23RD • ANNUAL • ANOMALOUS ABSORPTION • CONFERENCE

wintergreen virginia usa • 21 - 25 june 1993

Conference Organizers:
John Gardner
Jill Dahlburg
Mark Emery
Andy Schmitt

Conference Secretaries:
Joyce Del Giudice
Carole Mithen

Program Committee:
Steve Bodner
Jill Dahlburg
Andy Schmitt

NRL

Conference Schedule

23rd **Annual Anomalous Absorption Conference**
June 21 - 25, 1993, Wintergreen, VA USA

In Nature's infinite book of secrecy
A little can I read.
Shakespeare, 'Antony & Cleopatra'

SCHEDULE CHANGES

23rd Annual Anomalous Absorption Conference
June 21 - 25, 1993, Wintergreen, VA USA

POSTDEADLINE ABSTRACTS

PAPERS WITHDRAWN

Thursday

9:00 - 9:15	**4O**	**1**	Growth of Illumination Nonuniformities on Laser-Accelerated Flat Targets, *J.P.Knauer, C.P.Verdon, T.J.Kessler, S.Skupsky, R.L.McCrory, J.M.Soures, S.G.Glendenning, & S.Weber*	80
10:55 - 11:10	**4O**	**7**	Measurements of the Effects of Pulse Shaping on Rayleigh-Taylor Growth in Burnthrough Targets, *D.K.Bradley, J.A.Delettrez, P.A.Jaanimagi, S.Skupsky, & C.P.Verdon*	86
11:10 - 11:25	**4O**	**8**	3-D Laser Ray Trace Package in a Fully 3-D Radiation Hydro Code, *S.V.Coggeshall, H.X.Vu, J.P.Dahlburg, & J.H.Gardner*	87

Monday, June 21, 1993

Oral Session 1

Plasma Instabilities and Waves

L. Powers, Chair

OMEGA LONG-SCALE-LENGTH LASER-PLASMA INTERACTION EXPERIMENTS

W. Seka, R. S. Craxton, R. E. Bahr, A. V. Chirokikh,
A. Simon, R. W. Short, and E. M. Epperlein
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

H. Baldis
LAWRENCE LIVERMORE NATIONAL LABORATORY
University of California
Livermore, CA 94550

R. P. Drake
PLASMA PHYSICS RESEARCH INSTITUTE
University of California
Livermore, CA 94550

A number of long-scale-length laser-plasma interaction experiments have been carried out on OMEGA with interaction beams at 351 nm as well as at 1053 nm. The background plasma for these experiments is produced with 16 of OMEGA's 24 beams at 351 nm (0.7 ns) incident on a flat CH target of 600-μm diameter and 6-μm thickness. Eight of the 16 beams explode the target and the remaining 8 beams are delayed by 0.6 ns and keep the temperature of the plasma in the vicinity of 1 keV for periods of ~0.5 ns. The corresponding density scale lengths are ~0.5 mm. The interaction beam (λ_L = 351 nm or 1053 nm) is incident on this plasma at various times during the expansion phase. All beams are equipped with distributed phase plates for increased reproducibility of the irradiation conditions. Various other beams have been used as probe beams for Thomson scattering off plasmons generated by various nonlinear interaction processes.

We will highlight some recent results relating to the two-plasmon decay (TPD) instability and stimulated Brillouin scattering. The former were obtained at an interaction wavelength of 351 nm using Thomson scattering as the main diagnostic. The latter was obtained at 1053 nm and exhibits some interesting features that are discussed in the context of information obtained from two-dimensional hydrodynamic code simulations (*SAGE*).

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

10 1

SATURATION OF THE TWO PLASMON DECAY INSTABILITY BY THE EXCITATION OF LANGMUIR TURBULENCE

D. F. DuBois,[a] David Russell[b] and Harvey A. Rose[a]
[a]Los Alamos National Laboratory, MS B262, Los Alamos, NM 87545
[b]Lodestar Research Corp., 2400 Central Avenue, Boulder, CO 80301

The TPD instability has been studied for over 25 years.[1] It often has a lower damping or gradient threshold for absolute instability than either SRS or SBS which can also operate near quarter critical density, $n_c/4$. Experiments have measured $1/2\,\omega_o$ and $3/2\,\omega_o$ radiation signatures of TPD and it has been inferred from experiment that ion acoustic fluctuations, secondarily generated by TPD, can act as a seed for SBS near $n_c/4$.

We present preliminary results on the nonlinear saturation of TPD due to the excitation of Langmuir turbulence which are based on 2D pseudo-spectral simulations of an extended 'Zakharov' description. Our emphasis is on long scale-length plasmas with collisionality appropriate to sub micron laser wavelengths. Turbulence modal energy spectra and power spectra for Langmuir and ion density fields are computed, as well as radiation patterns and power spectra for the $\frac{1}{2}\omega_o, \omega_o$ and $\frac{3}{2}\omega_o$ secondary radiation. (See related poster presentation.) Arguments based on the weak coupling of linear modes have some validity for very weak drive. For intermediate drive a finite level of ion acoustic turbulence broadens spectra but Langmuir collapse is inhibited by collisional damping. For strong drive typical of many experiments, Langmuir collapse develops resulting in strong saturation, broad spectra and hot electron generation.

This research is supported by the USDOE.

(1) M. V. Goldman, Ann. Physics (N.Y.) **38**, 95 (1966).

Two Plasmon Decay, Ion Acoustic Waves, and the $(3/2)\omega_0$-Thermometer in Laser Produced Plasmas

J. Meyer, Y. Zhu, and R. McKenna

University of British Columbia

Vancouver, B.C., Canada V6T 1Z1

The commonly observed emission of (3/2)-harmonic radiation from laser produced plasmas is understood to be the result of a process in which incident photons are scattered off plasma waves, originally generated by the two plasmon decay (TPD) instability. Though the $(3/2)\omega_0$-spectrum shows characteristic T_e dependent features, efforts to analyze them on the basis of well understood linear TPD theory so far has not been very successful. An attempt to overcome some of the difficulties will be described which invokes mode coupling of TPD to ion acoustic waves. For the case of ion waves generated by stimulated Brillouin scattering (SBS) calculations show that coupling leads to saturation and temporal modulation of TPD at ion acoustic frequencies. In order to investigate the relation between TPD and $(3/2)\omega_0$-radiation and the validity of these ideas we have conducted an extensive experimental survey of the growth and saturation of TPD waves in a CO_2-laser irradiated long scale length plasma of ~quarter critical maximum density. Using ps-streak camera detection of visible Thomson scattered probe laser radiation the wave vector distribution of TPD waves in the complete k_x ($\|\mathbf{k_0}$), k_y ($\|\mathbf{E_0}$) plane has been measured. The $(3/2)\omega_0$-emission into various angles has been measured at the same time. The results show a close correlation between the saturated TPD wave amplitudes at the k_x, k_y locus for scattering of ω_0-radiation and the $(3/2)\omega_0$-emission into the corresponding angle. The saturated TPD wave intensity is temporally modulated at SBS ion acoustic frequencies. Initially the TPD growth proceeds mostly as predicted by linear theory. At saturation however, the wave vector distribution is strongly modified from that expected theoretically. Some features of this modification are consistent with coupling to SBS ion acoustic waves. The implications of the results for a $(3/2)\omega_0$ thermometer of sub-micron laser produced plasmas will be discussed.

10 3

SIMPLE MODELS OF SOURCE TERMS USED IN THE ANALYSIS OF PARAMETRIC INSTABILITIES

C. J. McKinstrie, J. S. Li, and R. Betti
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The initial evolution of stimulated Brillouin scattering (SBS), like that of many other parametric instabilities, is governed by two inhomogeneous first-order partial differential equations. To solve these equations exactly, one must specify the amplitudes of the Stokes light wave and the ion-acoustic wave at their respective boundaries of "incidence," together with the thermal source terms that maintain a constant level of amplitude fluctuations in the absence of the incident light wave. Since the governing equations are linear, they can be solved exactly in terms of Green functions. However, although this method is straightforward, it requires a considerable amount of algebra to implement. Consequently, some simplified models will be used to compare the relative importance of the boundary and source terms. Progress on the full problem will also be described.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

DENSITY AND FLOW GRADIENT FLATTENING BY PONDEROMOTIVE SELF FOCUSING OF RANDOM PHASE PLATE HOT SPOTS*

Harvey A. Rose and D. F. DuBois
Los Alamos National Laboratory

Density and velocity gradients are known to inhibit SRS and SBS respectively. Intensity thresholds for profile flattening are given.

Estimates have been given[1] of the intensity threshold, I_n^{fs}, for local creation of a density flat spot, $\partial n/\partial z = 0$, by an intense hot spot which is assumed not to self-focus. Based upon estimates of the hot spot nonlinear self-focusing threshold[2] , I_{hot}^{SF}, it is determined that $I_{hot}^{SF}/I_n^{fs} \sim (n_c/n_0)(L_n/\lambda_0)F^{-4}$, where L_n is the density gradient scale length and F is the optic f/#. If this ratio is less than one then as the laser intensity increases self-focusing occurs first.

In low density plasma a hot spot's location is fixed in the laser frame. If $\mathbf{v}_0$ is the background plasma flow velocity at the hot spot location then to 2nd order in the Mach number, $M = |\mathbf{v}_0|/c_s$, the steady state perturbation in the flow, $\delta\mathbf{v}$, caused by the ponderomotive density depletion, δn, is conveniently expressed in terms of a velocity potential, $\delta\mathbf{v} = -\vec{\nabla}\delta\phi$, with $\nabla^2\delta\phi = \left(\mathbf{v}_0 \cdot \vec{\nabla}\right)\delta n/n_0$. If the projection of $\mathbf{v}_0$ perpendicular to the hot spot axis, $\mathrm{v}_0^{\perp}$, satisfies $\left|\mathrm{v}_0^{\perp}\right| > \mathrm{v}_0^z/F$, where v_0^z is the axial component of $\mathbf{v}_0$ then the intensity threshold, I_{v}^{fs}, for local creation of an axial velocity flat spot, i.e. $\partial \mathrm{v}_z/\partial z = 0$, is related to I_n^{fs} by $I_{\mathrm{v}}^{fs}/I_n^{fs} \sim FL_n\left|\partial \mathrm{v}_0^z/\partial z\right|/\left|\mathrm{v}_0^{\perp}\right|$. If $\mathbf{v}_0$ is mainly axial then $I_{\mathrm{v}}^{fs}/I_n^{fs} \sim F^2 L_n\left|\partial \mathrm{v}_0^z/\partial z\right|/\left|\mathrm{v}_0^z\right|$

*Supported by USDOE

[1]Harvey A. Rose and D. F. DuBois, "Statistical properties of laser hot spots produced by a random phase plate", Phys. Fluids B 5, 590 (1993)
[2]Harvey A. Rose and D. F. DuBois, "Initial development of ponderomotive filaments in plasma from intense hot spots produced by a random phase plate", submitted to Phys. Fluids B.

10 5

THE EFFECT OF BEAM SMOOTHING ON FILAMENTATION* (A)

B. F. Lasinski, T. B. Kaiser, R. L. Berger, B. I. Cohen, W. L. Kruer, A. B. Langdon, C. H. Still, S. C. Wilks, and E. A. Williams

Lawrence Livermore National Laboratory
Livermore, California 94550.

We have been using our 3-D filamentation code, F3D, to study the effect of beam smoothing techniques on filamentation instabilities for parameters of current experiments. Our simulations of SSD beams show that ponderomotive filamentation is stabilized when

$$max\left(\frac{\Delta\omega}{\omega_0}, \frac{1}{16\pi f^2}\right) \gtrsim \frac{n}{8n_c} \cdot \frac{\overline{v_0^2}}{v_e^2}$$

where f is the f-number associated with the incident laser beam. This is a specific case of the general consideration that both ponderomotive and thermal filamentation are stabilized when the speckle length characteristic of the beam smoothing method is smaller than the filamentation spatial growth length. For SSD beams in which the speckle length is too long to prevent filamentation, a bandwidth greater than the filamentation growth rate will stabilize this instability provided the grating dispersion is large enough. Our SSD simulations show that bandwidth ($\Delta\omega$) is more important than speckle length in stabilizing filamentation if $\Delta\omega/\omega_0 \gtrsim 0.01 \cdot f^{-2}$. F3D simulations of CH foil irradiations on NOVA with SSD beams are consistent with the experimental observation that the SRS spectrum becomes narrower as the bandwidth increases.[1]

1. D. S. Montgomery, *et al.*, paper 4E9. Bulletin of the 1993 Division of Plasma Physics Meeting.

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

EIGENVALUE SOLUTION FOR THE ION-COLLISIONAL EFFECTS ON ION-ACOUSTIC AND ENTROPY WAVES

M. D. Tracy*
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

E. A. Williams, K. G. Estabrook, S. M. Cameron, and U. C. Davis
LAWRENCE LIVERMORE NATIONAL LABORATORY**
University of California
Livermore, CA 94550

The linearized ion Fokker-Planck equation is solved as an eigenvalue problem under the condition of collisionless electrons in the quasi-neutral limit ($\phi = 0$) for ionization-temperature ratios, $ZT_e/T_i = 2$, 4, and 8 for entropy waves and ionization-temperature ratios, $ZT_e/T_i = 4$, 8, 16, 32, 48, 64, and 80 for ion-acoustic waves. The collisionally dependent damping of the ion-acoustic and entropy waves is obtained directly from the computed eigenvalues. The perturbed ion distribution function for the ion-acoustic and entropy waves, formed from a Legendre polynomial expansion of eigenvectors, can be used to calculate collisionally dependent macroscopic quantities in the plasma such as gamma ($\Gamma = C_p/C_v$), the ratio of specific heats, and the ion thermal conductivity (κ_i).

The collisional theory for the damping on the entropy and ion-acoustic waves begins breaking down as $k\lambda_{ii}$ approaches unity, where k is the wave vector and λ_{ii} is the ion-ion mean free path. For the entropy wave, the breakdown in the collisional theory is characterized by a reduction in the ion thermal conductivity (κ_i) from the Braginskii limit, and manifests itself as a reduction in the damping rate for the entropy waves. Knowledge of the collisionally dependent damping rate for the entropy wave is important for analyzing results from Thomson scattering experiments in collisional plasmas. The damping of ion-acoustic waves at large ZT_e/T_i ratios, $ZT_e/T_i > 32$, has not been reported before. The computed damping rates from the solution of the Fokker-Planck equation smoothly connect from the collisional limit into the collisionless limit and the transition can be quantified by the ratio of the specific heats (Γ) that has a value of 5/3 and 3 in the ion-collisional and collisionless limits, respectively. Accurate values of the ion-acoustic wave damping for high ZT_e/T_i ratios is necessary for calculating threshold levels for ion-acoustic related phenomena like SBS and ion-acoustic turbulence.

*M. D. Tracy was a Hertz/Lawrence Livermore National Laboratory Fellow and would like to acknowledge his financial support from the Fannie and John Hertz Foundation during this work.

**Work supported under auspices of the Plasma Physics Research Institute and the U.S. Department of Energy under contract number #W-7405-ENG-48 (Lawrence Livermore National Laboratory).

Ion Acoustic Waves in mixed-species plasmas.

Edward A Williams and Richard L. Berger
Lawrence Livermore National Laboratory
Livermore, CA 94550

Plasmas containing more than one ionic species can support multiple ion-acoustic modes with different sound speeds. In the case of fully-ionized CH, which of the two modes is less ion Landau damped depends on the ratio of electron to ion temperature.

We show how these effects influence the growth rate and spectrum of Stimulated Brillouin Scattering, and how one may attempt to model them with fluid equations.

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

10 8

Fluid theory of the Ion Acoustic Decay Instability in warm, flowing, inhomogeneous plasmas*

R. Paul Drake, M.V. Goldman,[a] J.S. De Groot[b]

Plasma Physics Research Institute, Lawrence Livermore National Laboratory and University of California Davis, University of California, Livermore, CA, USA 94550,

ABSTRACT

We discuss the linear theory of the Ion Acoustic Decay Instability for warm, flowing, inhomogeneous, fluid plasmas. Such results are needed in the design and analysis of experiments. As usual, inhomogeneous effects markedly alter the predicted angular properties of this instability. For typical conditions, large amplification is possible over a wide range of angles. In the absence of flow there is a well-known resonance for decay waves directed perpendicular to the density gradient. In low-Z plasmas, increasing flow (plus a density gradient) alters the direction of the resonant waves and eventually, for supersonic flow, eliminates the resonance. Surprisingly, and in contrast to the case of SBS, it is the flow velocity and not its gradient that is critical here.

In typical high-Z laser plasmas, the Antistokes plasma wave is broad enough to overlap with the resonant ion acoustic wave. It acts to quench the instability in the direction of maximum homogeneous, 3-wave growth rate. This effect is quantitatively much more important that the effect of inhomogeneity and flow. The result is that one ends up with four directions of strongest growth rather than two.

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

a)Department of Astrophysical, Planetary, and Atmospheric Sciences, University of Colorado, Boulder, Colorado, 80309

(b)Department of Applied Science and Plasma Research Group, University of California Davis , Davis, California, 95616

Experimental Study of Ion Acoustic Waves in a Preformed Laser Produced Plasma

C. Labaune, H.A. Baldis*, S. D. Baton, A. Michard, N. Renard, E. Schifano
LULI, Ecole Polytechnique
91128 Palaiseau Cedex, France

W. Seka, R. Bahr
Laboratory of Laser Energetics
University of Rochester, NY 14623-1299

B. Bauer[a,b], K. Baker[a,b], K. Estabrook[b]
[a]Plasma Physics Research Institute, University of California Davis
and [b]Lawrence Livermore National Laboratory, CA 94550

Strongly driven ion acoustic waves (IAW) have been studied in a laser produced plasma, using Thomson scattering as diagnostic. A 1053 nm, 600 ps, pump laser beam was incident on a plasma, preformed by 3 beams at 527 nm. The Thomson scattering geometry at 351 nm was set to probe a range of IAW corresponding to the stimulated Brillouin scattering (SBS) instability. The IAW's were resolved in frequency and in space, along the axis of the pump beam. Enhanced levels of ion fluctuations were observed over two orders of magnitude of the pump intensity. At low pump intensities (~7x1012 W/cm2) the enhanced levels were just above the thermal scattering. Thermal Thomson scattering permitted to estimate the level of ion fluctuations associated with the IAW's, as well as providing an electron tempereture diagnostic. Other diagnostics included Thomson scattering of plasma waves from stimulated Raman scattering (SRS), SRS backscatter emission from one of the 527 nm beams to provide a measurement of the electron density, and backscatter SBS light.

* Permanet address: Lawrence Livermore National Laboratory.
-Some of 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.

Resonance absorption evolution into Langmuir turbulence

D.F. DuBois, E.M. Gavrilov, H.A. Rose
Los Alamos National Laboratory

A.M. Rubenchik
PPRI, UC Davis & Lawrence Livermore National Laboratory

In resonance absorption the component of the driving electric field parallel to the gradient tunnels into the resonant point and drives an intense peak of Langmuir oscillation. The amplitude of this resonantly driven field is usually thought to be limited by thermal convection and wave breaking. Stochastic acceleration of electrons occurs in the intense field region.

We will present 1D PIC simulations of a capacitor model of resonance absorption in very large systems ($L/r_D \sim 10000, M_i/m_e = 2000$). The conventional picture is seen to be valid for only the first few hundred plasma periods. At later times the smooth envelope of the resonant Langmuir field breaks up into narrower, localized structures with a simultaneous rippling of the ion density profile, initially without a significant change in the time averaged density. In this regime the maximum electric field drops significantly. The later time turbulence has many features in common with driven homogeneous Langmuir turbulence.

The major effect of the initial density gradient on the long time behavior is to determine the width of the turbulent zone. The turbulent regime arises because ion motion results in local density perturbations. Our simulations show that even for drive duration of a few hundred femtoseconds there can be enough time to reach the turbulent state. As a result the total absorption, fast electron distribution, etc, depends not only on the peak drive strength but depends strongly on the the drive duration and the Z/A of the target plasma.

Review Talk 1

P. Mora, Chair

Laser Acceleration, Optical Guiding and Synchrotron Radiation Generation

P. Sprangle, E. Esarey, J. Krall, A. Ting and G. Joyce

Beam Physics Branch
Plasma Physics Division
Washington, DC 20375-5346

The interaction of ultra-high power laser beams with plasmas is rich in a variety of wave-particle phenomena.[1,2] These phenomena become particularly interesting and involved when the laser power is high enough to cause the electron oscillation (quiver) velocity to become highly relativistic. Advances in the generation of ultra-high power, short-pulse lasers have resulted in power levels and intensities exceeding 10^{13}W and 10^{18}W/cm^2, respectively. These intensities result in extreme relativistic effects. Some of the laser-plasma processes include: a) the generation of large amplitude plasma waves (wakefields) for advanced accelerator, b) relativistic optical guiding of the laser beam and c) the generation of laser synchrotron radiation for advanced light sources. The development of a nonlinear, self-consistent model of intense laser-plasma interactions is discussed, and used to examine a number of the above phenomena.

Supported by DOE and ONR.

1. Phillip Sprangle and Eric Esarey, Phys. Fluids B 4 (7), (1992).
2 P. Sprangle, E. Esarey, J. Krall, and G. Joyce, Phys. Rev. Lett. 69, 2200 (1992).

Poster Session 1

Enhancement of inner shell excitation due to non-local transport in ultra-short pulse laser produced plasmas

Jean-Pierre Matte, J.C. Kieffer, M. Chaker, S. Ethier
INRS-Énergie et Matériaux, 1650 montée Ste-Julie, C.P. 1020, Varennes, Québec, Canada J3X 1S2

and

O. Peyrusse
CEA, Limeil-Valenton, 94195 Villeneuve-St-Georges cedex, France

Simulations of the interaction of ultra-short (400 fs) high intensity (10^{16} W/cm^2) laser pulses normally incident on aluminium pre-formed plasmas of gradient lengths 0.003, to 10 μm were performed with our electron kinetic code "FPI"[1]. In the cases with the shorter gradient lengths, absorption occurs at densities higher than critical, by the skin effect. In all cases, the simulations show a severe deformation of the electron energy distribution function compared to an equivalent maxwellian: there is a shortage of energetic electrons in the hot region which is directly heated, but a very large surplus in the cold, dense plasma. This latter feature continues for some picoseconds after the laser pulse is turned off: non-local transport persists as long as there is a hot plasma close to cold plasma. Detailed time dependent modelling of the ionization and excitation, using the non-maxwellian energy distributions, shows that there are very important qualitative effects in the X-ray emission due to this: in the cases withe the shortest scale-length, K-shell excitation occurs much more in depth, and collisional excitation of K-shell satellites of Li-like aluminium is greatly enhanced, compared to what would be predicted assuming maxwellian distribution functions. Comparisons with experimental, time resolved K-shell spectra confirm the existence of these non-maxwellian features.

[1] J.P. Matte, T.W. Johnston, J. Delettrez and R.L. McCrory, Phys. Rev. Lett. 53, 1461 (1984).

Possible Instability Mechanism for The ICF-Spherical Pinch

H. Chen, J. Chen, B. Hilko, and E. Panarella*
Advanced Laser and Fusion Technology, Inc.,
189 Deveault St., Unit 7, Hull, P.Q. J8Z 1S7 Canada

It is well known that instabilities in general and Rayleigh-Taylor instability in particular, are key obstacles for magnetic confinement fusion and inertial confinement fusion. While the instability mechanism for MCF and ICF has been studied extensively, the possible existence of instabilities in the spherical pinch [1] recently drew our attention.

Initial attempts to examine possible instability mechanisms for the spherical pinch have been carried out. Before performing a systematic stability analysis, we identify possible routes and scenarios following Landau's routes to turbulence style. Instability is distinguished in terms of convective instability and absolute instability.

The stability analysis begins with the identification of the basic state of the spherical pinch. Infinitesimal disturbances then are imposed on the basic state and the governing equations are derived. The solutions for the simplified case are given. A complete linear stability analysis combined with a two dimensional computational study of the spherical pinch is underway.

[1] H. Chen, E. Panarella, J. Chen,and B. Hilko (1993)
Poster this Conference.

* Also with the Department of Electrical and Computer Engineering, University of Tennessee, Knoxville, TN 37996-2100

1P 3

Pulsed Laser Heating Induced Increase of Multilayer Structure X-ray Reflectivity

by

Arie Zigler, Moshe Frenkel
Racah Institute of Physics , Hebrew University,
Jerusalem 91906, Israel

and

Zohar Henis, Eyal Kolka and Shalom Eliezer
Plasma Group, SNRC, Yavne 70600, Israel

The reflectivity of W-C multilayers during pulsed laser heating was measured using X-ray diffraction of soft X-ray radiation at 4.4 nm. The peaked reflectivity was permannently increased and the Bragg angle decreased due to 7ns, $1 J/cm^2$ laser heating.

1P 4

3d-3p Gain Monitoring in the Ne-like Germanium X-Ray Laser

M. Nantel, J.C. Kieffer
INRS-Energie et Matériaux, C.P. 1020, Varennes, Québec, Canada J3X 1S2

J. Dunn*, G.D. Enright, D.M. Villeneuve
Steacie Institute-NRCC, Ottawa, Ontario, Canada K1A 0R6

A. Wan, R.S. Walling, A.L. Osterheld
Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA, USA 94551

Large-scale inhomogeneities arising from nonuniform irridiation along the amplification axis of an X-ray laser have been shown to seriously reduce the inner-shell 3d-3p gain at 199 Å in Ne-like Germanium[1]. The dynamics of Ne-like Ge ions is studied with the time- and 2D space-resolved monochromatic imaging technique. Images of the regions of E2 quadrupole and 3A dipole emissions, originating from the upper and lower 3d-3p lasing levels (respectively) are used to diagnose the electronic density, and monitor the local X-ray gain along the amplification axis and in the density gradient. 2D LASNEX calculations are used to analyse the experimental results.

[1]G.D. Enright *et al*, J. Opt. Soc. Am. B **8**, 2047 (1991)

*presently at Lawrence Livermore National Laboratory

The frequency and damping of ion acoustic waves in CH plasmas*

R.P. Drake, A.V. Rubenchik,

Plasma Physics Research Institute, Lawrence Livermore National Laboratory and University of California Davis,

L-418, P.O.B. 808, Livermore CA 94551, and also

Department of Applied Science

University of California Davis , Davis, California, 95616

D.D. Meyerhofer

Deparment of Mechanical Engineering and Laboratory for Laser Energetics, University of Rochester ,

250 East River Road, Rochester, New York, 14619-1299

ABSTRACT

The kinetic theory of ion acoustic waves in CH plasmas is discussed. For ion temperatures above a tenth of the electron temperature, which are common, the frequency is substantially smaller than fluid theory or asymptotic expansions suggest. The damping is large, cannot be accurately calculated using large- or small-argument expansions of the dispersion function, and is dominated by the H ions. These results are quantitatively significant for nearly all laser-plasma phenomena involving acoustic waves in CH plasmas.

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

1P 6

Nonstationary Stimulated Brillouin Scattering in Laser Plasma*

A.V. Chirokikh,[a] A.M. Rubenchik[b, c]

(a) Laboratory for Laser Energetics, University of Rochester, Rochester, NY, USA 14623-1299

(b) Plasma Physics Research Institute, Lawrence Livermore National Laboratory and University of California Davis, Livermore, CA, USA 94550

(c) Institute for Automation and Electrometry, Russian Academy of Sciences, Siberian Branch, Novosibirsk, Russia

ABSTRACT

The stimulated Brillouin scattering of the intense Laser light is considered. Numerical simulation demonstrates strong SBS nonstationarity due to the interaction of SBS with radiation reflected from the critical surface. It is shown that SBS spectra structure is defined greatly by the critical surface motion, and by the reflectivity coefficient. SBS in this regime isn't only defined by the pulse intensity, but is sensitive to the process prehistory.

It is shown that SBS nonstationarity can arise in plasmas with density below critical if the plasmas are long enough. Mechanisms driving nonstationarity are discussed.

*Some of 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.

Stimulated Raman backscattering with and without optical-smoothing on Phébus laser facility.

C. Rousseaux and B. Meyer

Commissariat à l'Energie Atomique, Centre d'Etudes de Limeil-Valenton
94195 Villeneuve Saint-Georges Cedex, France

Backward stimulated Raman scattering (SRS) measurements have been performed using the optical fiber smoothing implemented on the high power Phébus laser facility (CEA-Limeil). The interaction occurred at 0.53 µm laser-wavelength in a CH-plasma. The goal of these experiments was to investigate this optical smoothing on the development of the parametric instability.

Comparative and absolute measurements of SRS-energy rate are reported as a function of the incident laser intensity (from 10^{14} W/cm^2 to 2.10^{15} W/cm^2), with or without beam smoothing, and from three density profiles (thick target, exploded foil target and preformed plasma, with the help of the second laser beam). Time-resolved SRS spectra have also been recorded at 148° with respect to the laser direction.

The experimental data show that the beam smoothing insufficiently reduces SRS, especially when this instability is its absolute regime. With or without smoothing, SRS-energy rates of the order of 10% have been measured. Although the beam smoothing efficiently reduces the contrast of the energy modulations in the focal spot, the spectral width may be insufficient to quench SRS development in these above conditions. This last assumption is in agreement with theoretical predictions.

1P 8

Langmuir turbulence generated by the ion acoustic decay instability*

B.S. Bauer, R.P Drake, K.L. Baker, K. Mizuno, B. Sleaford, Kent Estabrook, B.B. Afeyan, and A.M. Rubenchik,[a] C. Labaune, S.D. Baton, T. Jalinaud, and E. Schifano,[b] M.V. Goldman, and D.L. Newman,[c]

(a) *Plasma Physics Research Institute, Lawrence Livermore National Labratory and University of California Davis, Livermore, CA, USA 94550*

(b) *Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, Palaiseau 91128, France*

(c) *Department of Astrophysical, Planetary, and Atmospheric Sciences, University of Colorado, Boulder, Colorado, 80309*

ABSTRACT

Langmuir turbulence generated by the ion acoustic decay instability (IADI) is examined in a laser-plasma experiment. The instability was driven by irradiating Au targets with 1.053 μm laser light (T_L=500 ps, E_L<90J). Plasma waves were monitored by measuring the time and angle-resolved spectrum (resolutions of 2Å, 200 ps, and 13°) of the emissions near the second harmonic of the laser frequency. This spectrum is observed to contain a broad Stokes peak shifted too far in wavelength from the second harmonic to be produced by mechanisms involving the *linearly* fastest-growing IADI plasma wave. Comparisons are made with numerical sumulations of Langmuir turbulence.

*Some of 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. This work was also supported by CNRS and NSF.

1P 9

SECONDARY RADIATION FROM LANGMUIR TURBULENCE INDUCED BY THE TWO PLASMON DECAY INSTABILITY (TPD)

David Russell,[a] D. F. DuBois[b] and Harvey A. Rose[b]
[a]Lodestar Research Corp., 2400 Central Avenue, Boulder, CO 80301
[b]Los Alamos National Laboratory, MS B262, Los Alamos, NM 87545

Calculations of the saturated state of the TPD instability resulting from the excitation of Langmuir turbulence were reported in a talk at this meeting. Perturbative expressions are derived for the transverse currents generating radiation at $\frac{1}{2}\omega_o$, ω_o, and $\frac{3}{2}\omega_o$ in terms of the pump (laser) field and the computed longitudinal fields of the Langmuir turbulence. At $\frac{1}{2}\omega_o$ the current includes scattering of TPD plasmons from low frequency density fluctuations and Thomson down-scatteirng of the pump from TPD plasmons. At ω_o pump depletion currents arise and an anomalous absorption rate for the pump can be calculated. Thomson scattering of the pump from the low frequency density fluctuations provides a non thermal seed for SBS. At $\frac{3}{2}\omega_o$ the primary process is Thomson up-scattering of the pump from TPD plasmons. Radiation patterns and power spectra of the corresponding currents have been computed. The density matching conditions for $\frac{3}{2}\omega_o$ radiation or for an appreciable SBS seed involving the *primary* TPD plasmons are very restrictive. Propagation of plasmons in the density gradient is often invoked to relax these conditions. Strong turbulence effects are seen to broaden spectra and isotropize the radiation patterns and also lead to a relaxation of the matching conditions.

This research is supported by the USDOE.

1-D VLASOV SIMULATIONS OF STRONG LANGMUIR TURBULENCE IN A FIELD DRIVEN PLASMA

J. G. Wang, G. L. Payne
The University of Iowa
D. F. DuBois, H. A. Rose
Los Alamos National Laboratory

Abstract: 1-D full Vlasov simulations have been conducted to investigate the strong Langmuir turbulence in a plasma driven by an external pumping electric field. The pumping field $E_0 \cos(\omega_0 t)$ is chosen to be homogeneous with frequency close to the electron plasma frequency and strength larger than the modulational instability (MI) threshold.

Two types of boundary conditions have been employed: (1) Periodic Boundary Conditions (PBC); (2) Open Boundary Conditions (OBC), in which hot particles are replaced by the initial cold particles at both boundaries. The most unstable mode due to MI is excited from the self-consistent initial perturbations. Two runs using PBC in a weak driving, $W_0 \equiv \frac{E_0^2/16\pi}{n_0 k_B T_e} = 2.5 \times 10^{-3}$, have been done for: (a) $T_e = 10T_i$; (b) $T_e = T_i$. Two runs using OBC in a strong driving, $W_0 = 3.125 \times 10^{-2}$, have also been done for: (c) $T_e = 10T_i$; (d) $T_e = T_i$. All the symbols have their conventional meanings. The ion mass is set to the proton mass.

It has been observed that the MI is saturated by the Langmuir collapse, during which hot particles are generated due to the wave-particle interactions. The phase space plots reveal that these hot particles are ejected from the collapse sites like jet streams. The time interval between two adjacent jets is about one plasma period. Bump-on-tail appears on the instantaneous distributions. But the time averaged distributions over about 50 plasma periods have only monotonically decreasing high speed tails. The ion density holes break up and move away from the collapse sites via ion acoustic waves after the burnout of the cavitons. Collapse-Burnout-Nucleation (CBN) cycles have been observed. The equal temperature plasma has different behavior from the cold ion $T_i = 0.1T_e$ plasma. The ion distributions are more turbulent and less structured in the equal temperature plasma than in the cold ion plasma.

Modified Zakharov models, where the temperature does not vary, are simulated with the similar initial conditions for all the previous runs. It is found that there are no qualitative differences around the first collapse. More differences appear as time goes on. We believe that the temperature variation is important in such kinds of studies except for the very weak driving cases.

Generation of X–Rays by the Interaction of Intense Laser Fields with Beams and Plasmas*

E. Esarey, P. Sprangle, A. Ting, A. Fisher and S.K. Ride†
Beam Physics Branch, Plasma Physics Division
Naval Research Laboratory, Washington, DC 20375-5346

The interaction of intense ($\gtrsim 10^{18}$ W/cm^2), short pulse ($\lesssim 1$ ps) lasers with electron beams and underdense plasmas can lead to the generation of harmonic radiation by several mechanisms.[1–4] Laser synchrotron radiation from beams and plasmas may provide a practical method for generating tunable, near monochromatic, well collimated, short pulse x–rays in a compact, relatively inexpensive source.[2,3] The mechanism for the generation of laser synchrotron radiation is nonlinear Thomson scattering. Short wavelengths can be generated via Thomson scattering by two methods, (i) backscattering from relativistic electron beams, in which the radiation frequency is upshifted by the relativistic factor $4\gamma^2$, and (ii) harmonic scattering from plasmas, in which a multitude of harmonics are generated with harmonic numbers extending out to the critical harmonic number $n_c \simeq a_0^3 \gg 1$, where $a_0 \simeq 10^{-9}\lambda I^{1/2}$, λ is the laser wavelength in μm and I is the laser intensity in W/cm^2. Two examples of possible laser synchrotron sources (LSSs) will be presented: an electron beam LSS generating 30 keV (0.4 Å) x–rays and a plasma LSS generating 0.3 keV (40 Å) x–rays. These sources are capable of generating short ($\lesssim 1$ ps) x–ray pulses with high peak flux ($\gtrsim 10^{21}$ photon/s) and brightness ($\gtrsim 10^{19}$ photons/s-mm^2-mrad^2 0.1%BW). In addition, for sufficiently cold electron distributions, the generation of coherent harmonic radiation by stimulated backscattering is possible.[4]

*Supported by the Office of Naval Research and the Department of Energy.

† Department of Physics, University of California, San Diego.

[1]P. Sprangle and E. Esarey, Phys. Fluids B 4, 2241 (1992).
[2]P. Sprangle, A. Ting, E. Esarey, and A. Fisher, J. Appl. Phys. 72, 5032 (1992).
[3]E. Esarey, S.K. Ride, and P. Sprangle, submitted to Phys. Rev. E.
[4]E. Esarey and P. Sprangle, Phys. Rev. A 45, 5872 (1992).

Ponderomotive effect in short pulse interraction with steep gradien plasma at oblique incidence.

P. Audebert, F. Falliès, J.P. Geindre, J Delettrez*, A. Rousse, J.C. Gauthier
Laboratoire LULI, Ecole Polytechnique, 91128 Palaiseau, France

In recent years, the technology of short pulse laser generation has progressed to the point that optical pulses of 100 fs in duration are routinely produced. Such pulses can be amplified to energies of a few tens of mJ corresponding to focussed intensities exceeding 10^{18} W /cm^2

To simulate the interaction of this high laser intensity with solid targets, for different angles of incidence we have used the 1D code FILM in which collisionel absorption was calculated by solving the linear electromagnetic field for *p* and *s* polarization. For *p*-polarized light the collision frequency is adjusted so that the field in the critical region of the plasma is never higher than the maximum field allowed by the wave breaking limit. Energy transport by thermal conduction is described with the help of the delocalized heat flux theory.

The ponderomotive force resulting from the huge field is taken into account. In order to interpret pump/probe experiments we have calculated spectral profiles of the specularly reflected light of a probe beam by taking into account the time dependent phase shift due to the Doppler and plasma effects. Electron density and temperature profiles will be presented with and without ponderomotrice force for different laser conditions.

The solution of the linear electromagnetic equation will be compared to that of the 1 D 1/2 relativistic particle code EUTERPE as a function of laser intensity, pulse duration and angle of incidence.

* Permanent address: Laboratory of Laser Energetics, University of Rochester, N.Y. (USA).

PIC Code Simulations of the Interaction of Ultra-Short Laser Pulses with a Solid Target

J. Delettrez,* G. Bonnaud,§ P. Audebert, J. P. Geindre, and J. C. Gauthier

Laboratoire d'Utilisation des Lasers Intenses
Ecole Polytechnique, 91128 Palaiseau, France.
* Also at Centre d'Etude de Limeil-Valenton, 94195 Villeneuve St. Georges, France.
Permanent Address: LLE, University of Rochester, Rochester, NY 14623, USA.
§ Centre d'Etude de Limeil-Valenton, 94195 Villeneuve St. Georges, France.

The 1-D particle-in-cell (PIC) code EUTERPE was modified in order to model resonance absorption from obliquely incident P-polarized light. This was accomplished by transforming to a frame moving parallel to the target surface[1] with a velocity $v=c\sin\theta$, where θ is the angle of incidence of the light. With a 1-D code it is now possible to study in details the interaction of ultra-short pulses (< 200 fs) with matter through the entire laser pulse, something that is prohibitely expensive with a 2-D PIC code. An electron-ion collisional model was also added to the code in order to study the effect of collisions. We present the simulations of the interaction of ultra-short pulses with solid targets. The transition from the resonance absorption regime to the vacuum heating regime will be discussed in details. Also results of the interaction of 100-fs Gaussian pulses at intensities of about 10^{16} W/cm^2 will be presented. Several aspects of the interaction will be discussed, including the effects of moving ions, of collisions, and of the ponderomotive force. The diagnostics of interest are the laser absorption fraction, the electron spectrum and the reflected light spectrum.

1. A. Bourdier, Phys. Fluids **26**, 1804 (1983); P. Gibbon and A. R. Bell, Phys. Rev. Lett. **68**, 1535 (1992).

SUPRATHERMAL ELECTRONS AND IONS PRODUCED IN P-POLARIZED, PICOSECOND, LASER-PLASMA INTERACTIONS

Y. Fisher, H. Chen, B. Soom, and D. D. Meyerhofer
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The characteristics of suprathermal electrons and ions produced during high-contrast, picosecond, p-polarized laser-plasma interactions are presented. The laser system produces 1-ps, 1-μm laser pulses with intensities up to $\sim 10^{16}$ W/cm^2 with an intensity contrast of 5×10^5. Due to the relatively short duration of the prepulse, this contrast is sufficient to prevent the breakdown of the solid target before the arrival of the main pulse.

The interaction was studied with K_α emission from multilayer targets, fast ion blowoff, and other diagnostics. It is found that the characteristics of the interaction are determined by the intensity of the p-polarized component of the incoming laser field, rather than the total intensity. 20%–30% of the laser energy is deposited into suprathermal electrons that have temperatures from 2 keV to 10 keV. The suprathermal temperatures and the dependence of the absorption and K_α emission on the angle of incidence are consistent with resonance absorption models.

The partition of the suprathermal energy between K_α emission and fast ion blowoff for different conditions is currently under investigation.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the Swiss National Science Foundation. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Optical and X-Ray Characterization of an Intense Sub-Picosecond Laser-Plasma Interaction*

D. Umstadter, X. Liu, A. Maksimchuk, R. Wagner, and J. Workman

Center for Ultrafast Optical Science, University of Michigan, Ann Arbor

Reported are results of an experimental and numerical study of the interaction of an intense ($I \simeq 10^{18}$ W/cm^2) high-contrast subpicosecond laser pulse with a solid target. Various diagnostics are employed to characterize these ultrashort scale-length plasmas in which a significant portion of the radiation couples directly to the solid density region. Using a pump-probe configuration and optical diagnostics, the evolution of the expansion velocity of the critical surface is measured with femtosecond temporal resolution. High resolution x-ray diagnostics are used to characterize the x-ray emission and study the electron temperature and density. The results are found to be in good agreement with the predictions of a 1-D fluid-code computer simulation. Applications to the development of useful short-pulse x-ray sources are also discussed.

*Work supported by DOE, ONR, and NSF

Absorption Spectroscopy of X-ray Heated Foils

J. C. Moreno, R. W. Lee, C. Back, and J. Koch

Lawrence Livermore National Laboratory
P.O. Box 808, L-476
Livermore, CA 94550

Absorption spectroscopy can be a useful tool for studying radiative transfer in non-LTE plasmas. We are performing time-resolved line shape measurements of Li-like F in absorption using the Nova laser. One arm of the laser heats a Au burn-thru foil producing a soft x-ray source which radiatively heats a thin (≈1400Å) Teflon foil tamped on both sides with 1000Å of CH. Another arm of the laser heats a separate Au foil which backlights the observed sample. A varied line-space grating spectrograph with a streak camera is used to measure the absorption spectra while another spectrograph views the emission spectrum of the plasma. The width of the Li-like F 2p-4d line, which is Stark broadened, is observed to vary in time. This line width can be used to infer the electron density in these plasmas. Spectra are compared to a time-dependent collisional-radiative model FLY.

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

1P 17

*Fast Electrons for the Fast Ignitor

W. L. Kruer and S. C. Wilks
Lawrence Livermore National Laboratory
Livermore, CA 94550

The fast ignitor approach[1] to inertial fusion requires efficient generation of electrons with a temperature of order 1 Mev. We investigate fast electron generation by ultra-intense laser light incident onto a preformed plasma. Important dependences on the peak interface density[2], the angle of incidence and polarization, the intensity, and the laser beam structure are discussed.

(1) M. Tabak et al., private communication (1990).

(2) J. Denavit, *Phys. Rev. Letters* **69** , 3052 (1992), and references therein.

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

Characterization of short pulse laser-produced plasmas at the Lawrence Livermore National Laboratory Ultra short-Pulse Laser†, Ronnie Shepherd, Dwight Price, Bill White, Gary Guetlein, Bruce Young, Jim Dunn, Susana Gordan‡, Albert Osterheld, Rosemary Walling, William Goldstein, and Richard Stewart, Lawrence Livermore National Laboratory,P.O. 808, Livermore Ca., 94550.

abstract: Ultra-short pulse (USP) laser-produced plasmas have opened a new, exciting regime in plasma physics [1-3]. The USP experiments at LLNL have focused on the study of high energy-density matter. The K-shell emission from porous aluminum targets is used to infer the density and temperature of plasmas created with 800 nm and 400 nm, 140 fs laser light. The laser beam is focused to a minimum spot size of 5 μm with 800 nm light and 3 μm with 400 nm light, producing a normal incidence peak intensity of $\approx 10^{18}$ Watts/cm^2. A new 800 fs x-ray streak camera is used to study the broad band x-ray emission. The time resolved and time integrated x-ray emission implies substantial differences between the porous target and the flat target temperature. Additionally, absorption measurements have been made in both materials to determine if the enhanced temperature in the porous targets is due to the difference in absorption. The data and analysis from these experiments will be presented.

1. J.A Cobble, et al., Phys. Rev. A., **39**, 454 (1989).
2. M. M. Murname, H. Kapteyn, and R. Falcone, Phys. Rev. Lett. **62**, 155 (1989).
3. H. M. Milchberg, R. R. Freeman, S. C. Davey, and R. M. More, Phys. Rev. Lett. **61**, 2364 (1988).

†Livermore National Laboratory under contract number W-7405-ENG-48.
‡Physics Department, University of California, Berkeley.

Tuesday, June 22, 1993

Oral Session 2

Short Pulses and Laser Accelerators

P. Guzdar, Chair

20 I

Practical Model for Solid Target Heating by Ultrashort Laser Pulses

W. Rozmus
Department of Physics, University of Alberta, Edmonton, Canada

V. T. Tikhonchuk
P. N. Lebedev Physics Institute, Moscow, Russia

C. Capjack, C. Kan
Department of Electrical Engineering, University of Alberta, Edmonton, Canada

The simple, analytical model for the ultrashort laser pulse absorption and solid target heating has been proposed. The model combines in one expression different mechanisms of absorption related to normal and anomalous skin effects [1], as well as to an intermediate regime of weak collisions. The heat transport is described by the nonlocal thermal conductivity [2], which reproduces results of the Fokker-Planck simulatons [3]. We have tested assumption about steplike density profile by comparing predictions of the analytical model with the one dimensional hydrodynamical simulations. We have also explored corrections related to the strongly coupled plasma effects by applying collisional models valid in weakly degenarate plasmas [4]. The domain of applicability of the model and comparison with experimental results will be also discussed.

[1] W. Rozmus, V. T. Tikhonchuk, Phys. Rev. A **42**, 7401 (1990).
[2] W. Rozmus, V. T. Tikhonchuk, Phys. Rev. A **46**, 7810 (1993).
[3] E. M. Epperlein, R. W. Short, Phys. Fluids B **3**, 3092 (1991).
[4] R. Cauble, F. J. Rogers, W. Rozmus in *Strongly Coupled Plasmas*, S. Ichimaru editor, Elsevier, Amsterdam, 1990, p. 439.

20 1

Heating of Solid Targets by High-Intensity Lasers

R. S. Walling, J. Denavit, W. E. Alley,
A. L. Osterheld, R. E. Stewart, W. H. Goldstein, P. W. Rambo
A. B. Zimmerman
Lawrence Livermore National Laboratory
Livermore, CA 94550

We calculate the absorption of a short, high-intensity laser pulse on solid targets. In the solid, the electron density can be a few hundred times the critical density. For laser intensities of $I = 10^{15}$ to 10^{18} W/cm^2, we use a Helmholtz equation wave solver to model the absorption throughout the plasma, thereby including inverse bremsstrahlung and resonance absorption. For normal incidence of a 0.4-μm 100-fs laser pulse on solid aluminum, the absorption efficiency is found to be over 20% at 10^{15} W/cm^2 and decreases to under 1% for 10^{18} W/cm^2. These simulations include hydrodynamic expansion, the ponderomotive pressure from the laser, heat conduction, and non-lte ionization using LASNEX. The presence of a preformed plasma in front of the solid can increase the absorption efficiency. At higher laser intensity (10^{20} to 10^{21} W/cm^2) particle-in-cell simulations including collisions provide more insight. Electrons accelerated by the ponderomotive force of the laser couple their energy electrostatically to the ions and the absorption efficiency to the ions scales as $I^{1/2}$. For example, absorption in a carbon target is only a few percent, but a large fraction of the absorbed energy is transferred to the ions. After termination of the pulse, the resulting ion beam will heat the underlying material by energy deposition. We examine the absorption efficiencies, plasma temperatures and densities, and time-dependent x-ray spectra from aluminum targets heated by a wide range of laser intensities.

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

20 2

Absorption of Intense Subpicosecond 1.06 μm Laser Light Interacting with a Dense Preformed Plasma

D. E. Klem, C. Darrow, S. Lane, M. D. Perry
University Of California
Lawrence Livermore National Laboratory*
Box 808, Livermore, CA 94550

Abstract

The absorption of intense subpicosecond 1.06 μm laser pulses incident at 22.5° on solid targets is measured. The 800 fsec laser pulses are produced by a 10-TW glass laser system[1] and focused to a maximum intensity of 10^{18} W/cm^2 by an f/8 lens. These intense pulses interact with a plasma formed over the target by the laser prepulse. The absorption on various Z targets is shown to increase to more than 50% at the highest intensity. Such an increase with intensity has previously been observed in CO_2 experiments,[2] and may be indicative of new absorption mechanisms.[3,4] Preliminary correlations of the absorption with the production of hard x-rays and 2ω light will be given.

(1) F. G. Patterson and M. D. Perry, J. Opt. Soc.,8,(1991).
(2) Bach et al., Phys. Rev. Lett., 50, 2082 (1983).
(3) Kruer et al., Phys. Fluids, 28, 430 (1985).
(4) Brunel, Phys. Rev. Lett., 59, 52 (1987).

* 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.

Vlasov-Simulation of Short Laser Pulse-Matter Interaction

H. Ruhl and P. Mulser,
Theoretische Quantenelektronik, Technische Hochschule,
Hochschulstr. 4A, 6100 Darmstadt, FRG

Femtosecond laser pulses, though moderate in pulse energy, are capable of yielding very high intensities. They are an ideal tool for generating hot and dense plasma layers with steep density gradients. Ion motion is almost negligible and resonance absorption in the usual sense is inhibited. There is reason to assume that kinetic phenomena like anomalous skin effect and electron heating in the vacuum region in front of the target play an important role for the explanation of absorption rates as demonstrated by PIC (particle-in-cell) calculations. PIC calculations usually generate a high level of numerical noise. Vlasov calculations, as performed here, suppress numerical noise almost completely. Results of a relativistic kinetic calculation based on Vlasov's equation for the absorption rates of obliquely incident p-polarized light are presented. The transition from resonant to nonresonant absorption with decreasing scale length of the plasma profile is investigated.

Time-Resolved Probing of Electron Thermal Conduction in Femtosecond-Laser-Pulse-Produced Plasma†

Brian-Tinh V. Vu*, Abraham Szoke, and Otto L. Landen
Lawrence Livermore National Laboratory, Livermore, CA 94550
**and with Dept. of Applied Science, U.C.D., Livermore, CA 94550*

We report on time-resolved measurements of reflectivity, transmissivity and frequency shifts of probe light interacting with high temperature and solid density plasmas. The thin disk-like plasmas of 75μm in diameter are produced by irradiation of a transparent fused quartz target with 150fs FWHM laser pulses at peak intensity $5x10^{14}W/cm^2$. The target is coated with a thin (300Å) amorphous carbon film to enhance absorption and confine the deposition of laser energy at the target surface, thus setting up a high temperature surface heat source for subsequent generation and propagation of thermal wave supported by the electrons into the bulk region. The thermal wave is initially supersonic and eventually, as a result of hydrodynamic expansion of the plasma, overtaken by the rarefaction wave.[1] Time-resolved measurements of reflectivity and transmissivity of the plasma using a non-perturbative probe pulse incident from the rear side of the target show reflection enhancements and no transmission. The reflection increase suggests rapid formation of a super-critical density plasma layer. Also, from time-resolved frequency shifts of the reflected probe light we infer the velocity of the critical density surface where the plasma frequency is equal to that of the probe light. The nonlinear heat wave model[1] is used for calculation of plasma evolution and results in a maximum supersonic velocity of $2.6x10^7$cm/s for the motion of the critical surface, in good agreement with the experimental observations.

†This work was performed under the auspices of U. S. Dept. of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

[1]Y. B. Zeldovich & Y. P. Raizer. *Physics of Shoch Waves & High Temperature Hydrodynamic Phenomena* (Academic Press, 1966).

ENHANCED ACCELERATION IN A SELF-MODULATED-LASER WAKEFIELD ACCELERATOR*

J. Krall, A. Ting, E. Esarey and P. Sprangle

Beam Physics Branch, Plasma Physics Division
Naval Research Laboratory, 4555 Overlook Avenue, SW
Washington, DC 20375-5000

A configuration of the laser wakefield accelerator (LWFA) is proposed in which enhanced acceleration is achieved via resonant self-modulation of the laser pulse.[1] The LWFA is a device in which a high power ($P > 10^{12}$ W) laser pulse propagates in plasma to generate a large amplitude ($E > 1$ GV/m) wakefield for electron acceleration. Relative to other optical guiding mechanisms, such as plasma density-channel guiding[2] or pulse tailoring[2], the self-modulation process[1,3] has the advantage of simplicity. The self-modulated-LWFA requires: a) laser power in excess of the critical power for relativistic guiding and b) plasma wavelength short compared to the laser pulse-length. Both criteria can be satisfied by choosing a sufficiently high plasma density. In this regime, relativistic and density wake effects strongly modulate the laser pulse at the plasma wavelength, resonantly exciting the plasma wave and leading to enhanced field gradients. The pulse is also strongly self-focused and remains guided over several laser diffraction lengths. These effects significantly improve single-stage acceleration.

*Supported by the Department of Energy and the Office of Naval Research.

[1] J. Krall, A. Ting, E. Esarey and P. Sprangle, submitted to Phys. Rev. E.

[2] P. Sprangle, E. Esarey, J. Krall and G. Joyce, Phys. Rev. Lett. 69, 2200 (1992).

[3] N. E. Andreev, L. M. Gorbunov, V. I. Kirsanov, A. A. Pogosova and R. R. Ramazashvili, JETP Lett. 55, 571 (1992).

20 6

Large Amplitude Plasma Waves Driven by Optimally-Shaped Laser Pulses*

D. Umstadter and J. Kim

Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI

E. Esarey

Beam Physics Branch, Naval Research Laboratory, Washington, D.C.

Optimal shaping of the axial laser pulse profile is investigated as a means to drive relativistic plasma waves to near wavebreaking for the purpose of electron acceleration. Calculations are presented indicating that with this technique significantly less laser power (up to two orders of magnitude) is required to reach large plasma wave amplitudes than with the pulse employed in a conventional laser wake-field accelerator. Other advantages include the extraction of significantly more energy from the laser (an additional order of magnitude), and a reduction of the problems associated with the propagation of intense laser beams, such as laser-plasma instabilities. Analytical, numerical, and experimental results are presented.

*Work supported by DOE, ONR, and NSF

The Group Velocity of Large Amplitude Electromagnetic Waves in a Plasma

C.D. Decker and W.B. Mori
Departments of Physics and Electrical Engineering
UCLA

The nonlinear group velocity of a short intense laser pulse propagating in a cold underdense unmagnetized plasma is examined. Analytical expressions for the group velocity are derived. These expressions reduce to the usual $\partial\omega/\partial k$ form for small amplitude and is verified for arbitrary amplitude using PIC simulations on a cyclic mesh. We find that the leading edge of a pulse moves at the linear group velocity. The phase velocity of the plasma wake is found to be less than the pulse's group velocity. The techniques used can be applied to other waves in a plasma.

Work supported by DOE contract # DE-FG03-93ER40727 and LLNL task # 20.

2O 8

Coupling between Electron and Ion Waves in Nd Beat-Wave Experiments

F. Moulin, F. Amiranoff, J.R. Marquès
LULI, Ecole Polytechnique, 91128 Palaiseau Cedex*
B. Cros, G. Matthieussent
LPGP, Université Paris Sud, 91405 Orsay Cedex*
D. Bernard, F. Jacquet, J. Meyer, Ph. Miné, B. Montès, P. Poilleux, A. Specka
LPNHE, Ecole Polytechnique, 91128 Palaiseau Cedex*
C. Stenz
GREMI, Université d'Orléans, 45000 Orléans Cedex*
P. Mora
CPHT, Ecole Polytechnique, 91128 Palaiseau Cedex*
* Laboratoires associés au CNRS

We study the nonlinear coupling between electron and ion waves in Nd-laser beat-wave experiments
The Nd-YAG (λ = 1.064 μm) and Nd-YLF (λ = 1.053 μm) laser beams are focused into a gas vessel filled with deuterium or hydrogen. The beat-wave mechanism generates intense electron plasma waves which then couple to the ion density perturbations. The different waves are measured by Thomson scattering.

We present a whole set of results including time-resolved images of the electron and ion waves. These results are compared with theoretical predictions including

- generation of relativistic waves by beat-wave
- density evolutions with time due to the ponderomotive force of the laser
- "decay" of these electron waves into electron and ion waves
- saturation of the beat-wave mechanism.

2O 9

Beatwave Acceleration of 2 MeV Electrons to 20 MeV

C. E. Clayton, M. Everett, A. Lal, K. A. Marsh, and C. Joshi

Department of Electrical Engineering
University of California at Los Angeles
Los Angeles, CA 90024

We report on results from recent experiments where a two-frequency CO_2 laser beam beat-excites a large amplitude, relativistic electron plasma wave which subsequently accelerates externally injected electrons out to high energies. The plasma is produced early in the CO_2 laser pulse by tunneling ionization of a static fill of hydrogen gas to an electron density of around 8.6×10^{15} cm^{-3}. The plasma wave electric fields are probed directly by injecting a short train (at 9.3 GHz) of 10 psec electron pulses (2 MeV, $\approx$100 mA peak current) along the propagation direction of the plasma wave. Because the plasma wave is highly relativistic (γ_{ph}, the Lorentz factor associated with the phase velocity of the plasma wave, is $\omega_{CO2}/\omega_p \approx 34$), an electron which is "trapped" by the wave, i.e. one that is going forward in the frame of the wave, will also be highly relativistic with an energy larger than $\gamma_{ph}mc^2 \approx 17$ MeV. Electron energies higher than this have been observed in this experiment indicating that electrons have indeed been trapped by the wave and are thus in a position to gain energy at a high rate were the interaction length to be extended. Maximum energies of 20 MeV over a nominal 1 cm indicate accelerating gradients of around 1.8 GeV/m have been obtained.

This work is supported by DOE grant number DE-FG03-93ER40727.

Frequency Harmonics of the Mode Coupled Plasma Wave in Beat Excited Plasmas

M. Everett, C. E. Clayton, K.Marsh, A.Lal, W. Mori, and C. Joshi

Electrical Engineering Department
University of California, Los Angeles
Los Angeles, CA 90024

One of the most important parameters in interpreting the measured energies of accelerated electrons by a relativistic plasma wave is the absolute amplitude of the wave. The harmonic ratios of the fast wave scale as $(n_n/n_o) \propto (n_1/n_o)^n$; thus making the observation of the relative amplitudes of the harmonics a powerful diagnostic of the absolute amplitude of the relativistic plasma wave. Because of the difficulty in directly measuring the fast wave, we instead measure the so-called "mode-coupled" wave by Thomson scattering at $2k_o$. The "mode-coupled" wave arises because of coupling between the fast plasma wave and a periodic ion perturbation at $2k_o$. We have observed up to the fifth harmonic in the time and spectrally resolved mode coupled wave spectrum. However, because the mode coupling depends upon the plasma temperature, the use of the harmonic ratios to determine the amplitude of the fast wave becomes complex. Experimental results supported by PIC simulations and theory will be presented.

This work is supported by DOE grant no. DE-FG03-93ER40727.

Review Talk 2

R. Betti, Chair

2R I

Progress in Light Ion Beam Focusing and Target Experiments

D. Cook, Sandia National Laboratory

PROGRESS IN LIGHT ION BEAM FOCUSING AND TARGET EXPERIMENTS*

D. L. Cook
Sandia National Laboratories
Albuquerque, New Mexico, USA

Intense light ion beams are being developed to drive inertial confinement fusion (ICF) targets. Approximately one and one-half years ago, intense proton beams were used to conduct the first ion deposition physics experiments on the Particle Beam Fusion Accelerator (PBFA II). In the experiments, an intense proton beam (2-4 TW/cm^2) heated a low-density hydrocarbon foam contained within a gold cylinder with a specific power deposition of about 120 TW/gm for investigating ion deposition, foam heating, and generation of x-rays. Although 40 kJ of 6 MeV protons was focused onto the target, only about 1.6 kJ (4% of the beam energy) was deposited in the foam absorber due to the large ion range. The experiments were successful, and demonstrated three significant results for ion-driven ICF targets: (1) the foam enhanced the radiation output, (2) the foam provided an optically thin radiating region, and (3) the foam tamped the radiation case, retarding the motion of the gold.

To increase the specific power deposition in the target, we have been developing focused lithium beams. Because lithium ions have a much shorter range in target material than protons at comparable kinetic energy, the specific power deposition is much higher for lithium ions than for protons. Very recently, we conducted the first lithium beam driven target experiments on PBFA II. The available lithium beam intensity was in the range of 2-3 TW/cm^2, and the lithium kinetic energy was about 9 MeV. Approximately 30 kJ of lithium beam energy was focused onto the target, and because the range was matched to the target, about 21 kJ (70% of the beam energy) was deposited into the foam absorber. An important objective of these experiments was to increase the specific power deposition to > 500 TW/g, and this objective was accomplished. The specific power deposition achieved was about 1400 TW/g. The three significant results from the proton-driven target experiments listed above were reproduced at the higher specific power deposition level provided by the lithium beams.

The lithium beam driven target experiments were made possible by an order-of-magnitude increase in lithium beam intensity from 1990 (0.25 TW/cm^2) to 1993 (2-3 TW/cm^2). This increase was achieved by (1) increasing the electrical power and energy coupled from the accelerator to the lithium ion diode, (2) decreasing the ion beam horizontal and vertical divergence, (3) decreasing beam steering errors, and (4) vertically focusing the ion beam.

The lithium beam divergence has an inverse quadratic effect on the beam intensity, and control of divergence is therefore a critical step in demonstrating the feasibility of light ion fusion. Simulations using the three-dimensional electromagnetic particle-in-cell code QUICKSILVER showed a trend of decreasing ion divergence with decreasing ratio of ion current density over the Child-Langmuir current density. We learned we could control this ratio, and consequently the ion divergence, four ways by constraining the areal electron charge density (coul/cm^2) near the anode: (1) by increasing the ion emission area, (2) by increasing the magnetic field strength, (3) by limiting the electron proximity to the anode with an electron limiter, and (4) by injecting ions at high velocity into the main acceleration gap, as in a 2-stage diode. The divergence reduction in the PBFA II experiments was achieved mainly by increasing the ion emission area. In other smaller experiments, each of the four methods of controlling divergence has been demonstrated successfully. We hope to be able to make further reductions in ion divergence on PBFA II using several of these techniques together.

The target results achieved on PBFA II with light ions are the first ion-driven experiments which have exceeded specific deposition powers of 100 TW/g. The detailed information gained on ion deposition, material heating, x-ray production, and foam tamping of the radiation case, is in agreement with simulations is promising for the future. The latest results on intense ion beam interaction with matter will be described.

* Major collaborators in this research include Cornell University and the Naval Research Laboratory. Funding has been provided by the U. S. Department of Energy under contract DE-AC04-76-DP00789.

Poster Session 2

2P 1

THE PONDEROMOTIVE FORCE IN AN OVERDENSE, ABSORBING, DISPERSIVE PLASMA, CAUSED BY AN INTENSE LASER-MATTER INTERACTION

E.G.GAMALY

Laser Physics Centre , Research School of Physical Sciences and Engineering
The Australian National University
PO Box 4, Canberra , ACT, 2601 , Australia

Abstract

The ponderomotive force acting on an overdense, absorbing plasma with non-local electric properties is calculated from first principles. On the basis of the space-time dependence of the electric field and the electron distribution function which were calculated self-consistently, the conductivity, current and force in the plasma are calculated. The possibility of acceleration of ions by an intense laser beam is demonstrated and the proper conditions for this to occur are pointed out.

PACS number(s): 52.40 Db

Relativistic Filamentation and Absorption of Ultra-High Intensity Laser Light near the Critical Surface*

Scott C. Wilks and William L. Kruer
Lawrence Livermore National Laboratory
Livermore, CA 94550
Warren B. Mori
University of California, Los Angeles
Los Angeles CA 90024

Since the recent advent of chirped pulse amplification of short laser pulses, there has been considerable experimental progress in the development of ultra-intense lasers ($I > 10^{17}$ W/cm^2), with the prospects of higher intensities (10^{20} W/cm^2) just ahead. Because of this rapid experimental progress, these lasers are quickly moving into theoretically unexplored regimes of laser-matter interactions. One reason for this is that in this regime, the motion of electrons in the field of the laser is extremely relativistic and hence highly nonlinear. We use a relativistic, two-dimensional particle-in-cell (PIC) code (ZOHAR) to study the interaction of high-intensity lasers in the underdense region just in front of the critical surface. In particular, we examine how the filamentation of the laser beam affects the absorption of the light in this region and at the critical surface. Intense filamentation is observed to increase the intensity of the laser light and ripple the critical surface, making realistic estimates of the true intensity on a given target difficult at best. Some simple scaling of the number of filaments and the power in these filaments on initial beam radius and intensity will be given. The generation of hot electrons at the interface, as well as the propagation of these hot electrons into the overdense plasma and solid, will also be discussed.

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

2P 3

A Comparison of LASNEX Modeling to SXFRC Data on Spot Spreading in Conversion Efficiency Experiments*

Steven H. Langer and Frederic Ze
Lawrence Livermore National Laboratory

ABSTRACT

In an earlier paper (Ze, et al., *J. Appl. Phys.* **66**, 1989) we showed that the conversion efficiency of gold disks increases as the pulse length increases from 1 to 3 ns. This increase was explained in terms of an increasing x-ray spot size (at low energy) due to transverse heat conduction. We have obtained new data with the SXFRC, a three channel framing camera that shows spot spreading directly. The experiments used 1 and 2 ns laser pulses and the intensity varied between 5×10^{14} and 2×10^{15} W/cm^2.

In this paper, we summarize the data and present LASNEX models showing the spot spreading effect. We compare the models to the data in the 450 eV, 1.2 keV, and 2.2 keV channels for gold disk experiments, and relate the differences between the channels to the variations in the x-ray conversion layer across the spot. We will also discuss experiments with nickel disks, if time permits.

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

2P 4

Studies of Single and Dual Frequency Laser Heating in Tunnel Ionized Plasmas

A. Lal, K. Marsh, C. Clayton, M. Everett, and C. Joshi

Department of Electrical Engineering

UCLA

Experimental results are presented of laser heating in tunnel ionized underdense plasmas. A CCD camera was used as a single photon counter to monitor the x-ray emission due to bremsstrahlung from tunnel ionized plasmas ($n \approx 10^{16}\ cm^{-3}$) produced by an intense CO_2 laser ($I > 10^{14}\ W/cm^2$). From the energy distribution and the flux of the x-ray spectrum, information about the average plasma temperature can be obtained. Experiments were performed in both hydrogen and argon plasmas, with single (10.6μm) and dual (10.6μm, 10.3μm) frequency lasers. In addition, the effects of circular and linear (both vertical and horizontal) polarization were studied. Results show a higher plasma temperature in circular polarization relative to linear, as well as a larger x-ray flux in argon plasmas than in hydrogen. However, the largest x-ray emission (hence, the hottest plasma) is obtained when the laser is operated at two frequencies, with the frequency difference equal to the plasma frequency. In this case, a plasma beat wave is resonantly driven, and a component of plasma temperature of approximately 5 keV has been measured.

Work supported by DOE grant number DE-FG03-93ER40727 and LLNL.

T^3 SHORT PULSE X-RAY LASER CALCULATIONS FOR NEON-LIKE SELENIUM

K. G. Whitney, A. Dasgupta, and P. E. Pulsifer
Plasma Physics Division
Naval Research Laboratory, Washington D.C., 20375

ABSTRACT

In this paper, we investigate the influence of picosecond heating and time dependent ionization on the population dynamics of a selenium plasma. The selenium atomic model that is used is described in two previous references.[1,2] It is coupled to a hot spot model of a short pulse laser heated plasma[3] in which laser energy absorption competes with heat conduction energy losses. In particular, we will determine plasma heating conditions, with and without ion-acoustic microturbulence,[4] under which significant levels of neon-like ionization and a population inversion between neon-like 3s and 3p states are generated.[2] A comparison of the transient gains calculated will be made to CRE gains.
Work supported by SDIO/T/IS

REFERENCES

1. K. G. Whitney and M. C. Coulter, IEEE Trans. on Plasma Sci. **16**, 552, (1988).
2. A. Dasgupta, K. G. Whitney, M. Blaha, and M. Buie, Phys. Rev A **46**, 5973 (1992).
3. K. G. Whitney and J. Davis, J. Appl. Phys. **45**, 5294, (1974).
4. K. G. Whitney and P. E. Pulsifer, Phys. Rev. E **47**, 1968, (1993).

Generation of large high density plasmas by using a capillary discharge

Y. Ehrlich , C. Cohen , and A. Zigler
Hebrew University , Israel

Generation of high density long scale length plasmas is of interest for the study of laser plasma parametric instabilities such as Stimulated Brillouin or Raman Scattering. Measurements of the growth rate of these instabilities can be used for the prediction of laser plasma coupling for the large plasmas involved in the future ICF targets.

We will report on production of large plasmas using a capillary discharge. The plasma is emitted into free space from the body of the device through slits in the anode plate. The plasma is thus created in an open geometry so that it is accessible for laser interactions. For the parametric instability studies and collisional X-ray laser scheme, the plasma can be laser heated in line focus to give a long hot uniform plasma with electron densities above 10^{21} cm^{-3}.Using an improved capillary device the electron density of $8 \cdot 10^{18}$ cm^{-3} was measured at the exit of the anode .The obtained electron temperatures were about 1 eV, thus the particle density corresponding to the measured electron density was about $\boldsymbol{1 \cdot 10^{20}\ cm^{-3}}$. Plasma expansion at the exit of the anode channel was substantially reduced. An improved capillary design allows to take 10 - 15 shots with a good reproducibility, without replacing the whole devise.

Saturation of Stimulated Raman Scattering and Related Enhancement of Parametric Interactions in Laser Produced Plasmas

T. Kolber, W. Rozmus
Department of Physics, University of Alberta, Edmonton, Canada

V. T. Tikhonchuk
P. N. Lebedev Physics Institute, Moscow, Russia

We continue our studies of the nonlinear saturation of the backward stimulated Raman scattering (SRS) [1] by the parametric decay instabiltiy of the resonant Langmuir wave. Theoretical and numerical investigations of the Zakharov and electromagnetic wave equations show broad and enhanced Langmuir and ion acoustic wave spectra produced during saturation of SRS. The secondary scattering processes, like Brillouin, forward Raman [2], and upshifted Raman occur due to these increased fluctuation levels. We will discuss strong enhancement criteria, frequency spectra and reflectivity scaling laws corresponding to these processes. We will estimate the effect of hot electron production on the validity of our model. Comparisons with many experimental observations will be also discussed.

[1] T. Kolber, W. Rozmus, V. T. Tikhonchuk, Phys. Fluids B **5**, 138 (1993).
[2] T. Kolber, W. Rozmus, V. T. Tikhonchuk, Ph. Mounaix, D. Pesme, Phys. Rev. Lett. **70**, 1810 (1993).

2P 8

REFLECTIVITY OF AN INHOMOGENEOUS PLASMA SLAB

M. Casanova
C.E.A., Centre d'Etudes de Limeil-Valenton
94195 Villeneuve-St-Georges - Cedex - FRANCE

Ph. Mounaix
Centre de Physique Théorique, Ecole Polytechnique
91128 Palaiseau - Cedex - FRANCE

D. Pesme
Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique
91128 Palaiseau - Cedex - FRANCE

Parametric instabilities are studied in an inhomogeneous plasma slab, where noise sources due to thermal emission of waves are introduced as random functions of space and time. We restrict ourselves to a 1-D decay problem in the limit of the envelope approximation. The time reflectivity is computed numerically for both weakly and strongly damped low frequency electrostatic wave. In the strongly damped regime, the time-averaged asymptotic reflectivity satisfies a Tang-like relation, whatever the inhomogeneity. This result is in agreement with the theoretical predictions.

Time Resolved Measurements of Injected Electrons and Thomson Scattering in Beat Excited Plasmas

M. Everett, C. Clayton, K. Marsh, A. Lal, and C. Joshi

Electrical Engineering Department
University of California, Los Angeles
Los Angeles, CA 90024

A 2 MeV beam of electrons is injected collinearly with an intense (>4×10^{14} W/cm^2) CO_2 laser beam propagating in a vacuum and in a background gas. Both single and dual frequency laser pulses are used in these experiments. With a single frequency beam in vacuum the effects of the transverse ponderomotive force of the laser beam can be estimated on the injected electrons. When a beat wave is present, the electrons can be perturbed substantially even in vacuum. When a background gas is added, a plasma is formed via tunnel ionization. The electrons can now interact with collective fields (Raman, beatwave, etc.) of the plasma as well as be affected by the magnetic field that may arise due to the Weibel instability. Experimental results will be presented.

This work is supported by DOE grant DE-FG03-93ER40727 and LLNL.

2P 10

ION KINETIC EFFECTS AND NON-LOCAL ELECTRON HEAT FLOW IN SPHERICAL AND PLANAR SHOCK WAVES

F. Vidal and J.P. Matte, INRS-Energie et Matériaux,
C.P. 1020, Varennes, Québec, Canada, J3X-1S2.

M. Casanova and O. Larroche, CEA-CELV (Limeil)
94195 Villeneuve St. Georges CEDEX, France.

Implosion experiments are simulated by means of our kinetic code (1) suitably modified to handle spherical geometry. The shock is formed in an initially uniform plasma by the action of a contracting spherical shell. The velocity distribution function in the shock front appears to be strongly double-humped. A comparison with fluid simulations of the same situations, assuming Braginskii ion viscosity and heat conductivity, reveals that the shock structure is far less sharp. We have also compared the results of two well known non-local electron heat transport models: that of Luciani, Mora and Virmont (2) and that of Epperlein and Short (3) with those of the electron kinetic code FPI (4,5) in the context of planar shock waves. We find that the features of the T_e profile calculated by FPI are better reproduced by the latter model. However, the change in the T_e profile compared to classical heat flow (Spitzer-Härm), which is used in Ref. (1), is not sufficient to appreciably affect the ion dynamics.

(1) M. Casanova, O. Larroche and J.P. Matte, Phys. Rev. Lett. 67, 2143 (1991).
(2) J.F. Luciani, P. Mora and J. Virmont, Phys. Rev. Lett. 51, 1664 (1983).
(3) E.M. Epperlein and R.W. Short, Phys. Fluids B 3, 3092, (1991).
(4) J.P. Matte and J. Virmont, Phys. Rev. Lett. 49, 1936 (1982).
(5) J.P. Matte, T.W. Johnston, J. Delettrez and R.L. McCrory, Phys. Rev. Lett. 53, 1461 (1984).

Computer Simulations of Self-Modulation, Focusing and Wake Excitation by Short Laser Pulses in Plasma

C.D. Decker and W.B. Mori
Departments of Physics and Electrical Engineering
UCLA

T. Katsouleas
Department of Electrical Engineering
USC

In two recent papers[1,2] it was shown that pulses with powers exceeding the relativistic self-focusing threshold break up into axially separated beamlets spaced at approximately a plasma wavelength $2\pi c/\omega_p$. In both cases the phenomena was attributed to 2-D effects. However, their conclusions differed about the long time behavior. We present analytic PIC simulation results which indicate that 1-D Raman Forward Scattering can initially cause the beam break-up. The effects of Raman Backscatter and Sidescatter are also included in the simulations. Preliminary PIC simulations indicate that the pulse does not propagate stably after it initially breaks up into axial beamlets.

Work supported by DOE contract # DE-FG03-93ER40727 and LLNL Task #s 20 and 32.

---

1 P. Sprangle, E. Esarey, J. Krall, and G. Joyce, Phys. Rev. Lett. **69**, 2200(1992)

2. T. Antonsen and P. Mora , Phys. Rev. Lett. **69**, 2204 (1992)

Melting phenomema in Laser Induced Shock Waves

by

Zohar Henis and Shalom Eliezer

Plasma Physics Group, SNRC, Yavne 70600, Israel

The melting function in laser induced shock waves in aluminium was estimated as a function of the shock pressure. The results show that partial melting can begin during the relaxation of shock pressure of 680 kbar. It is also suggested that for very short laser pulses (femtoseconds) a supercooling phenomenon may occur without melting during the rarefaction wave.

2P 13

NUMERICAL SIMULATIONS OF OPTICALLY-GUIDED LASER WAKEFIELD ACCELERATOR CONFIGURATIONS*

J. Krall, G. Joyce, P. Sprangle, E. Esarey and A. Ting

Beam Physics Branch, Plasma Physics Division
Naval Research Laboratory, 4555 Overlook Avenue, SW
Washington, DC 20375-5000

In the laser wakefield accelerator, a short ($\tau_L < 1$ ps), high power ($P > 10^{12}$ W) laser pulse propagates in plasma to generate a large amplitude ($E > 1$ GV/m) wakefield. Of primary importance is the problem of guiding the laser pulse through the plasma over long distances, $z \gg Z_R$. Here, $Z_R = \pi r_L^2/\lambda$ is the diffraction length of the laser pulse in vacuum, λ is the laser wavelength and r_L is the laser radius. We find that optical guiding of a laser pulse can be accomplished by any of three methods: a) by using a plasma density channel[1,3], b) by tailoring the pulse profile to minimize diffraction[1,3] or c) via resonant self-modulation of the laser pulse[2,3]. The density channel LWFA configuration has the advantage of operating at arbitrary laser power. The tailored-pulse LWFA requires laser power greater than the critical power for relativistic guiding as well as a unique laser profile, but avoids the channel-creation problem. The self-modulated-LWFA has the advantages of extreme simplicity and enhanced accelerating fields, but remains guided over only moderate distances (5-10 Z_R).

*Supported by the Department of Energy and the Office of Naval Research.

[1] P. Sprangle, E. Esarey, J. Krall and G. Joyce, Phys. Rev. Lett. 69, 2200 (1992).

[2] J. Krall, A. Ting, E. Esarey and P. Sprangle, submitted to Phys. Rev. E.

[3] E. Esarey, P. Sprangle, J. Krall, A. Ting and G. Joyce, to appear in Phys. Fluids.

Hard X-Ray Production by the Interaction of Intense Subpicosecond 1.06 μm Laser Light with a Dense Preformed Plasma

D. E. Klem, C. Darrow, S. Lane, M. D. Perry
University Of California
Lawrence Livermore National Laboratory*
Box 808, Livermore, CA 94550

Abstract

Preliminary results on the production of hard x-rays by the interaction 1.06 μm laser pulses incident at 22.5° on solid targets are presented. The 800 fsec laser pulses are produced by a 10-TW glass laser system(1) and focused with an f/8 lens onto solid targets. A maximum intensity of 10^{18} W/cm^2 is obtained. These intense pulses interact with a dense plasma created by the laser prepulse. A nine channel filter scintillator spectrometer is used to measure the x-ray spectrum in the energy range from 15 keV to 500 keV. The production of such x-rays is expected based on past work with CO_2 lasers(2) as well as other recent work at shorter wavelengths.(3) Correlations with the production of 2ω light will be given.

(1) F. G. Patterson and M. D. Perry, J. Opt. Soc.,8,(1991).
(2) Priedhorsky et al., Phys. Rev. Lett., 47, 1661 (1981).
(3) Kmetec et al., Phys Rev. Lett., 68, 1527 (1992).

* 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.

2P 15

Raman Forward Scattering of Short-Pulse High-Intensity Lasers

W. B. Mori and C. D. Decker
Departments of Electrical Engineering and Physics
UCLA

and

D. Hinkel-Lipsker
Lawrence Livermore National Laboratory

and

T. Katsouleas
Electrical Engineering Department
USC

Raman Forward Scattering (RFS) of short-pulse relativistic-intensity lasers is investigated. Differential equations which model the instability for arbitrarily large pump strengths are derived. Exact solutions are obtained for a set of physically relevant initial conditions. The growth rate is found to asymptotically approach zero for ultra-relativistic laser intensities. As a result, there is no strongly-coupled temporal growth of RFS. The limitations of the quasi-static equations are discussed.

This work is supported by DOE grant DE-FG03-93ER40727 and LLNL tasks nos. 20 and 32.

2P 16

Low-Z Ne-like XUV Lasers in Laser-produced Plasmas with a Prepulse

J. C. Moreno, J. Nilsen, B. J. MacGowan, and L. B. DaSilva

Lawrence Livermore National Laboratory
P.O. Box 808, L-476
Livermore, CA 94550

Collisional excitation Ne-like X-ray lasers have in the past been made to work for elements ranging in atomic number from $29 \leq Z \leq 47$. We have extended the range of Ne-like x-ray lasers down to $Z = 22$ using a prepulse technique to produce the plasma. Low-Z elements now observed to lase include Ti, Cr, Mn, Fe, Co, and Ni. Experiments were conducted using the Nova laser with $\lambda = 0.53 \mu m$. Typically a 600 ps FWHM gaussian laser pulse was used with laser energy in the range $500 \text{ J} \leq E \leq 1100 \text{ J}$. A 6 J prepulse preceded the main pulse by 7 ns. Simulations using the LASNEX hydrocode indicate the prepulse creates a larger, more uniform density plasma at the densities required for lasing at these wavelengths.

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

2P 17

Time of Flight Measurements of Ion Energies Produced by 140 fS Laser Pulses at the Lawrence Livermore National Laboratory Ultra short-Pulse Laser†

G. Guethlein, D. Price, J. Swenson, M. Glinsky, R. Shepherd, and R. Stewart
Lawrence Livermore National Laboratory
P.O. 808, L-43
Livermore Ca., 94551

Abstract: Ion Energies (Z times E) ranging from hundreds of eV to tens of keV have been measured via time of flight to Faraday cups. (Al targets, I~10^18 W/cm^2) Since these ions have been accelerated by the ambipolar sheath of the expanding plasma, the electron temperature can, in principle, be deduced from the ion energy distribution. Comparison with LASNEX and ANTHEM[1] simulation codes will be given. A study is underway to determine the dependence of ion energy upon target type (shiny Al, black Al, anodized Al), laser intensity, laser wavelength (400nm and 800nm), and pre-pulse. Correlation to X-ray observations[2] will be discussed.
*Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

1. R.J. Mason, J. Comp. Phys. 71, 429 (1987).
2. R. Shepherd, et. al, this session.

Interaction of a 1.06 μm laser pulse with a preformed CH plasma

B. La Fontaine*, S. Baton, C. Labaune, P. Mounaix+, N. Renard, H.A. Baldis#, D. Pesme
Laboratoire pour l'Utilisation des Lasers Intenses, École Polytechnique, 91128 Palaiseau Cédex, France

C. Rousseaux, S. Gary and G. Nierat
CEA Centre d'études de Limeil-Valenton DLPP, B.P. 27, 94190 Villeneuve St-Georges, France

The behaviour of stimulated Brillouin scattering (SBS) in the picosecond regime has been studied with interest in the past few years.[1] In the present experiment[2], the integrated reflectivity of SBS was measured in preformed CH plasmas, with a λ=1.06 μm, 1.2 picosecond driving laser, at intensities ranging between 10^{15} to 10^{17} W/cm^2. This new information should be most valuable for the theoretical interpretation of this process since the data available up to now is scarce.

When trying to model instabilities such as SBS, it is important to know what the the plasma conditions are. We will present, in this paper, the characterisation of the plasma that complements these SBS measurements. In particular, we will show interferometric measurements of the electron density taken at the moment of the interaction. In addition, x-ray spectroscopy results obtained with an array of diodes equipped with different filters will be shown. Finally, we will present some preliminary results on the reflectivity of the stimulated Raman scattering (SRS) taken simultaneously with the SBS measurements.

---

[1] See, for instance, Ph. Mounaix *et al.* (1P12) or G. Bonnaud (1P13) in last year's conference.
[2] S. Baton *et al.*, ibid.
* INRS-Énergie, B.P. 1020, Varennes, Québec, Canada J3X 1S2
\+ Centre de Physique Théorique, École Polytechnique, 91128 Palaiseau Cédex, France
\# Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550 USA

Wednesday, June 23, 1993

Oral Session 3

Spectroscopy et Cetera

B. Bauer, Chair

301

SIMULATIONS OF SPECTRAL SIGNATURES AND IMAGES OF CORE-SHELL MIXING IN LASER-DRIVEN IMPLOSIONS

R. Epstein, C. P. Verdon, D. K. Bradley, J. Delettrez, F. J. Marshall, and B. Yaakobi
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

In laser-driven implosion experiments on polymer shells, the hydrodynamic instability near the interface between the decelerating shell and the DT fuel core is a crucial limitation on target performance. We consider how the resulting fuel-shell mixing can be observed through its effect on spectra and images of the x-ray emission from a signature layer in the shell or from a fuel additive. Simulated spectra and images are obtained using a non-LTE radiation-transport post-processor with input from one-dimensional hydrodynamic simulations. Opacity and intensity profiles change as mixing moves the signature material to regions of different temperature and density. Mixed concentration profiles are obtained directly as functions of time from the hydrodynamic simulations themselves on the basis of elementary considerations, such as free-fall trajectories or a multi-mode model of linear Rayleigh-Taylor growth. Relationships between the degree of mixing and changes in the resulting simulated spectra and images are described. Given anticipated instrumental sensitivities, the degree of mixing corresponding to observable quantities can be estimated.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Spectroscopy Based Mix Diagnostics for High Growth Factor Nova Implosion Experiments*

C.J. Keane, T.R. Dittrich, B.A. Hammel, R.W. Lee, W.K. Levedahl, H.A. Scott, S.H. Langer, and L.J. Suter
Lawrence Livermore National Laboratory

ABSTRACT

Line emission spectroscopy has been used in recent Nova implosion experiments as a diagnostic of fuel/pusher mix arising from hydrodynamic instabilities. The basic technique consists of doping the innermost region of the pusher nearest the fuel with a spectroscopic dopant which emits when the cool pusher is mixed into the hotter fuel region. (Spectral diagnostics of mix based on other techniques have also appeared in the literature.)[1,2] A dopant is also placed into the gaseous fuel region. The ratio of pusher dopant emission to fuel dopant emission increases with the amount of mix and thus provides a diagnostic of the degree of pusher/fuel mix present. To date, experiments on Nova have used Ar and Cl as the fuel and pusher dopants, respectively. In these experiments an increase in Cl emission relative to Ar is observed as the initial surface roughness (and thus degree of fuel/pusher mix) is increased, in accordance with expectation.

In the near future we plan to extend this diagnostic to implosions characterized by higher hydrodynamic instability growth. The higher pusher opacities in such implosions imply that Cl emission cannot escape the capsule, and hence higher photon energy diagnostics (in the 4.5-7 keV range) are required. The most straight forward way to do this is to dope metals with $22 \leq Z \leq 26$ into the pusher region. In addition, a fuel dopant emitting in the 5-7 keV region is also necessary. Xe suggests itself as a dopant for this purpose as the 3-2 Ne-like Xe lines are near 5 keV.

In this paper we present calculations aimed at identifying the optimum dopants and their concentration for these high growth factor experiments. We also will discuss the relevant physics issues underlying line formation in these targets. The fidelity of line spectroscopy as a mix diagnostic as a function of dopant properties will also be examined. It has been found that the degree of dopant emission is very sensitive to whether or not radiative transfer is considered in computing the dopant atomic level populations. The use of detailed spectroscopy postprocessors is very important for the design of these targets, both to ensure that radiative transfer is treated properly and to assess the effects on the computed spectra of varying the atomic model. In this way "error bars" can be placed on the theoretical calculation so as to better compare it to experiment. We discuss these and other issues.

[1] J.P. Apruzese and P.C. Kepple, Phys. Rev. A 43, 6964 (1991).
[2] R. Epstein, Phys. Rev. A 43, 961 (1991).

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

30 2

DENSE PLASMA SIMULATIONS OF SPECTROSCOPIC DIAGNOSTICS IN SPHERICAL IMPLOSIONS AT NOVA

by

G. D. Pollak and N. D. Delameter
University of California
Los Alamos National Laboratory
Los Alamos, NM 87545 USA

and

J. K. Nash and B. Hammel
Lawrence Livermore National Laboratory
Livermore, CA 94550

ABSTRACT

A brief review is presented of the recent additions that have been made to TDG for in-line detailed spectroscopy. This code is then used to model Ar-doped DD capsules imploded at NOVA. A comparison of the spectra that are obtained from 6 increasingly more comprehensive models is presented. Only the most detailed model substantially agrees with experiment. A preliminary analysis of detailed edit information for these runs (principally population fluxes) is presented.

30 3

Isoelectronic Line Ratios for Te Characterization in the Presence of a Radiation Field*

T.D. Shepard, C.J. Keane, C.A. Back, L.J. Suter, Y. Lee
Lawrence Livermore National Laboratory

J. Abdallah, Jr.
Los Alamos National Laboratory

ABSTRACT

An effective method to characterize laser-plasma electron temperatures involves analysis of impurity emission line-intensity ratios. However, for ablation plasmas from high-Z disks, an energetic radiation field will develop and introduce effects such as photoexcitation and photoionization which may significantly perturb the collisional-radiative equilibrium normally assumed in line ratio analysis. These effects render most conventional line-ratio diagnostics useless, except at supercritical densities, where opacity becomes a problem. Also, at the relatively low densities of ablation plasmas, the impurity ionization balance is in a transient state on time scales typical of nanosecond-scale laser pulses. Isoelectronic line ratios, formed using the same line from two adjacent members of an isoelectronic sequence, have recently been shown (by others)[1] to yield excellent electron temperature diagnostics, minimally sensitive to density and usable for short-pulse, high-density applications. We have found them also to be well suited for diagnosing ablation plasmas from high-Z disks. Compared to conventional ratios, they have comparable temperature sensitivity, less density sensitivity, less radiation temperature sensitivity, and are better able to respond to transient effects even at subcritical density.

[1]R.S.Marjoribanks, M.C.Richardson, P.A.Jaanimagi, R.Epstein, *Phys. Rev. A* **46**, No. 4 p. R1747 (1992).

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

30 3

Picosecond/Nanosecond Plasma Temperatures
from Quasi-Steady Isoelectronic Ratios

R.S. Marjoribanks, F.W. Budnik
Department of Physics, University of Toronto, and
Ontario Laser and Lightwave Research Centre

H. Chen, D.D. Meyerhofer
Laboratory for Laser Energetics, University of Rochester,

Since plasma temperature diagnosis from x-ray spectroscopy is complicated in a practical sense by atomic modelling, radiation transport, and quantitative reduction, and in a more fundamental sense by anomalous absorption and nonlocal transport—which contribute to a non-Maxwellian distribution of electron energies—we are pursuing simplified and well-defined spectroscopic diagnostics for picosecond and nanosecond plasmas.

We begin with targets which have a predetermined ratio of two elements of similar atomic number, and compare isoelectronic lines from ions which differ only in their nuclear charge Z, e.g., He-like Al and Mg. With two ion 'versions' of the same electron configuration, the same cross-section terms for excitation and ionization appear for each, but use different ionization potentials χ_i. Since these two have different values of the same dimensionless parameter T_e/χ_i, the two ions 'sample' slightly different regions of the electron distribution. For thermal plasmas, the ratio of intensities of isoelectronic lines gives the temperature T_e; for non-thermal plasmas, the technique gives a well-defined parameterization of the distribution in a given energy range.

We describe our recent theoretical and experimental investigations of this technique, and show a major benefit—that even where populations are far from steady-state values, the *ratio* of isoelectronic lines is nearly steady-state, even for picosecond plasmas, which very much simplifies interpretation.

30 5

Laser-Plasma Experiments Simulating Ionospheric Explosions*

Guy Dimonte, Larry Wiley, Greg Simonson, and Dana Shumaker

Lawrence Livermore National Laboratory
Livermore, CA 94550

At altitudes above 100 km, energetic plasmas created by explosions interact collisionlessly with the ambient ionosphere, producing a diamagnetic cavity that expands hundreds of kilometers until the plasma energy density is comparable to that of the earth's magnetic field. Due to the magnetic deceleration, the plasma undergoes Rayleigh-Taylor and lower-hybrid-drift type instabilities that produce plasma jets and cross field transport. For expansion speeds comparable to the ambient Alfven speed, Alfven waves are also generated that propagate around the globe. Since such effects are important and difficult to calculate, we investigate the expansion of collisionless plasmas in a magnetic field using laser produced plasmas at the JANUS laser facility. The plasma expansion and instabilities are diagnosed with gated optical images. The diamagnetic cavity is characterized with a new magneto-optic imaging probe that measures continuous magnetic field profiles in space and time. The results are compared with 2D and 3D particle-in-cell (PIC) simulations.

* Work performed under the auspices of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

PLASMA DENSITY PROFILES FROM GRID IMAGE REFRACTOMETRY

R. S. Craxton, R. Hoefen,[(a)*] F. S. Turner,[(b)*] C. Darrow,[(c)]
E. F. Gabl,[(d)] and Gar. E. Busch[(d)]

LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

Grid image refractometry (GIR), formerly known as refractive image distortion, is a technique for diagnosing long-scale-length plasmas that is based on geometrical optics and thus avoids some of the problems of interferometry. It entails passing a conventional optical probe beam through a grid before the plasma, and then forming images of the grid with the viewing system focused on two or more object planes. This can be simply implemented using a beam splitter and two cameras. From the difference in apparent locations of each grid point, two refraction angles (θ_x and θ_y) can be readily obtained for the ray passing through that grid point. The phase front can then be obtained by integration of either θ_x or θ_y and, assuming azimuthal symmetry, Abel inversion can be used to infer the density profile.

An experiment demonstrating the feasibility of GIR was carried out at KMS Fusion, Inc., in 1989. Here the transmitted wavefront was recorded holographically. Earlier analysis of this data[1] led to a determination of the refraction angles. The current work reports on integration of these angles to obtain the phase front, Abel inversion to obtain the two-dimensional density profile, and comparisons with two-dimensional *SAGE* simulations. Experimental and simulated density contours agree reasonable closely, with the differences sufficiently minor that they can probably be explained by uncertainties in the actual experimental parameters. Densities up to 10^{21} cm^{-3} were obtained with a density-length product equivalent to 80 fringes of a 0.25-μm probe, substantially more than the 5–20 fringes of previously reported interferometric determinations of laser-produced plasma density profiles. There is no reason why GIR should not be equally well-suited to mm-scale-length plasmas.

1. R. S. Craxton and F. S. Turner, 22nd Annual Anomalous Absorption Conference, 12–17 July 1992.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

* Supported by the Laboratory for Laser Energetics Summer High-School Program, which was partially funded by National Science Foundation Grant No. RCD9055084.

(a) Also Wayland Central School, Wayland, NY 14572
(b) Also Rush-Henrietta High School, Henrietta, NY 14467
(c) Lawrence Livermore National Laboratory, University of California, Livermore, CA 94550
(d) KMS Fusion, Inc., 3621 South State Road, Ann Arbor, MI 48106

3O 7

Light Pipe for High Intensity Laser Pulses

C.G. Durfee, III, and H.M. Milchberg
Institute for Physical Science and Technology
and Dept. of Electrical Engineering
University of Maryland
College Park, MD, 20742
ph. 301-405-4816, e-mail: milch@ipst.umd.edu

Abstract

Optical guiding of intense laser pulses is observed for the first time, over a distance in excess of 20 Rayleigh lengths. A two-pulse technique is used, where the first pulse prepares a shock-driven, axially extended radial electron density profile which guides a second pulse, injected after an optimum delay which increases with mass of the plasma ions. We will present the latest results from this experiment.

30 8

High Gain X-Ray Lasers at the Water Window*

S. Maxon and H. Dalhed
Lawrence Livermore National Laboratory

ABSTRACT

A recent publication[1] proposes a scheme for producing high gain (45 cm^{-1}) in Nickel-like Ta using a short pulse high intensity pump. The gain is produced in an essentially refractionless target. In this work we explore the dependence of gain on intensity, concentrating on improving the number of gain lengths.

[1] S. Maxon, K. G. Estabrook, M. K. Prasad, A. L. Osterheld, R. A. London, and D. C. Eder, *Phys. Rev. Lett.* **70**, 2285 (1993).

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

3O 9

Investigation of Energy Transfer in the Plane Laser-Irradiated Targets with High X-Ray Conversion Efficiency

B. N. Basylev,+ I. N. Burdonsky, V. V.Gavril, A. Yu. Goltsov,
E. V. Zhuzhukalo, N. G. Kovalsky, V. N. Kondrashov, M. O. Koshevoj,*
M. I. Pergament, G. S. Romanov,+ A. A. Rupasov,* A. S. Smetannikov,*
V. I. Tolkach+

Troitsk Institute of Innovation and Thermonuclear Investigations
142092 Troitsk, Moscow region, Russia

**P.N.Lebedev Physical Institute*
117942 Moscow, Russia

+Institute of Heat and Mass Exchange
220072 Minsk, Byelorusssia

Experiments and numerical simulations were carried out in planar geometry to model energy transport processes (collisional and radiative) in ICF targets. High X-ray yield targets have been irradiated with the main attention being paid to absolute X-ray energy measurments and temporal analysis of X-ray spectra.

1-D hydrocode with radiation transfer (continnum and line spectrum) was developed to examine plasma X-ray emission of laser-irradiated layered targets.

The experiments have been carried out on the "Mishen" facility under the following experimental conditions: output laser energy 100 – 200 J ($\lambda = 1.054$ μm) in 2 ns pulse, divergence – $\sim 2 \times 10^{-4}$ rad, constrast ratio – $\sim 10^6$, power density at the target surface – $(10^{13} - 10^{14})$ W/cm^2. Thin (0.025 μm – 0.8 μm) copper layers (0.3 – 3) mm in diameter coated on plastic substrate were irradiated. Multichannel X-ray calorimeter system, X-ray streak camera combined with transmission grating, and vacuum diodes were used for X-ray measurements.

Experimental data on temporal evolution of plasma X-ray spectra in the range of 10 – 100 Å have been obtained for different target parameters. Conversion efficiency as a function of laser pulse energy, thickness and diameter of copper layer, thickness of plastic substrate was measured. Particularly a critical value of coper layer thickness required for efficient X-ray conversion is found. A detailed comparison of experimental data with numerical calculations has enabled to study the re-emission zone formation in supercritical density regions of plasma corona.

Banquet Speech

S. Bodner, Chair

3R I

Darwin and the Changing World

R. Park, APS Director of Public Affairs

Business Meeting

J. Gardner, Chair

(2)

Thursday, June 24, 1993

Oral Session 4

Hydrodynamics and Symmetry

G. Pollak, Chair

Status and Plans for the NIKE Laser and Target Facility

John Stamper

Laser Plasma Branch, Plasma Physics Division
Naval Research Laboratory, WDC

The NIKE laser is a 56-beam, angularly-multiplexed KrF laser. Echelon-free ISI, using the broad-bandwidth of KrF, allows a highly-uniform focal distribution. Ablative-acceleration of planar targets will use 44 of the beams and 12 beams will be used for x-ray diagnostics. The 44-beam, 600-micron diameter composite focus will have 2 to3 kJ in 4 nsec for an intensity around 2×10^{14} W/cm^2.

The NIKE facility has been designed to study critical physics issues of direct-drive ICF, using ISI-smoothed laser beams. The Rayleigh-Taylor (RT) instability in the ablatively-accelerated, dense target material is of particular interest. The goal of the experimental program is to accelerate targets with less than 2% ablation-pressure non-uniformity and with acceptable levels of RT growth and payload preheat. Target diagnostics will include x-ray backlighting (for studying areal mass uniformity), x-ray side-lighting (for studying acceleration history), double-foils (for studying acceleration uniformity), and space-time resolved imaging of target rear surface (for studying pre-heat).

In the Spring of 1993, the laser is about half complete - with half (28) of the beams being amplified through the 20-cm aperture amplifier. The focal uniformity of these beams, using ISI, is encouraging. Fabrication of the target facility is underway. We expect to complete the laser early in 1994 and the target facility in the Summer of 1994.

Supported by the USDOE.

40 1

SCATTERING OF LASER LIGHT NEAR ω_0 CAUSED BY JETS OF ACCELERATED IONS

A. Simon

LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

We study the effect on the scattered light near ω_0 of the existence of transient 1-D pulses of accelerated ions. Experiments have seen highly directed fast ions when fast electrons are produced and also long, narrow structures moving down the density gradient at supersonic speeds. Associated with the latter is an intense, quite distinct, blue-shifted spectral line with larger shift than the Brillouin lines.

Using collisionless equations for the three species (background ions, electrons, and accelerated ions), we study the existence of unstable waves as a function of the fast-ion-directed velocity, plasma-flow velocity, relative densities, and species temperatures. This is then made self-consistent with the local wave-vector matching, frequency matching, and the e.m. dispersion relations for backscatter of the incident laser light. A unique blue-shifted line results for a given directed beam velocity. This is now combined with a model of ion-beam creation at n_c (and at $n_c/4$) and subsequent nearly uniform acceleration to produce a quantitative fit to recent experimental observations of increasingly blue-shifted features. The "fine structure" is the result of repeated transient ion bursts. Initially, red-shifted features, which then move steadily toward the blue, may be explained by the onset of jets at $n_c/4$ on the far side of the subcritical long-scale-length plasma. Numerical studies as well as qualitative explanations will be presented.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Withdrawn / Replaced by Al Simon

401

GROWTH OF ILLUMINATION NONUNIFORMITIES ON LASER-ACCELERATED FLAT TARGETS

J. P. Knauer, C. P. Verdon, T. J. Kessler, S. Skupsky, R. L. McCrory, and J. M. Soures
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

and

S. G. Glendinning and S. Weber
LAWRENCE LIVERMORE NATIONAL LABORATORY
University of California
Livermore, CA 94550

An experiment to study the growth of illumination nonuniformities on flat targets has been done on the NOVA laser system. The series of laser shots were done on flat CH_2 foils with no initial mass perturbations. The illumination intensity was 7–9 × 10^{13} W/cm^2 over an 800-μm-diameter spot. The laser beam was frequency doubled to a wavelength of 527 nm. Smoothing by spectral dispersion (SSD) was used on the drive beam in conjunction with a wedge array and random phase plates. The main drive beam temporal shape was a linear ramp 1-ns long followed by a 2-ns long flat top.

A backlighter beam incident onto a uranium target generated the x rays used to measure the growth of initial illumination perturbations with x-ray radiography. An x-ray framing camera was used to capture a two-dimensional image of the backlight foil at several times. The spatial uniformity of the backlighter was measured with a second x-ray framing camera.

The growth of the perturbations was measured as a function of bandwidth imposed on the laser. Data will be compared with two-dimensional hydrodynamic simulations.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

The Effect of Shape in the Three-Dimensional Ablative Rayleigh-Taylor Instability: Multimode Perturbations

Jill P. Dahlburg, John H. Gardner, David E. Fyfe,
LCP&FD, Naval Research Laboratory, Washington, DC
and Gary D. Doolen
CNLS, Los Alamos National Laboratory, Los Alamos, NM

It has been conjectured from two-dimensional [2D] multimode Rayleigh-Taylor [RT] theory and simulation results[1] that there will not be sufficient time for mode coupling to dominate the multimode RT perturbation on an optimized laser-target. Using results from our previous single-mode ablative RT shape studies, the implication of this conjecture is: the subset of RT unstable modes *(a)* that evolve to those with more spherical bubbles *(b)* that are of the highest wavenumber not subject to strong density gradient stabilization, and, *(c)* which are present from very early times, are likely to be most dangerous to the target survival. However, another 'likely story' can also be offered. Results from simulating the instability into late nonlinear times indicates that at times far in the nonlinear regime, the deformations produced by the RT bubbles strongly depend on the 3D topology immediately surrounding them. In multimode situations the transition to the time when surrounding mass deformations of the pellet dictates evolution may occur at even lower amplitudes than those for which it takes place in single mode studies, since the *overall* multimode perturbation amplitude has been found to determine the interaction time and approach to full saturation. Results from non-ablative turbulent mixing simulations in 2D and in 3D which show that the mixing region grows faster in 3D than in 2D tend to substantiate this.[3]

We present results from our study[4] of the ablative RT multimode instability in 2D and 3D to address the issue of which conjecture is correct, *i.e.*, whether it is the initial perturbation that directly determines target survival in ICF-relevant direct-drive ablative regimes, or whether multimode nonlinear effects come to dominate, leading to growth of perturbations in a way that cannot directly be determined just by looking at the initial perturbation seed. For this investigation, we use the recently-developed $RAD3D - CM$.[5] Our goal is to obtain predictive capability of how the presence of many RT-unstable modes affect RT single-mode saturation and shape effects, including finite-thickness target information like the target mass ratio ρR min / ρR max (what experimentalists can measure) and local minimum values of ρR (of primary interest for target design).

Work supported by USDOE and ONR.

[1] S.W.Haan, *Phys.Fluids B*, **3**, 2349 (1991).

[2] J.P.Dahlburg, J.H.Gardner, S.W.Haan, & G.D.Doolen, *Phys.Fluids B*, (Feb, 1993).

[3] D.L.Youngs, *Phys.Fluids A*, **3**, 1312 (1991).

[4] J.P.Dahlburg, J.H.Gardner, D.E.Fyfe, S.W.Haan, & G.D.Doolen, *in prep.*, (1993).

[5] D.E.Fyfe, J.P.Dahlburg, & J.H.Gardner, *this conference* (June, 1993).

40 3

Controlling Imprinting and Growth in NOVA Direct Drive Planar Rayleigh-Taylor Experiments*

S. V. Weber, S. G. Glendinning, and S. N. Dixit
Lawrence Livermore National Laboratory
and J. P. Knauer
LLE, University of Rochester

Simulations of imprinting of laser intensity perturbations upon foils driven with an SSD-smoothed beam have achieved improved agreement with NOVA experimental data. An important contribution to the improvement is the simulation of longer slices of the foil cross-section, which enables representation of a fuller spectrum of spatial modes. These simulations agree with data for nonzero bandwidth cases to within experimental errors. Foil modulation along the direction transverse to SSD spectral dispersion decreases only slowly with increasing bandwidth between 0.04% and 0.15%. Preheat by x-rays from the backlighter is predicted to reduce imprinting if the backlighter is turned on before the drive beam, while there is little reduction if the backlighter is turned on at the same time. This indicates that the important effect of the backlighter preheat is to generate a plasma which provides early time conduction smoothing. A pulse shape with a 100 ps rise time is predicted to imprint less than our nominal 1 ns rise pulse, while a 0.35 μm drive beam of the same fractional bandwidth is predicted to imprint more than the 0.51 μm beam we have been using.

Simulations predict slower growth of imposed surface perturbations for foils seeded with chlorine or bromine, but the amount of reduction is sensitive to atomic modeling in LASNEX. Quantitative spectroscopic data will be needed to test the atomic models before it will be possible to verify perturbation growth calculations.

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

HYDRODYNAMIC STABILITY OF UNSTEADY ABLATION FRONTS

R. Betti, R. L. McCrory, and C. P. Verdon
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The linear stability analysis of unsteady ablation fronts is carried out for a semi-infinite medium. The ablation velocity and the acceleration are treated as arbitrary functions of time. For a laser accelerated target, it is shown that a proper modulation of the laser intensity leads to large amplitude oscillations of the acceleration. Such an oscillating acceleration can induce the dynamic stabilization of the ablative Rayleigh-Taylor instability. The stabilizing effect is more effective at intermediate/short wavelengths. Very long wavelength modes remain unstable. The theory is compared with the result of numerical simulations obtained by using the code *ORCHID*.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Time Resolved Symmetry Modeling in Nova Hohlraums*

P. Amendt, L. Powers, and L. Suter
Lawrence Livermore National Laboratory

A. Hauer
Los Alamos National Laboratory

ABSTRACT

An ongoing series of "Build-a-Pulse" experiments is dedicated to evaluating our understanding of time-dependent symmetry variation by using sequentially truncated pulses and measuring the resulting capsule distortion. By comparing predicted capsule shapes based on integrated simulations with the x-ray imaged distortion, we are further able to test our modeling capability of hohlraum symmetry phenomena. We have modeled implosion symmetry in standard hohlraums for a sequentially truncated flat-top pulse and a more advanced pulse shape. For square-shaped pulses we find little symmetry excursion; however, a larger symmetry swing is expected for advanced pulse shapes. In the case of a highly truncated flat-top pulse, our modeling suggests that the 50% self-emission contour does not directly correlate with the distortion of the fuel region. However, a larger self-emission contour corresponding to the 90% level is found to reliably track the pusher-fuel boundary for all pulse cutoffs. In addition, the symmetry obtained by this method is less sensitive to the amount of residual drive after the laser is terminated. Because the 90% self-emission contour may be difficult to experimentally distinguish from background emission, a current focus is to explore techniques for more direct imaging of the capsule core, e.g., backlighting a suitably doped target.

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

Development Of Robust Short Wavelength Multilayer Optics For Use In High-Peak Power Radiation Environments*,

Brian J. MacGowan, S. Mrowka, T.W. Barbee, Jr., L.B. Da Silva, D.C. Eder, J.A. Turner, and J.H. Underwood†,

Lawrence Livermore National Laboratory, University of California, L-476, P.O. Box 808, Livermore, CA 94550,
†Lawrence Berkeley Laboratory, 1 Cyclotron Road, Building 2-400, Berkeley, CA 94720, U.S.A.

In many diagnostic applications, x-ray multilayer mirrors are exposed to high peak fluxes of x-rays and optical light with subsequent damage to the mirror. Mirror damage is a particularly severe problem with the use of multilayers as cavity optics for short wavelength x-ray lasers. Intense optical radiation (from Stimulated Brillouin Side-Scattering of the incident optical laser light) and x-ray radiation, (from the x-ray laser plasma amplifier), often damage the multilayer mirror on time scales of hundreds of picoseconds. The phenomenon of multilayer mirror damage by pulsed x-ray emission has been studied using short duration (500 psec) bursts of soft x-rays from a laser produced gold plasma. The results of the experiments will be compared with some simple models and designs for short wavelength multilayer optics with increased damage thresholds will be discussed.

*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.

Time-Resolved Probing of Electron Thermal Conduction in Femtosecond-Laser-Pulse-Produced Plasma†

Brian-Tinh V. Vu*, Abraham Szoke, and Otto L. Landen
Lawrence Livermore National Laboratory, Livermore, CA 94550
**and with Dept. of Applied Science, U.C.D., Livermore, CA 94550*

We report on time-resolved measurements of reflectivity, transmissivity and frequency shifts of probe light interacting with high temperature and solid density plasmas. The thin disk-like plasmas of 75μm in diameter are produced by irradiation of a transparent fused quartz target with 100fs FWHM laser pulses at peak intensity $5x10^{14}W/cm^2$. The target is coated with a thin (300Å) amorphous carbon film to enhance absorption and confine the deposition of laser energy at the target surface, thus setting up a high temperature surface heat source for subsequent generation and propagation of thermal wave supported by the electrons into the bulk region. The thermal wave is initially supersonic and eventually, as a result of hydrodynamic expansion of the plasma, overtaken by the rarefaction wave.[1] Time-resolved measurements of reflectivity and transmissivity of the plasma using a non-perturbative probe pulse incident from the rear side of the target show reflection enhancements and no transmission. The reflection increase suggests rapid formation of a super-critical density plasma layer. Also, from time-resolved frequency shifts of the reflected probe light we infer the velocity of the critical density surface where the plasma frequency is equal to that of the probe light. The nonlinear heat wave model[1] is used for calculation of plasma evolution and results in a maximum supersonic velocity of $1.8x10^7$cm/s for the motion of the critical surface, in good agreement with the experimental observations.

†This work was performed under the auspices of U. S. Dept. of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

[1]Y. B. Zeldovich & Y. P. Raizer, *Physics of Shock Waves & High Temperature Hydrodynamic Phenomena* (Academic Press, 1966).

MEASUREMENTS OF THE EFFECTS OF PULSE SHAPING ON RAYLEIGH-TAYLOR GROWTH IN BURNTHROUGH TARGETS

D. K. Bradley, J. A. Delettrez, P. A. Jaanimagi, S. Skupsky and C. P. Verdon
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The observation of anomalously early silicon x-ray emission from imploding CH-coated glass microballoons has been attributed to mixing caused by Rayleigh-Taylor growth during the acceleration phase of the implosion. The instability, which can develop at both the ablation surface and the glass-parylene interface, can be seeded by both laser nonuniformities and target imperfections. In this paper we present experimental data that investigates the effects of the drive laser pulse shape on instability growth over a range of initial uniformity conditions and target types. The data is in agreement with the results of a simple multimode one-dimensional mix model.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

4O 8

3-D LASER RAY TRACE PACKAGE IN A FULLY 3-D RADIATION HYDRO CODE

S. V. Coggeshall,[1] H. X. Vu,[1] J. P. Dahlburg,[2] J. H. Gardner[2]

[1] Los Alamos National Laboratory, Los Alamos, NM 87544
[2] Naval Research Laboratory, Washington, DC 20375

Recently a 3-D laser ray tracking routine has been added to the NRL code RAD3D, which is the radiation version of FAST3D. This code models multigroup radiation diffusion, separate ion and electron temperatures with fully 3-D nonlinear hydro using TOPS (SPOT) tabular opacities and ANEOS equation of state. The code is written for Cartesian (xyz) geometry, using a fixed Eulerian mesh perpendicular to the direction of the laser. In the laser direction the mesh with fixed spacing is allowed to slide so the location of peak density can be stationary in the grid.

The new ray trace routine takes into account refraction due to density gradients and inverse bremsstrahlung along the light path. It does not include the effects of diffraction. We will discuss the implementation of the ray trace algorithm and show examples of ICF-related calculations.

IMPLICIT-CONSERVATIVE FOKKER-PLANCK SIMULATIONS OF HEAT FLOW IN LASER-FUSION

E. M. Epperlein
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

An implicit and fully conservative method is proposed for numerically solving the Fokker-Planck equation. The method extends the standard Chang-Cooper scheme by conserving energy as well as particle number density. *SPARK* simulations using the new scheme demonstrate improved accuracy for modeling preheating phenomena in cold plasmas. The enhanced numerical stability has also allowed the use of larger time steps that typically give rise to over one order of magnitude increase in overall computational speed.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

4O 10

LINEAR GROWTH RATE OF THE ABLATIVE RAYLEIGH-TAYLOR INSTABILITY

R. Betti, R. L. McCrory, and C. P. Verdon
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The linear growth rate of the Rayleigh-Taylor instability is derived including the stabilizing effects of ablation and density gradient scale length. For modes with wavelengths larger than the density gradient scale length, a discontinuity model is adopted. In such a model the equation representing the evolution of the interface between the heavy and light fluid is derived from first principles. For modes with wavelengths shorter than the density gradient scale length, the stability analysis is carried out using the WKB approximation.[1] Neglecting the effect of modes localized downstream from the overdense region, an approximate formula for the growth rate valid for short as well as long wavelength perturbations is presented.

1. A. B. Bud'ko and M. A. Liberman, Phys. Fluids B **4**, 3499 (1992).

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Review Talk 4

E. Esarey, Chair

Laser Matter Interactions in Recent Experiments

O. Willi, Imperial College

Poster Session 4

Uniformity in Direct Drive Laser Fusion Can it be Achieved ?

O. Willi

Imperial College, London, UK.

For direct drive laser fusion it is essential that a high degree of symmetry is maintained during the implosion phase. Asymmetries in the ablation pressure must be smaller than a few percent, otherwise an unacceptable level of instability growth occurs, reducing the fusion gain. To reduce nonuniformities in laser beams, much effort has recently been invested in the development of beam smoothing techniques. However, these techniques have so far not eliminated the problem at the beginning of the pulse, during the so called 'start-up' phase. The imprint arises due to ineffective thermal smoothing, since the distance between the absorption and ablation regions is small at early times.

The presentation will summarise the present smoothing schemes, discuss the achieved levels of suppression of the various parametric instabilities, describe measurements showing early-time imprinting and examine early results on alternative schemes for the direct-drive approach.

4P 1

MEASUREMENTS OF BACKSCATTERED LIGHT NEAR 351 nm IN LONG-SCALE-LENGTH PLASMA EXPERIMENTS ON OMEGA

A. Gaeris, R. Bahr, R. S. Craxton, W. Seka, and D. D. Meyerhofer
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

The backscattered light of an interaction beam has been measured in the region near the laser wavelength (351 nm) during recent long-scale-length plasma experiments on the OMEGA laser. This light has been spectrally and temporally resolved. The interaction beam delay with respect to the plasma forming heating beams has been varied from 0.5 ns to 2.2 ns and the peak intensity was $\lesssim 10^{15}$ W/cm^2. The laser was always focused through a distributed phase plate and smoothing by spectral dispersion (SSD) was used on some shots.

Under these conditions, no evidence for stimulated Brillouin scattering (SBS) was observed. 10^{-3}~10^{-4} of the incident laser energy was backscattered through the lens. The temporal variation was smooth with a duration similar to that of the laser pulse. The backscattered light wavelength was blue shifted by at most 0.5 Å from that of the laser.

The lack of SBS is consistent with the velocity-gradient convective threshold that is approximately 10^{15} W/cm^2 in these plasmas. The observed light is probably reflected off the density variations in the plasma.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, and the University of Rochester. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

4P 2

New results in the ion-kinetic study of collisional plasma shock waves

Y. Grillon, M. Casanova, O. Larroche
Commissariat à l'Energie Atomique, Centre d'Etudes de Limeil-Valenton
94195 Villeneuve St Georges Cedex, France
S. Morin
Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau Cedex, France

An analysis of the non-Maxwellian features of the ion distribution function obtained in Fokker-Planck simulations of a plane collisional plasma shock wave[1] is presented, together with a comparative modified fluid calculation using a higher order moment description of the plasma, drawing from the work of Cuperman and co-workers[2]. These studies show that the distribution in the shock front cannot be approximated by a single more or less distorted Maxwellian, but instead must explicitly take into account two superposed components, each with a different behavior and contribution to the overall ionic transport properties. The contribution from the main component rather satisfactorily accounts for the near-Maxwellian transport as computed from both modified and non-modified[3] fluid simulations, whereas the other component, although much more tenuous, is responsible for the strong non-classical values of the ionic conductivity and viscosity recorded in the kinetic simulations. Kinetic results are also presented for values of Z higher than 1.

As a consequence, these results definitely establish the need for a delocalized theory of ionic transport, in the same spirit as in the case of non-classical electronic transport investigated by other authors[4].

[1] M. Casanova, O. Larroche, J.-P. Matte, Phys. Rev. Lett. 67, 2143 (1991).

[2] S. Cuperman, J. Tzur, M. Dryer, Astrophys. J. 286, 763 (1984) and references therein.

[3] F. Vidal, J.-P. Matte, M. Casanova, O. Larroche, to be published in Phys. Fluids B (1993).

[4] J.-F. Luciani, P. Mora, R. Pellat, Phys. Fluids 28, 835 (1985).

4P 3

The Development and Implementation of RAD3D-CM for the Investigation of the Multimode Rayleigh-Taylor Instability

David E. Fyfe, Jill P. Dahlburg, & John H. Gardner

LCP&FD, Naval Research Laboratory, Washington, DC

The computational requirements for a realistic investigation of the multimode Rayleigh-Taylor [RT] instability on planar laser-accelerated targets are severe. For a three-dimensional problem with perturbation wavelengths spanning the 'most dangerous' range, *i.e.* wavelengths between $\frac{1}{2}X$ and 2 X where X is the target thickness, a minimum of $200 \times 128 \times 128$ x, y, z grid points and 10^4 timesteps are needed. One ideal gas calculation of this magnitude takes more than 200 hours of single-processor Cray-YMP time. This makes impractical either the inclusion of additional physics (such as realistic equations of state and multigroup radiation transport) or the performing of an ensemble of such calculations.

However, as with most simple-geometry fluid problems, while existing modeling efforts and numerical algorithms are serial, the physics of the problem is inherently parallel. We have exploited the fully parallel nature of the planar, ablative Rayleigh-Taylor problem in directions (y, z) transverse to the incident laser beam (x), and have developed an algorithm for the Connection Machine SIMD architecture. By spreading the data in the y, z directions across the CM processors and keeping data in the x direction within a processor, we have efficiently rewritten *RAD3D*[1] in CM_FORTRAN. $RAD3D - CM$ has been run on the CM-200 in the slice-wise mode and the CM-5 with vector units. With the above data layout, all aspects of the *RAD3D* algorithm is performed in parallel including the implicit thermal diffusion algorithm and the laser energy deposition. The fast processing and large memory of the CM-5 have allowed us also to implement the table look-ups inherent in the real equation of state and the variable Eddington multigroup radiation transport calculations. Using CM_FORTRAN library routines allows all table look-ups within a physical processor to share the same table, minimizing memory usage as well as promoting parallel efficiency. Thus the entire *RAD3D* package is operational on the CM-5.

The computational speed-up on the NRL CM-5 makes routine calculations with the ideal gas version of the code possible. We also present preliminary multimode results in which the effects of radiation transport are included, using $RAD3D-CM$. We discuss the numerical features of the Connection Machine version of the code, and present relative timings of the code running in parallel SIMD mode on the CM-5 and on the Cray C-90.

Work supported by USDOE and ONR.

[1] J. P. Dahlburg, & J. H. Gardner, Bull. Am. Phys. Soc. **37**, 1471, (1992).

4P 4

CONVECTIVE AMPLIFICATION AND THE EFFECT OF BANDWIDTH ON SBS IN THE QUASIMODE REGIME[1]

P. N. GUZDAR AND C. S. LIU
LABORATORY FOR PLASMA RESEARCH
UNIVERSITY OF MARYLAND
COLLEGE PARK , MD 20742-3511

AND

R. H. LEHMBERG
NAVAL RESEARCH LABORATORY
WASHINGTON D. C. 20375-5344

The conventional theory for parametric instabilities in inhomogeneous plasmas, which use the WKB approximation in time for both the decay waves is not valid for SBS since the frequency of the acoustic waves is comparable to the growth rate and the bandwidths for present-day laser plasma studies. We have studied the conective amplification of SBS in the quasimode regime for which the full time dependence (no WKB approximation) for the low frequency wave is made. We find that the amplification factor is identical to that obtained in the conventional SBS theory. This is because the mode behaves as a quasimode in a localised region of space. The detuning, caused by the inhomogeniety decreases the growth rate spatially so that for sufficient detuning the mode couples to the usual acoustic wave. Thus the quasimode growth rate controls the width of the interaction region. At present we are examining the effect of bandwidth on SBS in the quasimode regime in an inhomogeneous plasma. The implication of our results to present-day experiments will be discussed.

---

[1]Work supported by Plasma Physics Div., NRL Contract No. N00014-90-K-2010

4P 5

High Intensity Irradiation of Long Scalelength, Underdense Plasmas with the LLNL 10 TW Glass Laser

C. A. Coverdale, C. B. Darrow, and M. D. Perry
Lawrence Livermore National Laboratory

W. B. Mori and C. Joshi
University of California, Los Angeles

We present preliminary results from a series of experiments designed to investigate the interaction of short-duration, high intensity laser pulses with long-scalelength plasmas. In these experiments, laser intensities up to 10^{18} W/cm^2 interact with underdense gas target plasmas ($n_e = 10^{17}$ to 10^{19} cm^{-3}, $L_n/\lambda > 1500$). Plasma focal-volume images and scattered and transmitted light spectra will be presented. The observations will be discussed within the context of relativistic self-focusing and the excitation of wave instabilities in the channel.

*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.

4P 6

Filament Interaction In Two Transverse Dimensions as modelled in Generalized Nonlinear Schrödinger Equations

F. VIDAL and T.W. JOHNSTON

INRS Énergie et Matériaux, Varennes, PQ, J3X 1S2

Typical results will be presented (for various inertialess NonLinear Schrödinger (NLS) nonlinearities) of examples of asymmetric interaction between filamentary structures displaying fascinating and complex behaviour such as:

(i) scattering (similar to results reported by Tappert[1]),
(ii) amalgamation (somewhat like the results of McKinstrie and Russell[2]),
(iii) ring break-up (resembling that of Feit and Fleck[3])
(iv) creation of a central stably oscillating filament and an expanding halo as discussed by two Russians[4]
(v) and much more.

While much remains to be understood, one thing is immediately clear; any circularly symmetric calculation involving strong annuli are extremely vulnerable to slight asymmetry and thus extremely suspect.

Even though the NLS is (relatively speaking) a very inexpensive model, far removed from the real world of dissipation, heat flow and fluid inertia, the general behaviour exhibited could well lead to useful paradigms for the more complicated and realistic models for which a large number of cases are extremely expensive to model.

[1] F.D. Tappert, Bull. APS ?(?) ? (19??) (Atlanta Div. Plasma Physics Mtg. invited talk).
[2] M.D.Feit and J.A. Fleck , J. Opt. Soc. Am. B **5**(3) 633-640 (1988).
[3] C.J.McKinstrie and D.A. Russell, Phys. Rev. Lett. **61**(26) 2929-32 (1988).
[4] A.I. Smirnov and G.M. Fraiman, Physica D **52**, 2-15 (1991).

Fast Plasma Wave Harmonics and Mode-Coupled Harmonics from Laser-Beatwave Drive.

T.W. JOHNSTON,
INRS Énergie et Matériaux, Varennes, PQ, J3X 1S2

and

W. MORI
Department of Physics, UCLA, Los Angeles CA

In connection with the recent demonstration[1] of electron acceleration to relativistic energies by beatwave-driven (at 10.3μ and 10.6μ laser wavelengths) fast plasma waves, scattering observations have been made up to the third plasma harmonic at an SBS mode-coupled wavenumber of $2\mathbf{k}_{incident}$. The need is to relate these striking mode-coupled harmonic (MCH) signals to the strength of the important fast (γ_{phase}=35) plasma wave. Using current and electric field eliminated in favour of the charge density in the plasma electron momentum equation, two sets of quantities have been derived. The fast wave harmonic number coefficients prove to be slightly less than 1 (i.e. for the nth harmonic, d_n is nearly d_1^n, where $d_n \equiv \rho_n/\rho_0$). The coefficient ratios for the MCH are more complicated (in the limit of negligible temperatures the first three MCH coefficients are 1/6, 5/36 and 57/572, in the equation for the nth MCH $d_{n,1}$ = coeff.$e^n{}_F d_R$, with e_F as the normalized fast wave field ($qE/\omega_p mc$) and d_R the normalized SBS-induced density ripple. These results will be applied to experiments at UCLA.

[1] C. Clayton *et al.*, Phys. Rev. Lett. **70**(1) 37-40 (1993) (January 4).

4P 8

Vlasov-Code for Short Laser Pulse-Matter Interaction

H. Ruhl
Theoretische Quantenelektronik, Technische Hochschule,
Hochschulstr. 4A, 6100 Darmstadt, FRG

Ideal plasmas are frequently studied by PIC calculations. However, in the case of collisionless plasmas the extremely low degree of numerical noise makes Vlasov's approach an alternative. A Vlasov-code is presented which is able to treat the problem of the oblique incidence of a p-polarized plane wave onto a plasma with finite density scale lenght in a fully selfconsistent way. The numerical effort for solving the appropriate equations is reduced to an acceptable level by reformulating them in a reference system in which longitudinal and transverse fields decouple. An adequate splitting of the transport equation guarantees a high computational performance of the code. It may thus be a tool for a wide range of applications.

4P 9

Three-Dimensional Filamentation and Whole Beam Self-focusing of Laser Light including Nonlinear Hydrodynamics*

S. C. Wilks, R. L. Berger, B. I. Cohen, W. L. Kruer, A. B. Langdon, B. F. Lasinski, D. S. Montgomery, and E. A. Williams
Lawrence Livermore National Laboratory
Livermore, CA 94550

We present results obtained using the three dimensional filamentation code F3D[1] in the limit of strong ponderomotive filamentation. The code employs the paraxial approximation for the laser light, and the modified version includes a self-consistent nonlinear hydrodynamics model for the ion motion. This allows accurate descriptions of the ion motion, even when the presence of a large ponderomotive force predicts the plasma density in a filament to be 1/100th of the original density. We compare the results of the modified F3D code to a number of experiments where filamentation has been observed. In particular, we are interested in comparing to the filamentation experiments performed by P. Young,[2] where intense ($I = 1\text{x}10^{15}$ W/cm^2) one micron laser light was focused in front of an exploding CH foil. In addition, we compare the simulation results to some recent experiments performed at LLNL. Initial studies concentrate on determining the character of the density depressions for the various beam smoothing techniques. Finally, we present results obtained with a version of the code that includes linearized dynamics. This allows for the inclusion of effects such as nonlocal heat transport and ion Landau damping. However, these effects are not as important as ponderomotive effects when the electron temperature is several keV and the laser intensity is $1\text{x}10^{15}$ W/cm^2.

1. R. L. Berger, et. al., "Theory and Three Dimensional Simulation of Light Filamentation in Laser-Produced Plasma", to be published in Phys. Fluids B, 1993.

2. P. Young, Phys. Fluids B **3** (8), August 1991.

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

Non-uniform laser energy deposition caused by optical interference

A. M. Azhar* and A. R. Bell
The Blackett Laboratory, Imperial College, London SW7 2BZ England

Laser driven implosions require a high degree of uniformity in laser energy deposition in order to achieve the high density compression required for sustaining a thermonuclear burn. A variety of processes, leading to the nonuniform energy deposition deposition, has been studied so for [1]. We have investigated the nonuniformities in laser energy deposition associated with the interference between the incident and reflected laser rays.

The wave equation is solved numerically using a finite difference scheme for a linear density profile and planar target at normal and oblique incidence. The approximate ray tracing solution is obtained by calculating the energy and phase of the incident and reflected rays corresponding to the numerical solution mesh points. The ray tracing approximation has been found to be in excellent agreement with the numerical solution for the normal and oblique incidence. The ray tracing approximation has been found to be also valid for spherical targets under the assumption that the scale length of the electron density profile is small compared to the target radius.

A more general theory for a 2D ray tracing code in spherical geometry is developed to examine the effects of interference on uniformity of energy deposition. The 2D code calculates the propagation and absorption of laser light in a plasma for a variety of electron density profiles [2]. The equations of geometrical optics for ray trajectory are solved numerically in a spherically symmetric plasma. Energy is deposited along the ray trajectory by inverse bremsstrahlung absorption. The energy and phase of the incident and reflected rays are calculated to describe the interference. For a single beam the analysis of absorption with and without interference effects has been performed. At the early times in the laser pulse interference has been found to increase the nonuniformity. This increase in nonuniformity can be reduced by using a shorter wavelength laser.

References:

[1] S. Skupsky and K. Lee, J. Appl. Phys. Vol. 54, 3662 (1983).
[2] I. N. Ross, J. Phys. D: Appl. Phys. Vol. 16, 1245 (1983).

*Present address: Physics Department, Quaid-i-Azam University, Islamabad 45320, Pakistan.

4P 11

The ICF-Spherical Pinch as a Neutron Generator and an X-Ray Emitter: A Computational Study

H. Chen, E. Panarella*, J. Chen, and B. Hilko
Advanced Laser and Fusion Technology, Inc.,
189 Deveault St., Unit 7, Hull, P.Q. J8Z 1S7 Canada

The spherical pinch concept grew out of the inertial confinement model. The salient feature of the spherical pinch concept is the creation of a hot plasma in the center of a sphere [1]. The plasma is then compressed by a strong imploding shock wave launched from the periphery of the vessel. Convergence of the shock is the main feature of the inertial confinement scheme.

In the first part of the study, we present the detailed computational comparison of the inertial confinement model and the spherical pinch as a neutron generator in terms of density, temperature, confinement time and total accumulated numbers of neutrons. It is shown that temperature, confinement time and total numbers of neutrons are favorable for the spherical pinch.

In the second part, the computational study of an inductively coupled spherical pinch as an X-Ray generator is presented. Computations are made for the free-free bremsstrahlung emission characteristics in the soft X-ray range (8 - 14 Å) with different parameters. The X-ray emission is a function of the radius of the vessel, and the timing difference between the central and the peripheral discharges.

[1] E. Panarella, J. Fusion Energy 6, 285 (1987)

* Also with the Department of Electrical and Computer Engineering, University of Tennessee, Knoxville, TN 37996-2100

4P 12

X-ray Production from Thin Au foils on Octal

R. L. Kauffman, D. S. Montgomery, and L. J. Suter
Lawrence Livermore National Laboratory
Livermore, California 94551

J. L. Bocher, J. P. LeBreton, and D. Babonneau
Centre d'Etudes de Limeil-Valenton
94195 Villeneuve-Saint George Cedex France

We have begun experiments investigating x-ray production in preformed Au foil plasmas using the Octal laser. The goal of the experiments was to study laser absorption and x-ray production in plasmas without a critical density surface. Approximately 400 J of 1.06 μm light from three beams of the eight beam Octal laser irradiated Au foils 1500 Å, 2500 Å, and 3500 Å thick to create preformed Au plasmas. A fourth Octal beam delayed by 2 ns irradiated the preformed plasma with ~ 30 J of 0.35 μm light at best focus of ~ 10^{15} W/cm^2 and at ~10^{14} W/cm^2 using an RPP beam. The preformed plasma was diagnosed using streaked x-ray radiography with a Gd backlighter. The time dependence of scattered and transmitted light near the 0.35 μm wavelength was monitored with an array of optical fibers coupled to a streak camera. The x-ray production was measured at several angles using diamond PCD detectors. The PCD detectors were filtered with thin CH filters to reduce the scattered XUV light that can saturate the detectors. Examples of the data and scattered light and x-ray production compared to solid disk levels will be presented.

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.

4P 13

A Review of Radiation-Hydrodynamics Approaches to Laser-Matter Interactions.

V. L. JACOBS

Condensed Matter and Radiation Sciences Division, Code 6693

Naval Research Laboratory

Washington, D. C. 20375-5345

A review of the radiation-hydrodynamics approaches employed in selected laser-matter interaction codes is in progress. Particular emphasis has been given to the more fundamental kinetic-theory foundations, which can allow for the investigation of phenomena that cannot be understood within the framework of a hydrodynamics viewpoint. Several different approaches to the electron heat conduction and radiation transport problems are described, and some of the inadequacies encountered in simple models are circumvented only by the adoption of the more fundamental, but more difficult, kinetic-theory descriptions. The energy exchange between matter and electromagnetic radiation includes both the laser deposition and plasma radiation processes, and particular emphasis is given to the possible importance of departures from local thermodynamic equilibrium.

X-Ray Production Using Ultra Short Laser Pulses

by

T.A. Hall, R.Evans, J. Ellison
Physics Department
University of Essex
UK

and

A. Djaoui and A. Ridgeley
Rutherford Appleton Laboratory
UK

Abstract

Results are presented of X-ray production using two laser systems: the SPRITE Raman shifted KrF laser operating at 268nm and producing 10psec pulses of energy up to 4J and irradiances on target up to 10^{16} W cm^{-2} and the CPA VULCAN laser operating at 1.06μm and producing 1-2 psec pulses of energies > 10J and irradiances on target of > 10^{17} W cm^{-2} . In each case, results of the absorption and time resolved soft X-ray spectra from aluminium, copper, germanium and uranium targets are presented and the two sets of results are compared.

The experimental results are compared with MEDUSA simulations using the FLY code.

Light Absorption and X-Ray Emission Measurements from 100 Femtosecond Laser Produced Plasmas*

D. Price, R. Shepherd, G. Guethlein, B. Young, J. Dunn, D. Reitze,
W. White, R. Stewart
Lawrence Livermore National Laboratory
P.O. Box 808, L-43
Livermore, CA 94551

Abstract: An overview of recent activity on the 100 femtosecond short pulse laser facility will be presented. Current absorption measurements on Aluminum and porous Aluminum targets indicates that absorption may exceed 40% on targets of interest at intensities exceeding 10^{17} W/cm^2. Intensity scaling and incidence angle dependence data will be presented for absorption and low resolution x-ray spectral measurements. The enhancement of x-ray emission by application of controlled prepulse will be discussed and correlations between the observed ion time of flight spectra and x-ray spectroscopy data will be made.

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

Friday, June 25, 1993

Oral Session 5

SBS & SRS

R. S. Craxton, Chair

"Modification of SRS by beam smoothing in large scale length plasmas"

D.S. Montgomery, H.A. Baldis, J.D. Moody,
B.B. Afeyan, R.L. Berger, K.G. Estabrook,
B.F. Lasinski, E.A. Williams, S.C. Wilks

Lawrence Livermore National Laboratory, Livermore, California 94551

C. Labaune

Ecole Polytechnique, 91128 Palaiseau Cedex, France

We report time-resolved spectral measurements of backward stimulated Raman scattering from the interaction of 527 nm laser radiation with a preformed plasma. The effect of laser smoothing by spectral dispersion (SSD) was studied by adding laser bandwidth ($\Delta\lambda/\lambda$ = 0.1%) and varying the laser intensity (2 - 30 x 10^{14} W/cm^2). A very broad SRS spectrum was observed for the high-intensity, $\Delta\lambda/\lambda$ = 0 case, and narrow spectra were observed for cases with either high-intensity, $\Delta\lambda/\lambda \sim$ 0.1% or low-intensity, $\Delta\lambda/\lambda$ = 0. The spectra are compared to a numerical model of SRS and filamentation, and are found to be consistent with SRS occuring in filaments for the high-intensity, no bandwidth case. The model also predicts the narrow spectra and modification of SRS due to the suppression of filaments using $\Delta\lambda/\lambda \sim$ 0.1% or lower laser intensity.

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.

50 1

Spatial and Temporal Beam Smoothing Effects on SBS Emission from Nova Exploding Foil Plasmas*

J. D. Moody, H. A. Baldis, D. S. Montgomery,
D. Berger, K. Estabrook, W. L. Kruer, C. Labaune[1], and S. Dixit,

Lawrence Livermore National Laboratory, Livermore, CA, 94550

We describe experimental studies of the effects of spatial and temporal laser beam smoothing on stimulated Brillouin scattered (SBS) emission from a long scalelength preformed Nova plasma. We use a random phase plate (RPP) to provide spatial smoothing and combine laser bandwidth of about 0.2% with a RPP to provide temporal smoothing by spectral dispersion (SSD). The experiments consist of measuring the temporal and spectral characteristics of the direct backscattered emission from the SBS instability which is driven by a laser beam having various types of applied smoothing. A plastic (CH) plasma is initially preformed with 2300 J of 0.351 μm RPP smoothed laser light with a 1 ns pulse duration and an average intensity of about 1×10^{14} W/cm^2. The interaction beam, which drives the instability, is a 1 ns square pulse of 0.527 μm laser light, has an energy between 100 J and about 2500 J, may have some form of beam smoothing applied, and arrives at the preformed plasma after an adjustable time delay. The backscattered light is imaged through a 1 meter spectrometer into a streak camera where a time resolved spectrum is recorded on photographic film. We find that neither RPP nor SSD beam smoothing significantly changes the charater of the backscattered light when the peak electron density is above approximately 0.3 n_{crit}. Both types of laser smoothing have strong effects on the backscattered light when the peak electron density is below 0.3 n_{crit}.

[1] *Permanent address: École Polytechnique, Palaiseau, France.*

*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.

*Fluid Simulations of Laser Beam Smoothing Effects on Stimulated Raman and Brillouin Backscattering Including Filamentation

R. L. Berger, B. F. Lasinski, B. I. Cohen, T. Kaiser, A. B. Langdon, and E. A. Williams
Lawrence Livermore National Laboratory.

Filamentation is often invoked to explain the observation of significant levels of stimulated Raman backscattering (SRBS) and stimulated Brillouin backscattering (SBBS) at laser intensities that are below the threshold for significant gain or the absolute threshold. Here we present the results of a self-consistent calculation in which filamentation is followed on the long wavelength scale along the laser propagation direction while SBBS and SRBS grow at faster spatial scales in this direction. Normal to this axial direction, the initial structure in the laser beam and filamentation determine the spatial variation. For small gain coefficients for scattering processes, filamentation can significantly augment the reflectivity. At higher scattering gain levels, SBBS can saturate the filamentation. Moreover, when v_0^2/v_e^2 is large, the plasma density has deep holes produced at the locations of high local intensity (in the spikes produced either by filamentation or laser beam incoherence). This local density depletion may have a compensating effect by reducing the gain coefficient either by detuning the resonance or reducing the coupling. Examples will be shown of relevance to current experiments.

withdrawn

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

50 3

A SIMPLE CALCULATION OF THE EFFECTS OF BEAM-SMOOTHING TECHNIQUES ON STIMULATED BRILLOUIN SCATTERING

R. W. Short
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

Contemporary beam-smoothing techniques involve dividing the laser beams into many smaller beamlets that overlap on the target. Under certain reasonable assumptions the driving term for the SBS instability can be written as a sum over these beamlets and a simple analytic dispersion relation obtained that can be solved for the growth rate. The approach is similar to that used by Langdon for filamentation.[1]

1. A. B. Langdon, Lawrence Livermore National Laboratory, Laser Program Annual Report 1983, UCRL-50021-83 (1984), p. 3-35.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

STIMULATED BRILLOUIN SCATTERING AT 1.053 μm IN OMEGA LONG-SCALE-LENGTH INTERACTION EXPERIMENTS

A. V. Chirokikh, W. Seka, R. S. Craxton, R. E. Bahr,
A. Simon, R. W. Short, and E. M. Epperlein
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

H. Baldis
LAWRENCE LIVERMORE NATIONAL LABORATORY
University of California
Livermore, CA 94550

R. P. Drake
PLASMA PHYSICS RESEARCH INSTITUTE
University of California
Livermore, CA 94550

We report on stimulated Brillouin backscattering (SBS) experiments at 1.053 μm carried out on OMEGA long-scale-length, preformed plasmas. These plasmas have densities at or below the critical density for the interaction beam with temperatures between 500 and 1000 eV. A striking characteristic of these SBS spectra is a dominant strong blue shift with a superposed fine structure that always evolves in time towards increasing blue shift. An analysis of these spectra on the basis of two-dimensional *SAGE* simulations shows that the dominant contribution to this blue shift arises from the supersonic expansion of the plasma towards the incident laser beam. The contributions to this frequency shift from the temporal evolution of the optical path length of the incident beam towards the SBS interaction region and the corresponding contribution from the scattered light exiting the plasma have been included in this analysis, but are generally not very important. The temporal evolution of the temperature and its spatial variations are also taken into account in obtaining the frequency shift of the scattered light. We conclude from this analysis that the SBS interaction region is almost always well within the region of falling electron density on the side of the incident laser. The fine structure consistently observed on the SBS spectra is interpreted as arising from a temporal shift of the interaction region towards the incident laser, i.e., lower densities and higher expansion velocities. One possible mechanism for this evolution could be spatial disturbances in the velocity (or density) profile that propagate down the density gradient with the acoustic speed.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

505

THE ANGULAR DEPENDENCE OF STIMULATED BRILLOUIN SCATTERING IN HOMOGENEOUS PLASMA

R. E. Giacone, C. J. McKinstrie, R. Betti, and H. Chen
LABORATORY FOR LASER ENERGETICS
University of Rochester
250 East River Road
Rochester, NY 14623-1299 USA

For most scattering angles, stimulated Brillouin scattering (SBS) is intrinsically two-dimensional. The Green functions describing the initial evolution of this two-dimensional instability will be determined and used to discuss quantitatively the conditions under which a simplified one-dimensional model[1] is applicable. Numerical simulations of the initial evolution of SBS will also be presented.

1. C. J. McKinstrie, R. E. Giacone, and R. Betti, Bull. Am. Phys. Soc. **37**, 1440 (1992).

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

50 6

Modeling of Large Scale Length Plasma Designs for Measuring Stimulated Brillouin Scattering on Nova

L. Powers, R. Berger, K. Estabrook, J. Harte, D. Hinkel-Lipsker, B. Lasinski, D. Munro, R. Procassini, P. Rambo, T. Shepard, E.A. Williams

Lawrence Livermore National Laboratory

ABSTRACT

An improved understanding of the scaling of Stimulated Brillouin Scattering (SBS) with plasma scale length, electron temperature, and focussing geometry is of critical importance in designing targets for the National Ignition Facility. An effort is underway to produce plasmas using the Nova laser facility with parameters appropriate for investigating these issues. The design goal is to create a well-characterized plasma with density of 10^{21}/cc, density and velocity scale lengths in excess of 1 mm, and electron temperatures in excess of 3 keV. With these parameters we can access the regime of high SBS gain using the moderate laser intensities of interest in NIF targets.

Several geometries that might produce such a plasma are under investigation. A variant of "exploding foil" geometries in which a scattering beam is oriented in the plane of the foil greatly reduces velocity gradients compared to previous SBS foil experiments. Colliding foils or disks may also produce a large region of low-density, low-velocity plasma in the region of stagnation. Other possible targets under investigation use low density media such as gas-filled balloons and foams to form a large, hot, stationary plasma. We will present modeling predictions of the plasma parameters and expected SBS scattering levels for each of these approaches, based on preliminary experimental designs. The potential and problems associated with each design will be addressed.

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

*The Strong Coupling Limit of Stimulated Brillouin Sidescattering in Inhomogeneous Plasmas

B. B. Afeyan and E. A. Williams
Lawrence Livermore National Laboratory
Livermore, CA 94550

The linear theory of Stimulated Brillouin Sidescattering (SBSS) in an inhomogeneous plasma is far from complete. To date, only the linear density and linear velocity-profile case has been considered, and even then, only in the weak coupling limit, and only through the approximations that the Liu, Rosenbluth and White(1) (LRW) sidescattering model entails.

Here, all these restrictions and limitations are removed by using a variational method(2) to estimate the eigenfrequency of the most unstable SBSS mode. Both linear the parabolic profiles are considered, in both the weak and strong coupling limits. Parameter regimes in between these limits are also treated. The ion-acoustic speed and the flow velocity are not assumed to vanish, and the governing equation is not a second order ODE as in the LRW model.

(1) Liu, C. S., Rosenbluth, M. N. and R. B. White, *Phys. Rev. Lett.* **31**, 697 (1973)

(2) Afeyan, B. B., "A Variational Approach to Parametric Instabilities in Inhomogeneous Plasmas," Ph.D. thesis, University of Rochester (1993).

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

5O 8

Temporal Evolution of Stimulated Brillouin Backscatter

D. E. Hinkel-Lipsker, E. A. Williams, and R. L. Berger, LLNL

When an electromagnetic wave is incident upon an underdense plasma, stimulated Brillouin scattering can occur, where the incident wave [vector potential A_o at $(\omega_o, \underline{k}_o)$] decays into a scattered wave [vector potential A_1 at $(\omega_1, \underline{k}_1)$] and an ion acoustic wave [density fluctuation δn at $(\omega_a, \underline{k}_a)$]. When the waves are weakly coupled (growth rate Γ small compared to ω_a), the time and spatial rate of change of the wave envelope amplitude is small compared to the wave envelope amplitude itself and thus second order time and space derivatives can be neglected, yielding the usual coupled mode equations. For intermediate times $L/|V_1| << t << L/|V_a|$ (where $L \equiv$ size of system; $V_1 \equiv$ group velocity of light wave; $V_a \equiv$ group velocity of ion acoustic wave) the instantaneous growth rate Γ is proportional to $t^{-1/2}$, and for times $t >> L/|V_a|$, Γ asymptotes to the absolute growth rate, $2\gamma_o(|V_1 V_a|)^{1/2}/(|V_1| + |V_a|)$. Here, γ_o is the coupling coefficient, which is a function of incident intensity and wavenumber, and ion plasma and acoustic frequencies. When the waves are not weakly coupled, but $\gamma_o(|V_a/V_1|)^{1/2} < \omega_a$ (strong coupling), the time rate of change of the amplitude is no longer negligible, and thus the second order time derivative in the ion acoustic wave equation becomes important. For intermediate times $L/|V_1| << t << L/|V_a|$, Γ falls off as $t^{-1/3}$, and for times $t >> L/|V_a|$, Γ approaches the weakly coupled asymptotic limit. When $\gamma_o(|V_a/V_1|)^{1/2} > \omega_a$ (very strong coupling), both the time and spatial rates of change of the wave amplitudes are no longer negligible, and so all spatial derivative terms as well as the time derivative terms in the ion acoustic wave equation must be kept. For intermediate times $L/|V_1| << t << [L/|V_1|](\gamma_o^2/\omega_a) << L/|V_a|$, Γ again behaves as $t^{-1/3}$. Asymptotically, Γ is proportional to the weakly coupled time asymptotic growth rate. Both analytic and numerical results will be presented.

Stimulate Brillouin Backscattering with a 1 ps interaction pulse on P102 laser facility

S.D. Baton[(a)] C. Rousseaux[(b)], S. Gary[(b)], C. Labaune[(a)], B. Lafontaine[(a)], Ph. Mounai , N. Renard[(a)] and H.A. Baldis[(d)].

[(a)]Laboratoire LULI, Ecole Polytechnique, 91128 Palaiseau Cedex, FRANCE
[(b)]CEA Limeil-Valenton, DLPP, Villeneuve St Georges, FRANCE
[(c)]Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau Cedex, FRANCE
[(d)]Lawrence Livermore National Laboratory, Livermore, CA, 94550 USA

A two beam experiment has been performed at P102 laser facility (CEA-Limeil) in order to measure the Stimulated Brillouin Scattering (SBS) reflectivity produced by the interaction between a short 1 ps laser pulse and a large underdense preformed plasma.

The first beam (1.06 μm and 300 ps FWHM) exploded a thin plastic foil and the second one (1.06 μm and 1.2 ps FWHM) interacted with the preformed plasma after a time delay of 1.2 ns.

The main result shows the SBS reflectivity increases from 10^{-4} to 10^{-1} as the intensity of the interaction beam raises from $5x10^{14}$ to 10^{16} W/cm^2 ; for intensities between 10^{16} and 10^{17} W/cm^2, the reflectivity saturates around 10%.

This experimental result is compared to theoretical estimates of SBS reflectivity in the so-called modified decay regime.

Index & Lists

Mr. Bedros Afeyan
Plasma Physics Research Institute
Lawrence Livermore National Laboratory
P. O. Box 808, L-418
Livermore, CA 94550
510 423 2013
bedros@icf.llnl.gov

Dr. Peter Amendt
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 423 9208

Dr. Francois Amiranoff
LULI
Ecole Polytechnique
91128 Palaiseau Cedex
FRANCE
(33) 1 69 33 4803
francois@greco2.polytechnique

Dr. Abdul Moeed Azhar
Physics Department
Quaid-i-Azam University
Islamabad 45320
PAKISTAN

Dr. Hector Baldis
Lawrence Livermore National Laboratory
Box 808, L-476
Livermore, Ca. 94550
510 423 0574

Sophie Baton
Laboratoire LULI
Ecole Polytechnique
91128 Palaiseau
Cedex
FRANCE

Bruno S. Bauer
Lawrence Livermore National Laboratory
P.O. Box 808, L-418
Livermore, CA 94550
510 422 9047
bbauer@sunlight.llnl.gov

Dr. Richard Berger
Lawrence Livermore National Laboratory
7000 East Ave., Mail Stop L-472
Livermore, CA 94550
510 422 7419

Dr. Riccardo Betti
Laboratory for Laser Energetics
University of Rochester
250 East River Rd.
Rochester, NY 14623
716 275 5101

Dr. Stephen Bodner
Naval Research Laboratory
Code 6730
Washington, DC 20375-5346
202 767 2730
bodner@this.nrl.navy.mil

Dr. Michel Casanova
Centre d'Etudes de Limeil-Valenton
94195 Villeneuve-St-Georges
Cedex
FRANCE
1 45 95 6945

Dr. Haibo Chen
Advanced Laser and Fusion Technology
189 Deveault St. Unit 7
Hull, P.O. J82 157
CANADA
819 770 0477

Alexer Chirokikh
Laboratory for Laser Energetics
250 East River Rd.
Rochester, NY 14623
716 275 5960

Dr. Stephen V. Coggeshall
Los Alamos National Laboratory
MS-F645, Box 1663
Los Alamos, NM 87545
505 665 7093
svc@demos.lanl.gov

Donald L. Cook
Sandia National Laboratory
Dept 1202 , PO Box 5800
Albuquerque NM 87185

Christina A. Coverdale
Lawrence Livermore National Laboratory
Box 808, L-473
Livermore, Ca. 94550
510 422 8334

Dr. R. Stephen Craxton
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Dr. Melissa Cray
Los Alamos National Laboratory
Box 1663, MS F645
Los Alamos, NM 87545
505 667 3038

Dr. Jill Dahlburg
Naval Research Laboratory
LCP & FD,Code 6440
Washington, DC 20375-5344
202 767 5398

Dr. Chris Darrow
Lawrence Livermore National Laboratory
Box 808, L-473
Livermore, CA 94550
510 423 7773

Dr. Jacques Delettrez
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299

Dr. Alban Deniz
Naval Research Laboratory
Code 6730
Washington, DC 20375-5346
202 767 2730
deniz@ccf.nrl.navy.mil

Guy Dimonte
Lawrence Livermore National Laboratory
Box 808, L-43
Livermore, CA 94550
510 423 0596

Dr. R. Paul Drake
Plasma Physics Research Institute
Lawrence Livermore National Laboratory
Box 808, L-418
Livermore, CA 94550
510 423 6755
drake1@llnl.gov

Dr. Don DuBois
Los Alamos National Laboratory
MS-B262, Box 1663
Los Alamos, NM 87545
505 667 4135

M. Everett
UCLA
Electrical Engineering Dept.
Los Angeles, CA 90024

Chip Durfee
University of Maryland
IPST Building
College Park, MD 20742
301 405 4816

Yoram Fisher
Laboratory for Laser Energetics
250 East River Rd.
Rochester, NY 14623
716 275 5101

Dr. Mark H. Emery
Computational Physics Laboratory
Naval Research Laboratory
Code 6440
Washington, DC 20375-5344

Dr. David E. Fyfe
Naval Research Laboratory
Code 6410
Washington DC 20375-5344

Dr. Eduardo M. Epperlein
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Andres C. Gaeris
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, N.Y. 14623-1299
716 275 5101

Dr. Reuben Epstein
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Eugene Gamaly
The Australian National University
Laser Physics Centre
Box 4
Canberra, ACT 2601
AUSTRALIA
61 6 249 4079
eggl11@rsphyl.anu.edu.au

Dr. Eric Esarey
Naval Research Laboratory
Code 6791
Washington, DC 20375-5346
202 404 7720
esary@ppd.nrl.navy.mil

Dr. John Gardner
Naval Research Laboratory
LCP & FD, Code 6440
Washington, DC 20735-5344
202 767 6582

Dr. Jean-Claude Gauthier
Physique des Milieux Ianises Laboratoire
Ecole Polytechnique
91128 Palaiseau Cedex
FRANCE
(33) 1 69 33 3260
gauthier@greco2.polytechnique

Eugene Gavrilov
Los Alamos National Laboratory
MS-B287, ACL
Los Alamos NM 87545
505 665 7448
evgeniy@acl.lanl.gov

Dr. V.V. Gavrilov
Troitsk Institute of Innovation and
Thermonuclear Investigations
142092 Troitsk
Moscow region
RUSSIA

Dr. Leonard Goldman
2307 Ridgefield Dr.
Chapel Hill, NC 27514
919 489 4550

Dr. Parvez N. Guzdar
Plasma Research Laboratory
University of Maryland
College Park, MD 20742-3511
301 405 5013
guzdar@fusion.umd.edu

Dr. Tom A. Hall
Physics Department
University of Essex
Wivenhoe Park
Colchester, CO4 3SQ
U.K.
206 873859

Dr. Zohar Henis
Plasma Physics Department
Soreq Nuclear Research Center
Yavne 70600
ISRAEL

Denise E. Hinkel-Lipsker
Lawrence Livermore National Laboratory
Box 5508, L-472
Livermore, CA 94550
510 423 2626

Dr. Verne L. Jacobs
National Research Laboratory
Code 6693
Washington, DC 20375-5345
202 404 7147
jacobs@dave.nrl.navy.mil

Dr. Tudor W. Johnston
INRS-Energie
Universite du Quebec
1650 Montee Ste-Julie, C.P. 1020
Varennes, Quebec J3X 1S2
CANADA
514 449 8125

Dr. Robert L. Kauffman
Lawrence Livermore National Laboratory
Box 808, L-473
Livermore, CA 94550
510 422 0419

Dr. Christopher Keane
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 423 4225

Dan Klem
Lawrence Livermore National Laboratory
Box 808, L-476
Livermore, CA 94550
510 423 4176

Dr. James Knauer
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Jonathan Krall
Beam Physics Branch, Plasma Physics Division
Naval Research Laboratory
Code 6790
Washington, DC 20375-5346
202 404 7719
krall@ppd.nrl.navy.mil

Dr. William L. Kruer
Lawrence Livermore National Laboratory
7000 East Ave., Mail Stop L-472
Livermore, CA 94550
510 422 5437

Dr. Christine Labaune
LULI
Ecole Polytechnique
91128 Palaiseau Cedex
FRANCE
1 69 33 4893

A. Lal
UCLA
Department of Electrical Engineering
7620 Boelter Hall
Los Angeles, CA 90024-1594

Dr. A. Bruce Langdon
Lawrence Livermore National Laboratory
Box 5508, L-472
Livermore, CA 94550
510 422 5444

Dr. Steven H. Langer
Lawrence Livermore National Laboratory
Box 5508, L-447
Livermore, CA 94550
510 423 1358

Dr. Olivier Larroche
Commissariat a l'Energie Atomique
Centre d'Etudes de Limeil-Valenton
B.P. 27
94195 Villeneuve -St-George Cedex
FRANCE
(33) 1 45 95 6000

Dr. Barbara Lasinski
Lawrence Livermore National Laboratory
Box 5508, L-472
Livermore, CA 94550
510 422 5443

Dr. Erick Lindman
Los Alamos National Laboratory
MS F645
Los Alamos, NM 87545
505 665 7519
ell@demos.lanl.gov

Dr. Brian MacGowan
Lawrence Livermore National Laboratory
Box 808, L-483
Livermore, CA 94550

Dr. Robin Marjoribanks
Department of Physics
University of Toronto
60 St. George St.
Toronto, Ontario M5S-1A7
CANADA
416 978 6769
marjoribanks@physics.toronto.

Dr. Jean-Pierre Matte
INRS-Energie et Matériaux
1650 montée Ste-Julie, C.P. 1020
Varennes, Québec J3X 1S2
CANADA
514 449 8127
matte@inrs-ener.uquebec.ca

Dr. Dennis L. Matthews
Lawrence Livermore National Laboratory
Box 5508, L-473
Livermore, CA 94550
510 422 5360

Dr. M. Steve Maxon
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 422 4091

Dr. Colin McKinstrie
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Dr. Jochen Meyer
Department of Physics
University of British Columbia
6224 Agriculture Road
Vancouver, BC V6T 1Z1
CANADA
604 822 6577

Dr. Howard Milchberg
University of Maryland
IPST Building
College Park, MD 20742
301 405 4816
milch@ipst.umd.edu

Dr. David Montgomery
Lawrence Livermore National Laboratory
Box 808, L-473
Livermore, CA 94551
510 423 6534

John Moody
Lawrence Livermore National Laboratory
Box 808, L-476
Livermore, CA 94550
510 423 9495

Dr. Patrick Mora
Physique Theorique Centre
Ecole Polytechnique
91128 Palaiseau Cedex
FRANCE
33 1 69 33 4725
mora@orphee.polytechnique.fr

Dr. Juan Moreno
Lawrence Livermore National Laboratory
P.O. Box 808, L-476
Livermore, CA 94551
510 423 4170
moreno4@llnl.gov

Frédéric Moulin
LULI
Ecole Polytechnique
91128 Palaiseau Cedex
FRANCE
33 1 69 33 4845

Marc Nantel
INRS-Energie Et Materiaux
C.P. 1020, Montee Ste-Julie
Varennes, Quebec J3X 1S2
CANADA
514 468 7700

Dr. Greg Pollak
Los Alamos National Laboratory
X-6, MS B226
Los Alamos, NM 87545
505 665 2048

Dr. Linda Powers
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 423 0300

Dr. Harvey A. Rose
Los Alamos National Laboratory
Box 1663
Los Alamos, NM 87545
505 667 7347

Dr. Mordy Rosen
Lawrence Livermore National Laboratory
7000 East Avenue, Mail Stop 477
Livermore, CA 94550
510 422 5427
mordy@icf.llnl.gov

Christophe Rousseaux
Commissariat a l'Energie Atomique
Centre d'Etudes de Limeil-Valenton
94195 Villeneuve-St-Georges, Cedex
FRANCE
1 45 95 6068

Dr. Wojciech Rozmus
University of Alberta
Theoretical Physics Institute
Department of Physics
Edmonton, Alberta, Canada T6G 2J1
CANADA
403 492 8486
rozmus@space.ualberta.ca

Dr. Alexander Rubenchik
LLNL
P.O. Box 808, L-418
Livermore, CA 94550
510 422 2956
ruben@venus.llnl.gov

Hartmut Ruhl
Theoretische Quantenelectronik
Hochschulstr 4A
6100 Darmstadt
FRG
0049 6151 162381
df67@hhlruxpm.hrz.th-darmsta

Dr. Andrew J. Schmitt
Naval Research Laboratory
Code 6730
Washington, DC 20375-5346
202 767 2730
schmitt@this.nrl.navy.mil

Dr. Wolf Seka
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Thomas D. Shepard
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 423 4018

Dr. Robert Short
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Mark D. Tracy
Laboratory for Laser Energetics
250 East River Rd.
Rochester, NY 14623
716 275 5101

Prof. Albert Simon
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
716 275 5101

Dr. Donald Umstadter
Ultrafast Science Laboratory
University of Michigan
1006 IST Building
Ann Arbor, MI 48109-2099
313 764 2284
dpu@dip.eecs.umich.edu

Dr. Phillip Sprangle
Naval Research Laboratory
Code 6790
Washington, DC 20375-5346
202 767 3493

F. Vidal
INRS-Energie et Matériaux
C.P. 1020
Varennes, Québec J3X-1S2
CANADA

Dr. John A. Stamper
Naval Research Laboratory
Plasma Physics Division
Code 6732
Washington, DC 20375-5346
202 767 2730

Brian-Tinh V. Vu
U. California Davis
Dept. of Applied Science
Livermore, CA 94550

Dr. Laurance J. Suter
Lawrence Livermore National Laboratory
Box 5508, L-477
Livermore, CA 94550
510 422 5423

Dr. Rosemary Walling
Lawrence Livermore National Laboratory
Box 808, L-59
Livermore, CA 94550
510 422 4104

Antonio C. Ting
Naval Research Laboratory
Code 6790
Washington, DC 20375-5346
202 767 3825

Jil-Gen Wang
University of Iowa
Department of Physics and Astronomy
Iowa City, IA 52242
319 335 1607
jgw120@iowa.physics.uiowa.e

Dr. Kenneth Whitney
Naval Research Laboratory
Plasma Physics Division
Code 6720
Washington, DC 20375-5346
202 767 2921
whitney@ppdf.nrl.navy.mil

Dr. Scott Wilks
Lawrence Livermore National Laboratory
Box 5508, L-472
Livermore, CA 94550
510 422 2974
wilks@icf.llnl.gov

Dr. O. Willi
Blackett Laboratory
Imperial College
Prince Consort Road
London SW7 2BZ
U.K.

Dr. Edward A. Williams
Lawrence Livermore National Laboratory
Box 5508, L-472
Livermore, CA 94550
510 423 4728

Dr. Arie Zigler
Hebrew University
Physics Dept.
Jerusalem
ISRAEL
972 258 515
zigler@muji.ac.il

Paper	Authors	Title of Paper
5O7	Afeyan, Bedros; Williams, E.A.	*The Strong Coupling Limit of Stimulated Brillouin Sidescattering in Inhomogeneous Plasmas*
4O6	Amendt, Peter; Powers, L.; Suter, L.; Hauer, A.	*Time Resolved Symmetry Modeling in Novas Hohlraums*
1P12	Audebert, Patrick; Fallies, F.; Geindre, J.P.; Delettrez, J.; Rousse, A.; Gauthier, J.C.	*Hydrodynamic simulation of a subpicosecond laser plasma*
3O9	Basylev, B.N.; Burdonsky, I.N.; Gavrilov, V.V.; Goltsov, A.Yu.; Zhuzhukalo, E.V.; Kovalsky, N.G.; Kondrashov, V.N.; Koshevoj, M.O.; Pergament, M.I.; Romanov, G.S.; Rupasov, A.A.; Smetannikov, A.S.; Tolkach, V.I.	*Investigation of Energy Transfer in the Plane Laser-Irradiated Targets with High X-Ray Conversion Efficiency*
5O9	Baton, Sophie; Rousseaux, C.; Gary, S.; Labaune, C.; Lafontaine, B.; Mounaix, Ph.; Renard, N.; Baldis, H.A.	*Stimulated Brillouin Backscattering with a 1ps interaction pulse on P102 laser facility*
1P8	Bauer, Bruno S.; Drake, R.P.; Baker, K.L.; Mizuno, K.; Sleaford, B.; Estabrook, K.; Afeyan, B.B.; Rubenchik, A.M.; Labaune, C.; Baton, S.D.; Jalinaud, T.; Schifano, E.; Goldman, M.V.; Newman, D.L.	*Langmuir Turbulence Generated by the Ion Acoustic Decay Instability*
5O2	Berger, Richard; Lasinski, B.F.; Cohen, B.I.; Kaiser, T.; Langdon, A.B.; Williams, E.A.	*Fluid Simulations of Laser Beam Smoothing Effects on Stimulated Raman and Brillouin Backscattering Including Filamentation*
4O4	Betti, Riccardo; McCrory, R.L.; Verdon, C.P.	*Hydrodynamic Stability of Unsteady Ablation Fronts*
4O10	Betti, Riccardo; McCrory, R.L.; Verdon, C.P.	*Linear Growth Rate of the Ablative Rayleigh-Taylor Instability*
4O7	Bradley, David ; Delettrez, J.A.; Jaanimagi, P.A.; Skupsky, S.; Verdon, C.P.	*Measurements of the Effects of Pulse Shaping on Rayleigh-Taylor Growth in Burnthrough Targets*
2P8	Casanova, Michel; Mounaix, Ph.; Pesme, D.	*Reflectivity of an Inhomogeneous Plasma Slab*
1P2	Chen, Haibo; Chen, J.; Hilko, B.; Panarella, E.	*The ICF-Spherical Pinch as a Neutron Generator and an X-Ray Emitter: A Computational Study*
4P11	Chen, Haibo; Panarella, E.; Chen, J.; Hilko, B.	*Possible Instability Mechanism for the ICF-Spherical Pinch*

Paper	Authors	Title of Paper
5O4	Chirokikh, Alexer; Seka, W.; Craxton, R.S.; Bahr, R.E.; Simon, A.; Short, R.W.; Epperlein, E.M.; Baldis, H.; Drake, R.P.	*Stimulated Brillouin Scattering at 1.053μm in Omega Long-Scale-Length Interaction Experiments*
2O9	Clayton, Chris; Everett, M.; Lal, A.; Marsh, K.A.; Joshi, C.	*Beatwave Acceleration of 2 MeV Electrons to 20 MeV*
4O8	Coggeshall, Stephen V. ; Vu. H.X.; Dahlburg, J.P.; Gardner, J.H.	*3-D Laser Ray Trace Package in a Fully 3-D Hydro Code*
2RI	Cook, Donald L	*Progress in Light Ion Beam Focusing and Target Experiments*
4P5	Coverdale, Christina A.; Darrow, C.B.; Perry, M.D.; Mori, W.B.; Joshi, C.	*High Intensity Irradiation of Long Scalelength Underdense Plasmas with LLNL 10 TW Glass Laser*
3O6	Craxton, R. Stephen; Hoefen, R.; Turner, F.S.; Darrow, C.; Gabl, E.F.; Busch, Gar. E.	*Plasma Density Profiles from Grid Image Refractometry*
4O2	Dahlburg, Jill; Gardner, J.H.; Fyfe, D.E.; Doolen, G.D.	*The Effect of Shape in the Three-Dimensional Ablative Rayleigh-Taylor Instability: Multimode Perturbations*
2O7	Decker, Chris; Mori, W.B.	*The Group Velocity of Large Amplitude Electromagnetic Waves in Plasma*
2P11	Decker, Chris; Mori, W.B.; Katsouleas, T.	*Computer Simulations of Self-Modulation, Focusing, and Wake Excitation by Short Laser Pulses in Plasma*
1P13	Delettrez, Jacques; Bonnaud, G.; Audebert, P.; Geindre, J.P.; Gauthier, J.C.	*PIC Code Simulations of the Interaction of Ultra-Short Laser Pulses with a Solid Target*
3O5	Dimonte, Guy; Wiley, L.; Simonson, G.; Shumaker, D.	*Laser-Plasma Experiments Simulating Ionospheric Explosions*
1O8	Drake, R. Paul; Goldman, M.V.; DeGroot, J.S.	*Fluid Theory of the Ion Acoustic Decay Instability in Warm, Flowing, Inhomogeneous Plasmas*
1P5	Drake, R. Paul; Rubenchik, A.M.; Meyerhofer, D.D.	*The Frequency and Damping of Ion Acoustic Waves in CH Plasmas*
1O10	DuBois, Don; Gavrilov, E.M.; Rose, H.A.; Rubenchik, A.M.	*Resonance Absorption Evolution into Langmuir Turbulence*
1O1	DuBois, Don; Russell, D.; Rose, H.A.	*Saturation of the Two Plasmon Decay Instability by the Excitation of Langmuir Turbulence*
3O7	Durfee, Chip; Milchberg, H.M.	*Light Pipe for High Intensity Laser Pulse*
2P6	Ehrlich, Y.; Cohen, C.; Zigler, A.	*Generation of Large High Density Plasmas by Using a Capillary Discharge*

Paper	Authors	Title of Paper
4O9	Epperlein, Eduardo M.	*Implicit-Conservative Fokker-Planck Simulations of Heat Flow in Laser-Fusion*
3OI	Epstein, Reuben; Verdon, C.P.; Bradley, D.K.; Delettrez, J.; Marshall, F.J.; Yaakobi, B.	*Simulations of Spectral Signatures and Images of Core-Shell Mixing in Laser-Driven Implosions*
1P11	Esarey, Eric; Sprangle, P.; Ting, A.; Fisher, A.; Ride, S.K.	*Generation of X-Rays by the Interaction of Intense Laser Fields with Beams and Plasmas*
2P9	Everett, M.; Clayton, C.E.; Marsh, K.; Lal, A.; Joshi, C.	*Time Resolved Measurements of Injected Electrons and Thomson Scattering in Beat Excited Plasmas*
2O10	Everett, M.; Clayton, C.E.; Marsh, K.; Lal, A.; Mori, W.; Joshi, C.	*Frequency Harmonics of the Mode Coupled Plasma Wave in Beat Excited Plasmas*
1P14	Fisher, Yoram; Chen, H.; Soom, B.; Meyerhofer, D.D.	*Suprathermal Electrons and Ions Produced in P-Polarized Picosecond, Laser-Plasma Interactions*
4P3	Fyfe, David E.; Dahlburg, J.P.; Gardner, J.H.	*The Development and Implementation of RAD3D-CM for the Investigation of the Multimode Rayleigh-Taylor Instability*
4P1	Gaeris, Andres C.; Bahr, R.; Craxton, R.S.; Seka, W.; Meyerhofer, D.D.	*Measurements of Backscattered Light Near 351 nm in Long-Scale-Length Plasma Experiments on OMEGA*
2P1	Gamaly, E.G.	*The Ponderomotive Force in an Overdense, Absorbing, Dispersive Plasma, Caused by an Intense Laser-Matter Interaction*
5O5	Giacone, Rodolfo E.; McKinstrie, C.J.; Betti, R.; Chen, H.	*The Angular Dependence of Stimulated Brillouin Scattering in Homogeneous Plasma*
4P2	Grillon, Y.; Casanova, M.; Larroche, O.; Morin, S.	*New Results in the Ion-Kinetic Study of Collisional Plasma Shock Waves*
4P4	Guzdar, Parvez N.; Liu, C.S.; Lehmberg, R.H.	*Convective Amplification and the Effect of Bandwidth on SBS in the Quasimode Regime*
4P14	Hall, T.A.; Evans, R.; Ellison, J.; Djaoui, A.; Ridgeley, A.	*X-Ray Production Using Ultra Short Laser Pulses*
2P12	Henis, Zohar; Eliezer, S.	*Melting Phenomena in Laser Induced Shock Waves*
5O8	Hinkel-Lipsker, Denise E.; Williams, E.A.; Berger, R.L.	*Temporal Evolution of Stimulated Brilloiun Backscatter*
4P13	Jacobs, V.L.	*Review of Radiation Hydrodynamics Approaches to Laser Matter Interactions*
4P7	Johnston, Tudor W. ; Mori, W.	*Fast Plasma Wave Harmonics and Mode-Coupled Harmonics from Laser-Beatwave Drive*

Paper	Authors	Title of Paper
4P12	Kauffman, R.L.; Montgomery, D.S.; Suter, L.J.; Bocher, J.L.; LeBreton, J.P.; Babonneau,D.	*X-Ray Production from Thin Au Foils on Octal*
3O1	Keane, Christopher; Dittrich, T.R.; Hammel, B.A.; Lee, R.W.; Levedahl, W.K.; Scott, H.A.; Langer, S.H.; Suter, L.J.	*Spectroscopy Based Mix Diagnostics for High Growth Factor Nova Implosion Experiments*
2O2	Klem, Dan; Darrow, C.; Lane, S.; Perry, M.D.	*Absorption of Intense Subpicosecond 1.06μm Laser Light Interacting with a Dense Preformed Plasma*
2P14	Klem, Dan; Darrow, C.; Lane, S.; Perry, M.D.	*Hard X-Ray Production by the Interaction of Intense Subpicosecond 1.06μm Laser Light with a Dense Preformed Plasma*
4O1	Knauer, James; Verdon, C.P.; Kessler, T.J.; Skupsky, S.; McCrory, R.L.; Soures, J.M.; Glendinning, S.G.; Weber, S.	*Growth of Illumination Nonuniformities of Laser-Accelerated Flat Targets*
2P7	Kolber, Terry; Rozmus, W.; Tikhonchuk, V.T.	*Saturation of Stimulated Raman Scattering and Related Enhancement of Parametric Interactions in Laser Produced Plasmas*
2P13	Krall, Jonathan; Joyce, G.; Sprangle, P.; Esarey, E.; Ting, A.	*Numerical Simulations of Optically-Guided Laser Wakefield Accelerator Configurations*
2O5	Krall, Jonathan; Ting, A.; Esarey, E.; Sprangle, P.	*Enhanced Acceleration in a Self-Modulated-Laser Wakefield Accelerator*
1P17	Kruer, W.L.; Wilks, S.C.	*Fast Electrons for the Fast Ignitor*
1O9	Labaune, Christine; Baldis, H.A.; Baton S.D.; Michard, A.; Renard, N.; Schifano, E.; Seka, W.	*Experimental Study of Ion Acoustic Waves in a Preformed Laser Produced Plasma*
2P4	Lal, A.; Marsh, K.; Clayton, C.; Everett, M.; Joshi, C.	*Studies of Single and Dual Frequency Laser Heating in Tunnel Ionized Plasmas*
2P3	Langer, Steven H.; Ze, F.	*A Comparison of LASNEX Modeling to SXFRC on Spot Spreading in Conversion Efficiency Experiments*
1O5	Lasinski, Barbara; Kaiser, T.B.; Berger, R.L.; Cohen, B.I.; Kruer, W.L.; Langdon, A.B.; Still, C.H.; Wilks, S.C.; Williams, E.A.	*The Effect of Beam Smoothing on Filamentation*
3O4	Marjoribanks, Robin; Budnik, F.W.; Chen, H.; Meyerhofer, D.D.	*Picosecond/Nanosecond Plasma Temperatures from Quasi-Steady Isoelectronic Ratios*
1P1	Matte, Jean-Pierre; Kieffer, J.C.; Chaker, M.; Ethier, S.; Peyrusse, O.	*Enhancement of Inner Shell Excitation due to Non-Local Transport in Ultra-Short Pulse Laser Produced Plasmas*

Paper	Authors	Title of Paper
3O8	Maxon, M. Steve; Dalhed, H.	*High Gain X-Ray Lasers at the Water Window*
1O3	McKinstrie, Colin; Li, J.S.; Betti, R.	*Simple Models of Source Terms Used in the Analysis of Parametric Instabilities*
1O2	Meyer, Jochen; Zhu, Y.; McKenna, R.	*Two Plasmon Decay, Ion Acoustic Waves and the (3/2) ω_0 -Thermometer in Laser Produced Plasmas*
5OI	Montgomery, David; Moody, J.D.; Baldis, H.A.; Estabrook, K.G.; Berger, R.L.; Lasinski, B.F.; Wilks, S.C.	*Modification of SRS by Beam Smoothing in Large Scale Length Plasmas*
5O1	Moody, John; Baldis, H.; Montgomery, D.S.; Berger, R.; Estabrook, K.; Kruer, W.L.; Labaune, C.; Dixit, S.	*Spatial and Temporal Beam Smoothing Effects on SBS Emission from Nova Exploding Foil Plasmas*
1P16	Moreno, Juan; Lee, R.W.; Back, C.; Koch, J.	*Absorption Spectroscopy of X-Ray Heated Foils*
2P16	Moreno, Juan; Nilsen, J.; MacGowan, B.J.; DaSilva, L.B.	*Low-Z Ne-like XUV Lasers in Laser-Produced Plasmas with a Prepulse*
2P15	Mori, Warren; Decker, C.D.; Hinkel-Lipsker, D.; Katsouleas, T.	*Raman Forward Scattering of Short-Pulse High-Intensity Lasers*
2O8	Moulin, Frédéric; Amiranoff, F.; Marguès, J.R.; Cros, B.; Matthieussent, G.; Bernard, D.; Jacquet, F.; Meyer, J.; Miné, Ph.; Montès, B.; Poilleux, P.; Specka, A.; Stenz, C.; Mora, P.	*Coupling between Electron and Ion Waves in Nd Beat-Wave Experiments*
1P4	Nantel, Marc; Kieffer, J.C.; Dunn, J.; Enright, G.; Villeneuve, D.M.; Wan, A.; Walling, R.S.; Osterheld, A.	*3d-3p Gain monitoring in the Ne-like Germanium X-Ray Laser*
3O2	Pollak, Greg; Delameter, N.D.; Nash, J.K.; Hammel, B.	*Dense Plasma Simulations of Spectroscopic Diagnostics in Spherical Implosions at NOVA*
5O6	Powers, Linda; Berger, R.; Estabrook, K.; Harte, J.; Hinkel-Lipsker, D.; Lasinksi, B.; Munro, D.; Procassini, R.; Rambo, P.; Shepard, T.; Williams, E.A.	*Modeling of Large Scale Length Plasma Designs for Measuring Stimulated Brillouin Scattering of Nova*
1O4	Rose, Harvey A. ; DuBois, D.F.	*Density and Flow Gradient Flattening by Ponderomotive Self Focusing of Random Phase Plate Hot Spots*
1P7	Rousseaux, Christophe; Meyer, B.	*Stimulated Raman Backscattering With and Without Optical Smoothing on Phébus Laser Facility*
2OI	Rozmus, Wojciech; Tikhonchuk, V.T.; Capjack, C.E.; Kan, C.	*Practical Model for Solid Target Heating by Ultrashort Laser Pulses*

Paper	Authors	Title of Paper
4P8	Ruhl, Hartmut	*Vlasov-Simulation of Short Laser Pulse Matter Interaction*
2O3	Ruhl, Hartmut; Mulser, P.	*Vlasov-Simulation of Short Laser Pulse Matter Interaction*
1P9	Russell, David; DuBois, D.F.; Rose, H.A.	*Secondary Radiation from Langmuir Turbulence Induced by the Two Plasmon Decay Instability (TPD)*
1OI	Seka, Wolf; Craxton, R.S.; Bahr, R.E.; Chirokikh, A.V.; Simon, A.; Short, R.W.; Epperlein, E.M.; Baldis, H.; Drake, R.P.	*OMEGA Long-Scale-Length Laser-Plasma Interaction Experiments*
3O3	Shepard, Thomas D.; Keane, C.J.; Back, C.A.; Suter, L.J.; Lee, Y.	*Isoelectronic Line Ratios for Te Characterization in the Presence of a Radiation Field*
5O3	Short, Robert	*A Simple Calculation of the Effects of Beam Smoothing Techniques on Stimulated Brillouin Scattering*
1R1	Sprangle, Phillip; Esarey, E.; Krall, J.; Ting, A.; Joyce, G.	*Laser Acceleration, Optical Guiding, and Synchrotron Radiation Generation*
4OI	Stamper, John	*Status and Plans for the NIKE Laser and Target Facility*
4O5	Suter, Laurance J.; Powers, L.V.; Amendt, P.A.; Ress, D.B.	*Analysis of Nova Hohlraum Symmetry Experiments*
1O6	Tracy, Mark D.; Williams, E.A.; Estabrook, K.G.; Cameron, S.M.; Davis, U.C.	*Eigenvalue Solution for the Ion-Collisional Effects on Ion-Acoustic and Entropy Waves*
1P15	Umstadter, Donald; Liu, X.; Maksimchuk, A.; Wagner, R.; Workman, J.	*Optical and X-Ray Characterization of an Intense Sub-Picosecond Laser-Plasma Interaction*
4P6	Vidal, F.; Johnston, T.W.	*Filament Interaction in Two Transverse Dimensions as Modelled in Generalized Nonlinear Schrödinger Equations*
2P10	Vidal, F.; Matte, J.P.; Casanova, M.; Larroche, O.	*Ion Kinetic Effects and Non-Local Electron Heat Flow in Spherical and Planar Shock Waves*
2O4	Vu, Brian-Tinh V.; Szoke, A.; Landen, O.L.	*Time-Resolved Probing of Electron Thermal Conduction in Femtosecond-Laser-Pulse-Produced Plasma*
2O1	Walling, Rosemary; Denavit, J.; Alley, W.E.; Osterheld, A.L.; Stewart, R.E.; Goldstein, W.H.; Rambo, P.W.	*Heating of Solid Targets by High-Intensity Lasers*
1P10	Wang, Jil-Gen; Payne, G.L.; DuBois, D.F.; Rose, H.A.	*1-D Vlasov Simulations of Strong Langmuir Turbulence in a Field Driven Plasma*

Paper	Authors	Title of Paper
4O3	Weber, Stephen; Glendinning, S.G.; Dixit, S.N.; Knauer, J.P.	*Controlling Imprinting and Growth in NOVA Direct Drive Planar Rayleigh-Taylor Experiments*
2P5	Whitney, Kenneth; Dasgupta, A.; Pulsifer, P.E.	*T3 Short Pulse X-Ray Laser Calculations for Neon-Like Selenium*
4P9	Wilks, Scott; Berger, R.L.; Cohen, B.I.; Kruer, W.L.; Langdon, A.B.; Lasinski, B.F.; Montgomery, D.S.; Williams, E.A.	*Three-Dimensional Filamentation and Whole-Beam Self-focusing of Laser Light Including Nonlinear Hydrodynamics*
2P2	Wilks, Scott; Kruer, W.L.; Mori, W.B.	*Relativistic Filamentation and Absorption of Ultra-High Intensity Laser Light near the Critical Surface*
4RI	Willi, O.	*Laser Matter Interactions in Recent Experiments*
1O7	Williams, Edward A.; Berger, R.L.	*Ion Acoustic Waves in Mixed-Species Plasmas*
1P3	Zigler, Arie; Frenkel, M.; Henis, Z.; Kolka, E.; Eliezer, S.	*Pulsed Laser Heating Induced Increase of Multilayer Structure X-Ray Reflectivity*