competition Between Two-Plasmon Decay and Stimulated Raman Scattering,** L.V. Powers and R.L. Berger (KMS Fusion)

F8 **Two Plasmon Decay, Linear and Nonlinear,** P.N. Guzdar, Y.C.Lee, and C.S. Liu (University of Maryland)

F9 **Numerical Solution of Time- and Space-Dependent Coupled Mode Equations in Inhomogeneous Plasma,** R.L. Berger (KMS Fusion)

F10 **Numerical Study of Two-Dimensional Three Wave Interactions in Inhomogeneous Media,** E.F. Gabl (KMS Fusion)

F11 **Transition to Turbulence in the Forced Non-Linear Schrödinger Equation,** O. Larroche (C.E.A.), D. Pesme (Ecole Polytechnique)

F12 **Experimental Results on Filamentation in 1 μm, 0.5 μm, and 0.25 μm Laser Produced Plasmas,** C. Arnas, J. Briand, J. C. Kieffer, A. Gomes, Y. Quemener, M. Armengaud, J. P. Dinguirard, L. Berge (Univ. of Sabatier and Ecole Polytechnique, France)

F13 **Study of the Coherence of the Second Harmonic Emission in 1.06 μm Laser Produced Plasmas,** J. Briand, J. C. Kieffer, A. Gomes, Y. Quemener, M. Armengaud, J. P. Dinguirard, C. Arnas, L. Berge (Univ. of Sabatier and Ecole Polytechnique, France)

<u>Wednesday</u> 8:30 AM

G <u>Parametric Instabilities in the Corona (Oral)</u>

Chairman: W. Kruer (LLNL)

8:30 G1 **Resonance Absorption and Parametric Decay in the Presence of a Wide Bandwidth Pump,** B. B. Afeyan, J. F. Drake, Y. C. Lee, and C. S. Liu (University of Maryland)

8:45 G2 **Model Simulations of Inhomogeneous Parametric Instabilities,** C. H. Aldrich, B. Bezzerides, and D. W. Forslund (LANL)

9:00 G3 **Parametric Instabilities in Parabolic Profiles,** E. A. Williams (LLNL) and T. W. Johnston (INRS Energie)

9:15 G4 **Raman Scattering Thresholds,** T. W. Johnston (INRS Energie), E. A. Williams, R. E. Turner, R. P. Drake, D. W. Phillion, and H. N. Kornblum (LLNL)

9:30 G5 **Simultaneous Raman and Brillouin Scattering Instabilities,** W. Rozmus, R.P. Sharma, W. Tighe, and A.A. Offenberger (University of Alberta)

9:45 G6 **Nucleation of Langmuir Caviton Collapse by Finite Amplitude Ion Sound Waves,** D. F. DuBois, B. Bezzerides, G. D. Doolen, and H. A. Rose (LANL)

10:00 Coffee Break

10:30 G7 **Nonlinear Coupling and Saturation of SRS and SBS in Finite Geometry,** H. A. Rose, B. Bezzerides, and D. F. DuBois (LANL)

10:45 G8 **Collapsing Caviton Turbulence in Two Dimensions,** D. Russell, D.F. DuBois and H.A. Rose (LANL)

11:00 G9 **Observation of Lateral Energy Transport by Superthermal Electrons from High Resolution Space Resolved K-alpha Emission in Layered Laser Irradiated Targets,** B. Luther-Davies, A.J. Perry and K.A. Nugent (Australian National University)

11:15 G10 **Non-local Treatment of the Collisional Weibel Instability in Laser-Produced Plasmas,** E.M. Epperlein and A.R. Bell (Imperial College of Science and Technology, London)

11:30 G11 **Intense Electromagnetic Wave Interactions in Very Large-Scale Plasmas,** J.P. Sheerin (KMS Fusion)

11:45 G12 **Theoretical Research of Two Dimensional Effects Under Laser Target Compression,** E. G. Gamaly (USSR Academy of Science)

Wednesday 7:30 PM

H Ionspheric Plasma Phenomena (Review)

Chairman: T.J.M. Boyd (Univ. of N.Wales)

Nonlinear Processes in Ionspheric Plasmas, A. Y. Wong (UCLA)

Wednesday 8:30 PM

I X Rays, Beat Waves (Poster)

I1 **Study of Laser Created X-Ray Sources,** H. Pépin, P. Alaterre, M. Chaker, P. Lavigne, and F. Martin (Université du Québec), R. Fabbro, B. Faval (Ecole Polytechnique)

I2 **Effect of the Atomic Number of the Target Material on the Soft X-Ray Emission of Laser Produced Plasmas at 1.06 μm, 0.53 μm and 0.26 μm,** R. Benattar and J. Godart (Ecole Polytechnique)

I3 **Intense Soft X-Ray Generation and its Energy Transport in Short Wavelength Laser-Produced Plasmas,** T. Mochizuki, K.A. Tanaka, R. Kodama, T. Yabe, and C. Yamanaka (Osaka University)

I4 **Dot Spectroscopy of Eu at the JANUS Laser,** S. Maxon, D. Bailey, J. Kilkenny, P. Hagelstein, D. Weber, J. Scofield, and Y. Lee (LLNL)

I5 **High-Z Laser Target Interaction at $\lambda = 0.35\ \mu m$,** S. R. Goldman, W. C. Mead, J. A. Cobble, N. Delamater, P. D. Goldstone, R. D. Jones, G. L. Stradling (LANL), P. A. Jaanimagi, R. S. Marjoribanks, F. J. Marshall, M. C. Richarson, and S. Skupsky (LLE)

I6 **Optimization Studies of X-Ray Conversion Efficiency,** S. V. Coggeshall and W.C. Mead (LANL)

I7 **Use of X-Ray Diagnostics for Testing Thermal Transport Models,** R. Marchand, D. Havazelet, C.E. Capjack, and A. Birnboim (University of Alberta)

I8 **Saturation and Asymptotic Behavior of Beat Excited Plasma Waves,** W.B.Mori (University of California)

I9 **Electron Acceleration in Localized Plasma Waves,** M. Colunga, J.F. Luciani, and P. Mora (Ecole Polytechnique)

I10 **Modelling of Beat Wave Generation in Laser Breakdown Plasmas,** J.P. Matte, F. Martin, and P. Brodeur (INRS-Enérgie)

I11 **Linear and Nonlinear Response of Ion Acoustic Waves Driven by Optical Mixing,** C.J. Pawley and N.C. Luhmann, Jr. (University of California)

I12 **Nonlinear Stimulated Raman Scattering in the Beat-Wave Accelerator,** C.J. McKinstrie and D.W. Forslund (LANL), S.H. Batha (LLE)

I13 **Space-Time Coherence of Beat Wave and Particle Acceleration,** K. Mima, H. Takabe, T. Oosuga, and K. Nishihara (Osaka Univeristy), T. Tajima and W. Horton (University of Texas)

I14 **Dissipation in Relativistic Collisionless Shocks,** A.B. Langdon, D.W. Hewett, C.E. Max, and J. Arons (LLNL)

Thursday 8:30 AM

J **ICF Experiments and Theory (Oral)**
Chairman: A. A. Offenberger (U of Alberta)

8:30 J1 **KrF Laser-Matter Interaction in the Long Pulse, Low Intensity Regime,** S.J. Gitomer, S.R. Goldman, R.A. Kopp, N.D. Delamater and J. Norton (LANL)

8:45 J2 **Au Disk Experiments Using the Nova Laser,** R.L. Kauffman, M. Cable, P. Drake, H. Kornblum, B. Lasinski, and R.E. Turner (LLNL)

<u>Thursday</u> 8:30 AM (continued)

9:00 J3 **Spherical Implosion Experiments with Cryogenic PVA Targets at 0.53 μm Laser Wavelength,** R.R. Johnson, Gar. E. Busch, J.S. Ankney, J.R. Brundage, B. H. Failor, G.J. Fomin, E.F. Gabl, J.T. Larsen, M.T. Mruzek, D.L. Musinski, L.V. Powers, P.D. Rockett, R.J. Schroeder, C.L. Si, J.D. Simpson, J.M. Stiegman, and D. Sullivan (KMS Fusion)

9:15 J4 **Results of Short Pulse UV Driven High Aspect Ratio Implosion Experiments on the University of Rochester OMEGA Laser System,** F.J. Marshall, L.B. DaSilva, G.G. Gregory, S.A. Letzring, R.L. McCrory, P.W. McKenty, M.C. Richardson, J.M. Soures, C.P. Verdon, and J.S. Wark (LLE)

9:30 J5 **Implosion Dynamics of Low Aspect Ratio Gas-Filled Targets Driven by UV Radiation,** M. C. Richardson, L. DaSilva, G. G. Gregory, P. A. Jaanimagi, S. A. Letzring, F.J. Marshall, R. L. McCrory, P. W. McKenty, D. M. Roback, J. M. Soures, C. P. Verdon, and J. S. Wark (LLE)

9:45 J6 **Hydrodynamic Properties of Planar Targets Accelerated by a Smooth Laser Beam,** J. Grun, J. Stamper, C. Manka, E.A. McLean, S. P. Obenschain, T. Y. Lee, B. H. Ripin, M.Emery, and S. Bodner (NRL)

10:00 Coffee Break

10:30 J7 **Measurements of SBS Backscattered Spectra with ISI Illumination,** A. N. Mostovych, S. P. Obenschain, E. A. McLean, A. J. Schmitt, J. Grun, and J. H. Gardner (NRL)

10:45 J8 **The Role of Filamentation in the NRL ISI Experiments,** A.J. Schmitt (NRL)

11:00 J9 **LASNEX Simulations of the Behavior of Thermal Self-Focusing in Large High-Z Plasmas,** W. C. Mead, R. D. Jones, S. V. Coggeshall, and J. L. Norton (LANL)

11:15 J10 **Modeling of Self-Focused Laser Beams Under Reactor Conditions,** R.D. Jones, W.C. Mead, and S.V. Coggeshall (LANL)

11:30 J11 **Kinetic Effects in the Self Focusing of Short Wavelength Laser Light in Reactor Targets,** J.M. Wallace and R.D. Jones (LANL)

11:45 J12 **Thermal Self-Focusing with Multiple Beams,** R.S. Craxton and R.L. McCrory (LLE)

12:00 J13 **UV Implosions at GRECO ILM,** E. Fabre (Ecole Polytechnique)

Thursday 8:00 PM

K **Review and Discussion** Chairman: E. Fabre (Ecole Polytechnique)

Symmetry and Stability Issues in Direct Drive Laser Fusion, S. Bodner (NRL)

Thursday 9:00 PM

Business Meeting Chairman: W. Seka (LLE)

Friday 8:30 AM

L **Beat Wave Accelerators, X-Ray Generation and Transport (Oral)** Chairman: J. Grun (NRL)

8:30 L1 **Experimental Test of the Laser Plasma Beatwave Accelerator Concept,** F. Martin, N.A. Ebrahim, P. Brodeur, E.A. Heighway, J.P. Matte, H.Pepin, P. Lavigne, and T.W. Johnston (INRS-Energie)

8:45 L2 **Excitation of Beat Waves in a Rippled Density Plasma,** C. Darrow, D. Umstadter, T. Katsouleas, W.B. Mori, C.E. Clayton, and C. Joshi (University of California)

9:00 L3 **Ponderomotively-Driven Ion Acoustic Waves: Simulation and Experiment,** W.L. Kruer and K. Estabrook (LLNL)

9:30 L4 **Solitary-Wave Solutions of the Beat-Wave Equations,** C. J. McKinstrie, D. F DuBois, and D. W. Forslund (LANL)

9:45 L5 **Various Aspects of Axially Fed Laser Electron Accelerator,** F. Brunel (NRC of Canada)

10:00 L6 **X-ray Energy Conversion Measurements in 0.25 μm Laser/Plasma Interaction,** R. Popil, P.D. Gupta, R. Fedosejevs, and A.A. Offenberger (University of Alberta)

10:15 L7 **Non-LTE Radiation and Ion-Dynamic Effects in Hydrodynamic Simulations of Laser-Driven Plasmas,** R. Epstein, J. Delettrez, and S. Skupsky (LLE)

10:30 L8 **X-Ray Line Transfer in Thick, Laser-Produced Plasmas,** D. Mostacci, R. Morse, and J. Dinguirard (University of Arizona)

Session A

(Oral)

Laser-Plasma Interactions

Monday, 8:30 AM

Chairman: H. A. Baldis (NRC)

Second Harmonic Emission from an Underdense CO_2-Laser Produced Plasma and Filamentation

J. Meyer and Y. Zhu (UBC)

Second harmonic emission is observed from an underdense gas jet target irradiated by a CO_2-laser at intensities $< 10^{14}$ W/cm^2. Maximum $2\omega_0$-intensities are observed in a forward directed cone with $18° < \Theta < 36°$ and in backward direction. The $2\omega_0$-power increases with the square of the incident laser energy. The forward emission is shown to be consistant with predictions derived from a theoretical model for filamentation. The backward emission shows significant spectral broadening and a blue shift of $4.7 \times 10^{-3}\ \lambda_0$ against $\lambda_0/2$. The back emission appears to originate from the breakdown wave propagating into the low-density background gas which stabilizes the jet. Gaussian waveguide

Supported by a grant from NSERC Canada.

Frequency Shift of Plasma Waves Driven by Absolute SRS

D. M. Villeneuve, H. A. Baldis, and J. E. Bernard (NRC of Canada)

The frequency of plasma waves driven by absolute stimulated Raman scattering (SRS) near the quarter-critical surface has commonly been estimated by determining the density at which the scattered wave is cut off. This approach suggests that $\omega_{pe} = \frac{\omega_0}{2} - \frac{9}{8}\left(\frac{v_e}{c}\right)^2$ and $\omega_p = \frac{\omega_0}{2} + \frac{9}{8}\left(\frac{v_e}{c}\right)^2$, where ω_{pe} is the electron plasma frequency, and ω_p is the plasma wave frequency. The frequency of the plasma waves has traditionally been difficult to measure experimentally, because the $\frac{\omega_0}{2}$ light spectrum is complicated by the re-emission of light by two-plasmon decay.

We have measured the frequency of the plasma waves in the vicinity of the quarter-critical surface in a preformed underdense plasma, using Thomson scattering techniques. The wavevectors being probed were restricted to the range $\mathbf{k}_p \approx \pm(0.5 - 1.5)\mathbf{k}_0$ to discriminate against waves driven by two-plasmon decay. The spectra were quite narrow, but were at a frequency lower than that expected, i.e., $\omega_p = \frac{\omega_0}{2} - \delta$. These results will be compared with current SRS theories.

Observation of Enhanced Short Wavelength Ion-Acoustic Fluctuations in a CO_2 Laser-Plasma Interaction

J. E. Bernard, H. A. Baldis, and D. M. Villeneuve (NRC of Canada)

Large angle, temporally and spectrally resolved Thomson scattering was used to study ion acoustic waves with k-vectors ranging from 9 to 33 k_{pump} ($k\lambda_{De} = 0.3$ to 1.2) which occurred in a CO_2 laser–plasma interaction. The ion feature in the Thomson scattering spectrum was temporally and spectrally resolved to < 150 ps and ~ 0.5 Å respectively. Fluctuations enhanced above thermal levels were observed for a wide range of incident CO_2 laser energies and for preformed plasma densities ranging from $0.02 - 0.5 n_{cr}$. Both the level of enhancement as well as the fraction of shots on which enhancement occurred increased as the magnitude of the probed k-vector was decreased. Unequal enhancement of the two peaks in the ion feature as well as different temporal behavior was observed. On most shots the ion acoustic waves which propagated anti-parallel to the incident CO_2 laser beam were more enhanced than those propagating along the beam. This feature was particularly evident for waves with larger k-vectors. Off resonance ion acoustic waves and a dependence of the time of the enhancement on the plasma Z were observed. The appearance of the enhancement late into the CO_2 laser pulse (FWHM$\sim$ 1 ns) as well as a complicated temporal behavior suggests that the enhanced ion acoustic waves were not generated through the decay of electron plasma waves produced by either stimulated Raman scattering or 2-plasmon decay. A turbulent k-vector spectrum is suggested by our observations. Models for generating the enhanced waves will be presented and discussed.

Observation of Forward SRS from Thin-Foil Targets*

R. E. Turner, K. Estabrook, R. P. Drake, H. Kornblum, and E. A. Williams (LLNL)

Abstract

We have observed Raman Forward Scattering (RFS) from underdense plasmas created by irradiating thin CH foils with 2 KJ of 0.53 μm light from the Nova laser. We present time-resolved spectroscopy of both the downshifted RFS and the upshifted anti-stokes component. This latter signal provides a relatively unambiguous signature of RFS. We have also observed, by measuring the x-ray bremsstrahlung, the extremely energetic (>100 keV) electrons created by RFS.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Effect of Angle of Incidence on Scattered Light in Nova Experiments*

R. P. Drake, D. Montgomery, R. E. Turner, and D. W. Phillion (LLNL)

Abstract

We have used the Nova laser to irradiate targets with 0.35 μm light at various angles of incidence. This paper reports measurements of scattered-light with particular attention to the effects of changing the angle of incidence of the laser beam on the target.

Our measurements of the anglular distributions, timing, and spectrum of the scattered light allow us to detect evidence of Brillouin scattering, reflected laser light, Raman scattering, and the two-plasmon decay instability. Other diagnostics provided supporting information.

The data indicates that the absorption and the amount of scattering in the specular direction change very little as the angle of incidence varies. This is in marked contrast to calculations of specular reflection in a planar plasma. We will consider possible explanations of this discrepancy.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Frequency Modulation of Laser Radiation Reflected from an Expanding Laser Produced Plasma

R. Dragila, A. Maddevar, B. Luther-Davies (Australian National University)

The spectrum of light emitted from a laser-produced plasma is frequently used as a diagnostic for processes occurring near the critical density surface. Conventionally the observation of a simple frequency shift in either the reflected laser light or the emitted second harmonic is attributed to the Doppler effect because of motion of the critical surface. Alternatively, if the spectrum is variously broadened, red-shifted and asymmetric, this is interpreted as indicating that an instability such as Stimulated Brillouin Scattering or the Parametric Decay instability is operating. Finally, modulation of the spectrum could be expected if ion waves with a well-defined frequency are present within the critical region.

In recent work [1] we reported second harmonic spectra which showed modulations, an intensity dependant red-shift and broad asymmetic spectrum which we interpreted using the mechanisms described above. A particular feature which intrigued us were the fine modulations o he spectrum that seemed to suggest that large amplitude ion waves were generated in our plasmas. In recent experiments we observed the same modulations on spectra of the reflected laser light and also discovered using Fourier analysis that these modulations were far from regular. This led us to reject our previous explanation and develop a completely new theory that appears to fully explain our results.

Briefly we have found that hydrodynamic motion of the plasma when affected by the ponderomotive force of the laser light can add a time dependent phase shift to the light emerging from the plasma. This, can be shown to both frequency shift (to the red by typically 10Å) and randomly modulate the observed spectrum. The modulations which are characteristic of this process will be only observed if very large F-number collection optics are used to detect the radiation, otherwise the spectra could be wrongly interpreted as demonstrating the existence of one of the instabilities described above.

Our experimental results and the theory we have developed to explain them are presented in this talk.

[1] M.D.J. Burgess, B. Luther-Davies and R Dragila Optics Comms. 50, 236 (1984)

Raman Scattering Via Enhanced Thomson; Further Studies

A. Simon, R.W. Short, K. Swartz, and W. Seka (LLE)

Abstract

We have continued to study the applicability and self-consistency of the enhanced Thomson scattering model of Raman radiation.[1, 2]. An internal consistency check is available through the use of the quasilinear theory of bump-on-tail saturation. If the fraction of hot electrons (f_h) is determined from the width of the Raman spectrum, one can predict the scattered intensity. This compares favorably with observations for six experiments. It is also possible to estimate f_h when one has measured the fraction of laser energy going into hot electrons. This has been done in two experiments and the results are in reasonable agreement with our theory.

We will also show some analysis applied to recent experiments at the Ecole Polytechnique and KMS and to an old experiment on Shiva. Shoucri et. al.[3] have recently used an analytic treatment to show that a bump-on-tail can result from flow of cold electrons through a resonant field structure, and have applied the resulting enhanced Thomson scattering to some ionospheric observations. We will comment further.

1. A. Simon and R.W. Short, Phys. Rev. Lett. 53, 1912 (1984).
2. A. Simon, W. Seka, L.M. Goldman and R.W. Short, Phys. Fluids, May, 1986.
3. M. Shoucri,G.J. Morales, and J.E. Maggs, PPG-913, UCLA, Dec. 1985.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Raman Scattering from Inhomogeneous Plasmas

S.H. Batha, W. Seka, and A. Simon (LLE)

Abstract

We have carried out experiments to determine the origin of broad band electro-magnetic emission from laser-produced plasmas which has been frequently attributed to stimulated Raman scattering. Our results support the alternate explanation of Thomson scattering enhanced by the presence of a non-thermal electron distribution. The hot electrons are produced by the two-plasmon decay and/or by resonance absorption. We observed two separate upscattered bands in the vicinity of the 3/2 harmonic of the laser frequency, consistent with electron temperatures of 10 keV and 25 keV. The experiments were carried out using planar plastic targets irradiated by a 527 nm laser at intensities up to 3 x 10^{15} W/cm^2. Scattered light spectra were collected in the ultraviolet and infrared wavelength regions using two 1/4 m spectrographs.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Simulations of Enhanced Thomson Scattering

T. J. M. Boyd and G. A. Gardner (University of Wales)

The model put forward by Simon and Short to explain, *inter alia*, observations of stimulated Raman scattering well below its theoretical threshold has been examined in simulations using a particle code. In this model laser light is scattered from plasma waves driven unstable by the bump-on-tail instability, the reversed slope velocity distribution being attributed to bursts of hot electrons moving out from the quarter-critical density surface where they may be generated by two-plasmon decay or SRS-A instabilities.

In the simulations a light wave propagated through a plasma characterized by two electron temperatures with the fraction of hot electrons varied between 0 and 0.05. With a hot-electron population unstable plasma waves were generated and saturated early in the simulation. The results obtained indicate that enhanced Thomson scattering may account for the emission observed in experiments. In simulations in which the SRS-C growth rate was large, emission from the plasma was reduced in the presence of a hot electron component.

Stimulated Raman Scattering in the Presence of Filamentation

H. C. Barr, T. J. M. Boyd, and G. A. Coutts (University of Wales)

Theory indicates and experiments suggest that the incident laser beam can filament and propagate in channels into target plasmas. We describe a model of stimulated Raman scattering in which the plasma density and laser intensity profiles have been corrupted by filamentation and which accounts for the interplay between the roles of the inhomogeneity, Landau damping and the self-focussing of the incident and scattered light waves.

The model assumes a plasma having an imposed sinusoidal density variation transverse to the incident laser light whose laser intensity profile is consistent with it. Such a density profile allows the Raman equations to be transformed to a difference equation representation which may be routinely solved yet caters in a unified way for the inhomogeneities and the kinetics without recourse to assumptions of weak inhomogeneity, a local approximation or to W.K.B. analysis.

The density modulation, through its effect on the plasma wave, reduces growth while the concentration of laser light can reverse this decrease giving modest increases in net growth. Both these effects concentrate SRS at the density minimum where the density gradients are least and the laser light most intense. However Landau damping is also strongest there and as the filament deepens this can dominate, strongly reducing growth and thereby leading to SRS occurring preferentially at locations higher up the filament wall. Ultimately, the densities where SRS might occur and the laser energy resides become mutually exclusive and then only stimulated Compton scattering remains.

Stimulated Raman Scattering in Filaments

R. W. Short (LLE)

Abstract

Raman scattered light has been observed at several laboratories at incident laser intensities below the theoretical threshold for the stimulated Raman scattering instability. One model which has been quite successful in accounting for the observed spectra ascribes them to enhanced Thomson scattering resulting from non-Maxwellian electron velocity distributions.[1] Here we explore an alternative hypothesis: that the scattering results from the SRS instability occuring in high intensity light filaments. Both the pump and scattered light waves propagate as waveguide modes in the filament; they are coupled by a region in the filament density profile where their beat frequency equals the local plasma frequency. Self-consistent filament density profiles and waveguide modes are calculated for parameters of interest to laser fusion, and the resulting SRS thresholds and growth rates are obtained.

1. A. Simon and R.W. Short, Phys. Rev. Lett. 53, 1912 (1984).

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Raman Scattering Driven by Multiple Pumps in Laser Fusion Plasmas

K. Swartz, R. W. Short, and A. Simon (LLE)

Abstract

The use of overlapping laser beams in direct drive laser fusion experiments creates the possibility of parametric instabilities driven by more than one pump. Results from 24 beam UV OMEGA experiments are examined for evidence of the occurrence of multiple pump Raman scattering. Taking the details of Raman matching, spherical target illumination geometry, and refraction in a time-varying density profile into account, all possible pairs of laser beams are considered as possible sources of detectable Raman-scattered light. The effect of constraints such as sidescattering and a plasma spectrum enhanced by hot electrons, as in the model of Simon and Short (Phys. Rev. Lett. 53 1912 [1984]), are also considered.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Session B

(Review)

Laser-Plasma Interactions

Where do we go from here?

E. M. Campbell (LLNL)

Monday, 7:30 PM

Chairman: R. L. McCrory (LLE)

Session C

(Poster)

Hydrodynamics, Transport, Diagnostics

Monday, 8:30 PM

The Generation and Transport of Hot Electrons in CO_2 Laser-Target Interactions at Intensities up to 5 x 10^{15} W/cm^2

G.D. Enright and N.H. Burnett (NRC of Canada)

We have previously characterized the generation and transport of superhot electrons for incident CO_2 laser intensities up to 3 x 10^{14} W/cm^{-2}. Recently we have utilized a new terawatt CO_2 laser system to extend these studies up to 5 x 10^{15} W/cm^{-2}. The scaling of the energy content and the temperature of this component will be discussed.

The effect of an applied magnetic field on the transport and generation of these superhot electrons has also been studied. A 100 kG transverse magnetic field imbedded in a thin mylar layer strongly inhibits the transport of these electrons.

It has recently been observed that magnetic fields up to ~1 MG can be generated by a CO_2 laser-driven coil at intensities of ~10^{14} W/cm^{-2}. We have made initial magnetic field measurements in a similar geometry with a view to using this technique to extend our transport measurements to even higher fields.

Time Resolved Thomson Scattering Measurements of the Electron and Ion Temperatures in a CO_2 Laser-Plasma Interaction

J.E. Bernard, H.A. Baldis, and D.M. Villeneuve (NRC of Canada)

We present the first reported time resolved electron and ion temperature measurements from large angle Thomson scattering in a laser-plasma interaction. Thomson scattering with a 0.53 μm probe has been performed on a preformed underdense carbon plasma for scattering angles of 90°, 45°, and 22° probing scattering k-vectors of $32k_{\text{pump}}$, $17k_{\text{pump}}$, and $9k_{\text{pump}}$ respectively ($\alpha = 1/k\lambda_{De} \simeq 0.8$ to 3.0). The thermal ion feature was temporally and spectrally resolved to resolutions of < 150 ps and ~ 0.5Å respectively using a grating spectrometer-streak camera combination. The heating of the electrons during the CO_2 laser pulse (FWHM$\sim$ 1 ns, maximum intensity$\sim 2 \times 10^{14}$ W/cm^2) and the cooling after the pulse were clearly evident from the observed increase and subsequent decrease in the spectral separation of the two peaks in the ion feature. Electron and ion temperatures were determined by fitting theoretically generated spectra to the observed spectra. In addition to the heating, the CO_2 laser was occasionally observed to drive short wavelength ion acoustic fluctuations enhanced above thermal levels.

Measurements of Scattered Light and Absorption Processes in Cavity Structured Targets

K.A. Tanaka, T. Boehly, T. Mochizuki, K. Nishihara, M. Mineo, M. Murakami, Y. Sakawa, K. Sakurai and C. Yamanaka (Osaka University)

Using a large green (530 nm) laser system, scattered light and absorption fractions are studied from cavity and cannonball targets.

Strong suppression of stimulated Brillouin scattering (SBS) is observed for cavity targets, while weak to modest suppression of SBS measured for cannonball targets. The observed damping is attributed to sudden temperature rise due to the plasma collisions in the cavities.

Noted are an increase in absorption and a reduced production of hard x rays and energetic electrons for a decrease in laser wavelength from 1060 nm to 530 nm. The absorption results are discussed in terms of the effects of target cavity filling and inlet hole closure. Simulations by a 1-D hydrocode are presented and used to qualify these results.

Compression Measurements from X-Ray Backlighting of Cryogenic Implosion Experiments

C.L. Shepard, R.R. Johnson, G. Charatis, B.H. Failor, E.F. Gabl, J.T. Larsen, L.V. Powers and P.D. Rockett (KMS Fusion)

P. Hammerling

LaJolla Institute

ABSTRACT

High compression of the deuterium fuel in the recent KMS cryogenic implosion experiments has been inferred from analysis of x-ray backlighting data. An aluminum x-ray backlighter was illuminated with 100J over 0.5 nsec. Streak camera photographs of x-radiation transmitted through the targets provided a time history of the implosion. The energy spectrum of the backlighting source was characterized by measuring the transmission through beryllium foils of various thicknesses. The spectrum is dominated by Bremsstrahlung emission at a temperature of about 3 keV.

Hydrodynamic simulations were used to infer compressed fuel densities in excess of 100 times liquid density. The simulations were constrained to match the plasma density profiles (from four-frame holographic interferometry) and the imploding shell trajectories. Observed trajectories were thus extrapolated to maximum compression to obtain the maximum fuel density.

Time-Resolved Absorption Measurements on OMEGA

P.A. Jaanimagi, L. DaSilva, J. Delettrez, G.G. Gregory, and M.C. Richardson (LLE)

Abstract

Time-resolved measurements of the incident laser light that is scattered and/or refracted from targets irradiated by the 24 UV-beam OMEGA laser at LLE, have provided some interesting features related to time-resolved absorption. The decrease in laser absorption characteristic of irradiating a target that implodes during the laser pulse has been observed. The increase in absorption expected as the critical density surface moves from a low to a high Z material in the target has also been noted. The detailed interpretation of these results is made through comparisons with simulation using the code LILAC, as well as with streak data from time-resolved x-ray imaging and spectroscopy. In addition, time and space-resolved imaging of the scattered light yields information on laser irradiation uniformity conditions on the target.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Space Resolved X-Ray Spectra of Imploding Laser Fusion Targets

P. Audebert, O. Barnouin, J. Delettrez, F.J. Marshall, and B. Yaakobi (LLE)

Abstract

We have obtained time integrated, space resolved x-ray spectra of DT filled glass microballons imploded by the OMEGA UV laser system in the range of wavelength between 2 and 6 Å. The spectra are obtained with a magnification ~ 5 and a spatial resolution of ~ 50 μm. The evolution of the intensity, the width of the lines, and the variation of the continuum is used to estimate the radial dependence of the plasma density and temperature in the imploding target shell. The measurements are compared to broad band x-ray images and predictions of the one-dimensional hydrodynamic code LILAC.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Alpha Particle Imaging of High-Yield Implosions

J.S. Wark, J. Delettrez, S. Letzring, F.J. Marshall, R.L. McCrory, M.C. Richardson,
J.M. Soures, and C.P. Verdon (LLE)

Abstract

Images of alpha particle emission from the fusion cores of high yield implosions have been obtained using zone plate coded apertures[1]. The sizes and shapes of the cores obtained are compared with those predicted by the 2-D hydrocode ORCHID. Comparison is also made with the core parameters determined from x-ray microscope images.

[1] N.M. Ceglio and L.W. Coleman, Phys. Rev. Lett. 39, 20 (1977).

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Simulation and Optimization of a Penumbral Neutron Imaging Camera

K.A. Nugent and B. Luther-Davies (Australian National University)

Imaging the thermonuclear neutrons that are generated within the core of a laser fusion pellet will become increasingly important as a diagnostic as densities increase preventing the use of x-rays to determine the size and shape of the compressed region. Both high sensitivity (able to image yields of around 10^{12}) and good resolution (better than 10μm) will be required of any such camera.

In this poster we describe the optimisation of one system, the penumbral imaging camera, which promises to satisfy both these requirements. The optimisation is qualified by a number of practical considerations and the resulting design tested using a full Monte-Carlo simulation. Most importantly we assume that an existing detector consisting of a 40x40 square array of 2mmx2mm detector elements each capable of detecting the entry of a single neutron was used. It is then shown that an object emitting only 1.3×10^{10} neutrons per resolution element should be imageable. The result is confirmed by simulations using three different object shapes which indicate that the shape of the core of a compressed inertial confinement fusion pellet may be determined using this technique with the required resolution. It is also shown that these results correspond to the lowest imageable yield for *any* coded-aperture technique using the existing detector.

We also present an alternative camera design that extends the penumbral technique to lower the yields by about one order of magnitude. However, since current yields are already well above the minimum we require for the simplest penumbral imaging system, there seems little incentive at present to develop this more complex geometry.

"Modulated Interferometry" for Fully Automated Analysis of Magnetic Field Measurements in Laser-Produced Plasmas

M. Kalal, K.A. Nugent and B. Luther-Davies (Australian National University)

The generation of spontaneous toroidal magnetic fields in the megagauss range in laser-produced plasmas have been theoretically predicted and experimentally confirmed. A detailed knowledge of the spatial profile of these fields is very important for they imply substantial modification to plasma transport properties and could influence the pellet design for inertial confinement fusion.

The most widely used technique to measure these fields near the critical density region is Faraday rotation of the plane of polarization of a probing beam. This technique requires simultaneous interferometry and shadowgraphy to be employed. Interferometry is used to measure the phase shift from which the plasma density profile can be calculated. Shadowgraphy is used to measure the rotation angle from which the product of plasma density and magnetic field can be found. Combining these two techniques the magnetic field can be obtained. For the analysis of interferograms an accurate fully automatic algorithm has been recently developed [1]. The analysis of shadowgrams is usually a more difficult task.

In this poster a novel diagnostic technique - modulated interferometry - is suggested. It is shown that this technique can replace the normal independent pair of optical systems (interferometry and shadowgraphy) by one single system (modulated interferometry) and use computer image processing to recover both the plasma density and magnetic field information with high accuracy. The fully automatic algorithm for the numerical analysis has been developed and succesfully tested so far for the case of simulated data. The experimental data are hoped to be processed in the second half of this year.

[1] K.A.Nugent, *Appl. Opt.* *24*, 3101 (1985)

Generation of Axial Magnetic Fields in a Laser-Produced Plasma by a Turbulent Dynamo

R. Dragila (Australian National University)

Generation of spontaneous dc-magnetic fields in laser-produced plasmas is a wellknown phenomenon which has been thoroughly investigated for many years. However, very little attention has been devoted to the so-called axial magnetic field, i.e. the field directed along the axis of the target normal or laser beam. Such fields have been observed experimentally [1] and their amplitude estimated to be of the same order as that of the toroidal field $\mathbf{B} \propto \nabla N \times \nabla T_e$ where N and T_e are respectively the electron density and temperature.

In [1] an attempt was made to to explain the presence of the axial magnetic field in terms of the dynamo effect. A dynamo theory was also applied [2] to describe the generation of a large scale magnetic field from a small scale coherent magnetic field in planar geometry. However, in both cases the dynamo action has been misinterpreted. For a hydrodynamic dynamo to operate two mechanisms are necessary: one producing a toroidal from a poloidal field and the other producing poloidal from a toroidal field. In an axially symmetric plasma only the presence of turbulent cyclonic events can allow both mechanisms to occur.

We have demonstrated that a turbulent dynamo can be responsible for the generation of axial magnetic fields observed in a laser-produced plasma. Moreover, it can lead to enhancement of the original toroidal magnetic field generated e.g. by crossed gradients of the electron density and temperature and/or by a beam of the fast electrons. Such a beam, in particular, can drive the ion acoustic instability which gives rise to the ion acoustic turbulence necessary for the turbulent dynamo to operate.

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[2] T. Yabe, Y. Kitigawa, A. Ishizaki, M. Naito, A. Nishiguchi, M. Yokoyama and C. Yamanaka, Phys. Rev. Lett. 51, 1869 (1983).

Smoothing of Non-Uniform Illumination of Laser Target

J. Sanz, J.R. Sanmartín, and J.A. Nicolás (Universidad Politécnica de Madrid)

For low intensity or short wavelength, heat conduction in the corona of a target irradiated with laser light is restricted to a quasisteady deflagration layer, whose structure is known for uniform conditions, and contains an underdense region. In this work we consider a weak non-uniformity of illumination of the target. The transverse perturbations produced result in refraction of light rays in the underdense region, refraction that modifies the distribution of light reaching the critical surface; this affects the smoothing by thermal conduction. A self-consistent analysis is carried out to determine the degree of smoothing of quantities such as ablation pressure or mass ablation rate, for arbitrary wavenumber of the non-uniformity.

Stability of Deflagration Layer in a Laser-Produced Plasma

J.R. Sanmartín, J.A. Nicolás, and J. Sanz (Universidad Politécnica de Madrid)

For low intensity or short wavelength, heat conduction in the corona of a target iradiated with laser light is restricted to a quasisteady deflagration layer, whose structure is known for uniform conditions, and contains an underdense region. In this work we consider the stability of that structure against transverse perturbations of arbitrary wavenumber. Though incident irradiation is assumed to be uniform, light refraction in the underdense region results in non-uniform absorption at the critical surface, feeding back the perturbations. An instability is found.

Evaporation of a Cold, Dense, Hydrogen Sphere in a Hot Plasma: The Evolution to Steady State

M.J. Dunning, F.J. Mayer, and S.B. Wineberg (KMS Fusion)

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ABSTRACT

Researchers in astrophysics,[1] magnetic confinement fusion,[2] and inertial confinement fusion[3,4] have studied the evaporation of cold dense materials in relatively hot tenuous plasmas with the use of models derived from solving the steady state hydrodynamic equations of mass, momentum, and energy conservation. In this paper we present a 1-D, spherically symmetric, two-temperature, time-dependent Lograngian fluid code that has been developed to examine the evolution to the hydrodynamic steady state. In our studies the evaporation is driven by electron thermal conduction as has been used by [1,3,4]. We compare our code results to the steady state model of [1]. We also present results on flux limited thermal transport and the effect of various choices for the flux limit parameter.

References

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4. C.E. Max, C.F. McKee and W.C. Mead, Phys. Fluids 23, 1620 (1980).

Generation of Ultra-High Pressures Obtained by Collision of a Foil Accelerated by a 0.26 μm Wavelength Laser. Experimental and Numerical Results Evidencing Two-Dimensional Effects

R. Fabbro, B. Faral, J. Virmont (Ecole Polytechnique), F. Cottet, and J.P. Romain (ENSMA, France) H. Pépin (INRS Enérgie)

The colliding technique (a laser accelerated foil impacts a motionless foil) is used to generate very high pressures, above 100-150 Mbars. The high ablation pressure (50 Mbars) is due to the use of a short wavelength laser and permits to obtain high velocities for the accelerated foil. The collision pressure, which is related to this velocity, is then very important.

The shock pressure inside the impact foil is measured by a step technique. This technique has been improved, replacing the step at the rear of the second foil by a groove of 10 μm width. The decay of this induced shock wave inside the second foil has been measured, using grooves of differents depths.

In order to suppress X-ray emission of the ablation plasma which causes preheating of the two foils, we use CH accelerated foils, colliding Al or Mo foils. Moreover, this kind of double foil targets increases the collision pressure, due to mismatch impedance between the two foils, and also increases the accuracy of the pressure measurement, because the velocity of the shock in a material is lower (so easiest to record) when this material has a higher density.

The induced shock wave is strong, but not sustained, and therefore its decay is fast (typically, the shock amplitude decreases by a factor of 2 on 5-10 μm of propagation). Experimentally, this observed decay becomes faster as the initial distance between the two foils increases. This is due to the diminution of the mass area of the accelerated foil when the distance of flight increases. This diminution results from a 2-dimensional effect due to the small dimensions of the focal spot. This effect is analysed with a 2-dimensional hydrodynamic lagrangian code, which shows the importance of the initial separation distance compared to the size of the focal spot.

Hydrodynamic Aspects of Pharos III X-Ray Laser Target Designs

J.P. Dahlburg, J.H. Gardner, M.H. Emery, and J.P. Boris (NRL)

The generation of uniform electron number densities in neon-like states of high-z plasmas which develop from exploding foils has become a topic of much recent interest. Such plasmas are necessary for the creation of a pumped soft x-ray laser. Considerable investigation into the use of the Naval Research Laboratory Pharos III laser system to generate a pumped soft x-ray laser has been undertaken (Elton *et al* 1986). We extend this research by means of hydrodynamic numerical simulation, performed with the *FAST2D* laser-shell simulation code. The code solves the equations of ideal compressible hydrodynamics in two full dimensions, using the flux-corrected transport algorithm (Boris and Book, 1976). In this code, energy is deposited in the plasma by the incident laser beam through classical inverse bremsstrahlung absorption, and transported through the plasma by classical nonlinear thermal conduction. Selected initial conditions and parameters are appropriate to the NRL Pharos III laser operating in its single-sided illumination mode.

Results from these hydrodynamic simulations of exploding copper foils which are irradiated on one side by $1.06\mu m$ laser light indicate that peak axial electron number density is more easily controlled with the split-foil target design. By means of a series of simulations with solid copper foils that range in width from $500\AA$ to $1500\AA$ it is observed that while peak electron temperature and time of burnthrough can be varied, evolved electron number densities are approximately bounded from above by 3×10^{20} particles/cc. By increasing foil thickness to $1\mu m$ and introducing a slit on the foil axis of $100\mu m$ width, uniform plasmas with electron number densities on the order of 6×10^{20} particles/cc can be generated. Essentially the same results are obtained from simulations with split selenium foils. Thus, by means of this new target foil design, we find that generated plasma densities may be controlled, both as a function of time and of space.

Boris, J.P. and Book, D.L. *J.Comp.Phys.*, **20**, 397-431, (1976) (and references therein).

Elton, R. C., Molander, W. A. and Lee, T. N. Proc. Third OSA Topical Conf. on Short Wavelength Coherent Radiation, *AIP Conf. Proc.* (to be published).

An Examination of Experimentally Measured Plasma Density Distributions Produced Between Two Exploding Foils

B.H. Failor, C.L. Shepard, E.F. Gabl, and G. Charatis (KMS Fusion)

ABSTRACT

We have performed experiments in which thin foils separated by several hundred microns have been irradiated with intense laser light. In some cases, a maximum in the electron density profile (as determined from holographic measurements) has been observed in the region between two exploding foils. In other cases no maximum has been observed. A detailed examination of the experimental data is underway to determine the differences which may be responsible for the observed variation in the data. The question of whether or not plasma collisionality is necessary to produce the observed peaking is also examined.

Lagrangian Simulation of Laser Heated Thin Foil Planar Targets

D. Havazelet,* C.E. Capjack, C.R. James, and R. Marchand (University of Alberta)

Computational results are presented for the time and spatial evolution of plasmas produced by laser irradiation of thin aluminum foils. The hydrodynamic behavior is modelled with a modified version of the 2-D Lagrangian SALE code. In the simulations, laser beam propagation is modelled by solving the paraxial wave equation. Effects accounted for include refraction, diffraction, absorption and pondermotive forces. The results that have been obtained suggest the formation of a ring-like plasma structure that has been identified in some experiments.

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Simulations of Reduced Burn Through Times During Long Scalelength Plasma Formation by CO_2 Lasers

R. Rankin, C.E. Capjack, and J. Meyer* (University of Alberta)

A two-dimensional Eulerian magnetohydrodynamic simulation code has been used to investigate the transient behaviour of a helium laminar gas jet target irradiated by a CO2 laser beam. Physical processes modelled in the simulation include laser beam propagation using a paraxial wave equation solver, and an implicit solution of the equations for the energy and ionization dynamics. Numerical results from the code support recent observations of significantly reduced burn through times of the laser, and asymetric plasma creation on the laser side of the target. A comparison is made of the results obtained using steady state and time dependent collisional-radiative ionization models.

*Department of Physics, U.B.C., Vancouver, Canada

Fokker Planck Modelling of Laser Plasma Interactions

L. Wood (St. Andrews University)

Time-Resolved Ablation Measurements of Imploding Targets

L. DaSilva*, J. Delettrez, R. Epstein, G.G. Gregory,
P.A. Jaanimagi, and M.C. Richardson (LLE)

Abstract

Time-resolved x-ray spectroscopy of multi-layer shell targets irradiated by the 24 UV-beam OMEGA laser at LLE has been used to infer the mass ablation rate during the implosion. The x-ray emission from Al and Mg signature layers imbedded in 10 microns of CH was recorded with an x-ray streak camera coupled to an elliptical crystal spectrometer. The radial position at the time of burn-through was measured directly using time-resolved x-ray imaging. The mass ablation rate calculated by this method, although confirming previous experimental measurements, continues to exceed that predicted by the hydrocode LILAC run with a flux limiter of 0.06. Furthermore, the time evolution of the Al and Mg emission indicate a characteristic rise-time longer than that observed in non-LTE simulations. One possible explanation of these discrepancies is beam nonuniformities, the effects of which are discussed.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

*Permanent address University of British Columbia, Vancouver, B.C., Canada.

Study of the Existence Conditions of the Dynamo Effect in Laser Matter Interaction

J. Briand, M. El Tamer, J. C. Kieffer, A. Gomes, Y. Quemener,
C. Arnas, J. P. Dinguirard, M. Armengaud, L. Berge
(Univ. P. Sabatier, France)

We present a parametric study of the conditions necessary for the development of the dynamo effect in laser produced plasmas. Working ranges are analytically determined in a $(n/n_c, T)$ diagram. Experiments have been conducted to explore the dynamo effect through axial magnetic fields. The development of the Zeeman splitting of the CV line (2271 Å) is used as diagnostic. A numerical study of the Zeeman effect in a laser produced plasma has been performed for various plasma and fields conditions. The first experimental results obtained at 0.25 μm with the GRECO laser are presented and discussed.

Session D

(Oral)

Hydrodynamics, Transport, Uniformity

Tuesday, 8:30 AM

Chairman: R. R. Johnson (KMS)

Dynamics of Laser-Driven Shock Waves in Fused Silica

A. Ng, P. Celliers, and D. Parfeniuk (UBC)

The formation and buildup of a laser-driven shock wave in fused silica have been examined from measurements of the shock trajectory and from 1-dimensional hydrodynamic simulations. The results revealed anomalously slow propagation of a high pressure wave front through the nearly isentropically compressed material. This was attributed to a phase transition in silica at ~100 GPa. A high speed transient was also observed in the measured shock trajectory, which might have resulted from the finite relaxation rate of the non-equilibrium state when pressure waves coalesced to form a single strong shock.

Measurements of Mass Ablation Rate and Pressure in Planar Targets Irradiated by 0.27 μm Laser Light

T. Boehly, K. A. Tanaka, T.Mochizuki, K. Nishihara, and C. Yamanaka (Osaka University)

Planar CH targets were irradiated by 400 psec and 1 nsec pulses of 0.27 μm and 0.53 μm light at intensities of 5×10^{12}-10^{14} W/cm^2. The mass ablation rate obtained from time integrated x-ray line emission from layered targets was found to scale as:

$$\dot{m} = \cancel{1.5}\;2.4\times10^{\cancel{5}\;4}\,(I/10^{13}\ \mathrm{W/cm^2})^{0.5}\,(\lambda/1\,\mu\mathrm{m})^{-1.5}\ \mathrm{gm/cm^2\text{-}sec.}$$

Using this result and the ion blowoff velocity the ablation pressure was found to scale as:

$$P_a = \cancel{5.5}\;1.2\ (I/10^{13}\ \mathrm{W/cm^2})^{0.6}\,(\lambda/1\,\mu\mathrm{m})^{-\cancel{1.5}\;0.9}\ \mathrm{Mbar.}$$

These results are compared to simulations which employ a non-local treatment for the electron energy transport. Comparisons are also made with previously reported measurements at other wavelengths and geometries.

burnthrough), time resolved X-ray emission, hydrodynamics of the ablated plasma, angular distribution of plasma energy, coronal electron temperature, XUV and soft X-ray emission levels respectively. The observed dependence of various measured quantities on laser intensity and gold layer thickness shows that hydrodynamics and energy transport in high-Z plasma are significantly affected by radiation. Evidence is seen for a significant fraction of energy to be transported to the plastic layer even when the laser intensity is well below the threshold for burning through the gold overlayer. These observations on the radiation effects are consistent with the measurements of plasma energy, ion velocity, electron temperature and its scaling with laser intensity in plasma produced from thick gold targets.

+ on leave from Bhabha Atomic Research Centre, Bombay, India

D4

Thermal Energy Transport in Spherical Geometry

D. Bassett, D. K. Bradley, J. D. Kilkenny, S. D. Tabatabaei, and O. Willi
(Imperial College of Science and Technology)

A. Cole
(Rutherford Appleton Laboratory)

N. Delamater & A. Hauer
(Los Alamos National Laboratory)

Thermal transport processes have been extensively studied in laser produced plasmas. Multi-layered spherical targets were illuminated uniformly with the Rutherford Appleton Nd glass laser system. Multiple diagnostics including x-ray spectroscopy and optical probing were used to investigate the underdense as well as the superdense plasma. Experimental observations covering a wide range of parameters will be presented.

Effects of Ilumination Non-Uniformities on the Interpretation of Spherical Transport Experiments

J. Delettrez, R. Epstein, P. Jaanimagi, T. Kessler, M. Richardson, W. Seka, and S. Skupsky (LLE)

Abstract

The effects of illumination non-uniformities on the simulation of thermal transport experiments carried out on the 24-beam u-v OMEGA laser facility at the University of Rochester are presented. In these experiments both time-resolved and time-integrated spectrocopic measurements were made on massive glass targets coated with varying thicknesses of plastic. To obtain an estimate of the laser intensity distribution on target, the equivalent-target-plane distribution of an OMEGA beam was superposed over the target surface. Simulations were carried out with the code LILAC over the range of intensity distributions on target. For each intensity on target the calculated line emission energies were weighted by the fraction of the incident energy at that intensity. The time-integrated line energy and the temporal emission obtained from the weighted average were compared to experimental results. Fair agreement was obtained for a flux-limiter value of 0.06 (sharp-cutoff) for targets with plastic thicknesses much smaller than the burnthrough depth. The effects of non-uniformities were more pronounced for the temporal line emission diagnostic and for plastic thicknesses comparable to burnthrough depths. The main effects are earlier onset times and longer rise times for the line emission. Comparison with experimental results indicates that the actual intensity distribution may contain more energy at high intensity than the distribution estimated from the superposition code.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Thermal Smoothing and Filamentation in Laser Irradiated Targets

R. J. Mason and J. M. Wallace (LANL)

The 2-D implicit hybrid simulation code ANTHEM has been used to study smoothing of the energy flow between the critical and ablation surfaces in laser illuminated targets. The code models transport and hydrodynamics in the x-y plane as affected by classical collisions — in the presence of self-consistent E_x, E_y and B_z fields. It applies to both collisionless and strongly collisional plasma regimes. We explore the spatial and temporal evolution of initial deposition non-uniformities. The energy is deposited in a hot component, described as either a fluid or a set of PIC particles. This hot component then spreads across the self-consitent fields, and throughout the background target material. The evolution of local thermo-electric B-fields is examined, along with consequent tendencies toward filamentation or advective B-field growth. The dependence of these effects on wavelength, on the background two-dimensional density profiles, on the initial temperature, and on collisionality (atomic Z) is explored.

LASNEX Laser Plasma Simulations Employing Nonlocal Electron Heat Transport*

R. A. Sacks, B. F. Lasinski, J. R. Albritton, and E. A. Williams (LLNL)

ABSTRACT

The nonlocal electron heat transport scheme described previously[1] has been implemented in LASNEX. We report results and analysis of initial calculations of some standard systems.

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1. "Nonlocal Electron Heat Transport by Not-Quite Maxwell-Boltzmann Distributions," J. R. Albritton, E. A. Williams, I. B. and K. P. Swa , UCRL-94334 (1986).

* 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.

Electro-Sound Solitary Wave in Rarefied Nonisothermic Plasma

O. N. Krokhin, S. P. Tsibenko
(P. N. Lebedev Physical Institute, Ac. Sci., Moscow, USSR)

The solution of the gas-dynamic and nonlinear electrodynamic equations in the form of the compression wave is obtained. Solution is defined in the plasma region of the negative dielectric permeability with striction effect and relativistic dependence of the electron mass in the high frequency electromagnetic field taken into account.

Delocalisation of Heat Flux

Pierre-André Holstein (CEA)

We have pointed out that the Luciani-Mora model for heat flux delocalisation is in reasonably good agreement with Fokker-Planck codes.[1] E.A. Williams *et al*.[2] have proposed another model for the delocalisation of the heat flux in which the electric field is calculated more exactly, but in which the inverse-bremsstrahlung absorption in not delocalized. We compare results using this model, with the delocalised absorption included, with those of Fokker-Planck codes for the conditions described in Ref. 1.

1. P.A. Holstein, J. Delettrez, K. Swartz, S. Skupsky, and J.P. Matte, Paper J11, 15th Annual Anomalous Absorption Conference, June 1985; P.A. Holstein, J. Delettrez, and S. Skupsky, J. Appl. Phys., to be published.
2. E.A. Williams, J.R. Albritton, K. Swartz, and I.B. Bernstein, Paper J10, 15th Annual Anomalous Absorption Conference, June 1985.

Rayleigh Taylor Instability and Implosion Uniformity

K. Mima, H. Takabe, F. Hattori, H. Nishimura, Y. Izawa, S. Nakai,
and C. Yamanaka (Osaka University)

It has been found that the ablation front is rather stable in the short wavelength irradiation because of the high mass ablation rate [1] [2]. Namely, the vortex shedding and/or the fire polishing stabilize the Rayleigh-Taylor modes. Our numerical analysis shows that the growth rate of the ablation front perturbations is reduced for the short wavelength laser, or for the x-ray driver.

However, the contact surface between fuel and pusher is found to be strongly unstable during the stagnation, since there is no ablative stabilization [3]. As the results, the fuel will mix with the pusher materials and will not be compressed by the pusher stagnation. Recently, it was shown that the neutron yield and the fuel compression in the GXII laser experiments agree reasonably well with 1D simulation results for the stagnation free implosion.

(1)H. Takabe etal, Phys. Fluids 28 (1985) 3670

(2)S. Bodner etal, Plasma Phys. and cont. Nucl. Fusion Res. (Proc. 10th IAEA Int. Conf. London 1984) vol.3, (1985) 155

(3)F. Hattori etal, Phys. Fluids, May (1986)

in planar targets

The Rayleigh-Taylor Instability with 1, 1/2 and 1/4 μm Laser Light

M. H. Emery, J. P. Dahlburg, and J. H. Gardner (NRL)

We present the results of a series of numerical simulations of the Rayleigh-Taylor instability in laser ablatively-accelerated targets for a fairly wide range of initial conditions. The initial target thicknesses vary from 20 to 150 μm with laser intensities spanning the range of 10^{13} to 3×10^{14} W/cm^2 for 1, 1/2 and 1/4 μm laser light. The perturbation wavelengths range from 5 to 200 μm.

The results indicate that the short wavelength modes are very strongly inhibited, 0(5) times smaller han cl sical, for all laser wavelengths. For modes about 3 times the in-flight target thic ess th ra io f the numerical growth rates to the classical growth rates are of the order 1/1.5, 1/ .5 d 1/3.5 for 1, 1/2 and 1/4 μm lasers respectively. The results ill be co pared our t eore ical model.

For he strongly nonlinear evolution of the instability, the Kelvin-Helmholtz-like roll-up of the spike tips is still apparent at the high intensities and short laser wavelengths.

Session E

(Review)

Summary of Experiments on Delfin-1

O. N. Krokhin (USSR Academy of Science)

Tuesday, 7:30 PM

Chairman: D. W. Forslund (LANL)

Session F

(Poster)

Interaction Physics

Tuesday, 8:30 PM

Raman Studies in a Long Homogeneous Plasma

F. Amiranoff, C. Labaune, E. Fabre, and C. Stenz (Ecole Polytechnique)
G. Matthieussent (Université Paris), M. Hagenauer and E. Parey (Ecole Polytechnique)

Parametric instabilities in homogeneous underdense plasmas are studied for applications both in laser fusion and new particle accelerators design.

We present some experimental results on backward and forward Raman scattering in a preformed plasma. The plasma is created by the explosion of a thin foil (5000 A to 1 μm of plastic) irradiated by a 600 ps FWHM 1.06 μm laser beam. A second beam (600 ps, 0.53 μm or 0.26 μm, $I \simeq 5.10^{14}$ W/cm^2) then interacts with this long (1 $\simeq$ 2 mm) underdense plasma. Time-resolved Raman spectra and electron emission are analysed.

This work is a part of the program of the GRECO I.L.M. CNRS

On the Stimulated Raman Scattering Threshold

H. C. Barr, T. J. M. Boyd, and G. A. Coutts
(University of Wales)

A model of stimulated Raman scattering in hot inhomogeneous plasmas is described which is readily amenable to analysis yet is able to account for both the plasma inhomogeneity and the kinetics without recourse to assumptions of weak inhomogeneity, a local approximation or to W.K.B. analysis. Using the model we report on predictions of the Raman threshold and on the transition from absolute instability at the quarter critical density to convective instability at lower densities.

Stimulated Raman Scattering from Hot Underdense Plasmas at 10.6 μm

S. Aithal, M. Chaker, P. Lavigne, H. Pépin, and T.W. Johnston (INRS-Enérgie)

Hot underdense plasmas were created by focussing 10.6 μm laser light up to 3 x 10^{14} W/cm^2 (60 J in 1 nsec) in intensity on planar carbon foils of thickness from 40Å - 8000Å. A complete study of angular distribution of Raman light scattering is done for the above targets; and in the backward direction (10°-60° with respect to incident laser) for glass target. The time integrated scattered light was spectrally resolved up to 35 μm by using series of IR narrow band interference filters. The incident laser energy was varied to study the behavior of light scattering and it was observed to have threshold for light emission. This threshold varies with the relative thickness of the target used. The ratio of backscattered Raman light to the incident light is 10^{-5}-10^{-7} which also depends upon the target thickness. We has also measured the Brillouin-scattered light and X-ray emission levels from the plasma. There is a relation between Raman scattering level and Brillouin scattering level and also X-ray emission levels. The results of scattered light measurements are interpreted in the light of our measurements of energetic electrons.

Temporal Behavior of Stimulated Raman Scattering in a CO_2-Laser Produced Plasma

J. Meyer, G. McIntosh, and Y. Zhang (UBC)

The stimulated Raman scattering (SRS) instability in a CO_2-laser produced plasma is studied by ps-resolution Thomson scattering, backscatter spectroscopy and hot electron diagnostics. The evolution of the spatial, wave vector and spectral distribution of the SRS-plasma waves indicate that the instability first appears near quarter critical density and then propagates to lower density at the group velocity of the electron plasma waves. Saturation and quenching of SRS appears to be associated with the generation of large amplitude ion acoustic fluctuations. Though the fluctuation spectrum shows no gap the backscatter spectrum only consists of a peak at $2\lambda_0$. This observation is explained in terms of refraction of the lR radiation. The hot electron numbers and spectra are correlated to the fluctuation and backscatter measurements and are shown to be consistent with theoretical model predictions.

Supported by a grant from NSERC Canada

Observation of $(3/2)\omega_0$ EM Radiation from the Resonant Layer in an Inhomogeneous Plasma

T. Tanikawa and A.Y. Wong (University of California)

We present a new observation of $(3/2)\omega_o$ electromagnetic (EM) radiation accompanying the resonant absorption of the high-power EM wave at frequency ω_o by an unmagnetized plasma. The experiment is performed in a large volume (140 cm dia., 230 cm length) microwave-plasma system. Our high-power microwave source is a magnetron (max peak power ~ 1 MW) operated at $f_o = (\omega_o/2\pi) = 2.8$ GHz (which corresponds to $n_c = 10^{11}$ cm^{-3}) in a pulsed mode (τ = 0.15-1.2 μs). Typical experimental condition with this source corresponds to $E_o^2/(4\pi n_c T_e) = 0.05\text{-}0.5$ and $(\omega_o/2\pi)\tau = 4.2 \times 10^2 - 3.4 \times 10^3$. With this device, we are able to generate a caviton with its depth of 50% or more at the critical layer. The $(3/2)\omega_o$ emissions which originate from the caviton region are detected by horn antennas mounted at the edges of the plasma column so as to avoid perturbations to the interaction region. Under the same condition, the radiation at $(1/2)\omega_o$ is detected by using a small magnetic loop antenna. The $(1/2)\omega_o$ wave is observed only when the antenna is very close or inside the caviton region, clearly demonstrating that the plasma surrounding the caviton has density much higher than $(1/4)n_c$. This coincident observation is particularly important to identify the origin of the $(3/2)\omega_o$ emissions, implying that they are due to the beating between waves at ω_o and $(1/2)\omega_o$ in the caviton region. The caviton which is surrounded by higher density plasmas can serve as a bounded plasma which supports electron plasma waves at frequencies lower than the local plasma frequency. We conjecture that the radiation at $(1/2)\omega_o$ results from electrostatic waves at this frequency in the caviton. Our observation of $(3/2)\omega_o$ emissions can be summarized as follows: (1) they are bursty in nature, (2) they usually appear at 0.2-0.3 μs after the turn-on of the microwave pulse, (3) their power level is almost 80 dB below that of the incident microwave, (4) emission bandwidth is relatively narrow ($\delta\omega/\omega < 5\%$), and (5) no preferential polarization is observed. Implication of our new observation to laser-plasma interactions will be discussed.

*Work supported by UC LLNL 8444105.

Heating of Electrons by the Langmuir Waves Produced in Stimulated Raman Scattering

W. Rozmus, R. P. Sharma,* J. Samson, W. Tighe**, and A. A. Offenberger

(University of Alberta)

Because of the co-existence of stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS), Langmuir waves produced by the SRS process have localized, and periodic structure with the spatial periodicity equal to that of the ion-acoustic wavelength[1]. We have studied the interaction of electrons with these structures using quasi-linear theory. The velocity space diffusion model can be used when the stochasticity threshold is exceeded by the components of the discrete Langmuir wave spectrum, provided the fields are below the trapping regime. The quasi-linear diffusion equations have been solved in the quasi-stationary approximation with a constant particle flux in the stochastic range. The effective Landau damping has been calculated for a field (E_k) spectrum approximated by the continuous function $\sim k^{-n}$ for the components satisfying overlapping criteria, giving $\gamma_k \sim k^{2n-3}$. This effective damping was self-consistently introduced into the hydrodynamic code[1] to study the effect of hot electron production on stimulated scattering instabilities. Other models using quasi-linear diffusion theory are also proposed to estimate the temperature and density of hot electrons and compared with particle stimulation results. The effect of the new damping on the forward SRS wave is also discussed.

1. W. Rozmus et al., Simultaneous Raman and Brillouin scattering instabilities, Abstract of this Conference.

* Permanent address: Centre for Energy Studies, Indian Institute of Technology, Delhi, India.

** Plasma Physics Laboratory, Princeton University, Princeton, U.S.A.

Nonlinear Competition Between Two-Plasmon Decay and Stimulated Raman Scattering

L.V. Powers and R.L. Berger (KMS Fusion)

ABSTRACT

Numerical solutions have been obtained for the coupled mode equations describing the nonlinear evolution of SRS and TPD in inhomogeneous plasma. The modes are restricted to the plane of polarization of the pump wave. The model equations are second order in the dimension of the spatial inhomogeneity and first order in time. The treatment allows for interaction of a wide spectrum of the decay modes. Saturation of the modes by pump depletion is included in the model.

We examine the interplay of the two instabilities in the parameter regime of laser fusion plasmas. Results characterizing the effects of this competition on thresholds, growth rates, and partitioning of energy among the decay modes will be presented.

Two Plasmon Decay, Linear and Nonlinear

P.N. Guzdar, Y.C.Lee, and C.S. Liu (University of Maryland)

The Two Plasmon decay process at the quarter critical density is an important parametric process for laser produced plasmas. The linear instability in an inhomogeneous plasma has been studied exhaustively. We have reexamined the linear instability including Landau damping and collisional damping for short wavelength laser ($\lambda_o < 1_{um}$) using an initial value code. This code has been modified to include the self consistent evolution of the background density along the inhomogeneity direction. Two basic models for the density evolution are being studied. Detailed comparison of the two models and the nonlinear saturation will be presented.

Work supported by a grant from the Naval Research Laboratory.

Numerical Solution of Time- and Space-Dependent Coupled Mode Equations in Inhomogeneous Plasma *

R.L. Berger (KMS Fusion)**

ABSTRACT

The equations describing the various parametric instabilities of interest to laser fusion can often be put in the form of coupled first-order differential equations. These equations have been studied extensively in one dimension with the effects of plasma inhomogenity. Important special cases exist for which analytic solutions are known. We have developed a numerical scheme that represents these solutions well in the region where the interaction is strong without the necessity of resolving the rapid phase variations that exist outside this region where the interaction is weak. The explicit numerical scheme with little numerical diffusion is being applied to find solutions in two dimensions.

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

** Temporary Address: Lawrence Livermore National Laboratory, University of California, P. O. Box 5508, L-477, Livermore, CA 94550.

Numerical Study of Two-Dimensional Three Wave Interactions in Inhomogeneous Media

E.F. Gabl (KMS Fusion)

ABSTRACT

The three wave interaction equations can be used to describe a host of parametric processes in plasmas. These are stimulated Raman scattering, stimulated Brillouin scattering, two plasmon decay, and parametric decay. In this study, the two-dimensional three wave interaction equations are integrated using the spectral method for the spatial integration and implicit time differencing. The effects of finite pump width, finite interaction width, and density inhomogeneity on growth rates and thresholds will be examined. These data will be compared to results obtained from one and two-dimensional analytic approximations.

Transition to Turbulence in the Forced Non-Linear Schrödinger Equation

O. Larroche (C.E.A.), D. Pesme (Ecole Polytechnique)

Abstract:

The plasma waves generated by resonant absorption of light in the vicinity of the critical density of laser-produced plasmas are modelized by a non-linear Schrodinger equation with additional terms accounting for the presence of a source and the inhomogeneity of the medium.

$$iE_t + E_{xx} + 2\,(|E|^2 - \alpha x)\,E = s$$

We study the transition from periodic to chaotic emission of solitons near the critical value of the non-linearity parameter $s^2/2\alpha^2 \simeq 1$ from the point of view of dynamical systems, through a numerical analysis of the phase portrait in a reconstructed finite-dimensional phase space.

Experimental Results on Filamentation in 1 μm, 0.5 μm, and 0.25 μm Laser Produced Plasmas

C. Arnas, J. Briand, J. C. Kieffer, A. Gomes, Y. Quemener,
M. Armengaud, J. P. Dinguirard, L. Berge
(Univ. P. Sabatier, France)

Experimental results on filamentation at 1 μm, 0.5 μm and 0.25 μm have been obtained with the GRECO laser at irradiançes 10^{11} W.μm^2/cm^2 < $I \times \lambda^2$ < 10^{14} W.μm^2/cm^2. X ray pinhole cameras with great magnifications have been used to image the plasma at various X ray wavelengths. A periodic structure of filaments is observed with is associated to a k turbulence spectrum. Evidences that thermal filamentation dominates at short laser wavelength are presented. The experimental results are discussed through a theoretical model of the filamentation instability.

Study of the Coherence of the Second Harmonic Emission in 1.06 μm Laser Produced Plasmas

J. Briand, J. C. Kieffer, A. Gomes, Y. Quemener, M. Armengaud,
J. P. Dinguirard, C. Arnas, L. Berge
(Univ. P. Sabatier, France)

We present experimental results on the time resolved second harmonic emission obtained with the GRECO laser at 1 μm and for irradiances between 10^{13} and 10^{16} W/cm^2. The study has been performed with a high resolution spectroscopic system of anamorphoser type. The temporal resolution on the 2ω emission is obtained with a streak camera. The spectra obtained at 90° of the laser axis are composed of three red components. Two narrow lines are related to the coherent scattering processes of photons off P.D.I. plasmons and of combination of plasmons. A third broadened line, whose red shift increases strongly with time is interpreted in term of incoherent scattering during electron wavebreaking of P.D.I. plasmons. The usefulness of the 2ω emission for the determination of the hot electron spectra is discussed. The results are found to be in good agreement with numerical simulations.

Session G

(Oral)

Parametric Instabilities in the Corona

Wednesday, 8:30 AM

Chairman: W. L. Kruer (LLNL)

Resonance Absorption and Parametric Decay in the Presence of a Wide Bandwidth Pump

B. B. Afeyan, J. F. Drake, Y. C. Lee, and C. S. Liu (University of Maryland)

The NRL 1 μm (RED) experiments employing their I.S.I. Technique[1] have shown an enhancement of activity at the critical surface together with a reduction in activity at the quarter-critical surface, as the temporal bandwidth of the laser is increased. The latter can be explained using conventional random-pump theory[2] while the former can not. A possible mechanism which accounts for an increase in $2\omega_o$ light generation and an increase in the x-ray signal when the laser has a wide temporal bandwidth is the subject of this investigation.

The model includes the parametric decay instability of plasma waves generated by resonance absorption over a density range proportional to the incident laser bandwidth. The mathematical model given in Equations 1 and 2 is the Zakharov Equations with spatial inhomogeneity, damping (Γ) and a stochastic driver $A_D(z,\tau)$.

$$i\frac{\partial A}{\partial \tau} + \frac{\partial^2 A}{\partial z^2} - (z - i\,\Gamma + pN)\,A = A_D(z,\tau) \qquad (1)$$

$$V^2\frac{\partial^2 N}{\partial \tau^2} - \frac{\partial^2 N}{\partial z^2} = \frac{\partial^2}{\partial z^2}\,|A|^2 \qquad (2)$$

This work extends previous studies of resonance absorption with a constant driver[3]. Our emphasis will be on the large p regime (p being the nonlinearity strength), spatially coherent structures with temporal chaos and the effects of random forcing.

(1) R. H. Lehmberg and S. P. Openchain, Optics Corp. 46, 27 (1983).

(2) E. J. Valeo and C. R. Oberman, Phys. Rev. Lett. 30, 21 (1973)
J. J. Thomson and J. I. Karush, Phys. Fluids 17, 8 (1974)
P. Guzdar et al. Anomalous absorption (1985).

(3) G.J. Morales and Y.C. Lee, Phys. Fluids 20, 7 (1977)
J. C. Adam, A. Serveniere, G. Laval, Phys. Fluids 25, 2 (1982).

Model Simulations of Inhomogeneous Parametric Instabilities

C. H. Aldrich, B. Bezzerides, and D. W. Forslund (LANL)

Linear parametric instabilities have been studied extensively for inhomogeneous plasmas. We re-examine some of the well-known results using a newly developed Code, Phase, operated in its linear mode. In particular, the usual analysis relies on coupled equations in which the WKB approximation is assumed valid. We present example calculations which provide some insight into the limits of validity of this assumption and some possible new effects when the assumption is violated.

Parametric Instabilities in Parabolic Profiles

E. A. Williams (LLNL) and T. W. Johnston (INRS Energie)

ABSTRACT

We have resolved some inconsistencies in previous analyses of convective gain in the presence and absence of damping and have more fully investigated the possibilities for absolute instability. A clearer picture emerges as to how parabolic density profiles interpolate between homogeneous plasmas and those with linear gradients.

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

Raman Scattering Thresholds*

T. W. Johnston (INRS Energie), E. A. Williams, R. E. Turner, R. P. Drake, D. W. Phillion, and H. N. Kornblum (LLNL)

ABSTRACT

Our best theoretical estimates for Raman scattering thresholds in exploding foil targets are compared to experimental observations. The role of collisions and gradients are discussed and the implications for coronal temperature are inferred.

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

Simultaneous Raman and Brillouin Scattering Instabilities

W. Rozmus, R.P. Sharma,* W. Tighe,**
and A.A. Offenberger (University of Alberta)

Numerical and theoretical calculations are presented which describe the competition between stimulated Brillouin (SBS) and Raman (SRS) scattering in uniform plasma. The model includes nonlinear coupling between ion and Langmuir waves as given by the Zakharov equations and the usual hydrodynamic equations for parametric instabilities. As a result of plasma wave growth in the presence of ion waves associated with SBS, localized structures in the Langmuir field emerge with the periodicity of the ion wavelength[1]. Electrons can be very effectively heated, while repeatedly interacting with these localized fields, provided the overlapping criteria is satisfied for the SRS Langmuir wave and its spatial harmonics[2]. The plasma wave field above stochasticity threshold (which increases with density) and the presence of Langmuir wave harmonics (which are larger at higher densities) are responsible for strong damping which limits the growth of backward SRS in the density range $0.08<n_e/n_{cr}<0.23$. At lower densities ($n_e/n_{cr}<0.07$) the Langmuir harmonics are not observed and SRS is eventually decoupled by SBS ion waves. Other possible scenarios of SBS and SRS coexistence and the role of forward SRS will also be discussed.

1. C.H. Aldrich et al., Bull. Am. Phys. Society 30, 1531 (1985).
2. W. Rozmus et al., Heating of electrons by the Langmuir waves produced in stimulated Raman instability, Abstract at this Conference.

* Permanent address: Centre for Energy Studies, Indian Institute of Technology, Delhi, India.
** Plasma Physics Laboratory, Princeton University, Princeton, U.S.A.

Nucleation of Langmuir Caviton Collapse by Finite Amplitude Ion Sound Waves

D. F. DuBois, B. Bezzerides, G. D. Doolen, and H. A. Rose (LANL)

It is known(1-2) that pre-existing, shallow, local density depressions (or "cavities") from the earlier burn-out of Langmuir cavitons are the sites for the nucleation of new collapsing cavitons in systems driven at long wavelengths and near the electron plasma frequency. In the presence of such driving sources we show that pre-existing ion sound waves "trigger" the collapse of Langmuir cavitons in the density minima of the waves. The Langmuir waves in the periodic density modulation of monochromatic sound waves become "Bloch waves" whose periodic spatial modulation produces a ponderomotive force which further deepens the density depressions and leads to collapse.

A growing, coherent Langmuir wave produced by some linear instability will induce secondary Langmuir waves by decay or modulational instability. The beat of the primary and secondary Langmuir waves produces a ponderomotive force and a resulting ion sound wave which can trigger collapse. For sufficiently rapid exponential growth of the ion sound amplitudes the Langmuir "Bloch wave" frequencies are significantly shifted from their plane wave values and the decay instability of the secondary Langmuir wave is detuned, thus terminating the decay cascade and leading directly to collapse. Another example(3) of this scenario is the collapse of Langmuir waves excited by stimulated Raman scattering in the ion sound waves excited by stimulated Brillouin scattering.

(1) David Russell, D. F. DuBois and Harvey A. Rose, Phys. Rev. Lett. 54, 804 (1985) and 56, 838 (1986).

(2) see paper by Russell et al. in this session.

(3) C. Aldrich, B. Bezzerides, D. F. DuBois and Harvey Rose, to be published in Comments in Plasma Phys. and Controlled Fusion (1986). See also following paper in this session.

Supported in part by U.S.D.O.E.

Nonlinear Coupling and Saturation of SRS and SBS in Finite Geometry*

H. A. Rose, B. Bezzerides, and D. F. DuBois (LANL)

In many situations it is expected that stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) can be simultaneously excited in a plasma.(1) We report here the results of simulation and theory of the excitation of these instabilities in finite slab geometry. The Zakharov model for the coupled Langmuir wave - ion sound wave system is used, driven by the appropriate ponderomotive force terms resulting from the incident light wave at wave number k_0 and the scattered light waves. The light waves are treated in the envelope approximation. At early times we observe the short scale modulation at $k \sim 2k_0$ of the initially smooth linear absolutely unstable SRS Langmuir modes appropriate to the slab geometry. This modulation is due to the ponderomotive force resulting from the decay or modulational instability or from the direct modulation resulting from a coexisting SBS ion density wave.(2) This modulation leads to the collapse and burn-out of Langmuir cavitons producing a turbulent region near the illuminated side of the slab in which SRS can no longer be excited. As a result the active SRS region moves further into the slab and results in a supersonically moving solitary wave of SRS activity with a wake of Langmuir turbulence. Under some conditions the burn-out density cavities in the turbulent wake become finite amplitude seeds for exciting SBS and we observe a SRS scattered signal followed by and SBS scattered signal. Such behavior has been observed in experiments by Walsh et al.(3) Since this study involves the nonlinear coupling of two instabilities the results are sensitive to initial amplitudes of Langmuir and ion sound fluctuations. Estimates will be made based on continuous thermal noise excitation with thermal initial values. The results are also sensitivily dependent on whether SBS is in an absolute or convective regime. An exponentially growing ion sound wave at early times can detune the SRS instability.

(1) C. Aldrich, B. Bezzerides, D. F. DuBois and Harvey A. Rose, to be published in Comments in Plasma Phys. and Controlled Fusion (1986).

(2) See preceding paper in this session.

(3) C. J. Walsh, D. M. Villeneuve and H. A. Baldis, Phys. Rev. Lett. 53, 1445 (1984).

* Supported in part by U.S.D.O.E.

Collapsing Caviton Turbulence in Two Dimensions

David Russell, D.F. DuBois and H.A. Rose (LANL)

We present numerical simulations of strong Langmuir turbulence by integrating the Zakharov equations in two spatial dimensions. Unlike previous studies these are long time simulations; nucleation of collapsing cavitons in the density depressions of previously burned-out cavitons is observed repeatedly. We describe in detail the characteristics of collapse (e.g., the universal geometry of collapsing cavitons) as well as the long-time-averaged properties of many-caviton systems for sources of free energy appropriate to laser-plasma interactions.

Supported in part by U.S.D.O.E. and U.S. Office of Naval Research Contract No. DP-F84-28.

Observation of Lateral Energy Transport by Superthermal Electrons from High Resolution Space Resolved K-alpha Emission in Layered Laser Irradiated Targets

B. Luther-Davies, A.J. Perry and K.A. Nugent* (Australian National University)

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AUSTRALIA

In laser plasma interaction experiments using high intensity long wavelength lasers, a large fraction of the absorped energy is directly converted into the superthermal electrons distribution. These electrons are generated by resonance absorption and are emitted primarily down the plasma density gradient and enter the corona. In the corona the presence of spontaneous magnetic fields, generated by the $\nabla n \times \nabla T$ source term associated with the superthermal electrons themselves, and the coronal electric field, leads to both dissipation of the superthermal electron energy by the acceleration of fast ions and the rapid lateral transport of the superthermal electrons via ExB forces.

Although a range of experimental evidence to support this scenario have been available for some years, it is only recently that computer models have been developed with the ability to describe this process. At the same time we have developed improved x-ray imaging diagnostics with the ability to provide very high resolution ($\approx 15\mu$) hard x-ray images from which the spatial distribution of the energy of the superthermal electrons entering the target can be determined with hitherto unobtainable accuracy.

In this talk I will describe the results of an extensive study of superthermal energy transport using high resolution K-alfa imaging to determine the spatial distribution of the electron energy over the target surface. The results of electron range measurements have been interpreted with the aid of a Monte-Carlo electron transport code. Features of the range measurement suggest that either the superthermal electron distribution entering the target is highly non-Maxwellian or that magnetic fields within the solid material are strongly affecting transport. The results will be compared with the results of recently published simulations [1].

[1] see for example Jon M Wallace, Phys. Rev. Letts. 55, 707, (1985).

Non-local Treatment of the Collisional Weibel Instability in Laser-Produced Plasmas

E.M. Epperlein and A.R. Bell (Imperial College of Science and Technology, London)

The collisional Weibel instability is investigated for a laser-ablated plasma in planar geometry. The exponential time dependence of the linear Weibel eigen modes is obtained by numerically solving the electron Fokker-Planck and Maxwell's equations in the inhomogeneous spatial direction, with a harmonic perturbation in the transverse direction. A Cartesian tensor expansion, $f_0 + \underline{v}.\underline{f}_1/v + \underline{vv}:\underline{\underline{f}}_2/v^2$, is used to approximate the electron distribution function. Local stability analysis predicts maximum growth rates γ of a few $10^9\ s^{-1}$ near the overdense side of the critical surface. The indusion of magnetic diffusion and electron viscosity decreases γ by a factor of ~ 6. By further including magnetic convection due to ion and Nernst velocities the Weibel is stabilized.

Intense Electromagnetic Wave Interactions in Very Large-Scale Plasmas

J.P. Sheerin (KMS Fusion)

ABSTRACT

Many of the interactions found to be important in laser-plasma experiments (e.g., filamentation and self-focusing of the beam, profile modification, parametric instabilities, soliton formation and collapse, and hot electron fluxes) may be explored in great detail viz., large, low-density laboratory and space plasma experiments. We review some of the unique measurements most recently made in these very large-scale experiments and their implications for laser-plasma experiments. Of particular interest are: detailed measurements of hot electrons, the spectrum of stimulated electromagnetic emissions, and the evolution and steady-state behavior of turbulence in the modified profile. These measurements require significant advances in theory and simulation to admit detailed comparisons. Progress in these areas will be reviewed.

Theoretical Research of Two-Dimensional Effects Under Laser Target Compression

N. G. Basov,N. Demchenko, A. P. Favorsky*, A. O. Fedyanin*,
G. Gamaly, S. Yu. Gus'kov, I. G. Lebo, E. E. Myshetskaya*,
V. B. R mov, A. A. amarsky*, L. M. Sergoyan, S. A. Shumsky, V. F. Tishkin
(P. N. Lebedev Physical Institute, USSR)
(*M. V. Keldysh Applied Mathematics Institute, USSR)

Abstract

Deviations from spherical symmetry can severely affect target compression. Investigations of two-dimensional effects are of importance to find limitations to the laser illumination symmetry and target surface finish. The present paper gives a review of theoretical investigations in the topics:

absorbed laser energy distribution at spherical target surface

- filamentation and self-focusing of laser beams

thermal smoothing of laser flux nonuniformities in corona for different laser wavelengths

- hydrodynamic instabilities in corona and on shell boundaries
- generation of spontaneous magnetic fields and its influence on charge particles transport

Session H

(Review)

Nonlinear Processes in Ionspheric Plasma

A. Wong (UCLA)

Wednesday, 7:30 PM

Chairman: T. J. M. Boyd (U of N. Wales)

Session I

(Poster)

X Rays, Beat Waves

~~Tuesday~~, 8:30 PM
Wednesday

Study of Laser Created X-Ray Sources

H. Pépin, P. Alaterre, M. Chaker, P. Lavigne, and F. Martin (Université du Québec), R. Fabbro, B. Faval (Ecole Polytechnique

X-ray sources created at various laser wavelengths λ = 0.26 μm, λ = 0.53 μm, λ = 1.06 μm and at various intensities for 16 atomic numbers are studied both experimentally and theoretically. The experimental X-ray emission is measured with a multichannel soft X-ray spectrometer. Computer reconstruction is used to get detailed X-ray spectra and conversion efficiencies. We use our simple atomic physics theoretical model XSOURCE to replicate consistently all the data. It is possible to simulate, with low resolution, X-ray emission for any given atomic number in any given spectral range for specified laser conditions.

Effect of the Atomic Number of the Target Material on the Soft X-Ray Emission of Laser Produced Plasmas at 1.06 μm, 0.53 μm and 0.26 μm

R. Benattar and J. Godart (Ecole Polytechnique)

The VUV emission (155 Å) of laser produced plasmas is recorded with a pinhole camera associated with a multilayered mirror. We compare the emission at 155 Å of Al, Cu, Au plasmas.

The dimensions of the images are analyzed taking into account the different lateral transfert processes (radiative, suprathermal electrons) according to the laser wavelength.

The sizes of these images are compared with the sizes of the focal spots and with the 1 keV pinhole image sizes.

Intense Soft X-Ray Generation and its Energy Transport in Short Wavelength Laser-Produced Plasmas

T. Mochizuki, K.A. Tanaka, R. Kodama, T. Yabe, and C. Yamanaka (Osaka University)

Intense soft x-ray generation in 530 nm and 260 nm laser-produced plasmas is investigated. X-ray spectra and conversion efficiencies as a function of atomic number and laser wavelengths are presented. The atomic number dependence is explained by Semi-Mosley's law. The spectra could be well reproduced by a non-LTE calculation which is coupled to a hydrodynamic code. Radiative energy transport in various Z foils is studied by observing the radiation at the rear side of the foil in optical and x-ray regimes.

Dot Spectroscopy of Eu at the JANUS Laser*

S. Maxon, D. Bailey, J. Kilkenny, P. Hagelstein, D. Weber,
J. Scofield, and Y. Lee (LLNL)

ABSTRACT

Both the hydrodynamics and radiation spectra for a Eu/Al dot irradiated by a 1 ns pulse of 0.53 μ light are calculated with 2D LASNEX and 2D XRASER. The results are compared with time-dependent spectroscopy of the 4-3 Eu lines corresponding to Ni-like, Co-like, and Fe-like. A pinhole shot of the time integrated x rays emitted by the plasma is also compared to 2D LASNEX calculations with reasonable agreement.

Using electron temperatures and densities from LASNEX, the distribution of ionization states seen in the experiment is interpreted in terms of steady state solutions of a collisional-radiative code.

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

High-Z Laser Target Interaction at λ=0.35 μm

S.R. Goldman, W.C. Mead, J. A. Cobble, N. Delamater, P.D. Goldstone, R.D. Jones, and G.L. Stradling (LANL), P.A. Jaanimagi, R.S. Marjoribanks, F.J. Marshall, M.C. Richardson, and S. Skupsky (LLE)

The University of Rochester Omega laser system at λ=0.35 μm with 24 beams and approximately 2 kJ incident energy has been used to illuminate spherical layered Au on CH targets at intensities ranging from 4×10^{12} to 4×10^{15} W/cm^2 and pulse widths of order 0.6 ns. We have examined time-resolved transmission grating spectrograph and SPEAX crystal streak spectrograph data, time integrated X-ray micrographs, and time integrated transmission grating spectra. The results are compared against LASNEX simulations. Since the RMS incident intensity variation on target is of the order of ± 25%, we have emphasized one-dimensional spherical modeling with the effects of intensity variation estimated by averaging over a succession of one-dimensional simulations. For the interesting range of mid-10^{14} W/cm^2, the temporal profiles of N-line (sub-kev) emission amd M-line (2.0 - 3.0 kev) emission have significant qualitative differences, which to some extent are reproduced by the simulations. The experimental X-ray micrograph results for M-line emission indicate an emitting region which is broader and extends closer to the original target radius than the simulational results with uniform incident intensity. The discrepancy in peak emission location and spatial width of emission persists over a wide range of parametric variations including thermal electron flux limit and atomic transition rate multipliers. The modeling of intensity variations and the possible role of filamentation is also discussed. Experimental and theoretical time and space integrated spectra will be compared as a function of gold layer thickness to obtain further insight into the atomic physics modeling. Finally, we present an assessment of the overall modeling of the experiment in terms of this data as well as previous comparisons of X-ray conversion efficiency as a function of incident laser intensity and gold layer thickness.

Optimization Studies of X-Ray Conversion Efficiency

S.V. Coggeshall and W.C. Mead (LANL)

Using 1-D, non-LTE LASNEX calculations we investigate the sensitivity of X-ray conversion efficiency to various aspects of material properties. We discuss some of the controlling physical processes including hydrodynamic expansion, the role of divergent plasma flow, atomic transition rates and electron transport. We examine the Z dependence of the conversion efficiency and the potential increase by using mixtures of high-Z materials such as gold, uranium, lead and tungsten in various combinations. We also explore the conversion efficiency dependence on initial material density.[1] Using a lower initial density, one can reduce the hydrodynamic losses resulting in an increase in conversion efficiency, although also increasing the emission time.

The parameters used in the study are chosen to be consistent with the performance of the OMEGA system at LLE, University of Rochester. We assume 2 kJ at 0.35 μm on target with a 0.6 ns FWHM beam and an intensity of about 3×10^{15} W/cm^2.

1. S. Pollaine, Lawrence Livermore National Laboratory, private communication, 1985.

Use of X-Ray Diagnostics for Testing Thermal Transport Models

R. Marchand, D. Havazelet,[a] C.E. Capjack, and A. Birnboim[b] (University of Alberta)

ABSTRACT

The energy radiated by laser-produced Al plasmas is calculated using a one-dimensional Lagrangian code and a collisional radiative equilibrium model. The predicted spectra are used to calculate the energy transmitted through Al foils of various thicknesses, and comparisons are made with experimental data. The sensitivity of the transmitted energies to the flux limiter f, used in the simulation is assessed, and it is suggested that this could be a useful independent technique for testing heat transport models in simulations.

a) On leave from Department of Physics, N.R.C.N. P.O. Box 09001 Beer-Sheva, Israel 84190.

b) Present address: A.D.A., P.O. Box 2250(24), Haifa 31021, Israel.

Saturation and Asymptotic Behavior of Beat Excited Plasma Waves

W.B.Mori (University of California)

ABSTRACT

We rederive the nonlinear beat wave excitation equations in the Eulerian fluid description using the pertubative procedure of Krylov, Bogoliubov, and Mitripolskii. In so doing we resolve a controversy that has recently arisen over the magnitude and sign of the nonlinear plasma frequency shift. In particular, the discrepancy exists between the use of the Eulerion or Lagrangian fluid description. Previous authors[1] who utilized Eulerian coordinates used the continuity equation resulting in an arbitrary d.c. velocity, $<v^1>$, which they ultimatley set to zero. We show that by using Amperes' Law, $<j_1>$ rather than $<v_1>$ is forced to vanish unambiguiously. The physical interpretation is that when $<v_1> = 0$ the plasma obtains a bulk drift resulting in a doppler frequency shift. Consequently, in both instances, in the electron's rest frame only a relativistic nonlinear frequency shift exists and for the case when $<j_1> = 0$ the electrons are at rest.

In addition, we present results on the asymptotic behavior of the plasma wave amplitude by investigating the properties of the fixed points to the envelope beat wave equations

$$\dot{a} = F\sin\phi - \gamma a$$
$$a\dot{\phi} = \Delta a + ca_3 + F\cos\phi$$

where $\Delta \approx \omega_o - \omega_p$, $c = \frac{3}{16}$, $F = \frac{1}{4}\frac{v_{o1}}{c}\frac{v_{o2}}{c}$ and γ is a phenomenological damping rate.

Work supported by DOE contract DE-AM03-76SF00034, NSF grant ECS 83-10972, LLNL grant 6223205 and the Los Alamos GRA program.

1. Rosenbluth and Liu, Phys. Rev. Lett. 29 , 701 (1972).
Tang, Sprangle and Sudan, Phys. Fluids 29 , 1974 (1985).
Bingham, Cairns and Evans, RAL-84-122 (1984).
Mendonca, J. Plasma Phys. 34 , 115 (1985).

Electron Acceleration in Localized Plasma Waves

M. Colunga, J.F. Luciani, and P. Mora (Ecole Polytechnique)

Particle acceleration in a localized electrostatic wave packet is studied. A weak field regime and a strong field regime are displayed. In the weak field limit one derives a quasi-linear relation for the velocity perturbation. When the particles cross several times the accelerating field, a quasi-linear equation for the distribution function is established. The theory is illustrated by numerical results from a model of resonance absorption of laser light by a plasma. Finally we present a model of reheating in the resonance absorption with the inclusion of collisions, leading to a nearly maxwellian behavior, for the hot component of the electron distribution function, $f \sim \exp -(v/v_0)^{8/3}$.

Modelling of Beat Wave Generation in Laser Breakdown Plasmas

J.P. Matte, F. Martin, and P. Brodeur (INRS-Enérgie)

ABSTRACT

We study numerically the resonnant excitation of a large amplitude plasma wave by the beating of two lasers with a frequency difference close to the plasma frequency in a plasma created by laser breakdown of low-pressure gas (nitrogen). A first code models the plasma density evolution: a fast rise due to direct (tunneling) ionization followed by a far slower rise (through resonance), due to collisional ionization. This implies easier tuning. A second code solves the Rosenbluth-Liu[1] equation for the plasma wave, assuming that the plasma density is slowly increasing in time through resonance. It is found that the plasma wave amplitude rises not only above the Rosenbluth-Liu limit but also above the (somewhat higher) Tang-Sprangle-Sudan[2] limit which was obtained for a fixed but optimized density (plasma frequency slightly higher than the laser frequency difference). The reason is that the density increase compensates approximately the relativistic mass increase, thus keeping the wave frequency in near resonance with the lasers' frequency difference.

1. M.N. Rosenbluth and C.S. Liu, Phys. Rev. Lett. 29, 701 (1972).
2. C.M. Tang, P. Sprangle and R.N. Sudan, Appl. Phys. Lett. 45, 375 (1984).

Linear and Nonlinear Response of Ion Acoustic Waves Driven by Optical Mixing*

C.J. Pawley and N.C. Luhmann, Jr. (University of California)

Plasma waves can be efficiently driven by the optical mixing of two electromagnetic waves when the frequency and wavenumber differences ($\omega_1 - \omega_2 = \Delta\omega$, $k_1 - k_2 = \Delta k$) satisfy the plasma dispersion relation. In this experiment two counterpropagating 3.3 GHz microwave pumps are used to drive ion acoustic waves into saturation. Data is taken by several diagnostics, including a phase-locked 92 GHz collective Thomson scattering system. The results of this experiment are intended to provide experimental and physical onsight into the saturation of SBS backscatter.

The data obtained in this experiment is compared with computer codes obtained through solving the Maxwell-Vlasov equations for both the temporal and spatial behavior of the electromagnetic waves, the driven ion wave, and the harmonics of the ion wave. The codes included inverse Bremstrahlung, hot ion tail distribution formation, and pump depletion (change of action potential) as saturation mechanisms.

The dominant saturation mechanism was found to be formation of a hot tail distribution. Specifically, both experimental data and computer codes suggested that ion tail formation reduced harmonic generation. Particle codes have also indicated that the finite harmonic content in the ion acoustic waves partially account for the formation of the ion tail. For large enough plasma densities ($n_e \geq 0.2\ n_{crit}$) pump depletion become important for the experimental parameters. Data for $0.2 \leq n_e/n_{crit} \leq 0.5$ shows the effect of pump depletion and is compared with computer predictions.

Additionally, the wave number resolution of Thomson scattering data appeared to broaden as a function of power. After eliminating other possible causes, it is proposed that the broadening is due to increased damping of the ion acoustic wave. Agreement between ion tail calculations and the damping inferred through the scattering shows this may be possible.

*Work supported by The Lawrence Livermore National Laboratory Laser Fusion Program under Contract #8442905.

Nonlinear Stimulated Raman Scattering in the Beat-Wave Accelerator

C.J. McKinstrie and D.W. Forslund (LANL), S.H. Batha (LLE)

In the beat-wave accelerator, a large amplitude Langmuir wave is produced by the beating of two collinear laser beams whose frequencies differ by approximately the plasma frequency. Previous studies have assumed that the growth of this Langmuir wave saturates due to a nonlinear shift in its natural frequency. While this assumption is justified for parameters which are typical of an actual beat-wave accelerator, it is totally unfounded for parameters which are typical of current experiments and computer simulations. Instead, significant pump depletion and transfer of energy to the sidebands of the incident light waves are observed. When these effects are taken into account, the agreement between theory, computer simulation and experiment is much improved.

This work was supported by the United States Department of Energy under contracts W-7405-ENG-36 and DE-FC08-85DP40200, and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics.

Space-Time Coherence of Beat Wave and Particle Acceleration

K. Mima, H. Takabe, T. Oosuga, and K. Nishihara (Osaka Univeristy),
T. Tajima and W. Horton (University of Texas)

We analyze the space-time evolutions of the electron plasma waves excited by the laser beat and introduce the concept of a wakeless triple soliton acceleration for efficient electron accelerator.

It is found that the plasma wave phase is modulated at a few tens picosecond after the two frequency CO_2 laser injection. Because of the phase modulation, the accelerated electrons become off-resonant and the acceleration stops. Therefore, the rise time of the laser pulse is required to be less than a few tens picosecond. Otherwise, the plasma wave excited at the laser peak is not useful for the acceleration.

Under appropriate conditions, the triple soliton with two electromagnetic and one electrostatic waves in the beat-wave resonance propagates with velocity c leaving no plasma wave behind. Therefore, the energy loss of the laser energy into the plasma can be reduced sufficiently.

Dissipation in Relativistic Collisionless Shocks

A.B. Langdon, D.W. Hewett, C.E. Max, and J. Arons†(LLNL)

We are studying the microscopic structure and particle acceleration in relativistic shock waves in a magnetized electron–positron plasma. Such shocks are believed to exist in sources of non-thermal synchrotron emission such as supernova remnants containing a central pulsar, and also in active galactic nuclei and quasars.

In the simulations, a cold e^-e^+ plasma is injected at one side with an embedded magnetic field, and flows through the shock transition and out the other side as a hot plasma, with its magnetic flux. In the shock frame, the upstream velocities are strongly relativistic. Mach numbers range from $\ll 1$ to $\gg 1$. So far we have not found a downstream energy spectrum extending to very high energies, as desired to explain the observed synchrotron spectrum.

Scaling analysis of the dissipation process, guided by the particle orbits and other diagnostics, is done in the spirit of Ref. 1, but differs qualitatively; because the electrons and positrons have the same q/m, shock transition processes need not involve charge-separation electric fields as they do in electron–ion plasmas.

1. "Nonadiabatic Electron Heating at High-Mach-Number Perpendicular Shocks", R. L. Tokar, C. H. Aldrich, D. W. Forslund, and K. B. Quest, *Phys. Rev. Lett.* **56**, 1059 (1985).

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

† Permanent address: Department of Astronomy, University of California, Berkeley.

Session J

(Oral)

ICF Experiments and Theory

Thursday, 8:30 AM

Chairman: A. A. Offenberger

(U of Alberta)

KrF Laser-Matter Interaction in the Long Pulse, Low Intensity Regime

S.J. Gitomer S.R. Goldman, R.A. Kopp, N.D. Delamater and J. Norton (LANL)

The physical phenomena present in the KrF laser matter interaction (.248 micron wavelength) have been studied with the Lagrangian radiation hydrodynamics code LASNEX. The code run in both 1D and 2D configurations has been used to model experiments performed to date on the Sprite laser at the Rutherford Laboratory (50 ns pulse, intensity < 10^{12} Watts/cm^2) or soon to be performed on the Aurora laser at Los Alamos National Laboratory (500 ns pulse, intensity < 2×10^{11} Watts/cm^2).

Comparisons will be made between experiment and simulation of imparted momentum, target mass loss, blowoff electron density and emission spectrum. We find that the incident laser light may be nearly completely absorbed in the blowoff plasma away from the ablation surface and it is the reradiated x-rays or electron thermal conduction which drive the target surface ablation. The calculated fluid quantities of velocity and mass density appear to behave self-similarly. The functional form of this behavior is, however, more complicated than the familiar adiabatic or isothermal rarefaction forms widely used in analytic modeling. 2D effects are found to become important at sufficiently high fluence levels, above about 10^4 Joules/ cm^2.

This work was performed under the auspices of the United States Department of Energy.

Au Disk Experiments Using the Nova Laser*

R.L. Kauffman, M. Cable, P. Drake, H. Kornblum,
B. Lasinski, and R.E. Turner (LLNL)

Abstract

Preliminary experiments have been performed using the Lawrence Livermore National Laboratory Nova Laser to study the coupling of 0.35 μm light to solid Au targets. Single beams of Nova were frequency tripled to 0.35 μm wavelength producing pulses with energies up to 2 kJ in a 1 ns square pulse. Energy absorption and coupling to high Z targets are studied as a function of incident intensity and angle. X-ray conversion efficiencies vary from greater than 60% at 6×10^{13} W/cm^2 to less than 35% above 10^{15} W/cm^2. This dependence is greater than observed at Argus using much less energy and smaller spots. The conversion efficiency appears to decrease slightly when the incident angle increases to 46°.

High energy x-ray yields, and Raman scattered light yields, correlate similarly to 0.53 μm light experiments on Nova, indicating Raman is the dominant suprathermal electron production mechanism. Examples of the data will be presented along with comparisons with modeling and previous experiments.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Spherical Implosion Experiments with Cryogenic PVA Targets at 0.53 μm Laser Wavelength

R.R. Johnson, Gar. E. Busch, J.S. Ankney, J.R. Brundage, B. H. Failor, G.J. Fomin, E.F. Gabl, J.T. Larsen, M.T. Mruzek, D.L. Musinski, L.V. Powers, P.D. Rockett, R.J. Schroeder, C.L. Si, J.D. Simpson, J.M. Stiegman, and D. Sullivan (KMS Fusion)

ABSTRACT

We have performed experiments in which deuterium-filled plastic (PVA) spherical shells were irradiated with 0.53 μm laser light. The deuterium fuel was cryogenically cooled to form a uniform frozen fuel layer on the inside surface of the targets. The targets were from 110- to 140-μm in diameter and wall thickness varied from 3- to 7-μm. The shell mass was a constant value for all targets. In attempts to keep the fuel on a near Fermi-degenerate adiabat, the laser pulse was shaped so that the leading edge was at low intensity (~ 3×10^{13} W/cm^2) and the intensity increased monotonically thereafter up to near the end of the 900 ps pulse. The peak intensity of the pulse was about 3×10^{14} W/cm^2. The energy from both beams of the CHROMA laser was focused nearly uniformly over the entire target surface with a fast optical system which combined both refractive and reflective elements.

Upon irradiation, the targets were backlit with an Al x-ray source and streak x-ray photographs of the imploding targets were obtained. Other diagnostics included four-frame holographic interferometry, plasma calorimeters, and time integrated x-ray camera images. Compression of the fuel to values of ~ 150 times liquid density were inferred. The hydrodynamic code TRHYD was used to simulate the experiments and detailed comparisons to the experimental data will be presented.

Results of Short Pulse UV Driven High Aspect Ratio Implosion Experiments on the University of Rochester OMEGA Laser System

F.J. Marshall, L.B. DaSilva, G.G. Gregory, S.A. Letzring, R.L. McCrory, P.W. McKenty, M.C. Richardson, J.M. Soures, C.P. Verdon, and J.S. Wark (LLE)

Abstract

The 24 beam UV Omega laser system has been used to implode thin-walled high aspect ratio DT filled glass microballoons. The system was configured to deliver in excess of 1 kJ of 351 nm light in 24 beams with ~450 ps pulse widths synchronized on target to within ~10 ps. The targets were thin walled (1 to 2 micron) glass microballoons of radii 150 to 500 microns filled with equimolar mixtures of deuterium and tritium at a pressure of 10 atmospheres.

In these experiments, which are a continuation of a previously reported series[(1)], we have diagnosed the performance of the targets with instruments which are sensitive to the symmetry of the target implosions. These instruments include alpha-particle and x-ray imaging and neutron activation and spectroscopy. The measurements are compared to predictions of the one-dimensional hydrodynamic code LILAC and the two-dimensional hydrodynamic code ORCHID.

(1) M.C. Richardson, P.W. McKenty, R.F. Keck, F.J. Marshall, D.M. Roback, C.P. Verdon, R.L. McCrory, J.M. Soures, Phys. Rev. Lett. (to be published).

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Implosion Dynamics of Low Aspect Ratio Gas-Filled Targets Driven by UV Radiation

M.C. Richardson, L. DaSilva, G.G. Gregory, P.A. Jaanimagi, S.A. Letzring, F.J. Marshall, R.L. McCrory, P.W. McKenty, D.M. Roback, J.M. Soures, C.P. Verdon, and J.S. Wark (LLE)

Abstract

The implosion of low-aspect-ratio, high pressure gas filled targets driven directly by UV radiation is being pursued for the production of high core densities (≥50 XLD). We report the results of an on-going experimental and theoretical study of D-T filled glass microballoons, some overcoated with low-Z ablators, irradiated by 600 ps, 2 kJ, 351 nm radiation from the 24 beam OMEGA system. A broad range of plasma, x-ray and nuclear diagnostics analyses the hydrodynamics and final core conditions of the implosion. These studies include comparisons of the x-ray emission from metallic signature layers embedded at various depths in the ablator with the predictions of the one-dimensional and two-dimensional hydrodynamics codes, LILAC and ORCHID respectively. The effect of irradiation uniformity on implosion symmetry will be discussed.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

Hydrodynamic Properties of Planar Targets Accelerated by a Smooth Laser Beam*

J. Grun, J. Stamper, C. Manka E.A. McLean, S. P. Obenschain, T.Y. Lee, B.H. Ripin, M.Emery, and S. Bodner (NRL)

Inertial confinement fusion requires that pellets be imploded uniformly to speeds of a few hundred km/sec and that the Rayleigh-Taylor (RT) growth rate be low enough so as not to lead to a significant degradation of pellet efficiency. Recent advances in the smoothing of laser beams[1] and code simulations of RT growth[2] indicate that these goals may be realizable. We discuss experiments at NRL that measure the speed, uniformity, and RT growth rate of planar targets which model a pellet shell early in the implosion phase. The targets, made of carbon or plastic, are illuminated to an irradiance of 10^{13} W/cm^2 by a 5-nsec long, smooth, ISI laser beam that operates at a 1.05 or 0.53 micron wavelength. The properties of the foil motion are studied using streaked x-ray shadowgraphy and double foil methods.

* Supported by The United States Department of Energy

1. R.H. Lehmberg and S.P. Obenschain, Optics Comm. **46**, 27 (1983).

2. M.H. Emery, Bull. Am. Phys. Soc., **29**, 1231 (1984).

Measurements of SBS Backscattered Spectra with ISI Illumination*

.N. Mostovych, S.P. Obenschain, E.A. McLean, A.J. Schmitt, J. Grun, and J.H. Gardner (NRL)**

For laser produced plasmas the exact experimental conditions which determine the nature of any parametric process are typically unmeasurable. However, by use of spatially and temporally incoherent laser beams (ISI)[1] we have achieved very uniform target illumination, which for the first time, provides an opportunity for careful study of parametric processes under more controlled laser conditions.

We present spectrally and temporally resolved measurements of Brillouin backscatter under various conditions. Measurements were made at .528 microns with and without ISI smoothing and at two different bandwidths. Preliminary interpretations of the data suggest that SBS is fundamentally related to laser filamentation in the underdense plasma. Without ISI smoothing SBS backscatter appears to originate in the underdense plasma where substantial filaments can form. Under conditions of ISI smoothing, however, the only visible backscatter appears to originate from regions very close to the critical surface.

1. R.H. Lehmberg and S.P Obenschain, Opt. Comm. 46, 27 (1983).

* This work was sponsored by the U.S. Department of Energy

** Laboratory for Computational Physics, NRL

The Role of Filamentation in the NRL ISI Experiments*

A.J. Schmitt (NRL)

Recent NRL experiments using the Pharos III laser at 0.53μm wavelength have shown that the physics of the laser plasma interaction is fundamentally changed when the ISI method is used[1]. Hard X-rays (indicative of the hot-electron population), $2\omega_0$ and $3\omega_0/2$ emission, and backscatter levels are all markedly decreased when broad bandwidth light is used in conjunction with ISI echelons. It has been suggested that suppression of laser hot spots or filaments by the rapidly shifting intensity distribution due to the ISI method is responsible, at least in part, for much of this observed behavior.

We investigate the role of filamentation in these experiments with time-dependent 2-D and time-independent 3-D laser propagation codes that simulate the laser-plasma interaction under the relevant experimental conditions. We are interested in the characterization of the interaction under full ISI conditions as well as the modification of the filamentation thresholds and behavior. Implications for the implementation of ISI to higher incident intensity and shorter wavelengths will also be discussed.

1. S.P. Obenschain, Bull. Am. Phys. Soc. 30, 1382 (1985).

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

LASNEX Simulations of the Behavior of Thermal Self-Focusing in Large High-Z Plasmas

W.C. Mead, R.D. Jones, S.V. Coggeshall, and J.L. Norton (LANL)

Thermal self-focusing can lead to enormous changes in the laser light intensity, spatial distribution, and local plasma conditions in the absorption region of a laser-produced plasma. Since the process becomes generally stronger at shorter wavelengths, it has received increasing study [1] in recent years. Using mainly homogeneous plasmas and 0.25 μm laser light, we have performed extensive two-dimensional LASNEX simulations to study the behavior and effects of thermal self-focusing and its dependence upon the critical parameters. Careful tests have indicated that adequate numerical convergence has been achieved. In these 2D simulations, self-focusing occurs in both "on-axis" and "off-axis" modes, exhibiting similar focusing distances, but different intensity and density configurations; the two modes interchange rather freely as a result of changes in plasma conditions (both initial and dynamic), and physical assumptions. The focusing dynamics and distances depend greatly on many factors: the laser beam intensity, diameter, angular convergence, and spatial intensity profile; the plasma background density and temperature; and details of the physics of absorption and thermal transport. Our modeling suggests that only limited regions of parameter space lead to severe self-focusing within distances of interest for Inertial Confinement Fusion targets, and that many factors control the location of the strong-focusing regime and the self-focusing behavior within that regime.

[1] M.J.Herbst, _et al._, Phys. Rev. Lett. _46_, 328 (1981); R.S.Craxton and R.L.McCrory, J. Appl. Phys. _56_, 108 (1984); K.G.Estabrook, W.L.Kruer, and D.S.Bailey, Phys. Fl. _28_, 19 (1985).

Modeling of Self-Focused Laser Beams Under Reactor Conditions

R. D. Jones, W.C. Mead, and S.V. Coggeshall (LANL)

The simple steady state isobaric code JAMBO is used to model LASNEX self-focusing calculations. The intensity in JAMBO is assumed to have the form

$$I = \frac{I_o}{f^2} \exp\left[\frac{-r^2}{r_o^{\,2} f^2} \qquad Kz\right]\left(1-g + \frac{gr^2}{r_o^{\,2} f^2}\right)$$

Here, f and g are functions of z determined by Maxwell's equations. The temperature is taken from the steady state Fourier's Law with an inverse bremsstrahlung source. The plasma is assumed to be in pressure balance where the pondermotive force is included in the pressure. An extension of the paraxial ray approximation is assumed. The model itself is a significant extension of nonlinear optics techniques.[1] Comparison of intensity, density, temperature, self-focusing length, and beam profile give reasonable quantitative agreement with LASNEX for intensities of ICF interest and for times long compared with a sound transit time. A potentially very important result is that the self-focusing distance is a sensitive function of the spatial beam profile.

[1] M. S. Sodha, A. K. Ghatak, and V. K. Tripathi, in Progress in Optics (North-Holland, 1976).

This work was supported by the USDOE.

Kinetic Effect in the Self Focusing of Short Wavelength Laser Light in Reactor Targets*

J.M. Wallace and R.D. Jones (LANL)

The effects of filamentation produced by the self focusing of short wavelength laser light is a central issue in the assessment of laser fusion reactor targets. LASNEX simulations indicate that the hydrodynamic treatment of such filamentation is questionable because the electron Larmor radii and density scalelengths are calculated to be comparable to the electron-ion collision mean free paths. It is necessary that kinetic effects be considered. To this end we have employed the VENUS implicit plasma simulation code in a preliminary investigation of B-field generation and energy transport in a filamented, long-scalelength plasma target. The simulation results will be discussed.

*This work was performed under the auspices of the United States Department of Energy.

Thermal Self-Focusing with Multiple Beams

R.S. Craxton and R.L. McCrory (LLE)

Abstract

Self-focusing in underdense plasmas in the presence of overlapping beams is of interest for multibeam laser-irradiation systems. The hydrodynamics/ray-tracing simulation code SAGE is used to model thermal self-focusing in two-dimensional line-focus geometry with beams incident obliquely at different angles. The conjecture that multiple overlapping beams may suppress self-focusing is investigated for parameters appropriate to reactor-sized targets; in particular, the dependence upon intensity, scale length and pulse width is examined. While the full problem is three-dimensional, insight may be gained from two-dimensional simulations.

"This work was supported by the U.S. Department of Energy Office Of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by the Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

UV Implosions at GRECO ILM

E. Fabre (Ecole Polytechnique)

Session K

(Review)

Symmetry and Stability Issues in Direct Drive Laser Fusion

S. E. Bodner (NRL)

Thursday, 8:00 PM

Chairman: E. Fabre (Ecole Polytechnique)

Session L

(Oral)

Beat Wave Accelerators,

X Ray Generation and Transport

Friday, 8:30 AM

Chairman: J. Grun (NRL)

Experimental Test of the Laser Plasma Beatwave Accelerator Concept

F. Marti , N.A. Ebrahim,* . Brodeur, E.A. Heighway,** J.P. Matte, H.Pepin, P. Lavign , and T.W. Johnston (INRS-Energie)

Abstract

We report the first experimental observations of acceleration of injected electrons in a laser driven plasma beatwave. The plasma waves were excited in an ionized gas jet, using a short pulse high intensity CO_2 laser with two colinearly propagating beams (λ = 9.6 µm and 10.6 µm) to excite a fast wave ($v_p \approx c$). The source of electrons was a laser plasma produced on an aluminum slab target by a third, synchronized CO_2 laser beam that produces electrons up to 1.5 MeV. A double-focusing dipole magnet was used to energy select and inject electrons into the beatwave, and a second magnetic spectrograph was used to analyze the accelerated electrons. Electron acceleration was only observed when the appropriate resonant plasma density was produced ($\approx 10^{17}$ cm^{-3}), the two laser lines (λ = 9.6 µm and 10.6 µm) were incident on the plasma and the injection energy was above the threshold for particle trapping. Details of the experiment and recent results will be presented.

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Excitation of Beat Waves in a Rippled Density Plasma

C. Darrow, D. Umstadter, T. Katsouleas, W.B. Mori, C.E. Clayton,
and C. Joshi (University of California)

ABSTRACT

Results of recent experimental and theoretical studies of the beat excitation of electron plasma waves in a rippled density plasma will be presented. Experimentally, the density ripple arises due to the excitation of the SBS instability. To describe this process a theoretical model has been developed which provides for the coupling of the beat excited plasma wave ($v_\phi \simeq c$) to a spectrum of larger-k electrostatic modes ($v_\phi \ll c$). These larger-k modes act as an energy sink for the beat-wave driver and bring about rapid saturation of the beat excited plasma wave. For easily realizable experimental parameters the saturation can be well below that predicted by relativistic detuning. Interpretations and comparisons of experimental and theoretical results will also be discussed.

Work supported by DOE contract DE-AM03-76SF00034, NSF grant ECS 83-10972 and LLNL grant 6223205.

Ponderomotively-Driven Ion Acoustic Waves: Simulation and Experiment*

W.L. Kruer and K. Estabrook (LLNL)

ABSTRACT

In recent experiments[1] ion acoustic waves generated by the beat between two electromagnetic waves have been studied in some detail. A particle ion, fluid electron code (including ion-neutral collisions) has been used to simulate these experiments. The amplitudes of the ponderomotively-driven ion wave and its second harmonic compare favorably with the measurements. We also show that ion tail formation occurs at a quite modest ion wave amplitude consistent with the experiments. Detailed comparisons will be given and some differences discussed.

1. C. Pawley a N. Luhm Jr., Bulletin of the American Physical Society, 30 26 19

* 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.

Solitary-Wave Solutions of the Beat-Wave Equations

C.J. McKinstrie, D.F DuBois, and D.W. Forslund (LANL)

In the beat-wave accelerator, a large-amplitude Langmuir wave is produced by the beating of two laser beams whose frequencies differ by approximately the plasma frequency. The growth of this wave saturates due to a combination of pump depletion and a nonlinear shift in its natural frequency. With both of these physical effects taken into account, the governing equations for this three-wave interaction are shown to admit solitary-wave solutions. Analytic expressions are obtained for the envelopes of these waves, and for the relationship between their speed and maximum amplitude. The possible use of these waves for particle acceleration is discussed.

Supported by the United States Department of Energy under contract W-7405-ENG-36.

Various Aspects of Axially Fed Laser Electron Accelerator

F. Brunel (NRC of Canada)

In comparison to other concepts, Laser Wake Plasmon accelerators offer the possibility of producing the cleanest plasma wave with a plasma wave quiver velocity v_p given by $v_p/c = (\sqrt{2\pi}/8)(v_{osc}{}^2/c^2)\omega_p \Delta t$ $\exp(-\omega\ {}^2\Delta t^2/8)$ for a Gaussian profile. There is no relativistic saturation in this case. However, if a small counter propagating signal is present, the electrons are left with a random velocity behind the wave packet. For long pulses, one can use the forward Raman growth to generate the plasma wave. From 1 2/2D particle simulation results, at $v_{osc} \gtrsim .5$ c, we observe stochastic heating behind the wave front when no daughter wave is present. If a daughter wave is seeded, a plasma wave is therefore observed to grow. A good estimate for the plasma wave saturation amplitude is given through Rosenbluth and Liu's saturation mechanism using for the daughter wave the maximum amplitude allowed through energy and momentum conservation consideration. 2½D particle simulations with $(\omega_o/\omega_p = 4)$ show that the forward plasmon grows before side plasmons set in, in the seeded case. However, in all axially fed laser accelerator concepts, if conventional optics are used, a severe limitation on the accelerator length arises from the fact that the ratio R of the focal length over the interaction length, is given by $R = (I_o/I_{dam})^{1/2}$, which can be very large: I_o is the required laser intensity to produce the plasma wave while I_{dam} is the threshold intensity that produces damage on the mirror (i.e. $I \sim 10^{12}$ W/cm^2 or less). In the stage concept, we can see that no gain in accelerator length can be achieved by going to shorter wavelengths. If self focussing takes place, R can be reduced by a factor ω_{laser}/ω_p.

1. M.N. Rosenbluth and C.S. Liu, Phys. Rev. Lett., 29, 701 (1972).
2. Paul Corkum, private communication.

X-ray Energy Conversion Measurements in 0.25 μm Laser/Plasma Interaction

R. Popil, P.D. Gupta,+ R. Fedosejevs, and A.A. Offenberger
(University of Alberta)

The energy conversion of KrF laser radiation to X-rays is investigated using an array of filtered X-ray diodes, PIN diodes and scintillator-photomultiplier detectors. Brillouin compressed KrF laser pulses of intensities ranging from 0.1-2x10^{13} W/cm^2 are focused through f/10 optics onto planar solid targets ranging in atomic number from 3 to 82. X-ray emission was observed in the energy range from 0.06 to 10 keV. X-ray intensities as a function of atomic number show characteristic undulatory structures that become increasingly more pronounced with hardness of X-rays. The scaling of the X-ray emission with laser intensity is also found to vary with the X-ray energy range observed and atomic number of the target. The energy conversion efficiency is determined from these observations and published quantum efficiencies for the various detectors. The azimuthal isotropy, spatial and temporal properties of the X-ray emission as a function of target atomic number of laser intensity are also characterized, the latter by a high speed X-ray streak camera and pinhole imaging camera. The pulse duration for X-ray energies >1 keV is compared to that of the laser pulse, and the X-ray pinhole image is compared to the laser focal spot size to assess the role of radial energy transport in X-ray energy conversion.

+ on leave from Bhabha Atomic Research Centre, Bombay, India

Non-LTE Radiation and Ion-Dynamic Effects in Hydrodynamic Simulations of Laser-Driven Plasmas

R. Epstein, J. Delettrez, and S. Skupsky (LLE)

Simulations of several cases of laser-driven plasmas have been obtained using a version of the 1-D Lagrangian hydrodynamic code LILAC that has been upgraded to include the effects of time-dependent non-LTE ion dynamics on the thermal-electron and radiation energy transport. The average-ion model is used to describe the plasma and to calculate the radiative opacity and emissivity. Comparisons of results obtained using non-LTE and LTE (Saha) ion populations show under what conditions the LTE approximation significantly affects the results of hydrodynamic simulations. A non-LTE post-processor is used with output from the hydrodynamic code to obtain much more detailed radiation spectra than is available from the average-ion model in the hydrodynamic code. An important result of the upgrade is that the post-processor can now be run more self-consistently with input based on a non-LTE assumption.

"This work was supported by the U.S. Department of Energy Office of Inertial Fusion under agreement No. DE-FC08-85DP40200 and by Sponsors of the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics."

X-Ray Line Transfer in Thick, Laser-Produced Plasmas

D. Mostacci, R. Morse, and J. Dinguirard (University of Arizona)

A model was developed for calculations X-ray line emission from spherical plasmas.

The main features of the method are:

0) Plasma parameters are obtained from a one-dimensional Lagrangian hydrodynamics and heat flow code.
1) Multi-frequency groups.
2) Self consistent, time dependent excited level populations and radiation fluxes.
3) Groups of rays grouped by impact parameter.
4) Doppler broadening, Doppler shift due to the net plasma flow velocity.
5) Multi-level treatment.

The method has been applied to an aluminum target, and the results are in good agreement with previous experimental work. An interesting phenomenon of competition between the two lines of the H_α doublet, strongly dependent on the magnitude of the plasma flow velocity and, hence, Doppler shift has been observed: as Doppler shift increases, the intensity in the lower line increases at the expenses of the higher line, until, for large enough shift, the latter disappears completely.

The method is now being generalized to cylindrical geometry, with the goal of x-ray laser simulation. Preliminary results in cylindrical symmetry will be presented here.

Anomalous Absorption Preregistered Attendees

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