Ocean City 2000

30th Annual Anomalous Absorption Conference

Thirtieth Annual Anomalous Absorption Conference

The Sheraton Fontainebleau Hotel
Ocean City, Maryland
May 21-26th, 2000

Conference Organizers:	Yefim Aglitskiy
	John Gardner
	Andrew Schmitt
	Alexander Velikovich
Conference Secretaries:	Stephanie Winegar
	Tovah Gerber

Monday, May 22, 2000

8:15 AM		Introductory Remarks Co-chairs
		Oral Session 1 - Laser Plasma Interactions (B. B. Afeyan, Chair)
8:30 AM	1O1	Laser plasma simulations using entire smoothed and aberrated laser beams *C. H. Still, R. L. Berger, A. B. Langdon, D. E. Hinkel, and E. A. Williams*
8:50	1O2	Large scale simulations of the interaction of a randomized laser beam with an underdense expanding plasma *J. Myatt, D. Pesme, V. T. Tikhonchuk, S. Hüller, and C. Riconda*
9:10	1O3	Polarization-smoothing in laser-plasma interactions *J. Fuchs, C. Labaune, S. T. Depierreux, H. A. Baldis, V. T. Tikhonchuk, S. Hüller, J. Myatt, and D. Pesme*
9:30	1O4	The effects of beam-intensity structure on two-plasmon decay in direct-drive laser fusion targets *R. W. Short*
9:50	1O5	Observation of ion waves driven by Langmuir turbulence in a single hot spot *D. S. Montgomery, J. C. Fernandez, R. Focia, and N. Le Galloudec*
10:10		**Break**
10:30	1O6	Observed dependence of stimulated Raman scattering on the damping rate of electron plasma waves in a diffraction-limited laser beam *J. C. Fernandez and D. S. Montgomery*
10:50	1O7	A self-consistent trapping model of driven electron plasma waves at low density. *H. A. Rose*
11:10	1O8	Interaction of spatially incoherent laser beams with collisional plasmas *A. Maximov, W. Rozmus, and C. E. Capjack*
11:30	1O9	Quantum and strong coupling effects in the laser energy deposition process *G. Hazak, N. Metzler, M. Klapisch, and J. H. Gardner*
11:50	1O10	Absorption and energy transfer in low-density foam-like materials irradiated by a powerful laser beam *A. U. Bugrov, I. N. Burdonsky, V. V. Gavrilov, A. Yu. Goltsov, V. N. Kondrashov, N. G. Kovalskiy, M. I. Pergament, V. M. Petryakov, and E. V. Zhuzhukalo*
		Invited Talk 1
7:30 PM	1IT	Transient enhancement and detuning of laser-driven parametric instabilities by particle trapping, *H. X. Vu*
8:30-11 PM		**Poster Session 1**
	1P1	Guiding high intensity laser pulses in a capillary *Z. Bian and T. M. Antonsen, Jr.*
	1P2	Generation of axially modulated plasma channels *J. Cooley, T. M. Antonsen, Jr., and H. Milchberg*
	1P3	Irradiation of Ar and Kr clusters with variable laser pulses *E. Parra, I. Alexeev, J. Fan, K. Kim, and H. Milchberg*
	1P4	Resonant self-trapping and absorption of intense Bessel beams *J. Fan, I. Alexeev, K. Y. Kim, E. Parra, and H. Milchberg*

1P5 Magnetic field-induced absorption in short ultra-intense laser pulses
K. A. Tartt, S. C. Wilks, and W. L. Kruer

1P6 Propagation of relativistic laser pulses through underdense plasmas
C. Rousseaux, F. Amiranoff, S. D. Baton, J. Fuchs, L. Gremillet, J. L. Miquel, M. Rabec de Gloahec, J. J. Santos, J. C. Adam, A. Héron, and P. Mora

1P7 3D simulations of fast electron propagation into solid-density matter by hybrid PIC code.
L. Gremillet, G. Bonnaud, C. Lebourg, C. Toupin, and F. Amiranoff

1P8 Cone-focussed target design for fast ignition
S. Hatchett

1P9 Hot-electron influence for K spectra emission of Ar clusters heated by 65 fs high-intensive laser radiation
A. Ya. Faenov, I. Yu. Skobelev, A. I. Magunov, T. A. Pikuz, J. Abdallah, Jr., T. Auguste, P. d'Oliveira, S. Hulin, and P. Monot

1P10 Direct experimental determination of temperature, density, and mix for LTE implosions as a function of space and time
G. Pollack

1P11 Fast infrared pyrometry on Nike targets
M. Karasik, E. A. McLean, and J. A. Stamper

1P12 Radiation-preheated targets for NIF
D. G. Colombant, A. J. Schmitt, J. H. Gardner, M. Klapisch, S. E. Bodner, and S. Obenschain

1P13 Long-term instability of thin planar foils under radiative drive
R. J. Mason, D. E. Hollowell, G. T. Schappert, and S. H. Batha

1P14 Single and multimode simulations of the Richtmyer-Meshkov and Rayleigh-Taylor instabilities from laser imprint
A. J. Schmitt, A. L. Velikovich, and J. H. Gardner

1P15 Numerical simulations of spontaneous magnetic fields in laser-produced plasma jets using MAG code
O. V. Diyankov, I. V. Glazyrin, S. V. Koshelev, and V. A. Lykov.

1P16 Symmetry of 96-beam NIF experiments
O. S. Jones, M. M. Marinak, L. J. Suter, S. M. Pollaine, and J. E. Rothenberg

1P17 Variational principle approach to the study of the coupling between forward Brillouin scattering and self-focusing
B. J. Duda, C. Ren, W. B. Mori, and E. Esarey

1P18 Subharmonic resonances of driven relativistic plasma waves: exponential and explosive growth
C. Ren, D. Gordan, E. S. Dodd, and W. B. Mori

1P19 Three-dimensional PIC simulation of laser-plasma interaction near quarter critical
F. S. Tsung, C. Ren, R. G. Hemker, B. J. Duda, and W. B. Mori

1P20 OSIRIS – a multi-dimensional object-oriented parallel PIC code for modeling laser-plasma and particle beam-plasma interactions
R. G. Hemker, F. S. Tsung, E. S. Dodd, R. Fonseca, B. J. Duda, L. O. Silva, C. Ren, V. K. Decyk, W. B. Mori, S. Lee, and T. Katsouleas

1P21 Stability modeling of NIF direct drive pellet designs
J. H. Gardner, D. Colombant, A. J. Schmitt, and M. Klapisch

Tuesday, May 23, 2000

Oral Session 2 – Hydrodynamics and Implosions (R. J. Mason, Chair)

8:30	**2O1**	Directly driven Richtmyer-Meshkov experiments *E. J. Turano, M. J. Edwards, C. P. Verdon, S. G. Glendinning, J. C. Moreno, H. Louis, and B. A. Remington*
8:50	**2O2**	Analysis of unstable structures in laboratory experiments to simulate supernova remnants *R. P. Drake, P. Keiter, J. J. Carrol III, S. G. Glendinning, O. Hurricane, K. Estabrook, B. A. Remington, E. Michael, and R. McCray*
9:10	**2O3**	Laser-driven burnthrough experiments on Omega *S. P. Regan, J. A. Delettrez, B. Yaakobi, R. Epstein, D. D. Meyerhofer, and W. Seka*
9:30	**2O4**	Two-dimensional simulations of cryogenic deuterium foil acceleration for NIF instability experiments *R. S. Craxton, J. P. Knauer, and R. P. J. Town*
9:50	**2O5**	Results of two-dimensional simulations of implosions of DD-filled CH shell targets on the OMEGA laser *J. Delettrez, V. Yu. Glebov, F. J. Marshall, C. Stoeckl, B. Yaakobi, and D. D. Meyerhofer.*
10:10		**Break**
10:30	**2O6**	One-dimensional simulation of the effects of unstable mix on neutron and charged-particle spectra from laser-driven implosion experiments *R. Epstein, J. Delettrez, V. Yu. Glebov, V. N. Goncharov, P. W. McKenty, P. B. Radha, and S. Skupsky*
10:50	**2O7**	Status of the Los Alamos ICF high convergence implosion campaigns at the Omega laser facility *N. D. Delamater, T. J. Murphy, R. G. Watt, W. S. Varnum, D. C. Wilson, S. C. Evans, P. L. Gobby, J. D. Colvin, S. M. Pollaine, R. E. Turner, V. Glebov, C. Stoeckl, and J. Soures*
11:10	**2O8**	High-convergence indirect-drive implosions on OMEGA in the absence of argon fuel dopant *P. Amendt, R. E. Turner, D. Bradley, O. Landen, S. Haan, L. J. Suter, R. Wallace, S. Morse, G. Pien, W. Seka, and J. M. Soures*
11:30	**2O9**	Scaled targets for the National Ignition Facility *D. E. Hinkel, S.W. Haan, S. M. Pollaine, T. R. Dittrich, O. S. Jones, L. J. Suter, and A. B. Langdon*
11:50	**2O10**	Exploring the upper limit of NIF multi-keV source efficiency *L. Suter, M. Miller, and C. Back*
		Invited Talk 2
7:30 PM	**2IT**	Hydrodynamic instabilities from the beginning to the end *R. Betti*
8:30-11 PM		**Poster Session 2**
	2P1	Simulation of laser plasma filamentation using adaptive mesh refinement *M. R. Dorr and F. Xabier Garaizar*

2P2 3D PIC simulations of the Weibel instability and the nonlinear structure of the self-generated magnetic field
R. A. Fonseca, J. Tonge, R. G. Hemker, L. O. Silva, J. M. Dawson, and W. B. Mori

2P3 Relativistic focusing and ponderomotive channeling of intense laser beams in plasmas
B. Hafizi, A. Ting, P. Sprangle, and R. F. Hubbard

2P4 Simulation of absolute emission from Nike targets
M. Klapisch and D. Colombant

2P5 Time resolved, absolutely calibrated observations of soft x-rays with the transmission grating spectrometer at Nike laser facility
J. L. Weaver, G. Holland, U. Feldman, J. F. Seeley, C. M. Brown, V. Serlin, A. V. Deniz, M. Klapisch, A. Mostovych, D. Colombant, and S. Obenschain

2P6 Absolute soft x-ray emission measurements and calculations on the Nike laser
A. V. Deniz, J. L. Weaver, M. Klapisch, D. Colombant, G. Holland, J. Seeley, U. Feldman, and C. Brown

2P7 X-ray spectromicroscopy investigations of fast ions and hot electrons in plasmas, heated by nanosecond laser radiation with different wavelengths
A. Ya. Faenov, I. Yu. Skobelev, A. I. Magunov, T. A. Pikuz, F. B. Rosmej, D. H. H. Hoffman, W. Süß, M. Geißel, R. Bock, T. Letardi, F. Flora, S. Bollanti, P. Di Lazzaro, Yu. A. Satov, Yu. B. Smakovskii, A. E. Stepanov, V. K. Roerich, S. V. Khomenko, S. Nischuk, K. N. Makarov, A. Reale, A. Scafati, T. Auguste, P. d'Oliveira, S. Hulin, P. Monot, and B. Yu. Sharkov

2P8 Using spherically bent crystals for obtaining high-resolution, large field, monochromatic x-ray backlighting imaging for wide range of Bragg angles
T. A. Pikuz, A. Ya. Faenov, M. Fraenkel, A. Zigler, F. Flora, S. Bollanti, P. Di Lazzaro, T. Letardi, A. Grilli, L. Palladino, G. Tomasetti, A. Reale, L. Reale, A. Scafati, T. Limongi, F. Bonfigli, L. Alainelli, and M. Sanchez del Rio

2P9 Target designs of table-top X-ray laser
V. N. Shlyaptsev, J. Dunn, A. L. Osterheld, J. Nilsen, H. Fiedorowizs, and A. Bartnik

2P10 Inelastic electron-ion collisions and plasma heating by inverse bremsstrahlung
E. Fourkal, V. Bychenkov, C. Kirkby, W. Rozmus, R. Sydora, and C. E. Capjack

2P11 DRACO – a multidimensional hydrocode for ICF
P. B. Radha, T. J. B. Collins, J. A. Delettrez, D. Keller, P. W. McKenty, and R. P. J. Town

2P12 Numerical modeling of heating and compression of spherical shell targets with a low-density coating using a two-beam laser
A. B. Iskakov, I. G. Lebo, V. B. Rozanov, and V. F. Tishkin

2P13 Further progress towards high-coupling efficiency, high yield NIF capsules
L. J. Suter, J. Rothenberg, S. Haan, J. Lindl

2P14 Implosion target surrogacy studies on Omega for the National Ignition Facility
P. Amendt, O. Landen, S. Pollaine, L. J. Suter, and B. Hammel

2P15 Design of hydrodynamically driven, radiative precursor shock experiments
P. Keiter, R. P. Drake, T. S. Perry, H. Robey, S. G. Glendinning, B. A. Remington, N. Turner, and J. Stone

2P16 Observation of stimulated Brillouin scattering in single hot spot laser plasma interaction experiments
R. J. Focia, D. S. Montgomery, and J. C. Fernandez

2P17 Numerical simulation of the SSD smoothed laser beam filamentation and forward stimulated Brillouin scattering in Plasmas
A. V. Kanaev and C. J. McKinstrie

	2P18	Speckle statistics in self-focusing smoothed laser beams *S. Hüller, J. Myatt, D. Pesme, and V. T. Tikhonchuk*
	2P19	Modeling of the competition of stimulated Raman and Brillouin scatter in LULI multiple beam experiments *B. I. Cohen, H. A. Baldis, R. L. Berger, K. G. Estabrook, E. A. Williams, and C. Labaune*
	2P20	P6 and P8 modes in NIF hohlraums *S. Pollaine, D. Bradley, O. Landen, P. Amendt, O. Jones, R. Wallace, G. Glendinning, R. Turner, and L. Suter*
	2P21	Diffusion of light in a smoothing mirror laser *M. B. Mensky and A. V. Yurkin*

Wednesday, May 24, 2000

Oral Session 3 – Ultra Intense, Short Laser Pulse Interactions (S. P. Hatchett, Chair)

8:30 AM	**3O1**	Powerful subpicosecond beam propagation in high density microcapillary plasma *A. Goltsov, I. Geltner, D. Korobkin, Y. Ping, and S. Sukewer*
8:50	**3O2**	Ultrafast neutron generation by Coulomb explosions of deuterium clusters *J. Zweiback, R. A. Smith, T. E. Cowan, G. Hays, J. H. Hartley, R. Howell, C. A. Steinke, K. B. Wharton, and T. Ditmire*
9:10	**3O3**	Computational relativistic hydrodynamics as applied for simulations of strong laser pulses and relativistic cumulative jets *I. V. Sokolov*
9:30	**3O4**	Recent topics on the fast ignitor research at ILE, Osaka University *Y. Kitagawa*
9:50	**3O5**	Experimental and numerical studies on fast electron transport in relativistic laser-solid interactions *L. Gremillet, F. Amiranoff, S. D. Baton, J.-C.Gauthier, M. Koenig, E. Martinolli, F. Pisani, J. J. Santos, G. Bonnaud, C. Lebourg, M. Rabec Le Gloahec, C. Rousseaux, C. Toupin, A. Antonicci, D. Batani, A. Bernardiello, T. Hall, D. Scott, H. Bandulet, and H. Pépin*
10:10		**Break**
10:30	**3O6**	On the generation of multi-MeV electrons and positrons using fs-laser pulses *C. Gahn, G. D. Tsarikis, G. Pretzler, C. Delfin, A. Pukhov, V. K. Tripathi, P. Thirolf, C.-G. Wahlstrom, J. Meyer-ter-Vehn, D. Habs, and K. J. Witte*
10:50	**3O7**	Multi-species ion acceleration in ultra-intense laser-plasma interactions *S. C. Wilks, T. Cowan, M. Key, W. L. Kruer, A. B. Langdon, A. Mackinnon, and M. Roth*
11:10	**3O8**	Detailed study of Raman instabilities and electron acceleration in the self-modulated laser wake field accelerator *J. Faure, V. Malka, J. R. Marquès, F. Amiranoff, J. P. Rousseau, S. Ranc, J. P. Chambaret, Z. Najmudin, B. Walton, P. Mora, and A. Solodov*
11:30	**3O9**	Mutual interaction of photon beams in a plasma: braided lights *C. Ren, R. G. Hemker, R. Fonseca, and W. B. Mori*
11:50	**3O10**	Short intense laser pulses in plasmas *P. Sprangle, B. Hafizi, J. Peñano, R. F. Hubbard, and D. Gordon*
7-11 PM	**Banquet**	

Thursday, May 25, 2000

Oral Session 4 – Laser Plasma Interactions (M. Casanova, Chair)

8:30 AM	**4O1**	Interplay of Raman and Compton scattering *C. S. Liu, T. Taguchi, and V. Tripathi*
8:50	**4O2**	Experimental observation of secondary waves produced in the non-linear evolution of stimulated Raman scattering *S. Depierreux, C. Labaune, H. A. Baldis, J. Fuchs, D. Pesme, V. T. Tikhonchuk, S. Hüller, and G. Laval*
9:10	**4O3**	Optical mixing controlled stimulated scattering instabilities: demonstration of large SBBS and SRBS reflectivity reduction in specific temporal and spectral windows *B. B. Afeyan, C. Geddes, D. S. Montgomery, R. Kirkwood, J. Hammer, A. J. Schmitt, S. Regan, D. D. Meyerhofer, and W. Seka*
9:30	**4O4**	Power transfer between smoothed laser beams *A. B. Langdon, R. L. Berger, B. I. Cohen, C. D. Decker, D. E. Hinkel, R. K. Kirkwood, C. H. Still, and E. A. Williams*
9:50	**4O5**	Laser plasma interactions using green (2ω) light *E. A. Williams, R. L. Berger, A. B. Langdon, and C. H. Still*
10:10		**Break**
10:30	**4O6**	Exploring new interaction regimes and options for NIF *W. A. Kruer*
10:50	**4O7**	Return current instability and its effect on the Thomson scattering spectra in laser produced plasmas *W. Rozmus, V. Bychenkov, A. V. Brantov, S. Glenzer, K. Estabrook, and H. A. Baldis*
11:10	**4O8**	Optical and x-ray signatures for the two-plasmon-decay instability on OMEGA *C. Stoeckl, V. Yu. Glebov, D. D. Meyerhofer, W. Seka, B. Yaakobi, and J. D. Zuegel*
11:30	**4O9**	Ion sound wave stability analysis *C. Riconda, D. Pesme, J. Myatt, S. Hüller, and V. T. Tikhonchuk*

Invited Talk 3

7:30 PM	**3IT**	An overview of fusion enabling technology with emphasis on inertial fusion energy *C. C. Baker*

8:30-11 PM **Poster Session 3**

	3P1	The influence of electron viscosity in Ion heating in shock-heated, moderate atomic number plasmas *K. G. Whitney, J. W. Thornhill, and A. L. Velikovich*
	3P2	Time-resolved x-ray spectra from laser-generated high-density plasmas *U. Andiel, K. Eidmann, and K. Witte*
	3P3	High-resolution x-ray radiography using x-pinches *T. A. Shelkovenko, S. A. Pikuz, D. B. Sinars, K. M. Chandler, and D. A. Hammer*
	3P4	Smoothing mirror and the effect of light beam self-symmetrization in laser beams with the experimental demonstration *in situ* *A. V. Yurkin, S. L. Popyrin, and I. V. Sokolov*

3P5 Numerical study of deceleration-phase Rayleigh-Taylor instability
V. Lobatchev, R. Betti, and M. Umansky

3P6 Mitigation of laser imprint in direct-drive using tailored density targets
N. Metzler, A. L. Velikovich, J. H. Gardner, and A. J. Schmitt

3P7 Observation of compressible plasma mix in cylindrically convergent implosions
N. A. Lanier, C. W. Barnes, S. H. Batha, G. R. Magelssen, D. L. Tubbs, M. Dunne, S. D. Rothman, and D. L. Youngs

3P8 Status of the LANL ICF double-shell implosion campaign
W. S. Varnum, N. D. Delamater, S. C. Evans, P. L. Gobby, J. E. Moore, R. G. Watt, J. D. Colvin, R. Turner, V. Glebov, J. Soures, and C. Stoeckl

3P9 Laser-driven hydrodynamic instabilities in the solid state and sensitivity to nature of flow
M. Legrand, G. Schurtz, S. V. Weber, B. A. Remington, and J. D. Colvin

3P10 Modeling of hohlraum stagnation pressure in a supernova remnant simulation experiment
P. Keiter, R. P. Drake, K. K. Dannenberg, J. J. Carroll III, S. G. Glendinning, O. Hurricane, K. Estabrook, B. A. Remington, E. Michael, and R. McCray

3P11 Plasma channel formation in a high-density gas puff target irradiated with a nanosecond laser pulse
H. Fiedorowicz, A. Bartnik, M. Szczurek, I. Glazyrin, O. Diyankov, I. Krasnogorov, S. Koshelev, and P. Loboda

3P12 Discrete wavelet transforms, multi-resolution analysis, and tackling physics on disparate scales
B.B. Afeyan, P. Bellomo, R. Spielman, M. Douglas, P.Bertrand, and E. Sonnendrucker

3P13 Laser-plasma interaction studies for the LIL facility
M. Casanova, L. Divol, P. Loiseau, D. Mourenas, M. Sabatier, and R. Sentis

3P14 δf simulations of nonclassical drive and transport of electrons in LPI
S. Brunner, E. Valeo, and J. Krommes

3P15 Raman forward scattering by broadband radiation sources
L. O. Silva, R. Bingham, J. M. Dawson, and W. B. Mori

3P16 Self-induced plasma smoothing of an intense laser beam propagating in underdense plasmas
J. Fuchs, C. Labaune, S. Depierreux, and H. A. Baldis

3P17 Variational principle approach to the study of whole-beam, short-pulse laser-plasma interactions, and the effects of dispersion
B. J. Duda and W. B. Mori

3P18 Seeding of the forward Raman instability via Raman backscatter and ionization effects
D. F. Gordon, R. F. Hubbard, P. Sprangle, and B. Hafizi

3P19 Propagation of intense short laser pulses in a plasma
J. R. Peñano, P. Sprangle, B. Hafizi, and R. F. Hubbard

3P20 Proton acceleration by virtual cathode on the rear surface of the ultra-intense laser illuminated plastics
Y. Murakami, Y. Kitagawa, R. Kodama, and K. Tanaka

3P21 Detailed study of Raman instabilities and electron acceleration in the self-modulated laser wake field accelerator
J. Faure, V. Malka, J. R. Marquès, F. Amiranoff, J. P. Rousseau, S. Ranc, J. P. Chambaret, Z. Najmudin, B. Walton, P. Mora, and A. Solodov

Friday, May 26, 2000

Oral Session 5 – Diagnostics and Spectroscopy
(D. G. Colombant, Chair)

8:30 AM	**5O1**	Development and characterization of a K_α x-ray source for time-resolved diffraction *K. B. Wharton, J. Zweiback, S. Hatchett, J. Crane, G. Hays, T. Cowan, and T. Ditmire*
8:50	**5O2**	Aluminum K-shell emission of laser-generated hot plasma at solid density in high spectral and sub-ps time resolution *U. Andiel, K. Eidmann, R. Mancini, I. E. Golovkin, I. Uschmann, E. Förster, and K. Witte*
9:10	**5O3**	Temporal, spatial, and spectral parameters of the x-ray emission produced by X pinches *S. A. Pikuz, T. A. Shelkovenko, D. B. Sinars, K. M. Chandler, and D. A. Hammer*
9:30	**5O4**	Direct spectroscopic observation of multicharged MeV ions in plasma heated by intense femtosecond laser radiation *A. Ya. Faenov, I. Yu. Skobelev, A. I. Magunov, T. A. Pikuz, T. Auguste, P. d'Oliveira, S. Hulin, P. Monot, A. G. Zhidkov, A. Sasaki, and T. Tajima*
10:10	**5O5**	A powerful source of thermonuclear neutrons on the basis of a KrF laser *I. G. Lebo, V. D. Zvorykin*
10:30	**5O6**	X-ray imaging diagnostics for inertial confinement fusion experiments *Y. Aglitskiy, T. Lehecka, S. Obenschain, C. Pawley, C. M. Brown, J. Seely, and J. A. Koch*
10:50	**5O7**	Multi-kilovolt x-ray driven ablation and closure of 5 μm and 10 μm pinholes during point-projection backlit imaging *A. B. Bullock, O. L. Landen, and D. K. Bradley*

11:10 **Conference ends**

Monday, May 22nd, 2000

8:15 AM	Conference begins
8:30 AM to 12:10 PM	Oral Session 1 Laser Plasma Interactions *B. B. Afeyan, Chair*
7:30 to 8:30 PM	Invited Talk 1 Transient enhancement and detuning of laser-driven parametric instabilities by particle trapping, *H. X. Vu*
8:30 to 11 PM	Poster Session 1

ORAL SESSION 1

LASER PLASMA INTERACTIONS

Bedros B. Afeyan, Chair

Monday, May 22nd, 2000
8:30 AM

Laser plasma simulations using entire smoothed and aberrated laser beams

C. H. Still, R. L. Berger, A. B. Langdon, D. E. Hinkel and E. A. Williams

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Laser plasma interactions are sensitive to both the fine-scale speckle and the larger scale envelope intensity of the beam. For some time, simulations have been done on volumes taken from part of the laser beam cross-section, and the results of multiple simulations extrapolated to predict the behavior of the entire beam. However, such extrapolation could very well miss effects of the larger scale structure on the fine-scale. The only definitive method is to simulate the entire beam. These very large calculations have not been feasible until recently, but they are now possible on massively parallel computers using the code F3D. We present whole beam simulations showing the dramatic difference in the propagation and break up of smooth and aberrated beams.

Preferred format: Oral

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Large scale simulations of the interaction of a randomized laser beam with an underdense expanding plasma

J. Myatt, D. Pesme, V. T. Tikhonchuk*, S. Hüller, and C. Riconda,

Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau Cedex, France.

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Abstract

We present the results of 2D simulations of the interaction of an RPP laser beam with an underdense, expanding plasma for conditions typical of recent LULI experiments[1]. The code describes the paraxial propagation of the incident laser and backward SBS[2] beams, accounting for the nonlinear evolution of the background plasma in a one-fluid, isothermal description, with Boltzmann electrons. It includes both thermal and ponderomotive contributions for the speckle self-focusing, and nonlocal electron heat conductivity.

The simulations follow the entire duration of the laser pulse ($\sim$ 600 ps FWHM) and include most of the expanding plasma, $L_{axis} = 1.4\,\mathrm{mm}$, which is characterized by a strongly inhomogeneous flow velocity, $L_v \sim 100 - 200\,\mu\mathrm{m}$, and time-dependent density, $n_e/n_c \sim 0.4 - 0.04$. We diagnose the time resolved backscattered reflectivity, the location and temporal dependence of the backward SBS driven sound waves, as well as the angular distribution and spectrum of transmitted light.

We investigate the respective roles of collisional and ponderomotive effects on the SBS, self–focusing, and self–induced smoothing of transmitted light. Our simulations results are then compared to a reduced SBS model[3], and to the experimental data[1]. Simulations demonstrate the important role of the collisions for the LULI experimental conditions, which enhance the beam self–smoothing due to speckle self–focusing.

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Polarization-smoothing in laser-plasma interactions

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Experiments have been conducted at the LULI multi-beam facility by applying either (i) Polarization Smoothing (PS) to an intense (mean average intensity up to 10^{14} W/cm^2) long (600 ps FWHM) laser beam at •=1.053 μm initially smoothed with a Random Phase Plate (RPP) or (ii) RPP only. The experiments use underdense plasmas from CH exploded foils (n/n_c~$0.2\times n_c$).

The results demonstrate the effectiveness of PS technique in controlling the SBS and SRS instabilities: we observe remarkable reduction of SBS and SRS reflectivities in backward direction, by up to a factor of 10 for SBS and 3 for SRS. Direct and simultaneous Thomson scattering measurements of the associated plasma waves show that these are spatially and temporally modified and reveal that the interplay between SBS and SRS has to be taken into account to understand the effect of the smoothing.

Supporting the experimental results, we present results from an advanced statistical model which describes the SBS of a randomized laser beam interacting with an underdense, expanding plasma. It shows remarkably good agreement with the measured SBS levels for a broad range of the laser pulse energy, various targets, and both types of beam smoothing. The model accounts for the self-focusing of speckles with the inclusion of heating effects, which are shown to be important. The model, coupled to the experimental results, demonstrates that PS technique allows a reduction of self-focusing with PS, resulting in a decrease of the maximum laser intensity and consequently of SBS gains.

* This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory, through the Institute for Laser Science and Applications, under contract No. W-7405-Eng-48.

oral preferred

4/6/00

The Effects of Beam-Intensity Structure on Two-Plasmon Decay in Direct-Drive Laser Fusion Targets

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Abstract

Two-plasmon decay involves the conversion of an incident electromagnetic wave into two Langmuir waves at the quarter-critical density. Because of its comparatively low threshold and potential for hot-electron production, the theory of this instability has been extensively studied. Its linear behavior for idealized pump and plasma structures is well known. Two-plasmon decay is essentially a two-dimensional instability, however, since at least one of the product plasma waves must propagate at a finite angle to the pump. Thus the short-scalelength azimuthal intensity variations produced by beam-smoothing techniques such as SSD can be expected to affect the growth rate and saturation levels of the instability. The typical structure of these intensity variations near quarter-critical density in a spherical plasma corona is calculated using a full wave-equation model, and the effects on two-plasmon decay levels are 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.

Prefer oral session

Observation of ion waves driven by Langmuir turbulence in a single hot spot

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Stimulated Raman scattering (SRS) is driven in a large, quasi-homogeneous plasma using a 527-nm near-diffraction-limited laser beam to produce a single hot spot (SHS). The SHS laser is focused with a *f/4.5* optic to produce a 2.5μm diameter spot, with peak intensity ~ 8×10^{15} W/cm^2. SRS is observed to be large (~ 1%) in the regime of $k_{EPW}\lambda_{De} \sim 0.21 - 0.32$, where k_{epw} is the wave-number of the SRS Langmuir wave.

An additional 263.5-nm beam is used to probe ion waves with $k_{IAW}\lambda_{De} \sim 0.42 - 0.64$, where $k_{IAW} \sim 2\, k_{EPW}$ is the wave-number of the ion waves. These waves satisfy the wave-matching conditions for the Langmuir decay instability (LDI). The Thomson scattered light from these ion waves is detected with time-resolved spectroscopy ($\Delta\lambda \sim 0.2$Å, $\Delta\tau \sim 100$ ps). Driven levels of ion waves are observed, and correlate with the SRS reflectivity measured from the SHS beam. Additionally, the high spectral resolution and the range of probe angles allows the observation of up to four ion waves generated by LDI cascade. Spectral structure observed in the forward propagating and backward propagating ion waves is consistent with the kinematics of LDI cascade.

*This work was performed under the auspices of the U.S. Department of Energy by the Los Alamos National Laboratory under Contract No. W-7405-ENG-36.

Prefer Oral Session

Observed Dependence of Stimulated Raman Scattering on the Damping Rate of Electron Plasma Waves in a Diffraction-Limited Laser Beam

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We have studied stimulated Raman back scattering (SRS) of a diffraction-limited laser beam as the plasma-wave damping is varied. This study has been performed at the Trident laser facility at Los Alamos National Laboratory. The damping is changed by changing the electron density at the interaction region, which is done in turn by changing the aim of the diffraction-limited interaction beam within the volume of isothermal CH plasmas that have been extensively characterized and are very repeatable. The plasma is homogeneous within the spatial scale of the interaction beam. These results are consistent with those from quasi-homogeneous hohlraum plasmas that approach the plasma conditions expected within present ignition-hohlraum designs for the National Ignition Facility. High Raman reflectivity ($\approx$ 10%) persists until $k\lambda_D \approx 0.45$ is exceeded. There are two straightforward conclusions from our study. (1) The convective spatial gain is much too small in these plasmas to support any observable SRS, unless the plasma-wave damping is significantly below that in a Maxwellian electron distribution. (2) SRS is limited by some non-linear process that maintains the reflectivity approximately constant as $k\lambda_D$ is varied.

A self consistent trapping model of driven electron plasma waves at low density*

Harvey A. Rose
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A Vlasov equation based model of driven electron plasma waves (EPW) is used to determine the nonlinear response to a coherent EPW source in a laser hot spot. It incorporates trapped particle effects such as the standard nonlinear frequency shift, extended beyond the weak regime. The results are consistent with those of Holloway and Dorning [Phys. Rev. **A44**, 3856 (1991) for small amplitude BGK modes. This leads to the prediction that so long as $k\lambda_D \lesssim 0.53$ for a background Maxwellian distribution function, *e.g.*, a 5 keV plasma with $n_e/n_c \gtrsim 0.075$, SRS levels large compared to linearized Vlasov equation predictions, cannot be excluded. Also, the domain of LDI accessibility may be significantly increased.

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Interaction of Spatialy Incoherent Laser Beams with Collisional Plasmas

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Interactions of laser light with plasmas depend on the degree of plasma collisionality which is characterized by the ratio of a typical spatial scale L to the electron mean free path λ_{ei}. The propagation of spatially incoherent RPP beams in collisionless plasmas, where $L \ll \lambda_{ei}$, have been studied in detail in recent years. At the same time in many realistic experimental conditions the electron mean free path can be on the order of the ion-acoustic wavelength. The collisional effects are especially important for beam self-focusing and forward SBS instability that generate density perturbations with wavelengths much larger than the laser wavelength.

The collisional effects in the interaction of RPP laser beams with plasma are studied with a non-paraxial code solving Maxwell and ion acoustic wave equations in two and three spatial dimensions. Thermal response has modified the electromagnetic driver term in the ion acoustic wave equation and the damping of ion acoustic waves [1]. The results are compared with the previous theoretical and numerical studies of filamentation and forward Brillouin scattering. Collisional effects change both the threshold conditions and the spectral characteristics for the process of the plasma-induced beam smoothing. We have examined numerically the instability of nonlinear filaments [2] in the presence of thermal effects.

Thermally enhanced beam smoothing increases energy exchange and effective interactions between crossing beams in weakly collisional plasmas.

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Quantum and strong coupling effects in the laser energy deposition process

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In most radiation hydrodynamics codes for ICF , the laser energy deposition in the plasma is evaluated by the formula for the inverse bremstrahlung process in plasmas as derived by Dawson and Oberman[1].
In this theory, electrons are treated as classical weakly coupled plasma obeying the Vlassov equation and ions are treated as an ensemble of point scatterers with a Debye Hückel form factor.
In ICF oriented experiments, during the foot of the pulse, a few nanoseconds after the laser is turned on, the temperature of the blow off plasma exceeds few tens of eV. As the density is below critical (1.7e22/cc for 0.25 micron laser) the plasma is within the weak coupling and classical regime where the Dawson&Oberman formula presents a fair approximation [2].
Nevertheless, in some cases, the few tens of percents of difference between the classical and the more general quantum absorption rate may have a significant effect on the behavior of the system.
In the talk we will describe a systematic derivation of a formula for the inverse bremstrahlung process. The derivation is based on the quantum analog of the BBGKY hierarchy, and includes both quantum and strong coupling effects.
The resulting formula was implemented in the NRL radiation hydrodynamics code FAST2D. We will present some examples of hydro simulation with the new formula. As an example we will show that quantum effects have a significant, though not dramatic, effect on the emergence and propagation of Radiating Plasma Structures [3].

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Absorption and Energy Transfer in Low-Density Foam-Like Materials Irradiated by Powerful Laser Beam

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The interaction of powerful laser pulses (λ = 1,054 μm; τ = 2,5 ns; I = 10^{13} - 10^{14} Wt/cm^2) with low-density porous and foam-like materials (the average density varied from 0,5 mg/cm^3 to 20 mg/cm^3) was experimentally studied under conditions being of interest for the ICF problem and the development of bright X-ray sources. Parameters of a laser-produced plasma inside planar samples of low-density organic materials with and without high-Z element admixtures were measured by a number of optical and X-ray diagnostic methods providing high spatial and temporal resolution. In some experiments the 0,2 μm – thick copper layer deposited onto the surface of low-density targets was used as an effective external X-ray convertor. The mechanisms of energy transport from the absorption region inward a low-density matter of different structure were identified. Doping of organic porous targets with high-Z materials was shown to result in the significant growth of energy transport rate. Possibility to control the uniformity and X-ray spectra of laser- produced plasma was demonstrated in experiments with low-density porous or foam-like targets. The simple theoretical model describing the physics of laser-target interaction in investigated conditions is presented.

INVITED TALK 1

Transient Enhancement and Detuning of Laser-Driven Parametric Instabilities by Particle Trapping

Hoanh X. Vu
Los Alamos National Laboratory

Monday, May 22nd, 2000
7:30 PM

Andrew Schmitt, Chair

Transient enhancement and detuning of laser- driven parametric instabilities by particle trapping.

H.X. Vu, D.F. DuBois, and B.Bezzerides, Los Alamos National Laboratory

We present preliminary results on kinetic regimes of stimulated Raman scattering (SRS) which are dominated by the trapping of electrons in the primary daughter Langmuir waves (LWs). This trapping can lead to much larger transient reflectivities than predicted by standard fluid-like models in regimes with high Landau damping of the primary LWs with large values of $k_1\lambda_D$. We believe that this phenomenon may be the explanation of high reflectivities observed in such regimes, with low densities and high electron temperatures, which cannot be explained by such fluid models. We compare the reflectivities calculated form the reduced particle in cell code (RPIC) ASPEN [1] and a hybrid Zakharov code ODYSSEUS [2]. The reflectivity computed from the hybrid model is much smaller and has a distinctly different time dependence than that computed from RPIC. Similar results were found in Sanbomatsu et al [3] for LWs with large $k_1\lambda_D$ driven by the electron-ion parametric decay instability (PDI) with $\omega_0 \sim \omega_p$. In each case the k space spectrum of LWs was such that the correlation time $\tau_c \sim (v_g \Delta k)^{-1}$ was longer than the electron trapping period, i.e. $\omega_b \tau_c > 1$, where $\omega_b = (eE k_1/m_e)^{1/2}$ is the bounce frequency. Saturation by the Langmuir decay instability of the primary LW is very weak in these regimes. Trapping reduces the LW damping from the Landau value for times t such that $\omega_b t > 1$. The turn over (or saturation) of the reflectivity is due to a time dependent frequency shift of the driven LW containing trapped electrons which phase-detunes the SRS instability. The LW saturates at an amplitude that is much smaller than the wave-breaking limit. A similar saturation scenario is now understood to be the saturation mechanism in PIC simulations by Giacone and Vu [4] for SBS where the ion acoustic wave (IAW) was observed to trap ions and developed a frequency shift.

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[2] H.X. Vu, K.Y. Sanbonmatsu, B. Bezzerides, and D.F. DuBois, Laying a Foundation for Laser-Plasma Modeling for the National Ignition Facility, Comput. Phys. Commun., in press (2000).
[3] K.Y. Sanbonmatsu, H.X. Vu, B. Bezzerides, and D.F. DuBois, Phys. Plasmas 7, 1 (2000).
[4] R.E. Giacone and H.X. Vu, Phys. Plasmas 5, 1455 (1998).

POSTER SESSION 1

Monday, May 22nd, 2000
8:30 to 11 PM

Guiding high intensity laser pulses in a capillary*

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Abstract:

Studies of the propagation of short laser pulses in a glass capillary are presented. The propagation is simulated using the code WAKE, which we have modified to treat the case in which the simulation boundary is the wall of a capillary. The specific modification assumes that the laser light inside the capillary is obliquely incident on the capillary wall and as a consequence the rays in the wall are at the critical angle for total internal reflection. Simulation results are compared to similar experiment conditions [1]. Parameters that were examined include transmission efficiency of the waveguide as a function of gas pressure, laser intensity, and waveguide length which is up to 40 Rayleigh length. The intensity on the inner wall of the capillary is also monitored to assure the realistic simulations consistent with the optical breakdown of the waveguide material. generally speaking the intensity on the wall increases with gas pressure due to scattering of the lowest order capillary mode.

* Supported by USDOE and NSF

* Also Department of Physics.

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prefer poster

Generation of Axially Modulated Plasma Channels*

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University of Maryland, College Park MD 20742

Plasma waveguides for guiding intense laser pulses have applications in particle acceleration and x-ray generation schemes. Waveguides can be formed using a variety of methods. One method [1] is to create a plasma channel by breaking down a gas with a laser pulse focused through an axicon. Ideally, the plasma channel will be axially symmetric and allow for guided single mode propagation of short laser pulses. However, for certain experimental conditions the channel develops periodic axial modulations. The onset of these modulations appears to correlate with the conditions for self trapping and resonant absorption of the axicon pulse by the plasma waveguide. Resonant absorption occurs under the following scenario [2]. As the channel is expanding the axial wave numbers of the modes of the leaky waveguide defined by the channel evolve as well. At certain times one of these axial wave numbers will correspond to that of the formation pulse, which is defined by the axicon. At this time the formation pulse couples linearly to the confined mode of the channel and is strongly absorbed. According to our model the modulations are due to a nonlinear coupling of the axicon field to the confined modes of the channel. Small axial modulations in the expansion rate of the channel can scatter the incident axicon field into the guided mode of the waveguide. The beating of the guided mode and the axicon field leads to modulations in the heating rate and ponderomotive force which reinforce the modulations in the expansion rate, in other words, there is a parametric instability. A simple model of this process will be presented.

*Supported by USDOE and NSF
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[2] J.Fan, E. Parra, and H.M. Milchberg, Phys. Rev. Lett. **84**, 3085 (2000)

prefer poster

Irradiation of Ar and Kr clusters with variable width laser pulses

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Abstract

We examine the soft x-ray (20-440 Å) and X-ray (>2 keV) emission of Argon and Krypton clusters irradiated with 50 mJ laser pulses with pulse width in the range 100fs through 10 ns. In general, charge states 2+ through 9+ are observed in the Argon spectra, while charge states 5+ through 13+ are present in the Kr spectra. Inferring the degree of cluster heating from the emission yields of the highest observed ion stages, we find for our range of pulses that the hottest Argon cluster plasmas occur for ~300 fs pulse irradiation. The hottest Krypton cluster plasmas occur using pulses in the range of 100 ps, several hundred times longer in duration, and a time scale greatly in excess of the expected cluster disassembly time [1]. We will discuss these results in terms of several cluster heating models.

This work is supported by NSF Grant ECS96-12204.

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Resonant self-trapping and absorption of intense Bessel beams

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We report the first observation of *resonant* self-trapping in a subcritical density plasma, which takes place during the laser breakdown and heating of a gas with a Bessel beam [1]. The spatial trapping of laser radiation in the plasma is directly correlated to an enhancement in plasma absorption and heating. We present results for several laser wavelengths and Bessel beam parameters. Simulations of this absorption consistently explain the experimental observations.

This work is supported by the National Science Foundation (PHY-9515509) and the US Department of Energy (DEF G0297 ER 41039)

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Magnetic Field- Induced Absorption of Short Ultra-Intense Laser Pulses

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2. Lawrence Livermore National Lab Livermore, Ca.

Computer simulations have shown that magnetic fields up to 10^9 Gauss can be generated by the interaction of short ultra-intense laser pulses with overdense plasmas. We find that the laser absorption can be significantly enhanced by the oscillation of electrons across these fields. This process is a highly nonlinear, nonresonant version of linear mode conversion into upper hybrid waves; *i.e.*, the magnetic analogue of not-so-resonant absorption of obliquely incident light. We also show that large magnetic fields can be significantly amplified to even larger values by the pressure of the light pulse. Potential applications are discussed.

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Prefer Poster

Propagation of relativistic laser pulses through underdense plasmas

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The propagation of an intense laser pulse ($I\lambda^2 > 10^{19}$ Wμm^2/cm^2) in a long underdense preformed plasma is a key issue for the Fast Ignitor concept. In this respect, the role of the electronic instabilities arising at relativistic intensities must be clarified both experimentally and theoretically.

We will present experimental results obtained during experiments performed at ω on the P102 laser facility at CEA and on the 100-TW laser facility at LULI. The transmission, the reflection, as well as the Raman forward/backward scattered light and the fast electron generation have been measured as a function of the laser intensity in variable density preformed CH plasmas. It is shown that :

(i) the transmission rate depends very little on the laser intensity ;

(ii) the backward-SRS fraction quickly saturates and then decreases at the highest intensities ;

(iii) the forward-SRS fraction continuously increases (up to several percent of the laser energy) as the plasma density decreases and/or the laser intensity increases ; the Raman spectra appear substantially wide (> 400 nm) ;

(iv) the emission of fast electrons in the range 0.5-5.5 MeV is correlated to forward Raman, and its aperture is reduced to the focusing aperture (f/3) at high intensities and in low density plasmas.

The strong heating of the plasma is likely to play an active role in the temporal growth or inhibition of the instabilities. The results will be discussed with the help of the first steps of a numerical approach.

Poster session preferred.

3D simulations of fast electron propagation into solid-density matter by hybrid PIC code

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Hybrid codes using a simplified set of the Maxwell equations along with a PIC/fluid treatment of the fast/cold particles allow for large-scale modeling of intense electron beam transport into solid-density targets. We present different 3D simulations, from 'academic', i.e. with monoenergetic and monodirectional electron source, to 'real-life', i.e. with laser-profile-dependent electron source, of the interaction of an intense fast electron current with an initially conductor or insulator medium. Among the topical issues addressed are the capability of the beam to experience magnetic pinching over long distances (~100 μm), and to heat this jet-like strucure up to 1 keV. We also present different scenarii where the beam is seen to exhibit various instabilities, depending on its total energy, its energy spectrum, its radial profile or the target resistivity. As regards the resistive filamentation process, we find the numerical growth rate in fair agreement with a relativistic cold-fluid model. Furthermore, by following the particles' trajectories for various times of injection, we demonstrate the more and more favorable conditions of transport met by successive electron bunches.

Poster presentation preferred

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One advantage to the fast-ignition approach to IFE over more "conventional" approaches is that the implosion symmetry requirements are greatly relaxed since no hot spot must be formed. The imploded configuration of high density DT need not have much symmetry as long as it has sufficient ρR. However, the usual fast-ignition approach requires that somehow the high intensity (igniter) laser beam penetrates through the capsule blowoff plasma (underdense and overdense) to convert its energy into a forward-directed beam of fast electrons that then deposit their energy in a spot within the high density DT. This scenario is where the "miracle occurs" [ref. S. Harris cartoon]. M. Tabak and S. Wilks [private communication] have proposed a way to take advantage of the low symmetry requirement to finesse most of the laser and electron beam propagation problems. The initial capsule has a conical shell of dense material penetrating through one side to near capsule center. Then the implosion proceeds as usual with the cone holding open a channel for the high intensity laser so that its energy will be deposited very close to the high density DT at peak compression time.

We report the results of a series of 2-D simulations undertaken to explore the promises and pitfalls of this "cone-focussing" concept for indirectly driven capsules. We suggest ways to optimize such a target design, and we provide estimates of the final plasma environment within which the igniter laser and fast electrons must propagate.

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

Hot-electron influence for K spectra emission of Ar clusters, heated by 65 fs high-intensive laser radiation.

A.Ya. Faenov[1], *I. Yu. Skobelev*[1], *A.I. Magunov*[1], *T.A.Pikuz*[1], *J. Abdallah*[2], *Jr., T. Auguste*[3], *P. d' Oliveira*[3], *S. Hulin*[3], *P. Monot*[3]

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The high-resolved X-ray spectra resulting from the interaction of argon gas clusters with short-pulse laser radiation was studied. The cluster target was formed by the adiabatic expansion in vacuum of an argon gas puff produced by a pulsed valve with a conical nozzle. The gas jet was characterized by interferometry. The density profile has a Gaussian shape with a 4 mm width (at 1/e), and the peak density is 4.6×10^{18} cm^{-3} for a maximum gas backing pressure of 15 bars. The experiments were carried out using the UHI10 laser. It is a two-beam 10 Hz Ti:Sapphire system (λ = 800 nm). In our particulare experiments the main beam has a 7 TW peak power. The low energy ultrashort pulse produced by a modified commercial Ti:Sapphire oscillator. The post- and pre-pulses amplitudes are less than 10^{-5}. The 80-mm diameter laser beam is focused with an f/6.25 off-axis parabolic mirror. The focal spot radius is w_0 = 25μm. The corresponding Rayleigh length and vacuum intensity are 600-μm and 7×10^{17} W/cm^2, respectively. The laser was focused at the vacuum-gas interface, about 1.5 mm below the nozzle. High spectrally ($\lambda/\delta\lambda$=3000-5000) and spatially (about 40 μm) resolved X-Ray spectra of argon in the spectral range 3.35-4.2 Å have been obtained by means of two Focusing Spectrometers with Spatial Resolution. Spherically bent mica crystals with R=150 mm radius of curvature were used in these spectrometers. Spectra near the He_a and He_β, were recorded. It was obtained that The observed spectrum are compared to simulations using the Los Alamos suite of atomic physics and kinetics code. Big influence of hot electrons on the intensity of X-Ray spectra was demonstrated. This work was performed under the auspices of the US Department of Energy.

DIRECT EXPERIMENTAL DETERMINATION OF TEMPERATURE, DENSITY, AND MIX FOR LTE IMPLOSIONS AS A FUNCTION OF SPACE AND TIME

Greg Pollak
Los Alamos National Laboratory

Advances in diagnostics development and related image analysis procedures are enabling a more fundamental understanding of LTE implosions than previously possible. The most conceptually direct diagnostics suite utilizes gated monochromatic imager(s) (GMXI), a streaked spectrometer, and an absolutely calibrated, time-integrated spectrograph. Although spectrometers are used, the imaged capsules should be in LTE, normally viewing continuum emission. The GMXI should be run in 2-color mode (for T and rho only), or 3-color mode (including mix). Data analysis involves 2 other inputs: an opacity at the 2 or more colors; and the analytic LOS emission-absorption equation. The key concept is that the number of unknowns should equal the number of quantities measured. The unknowns are extracted by linearizing the LOS equation and iterating a multi-variable Newton procedure to convergence. A variation on this theme uses 4 colors of GMXI, but no absolutely calibrated spectrograph. If one uses 4 colors, and the spectrograph as well, then only the frequency dependence of the opacity need be known--the absolute magnitude can be extracted from the data as well. The LTE character of the analysis is very useful, since NIF-class ignition capsules will almost certainly be cryogenic, and thus not amenable to the use of non-LTE dopants in the critical regions of the capsule. Derivations of all relevant equations will be presented, as well as preliminary results for an uncertainty analysis. The latter analysis is based on the fact that it is possible to produce synthetic images from RadHydro codes and pass these thru the algorithms described here to extract T, rho, and mix, and then compare these outputs to the RadHydro results.

Fast Infrared Pyrometry on Nike Targets

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A new front-surface infrared diagnostic has been installed on the Naval Research Laboratory Nike KrF Laser target chamber. The purpose of the diagnostic is to determine whether significant target preheat exists prior to the main laser pulse. Possible sources of preheat are Amplified Spontaneous Emission (ASE) from the laser amplifiers and beam-to-beam scattering that would result in some energy reaching the target ahead of the main pulse.

The present diagnostic setup consists of a large-aperture Cassegrain telescope imaging the target onto a fast high-detectivity HgCdZnTe infrared detector. The telescope has a 6" diameter primary mirror and a 2" diameter secondary mirror, both of which are gold-coated for optimum reflectivity in the infrared. The effective f-number of the system is approximately 8 and the magnification is 1.5x. The angle of the telescope axis is 39.2° w.r.t. the laser beam axis. The telescope mirrors are protected with a blast shield made of the infrared-transmitting PolyIR-5 material.

The infrared detector is thermoelectrically cooled and has a 10 nsec rise time and a 3 mm diameter effective sensitive area. The spectral bandwidth of the measurement is 2-4 μm, with the lower bound due to a germanium filter in front of the detector, and the upper bound due to the response of the detector itself. The detector signal is digitized by a fast oscilloscope via a low noise voltage preamplifier with a gain of 100. The noise floor of the system corresponds to a black body at approximately 400°C.

Preliminary results indicate the presence of an infrared signal ~ 40 nsec prior to the main pulse. Estimates of the target temperature prior to the main pulse for several target materials and different laser configurations will be presented.

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Radiation-preheated targets for NIF*

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Radiation-preheated targets have been developed for KrF lasers[1] and high gain applications. The designs take advantage of the short laser wavelength, the possibility of zooming the laser focal spot and a large contrast ratio between the foot and the final drive of the pulse. They are also based on the concept of 'tailored adiabat' which favors preheating of the ablator to that of the fuel.

We have applied these ideas to the NIF and modified the all-DT NIF targets[2] by including a DT-wetted foam ablator and a plastic shell surrounding the target. Although there are more limitations on the NIF laser pulse- 1/3 μm laser wavelength, no zooming, and laser contrast ratio less than 100- we have obtained targets which can exhibit significant gain (>45) as well as targets with 'good' stability (maximum number of e-folds < 4 for the Rayleigh-Taylor ablative instability), based on 1D dispersion relations. A few examples of these targets will be shown and discussed.

1 S.E.Bodner, D.G.Colombant, J.H.Gardner et al, Phys. Plasmas **5**, *1901 (1998); also S.E.Bodner, D.G.Colombant, A.J.Schmitt and M.Klapisch, to be published in Phys. Plasmas, May 2000.*

2 S.V.Weber, S.G.Glendinning, D.H.Kalantar et al, Phys. Plasmas **4**,*1978 (1997)*

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

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Poster-Preferred

Long-term Instability of Thin Planar Foils under Radiative Drive

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We have continued earlier computational and experimental studies[1] of Rayleigh-Taylor instability in thin planar bare and beryllium-buffered copper foils under radiative drive. The experiments were performed on the OMEGA laser, and simulated in 2-D with the Eulerian AMR code RAGE. The present emphasis is a study of the long-term evolution of the R-T spikes. The foils were typically 11.5 μm thick, with 45 μm wavelength cosine drive-side surface perturbations of 0.5 μm amplitude, with and without a 5 μm Be-buffer layer on the drive side. The foils were driven by a "P26" laser pulse with peak radiation temperatures near 170 eV after about 1.5 and 90 eV at 2.3 ns. The developing bubble-and-spike pattern in the foil was initially probed with an iron backlighter, looking normal to the foil and its initial corrugations. Over 6 ns R-T growth in the foils results in experimentally measured 1st harmonic perturbation amplitudes of 4.5 μm in the bare foils and 5.5 μm in the buffered targets. The added hydrodynamic pressure leads to increased acceleration and growth for the buffered foil. The measured 2nd harmonics grow to about 3 μm in both the bare and buffered targets. At 6 ns the *directly* calculated harmonic amplitudes from RAGE are substantially larger, i.e. 10 and 9 μm for the 1st and 2nd harmonics, than the measured values. However, a significantly improved match to the data is achieved by *adjustment* of the calculated foil thickness to account for a ranging out of the 6.7 keV backlighter probe illumination upon transmission through copper spikes exceeding 25 μm. We also discuss the results of recent side-lighter experiments aimed at capturing the spike development at ~10 ns.

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1. R. J. Mason, D. E. Hollowell, G. T. Schappert, and S. H. Batha, Bull. Am. Phys. Soc. **44**, 57 (1999), and S. H. Batha, G. T. Schappert, K. A. Klare, D. E. Hollowell, and R. J. Mason, Bull. Am. Phys. Soc. **44**, 57 (1999).

30th Annual Anomalous Absorption Conference
21 – 26 May 2000 Ocean City, MD

Single and multimode simulations of the Richtmyer-Meshkov and Rayleigh-Taylor instabilities from laser imprint†

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Simulations of the hydrodynamic instability of laser driven targets require resolution of the physics on very different spatial scales. A conventional approach begins with single-mode simulations of imprint and RT seeding of the target. The resulting "imprints" can then be used as the basis of a Takabe-Haan type analysis[1], which uses a dispersion relation with secular-growth nonlinear saturation to predict the evolution of the instability. Or, these imprints can be used to start a multimode simulation of the RT phase of the target acceleration. Calculation of the target behavior from start to finish with a multi-mode hydrodynamic simulation is much more difficult. We present here results of start-to-finish FAST hydrocode simulations[2] of laser imprinted targets, and compare them to combined single-mode simulations, and to theories for imprinting and RT growth[3].

1. *H. Takabe, et al., Phys. Fluids 28, 3676 (1985); S.W. Haan, Phys. Fluids* ***B3****, 2349 (1991).*
2. *J. H. Gardner, et al., Phys. Plasmas* ***5****, 1935 (1998).*
3. *E.g., A. Velikovich et al., Phys Plasmas 7 1662 (2000), or V. Goncharov et al., ibid., p.2062.*

†Work supported by U.S. Department of Energy

NUMERICAL SIMULATION OF SPONTANEOUS MAGNETIC FIELDS IN LASER PRODUCED PLASMA JETS USING MAG CODE

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The results of numerical simulation of spontaneous magnetic field generation and its influence of this field on laser produced plasma jet expansion in vacuum and low density gas are presented. The numerical simulation has been carried out using MAG code [1] for the case of aluminum plate of 5 μm of thickness irradiated by Nd laser. The laser pulse duration was 0.5 ns at half-width, laser irradiation intensity was up to 10^{13} W/cm^2 and laser focal spot diameter was about 100 μm. According to the received results, the magnetic field amplitude achieves the value of 150 kGs. This fact has no considerable influence on the temperature maximum in laser produced plasma, but significantly affects the process of the energy transport from plasma jet to low density gas.

References:

[1] O.V.Diyankov, I.V.Glazyrin, S.V.Koshelev: Computer Physics Communications, 106 (1997) 76

Symmetry of 96-beam NIF Experiments*

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During the early period of NIF operation, it is likely that there will be a time during which it is useful to do experiments with 96 of the eventual 192 laser beams. There is interest in doing indirect-drive ICF experiments with 96 beams using reduced-scale hohlraums and capsules. A critical question for these experiments is whether we can achieve adequate radiation symmetry. In general, we expect the radiation symmetry with 96-beam illumination to be somewhat degraded as compared to that for 192-beam NIF. However, we are investigating several techniques that potentially can improve the symmetry for reduced-scale, 96-beam hohlraums to the point that it is approximately as good as for the original 192-beam baseline hohlraum (NIF scale 1.0).

In particular, we have investigated the symmetry for a NIF scale 0.6 hohlraum driven by a shaped pulse having a peak power of 140 TW and a total laser energy of 355 kJ. The reduced number of independent laser spots, the reduced hohlraum scale, and the reduced laser power combine to increase the random asymmetries due to laser power imbalance and pointing errors. Also, the azimuthal contribution to the intrinsic asymmetry is larger. These effects can be compensated for by using mixtures of several different materials in the hohlraum wall, which increases the albedo of the wall, especially during the foot of the shaped pulse, when the radiation asymmetry is typically largest. Further improvement is available through the use of laser techniques that increase the conversion efficiency during the foot and thus reduce the laser power imbalance. Finally, the beams can be repointed azimuthally to improve the azimuthal symmetry. We will present the results of radiation viewfactor and radiation hydrodynamics calculations that assess the symmetry of this 96-beam, scale 0.6 hohlraum as a function of the various techniques that can be used to improve the symmetry.

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Variational Principle Approach to the Study of the Coupling between Forward Brillouin Scattering and Self-Focusing

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E. Esarey, Lawrence Berkeley National Laboratory.

The evolution and stability of single speckles in long scale-length plasma is of interest to ICF applications [1]. In this paper, we use a variational principle approach [2] to study the evolution of a single isolated speckle. We start from the coupled equations between the laser and the ion acoustic wave. An action is derived whose Euler-Lagrange equations recover the starting equations. A trial function which parametrizes the speckle in terms of a spot-size, centroid position, amplitude, phase velocity, etc. is inserted into the action and the integration in the transverse direction is performed. Requiring that this action be stationary gives envelope equations for the trial function parameters. Using this approach we will provide growth rates for spot-size self-modulation and hosing instabilities which couple the forward Brillouin Scattering and self-focusing instabilities. A comparison between the whole-beam Brillouin envelope instabilities and the whole-beam Raman envelope instabilities [2] will be presented. Direction for future work will also be given.

Work supported by grants DOE DE-FG03-98DP00211, DOE DE-FG03-92ER40727, NSF DMS-9722121, and LLNL W-7405-ENG-48.

[1] Tikhonchuk et al., Presented at the 1999 Anomalous Absorption Conference.

[2] D. Pesme et al., Phys. Rev. Lett. 84, 278 (2000).

[2] Brian J. Duda and W.B. Mori, Phys. Rev. E 61, 1925 (2000).

Subharmonic Resonances of Driven Relativistic Plasma Waves: Exponential and Explosive Growth

C. Ren, D. Gordan*, E. S. Dodd, and W. B. Mori
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Subharmonic resonant beat-wave excitation of nonlinear relativistic plasma waves is studied analytically and in Particle-in-Cell simulations. We find that if the frequency separation of the lasers, $\Delta\omega$, is $2\omega_p$ or $3\omega_p$ (ω_p is the plasma frequency), then plasma waves are still excited at ω_p but they grow exponentially or explosively rather than secularly. Both of these new subharmonic resonant instabilities saturate due to relativistic detuning. The analytical growth rates and saturation levels agree with the simulation results.

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Three-Dimensional PIC Simulation of Laser-Plasma Interaction near Quarter Critical

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Abstract

Laser-plasma interactions near the quarter-critical density are inherently three-dimensional. Even for plane waves, the mixture of the two-plasmon decay and stimulated Raman scattering instabilities require 3D simulations. At this density, in the plane subtended by the laser's E field and the wave vector, k, an electromagnetic wave can decay into an longitudinal wave, i.e., electrostatic plasma wave, and a wave with both longitudinal and transverse components. On the other hand in the orthogonal plane it can only decay into a plasma wave and a purely transverse wave, i.e., an electromagnetic wave. Furthermore, at these densities a Gaussian laser pulse will self-focus differently in the two planes. We have begun to study both $2\omega_p$ and asymmetric self-focusing using 2D and 3D PIC simulations. In the $2\omega_p$ case we have been using parameters similar to those used in the work of Langdon et al. (Phys. Rev. Lett. **43**, 133-136 (1979)). In 2D PIC simulations, filamentation takes place only when the incident laser is polarized in the plane of our simulation. The simulations show that for Gaussian pulses the $2\omega_p$ and self-focusing processes are strongly coupled. Although the laser powers are much below the threshold for self-focusing, we find that the Gaussian pulses strongly self-focus in the $2\omega_p$ plane. At higher laser intensities, 3D simulations of Gaussian pulses show asymmetric self-focusing

Work supported by DOE, NSF and LLNL.

OSIRIS - A Multi-Dimensional Object-Oriented Parallel PIC Code for Modeling Laser-Plasma and Particle Beam-Plasma Interactions

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The advance in computational speed and memory now make it possible to do full scale 2D and 3D PIC simulations of laser-plasma and beam-plasma interactions. However, the increased complexity of the simulation codes and the simulated problems makes it necessary to apply modern programming approaches like object oriented frameworks to the development of these codes. We report here on our present status in developing an object-oriented parallel PIC code using Fortran 90 which we call OSIRIS. In its current state, the code contains algorithms for 1D, 2D, and 3D simulations in cartesian coordinates and for 2D simulations in cylindrically-symmetric coordinates. For all of these algorithms the code allows for a moving simulation window and arbitrary domain decomposition for any number of dimensions. The code has the option of initializing complete laser pulses inside the simulation window or of injecting them at boundary by an antenna. We are currently working on adding several boundary conditions for the electromagnetic fields and particles and on adding modules which should allow us to include ionization processes and dielectric media into the simulations. We are also working on the development of data visualization packages based on IDL for efficient postprocessing of the large amounts of data generated by our simulations. Recent 2D and 3D simulation results on the propagation of intense laser beams and charged particle beams through plasmas will be presented.

* *Work supported by NSF, DOE, and LLNL*

Stability modeling of NIF direct drive pellet designs

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We present the results from multidimensional modeling of a series of direct drive pellets designed to achieve ignition on the national ignition facility (NIF). These pellets generally consist of an inner solid pure DT layer that becomes the fuel for the pellet, a low density foam layer wicked with DT that provides a radiation barrier and the tailored adiabat ablation layer, and a pure CH mandrel that acts as both a vapor barrier and a means of controlling the adiabat of the ablation layer.

The simulations were preformed using the NRL FAST radiation hydrodynamics code. This code solves the two temperature (electron/ion) fluid equations using an Eulerian grid that models fluid instabilities well into the nonlinear regime. Multiple materials are treated with a novel partial fraction technique that keeps the materials well separated even when interfaces are highly distorted. The code includes classical Spitzer-Harm electron thermal conduction, inverse bremsstrahlung laser deposition, a table look-up equation of state, and a non-LTE (Busquet model) multigroup radiation diffusion package with opacities supplied by the NRL-STA code.

For the limited range of contrast ratios available on the NIF, the thickness of the CH layer is used as a control of the adiabat of the ablation layer. Two dimensional simulations will be presented which show the effect of the thickness of the plastic mandrel on the stability of the pellet.

Work supported by DOE and ONR.

Poster presentation preferred.

Tuesday, May 23rd, 2000

8:30 AM to 12:10 PM	**Oral Session 2** **Hydrodynamics and Implosions** ***R. J. Mason, Chair***
7:30 to 8:30 PM	**Invited Talk 2** **Hydrodynamic instabilities from the beginning to the end** ***R. Betti***
8:30 to 11 PM	**Poster Session 2**

ORAL SESSION 2

HYDRODYNAMICS AND IMPLOSIONS

Rodney J. Mason, Chair

Tuesday, May 23rd, 2000
8:30 AM

Directly Driven Richtmyer-Meshkov Experiments

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Richtmyer-Meshkov interactions are fundamental to fluid dynamics, astrophysics, and inertial confinement fusion. It is well known that the number of Richtmyer-Meshkov growth foldings is dependent on the initial two-fluid perturbation amplitude to wavelength ratio and the distance with which this two-fluid interface is pushed at a constant velocity. Consequently diagnostic resolution and finite pulse lengths limit the instability growth achievable on laser facilities. We will discuss optimization techniques for maximizing the growth foldings of laser driven Richtmyer-Meshkov interactions with specific references to directly illuminated targets for the Omega laser and the National Ignition Facility.

This work was performed under the auspices of the United States Department of Energy by the University of California Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Prefer Oral Presentation

30th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

Analysis of Unstable Structures in Laboratory Experiments to Simulate Supernova Remnants

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J.J. Carroll III, *Eastern Michigan University*

S. Gail Glendinning, Omar Hurricane, Kent Estabrook, B.A. Remington

Lawrence Livermore National Laboratory

Eli Michael, R. McCray, *JILA, University of Colorado*

Some of the experiments [1,2] that used the Nova laser facility to simulate young supernova remnants (SNRs) were designed to probe hydrodynamic instabilities. Analogous to an SNR, the laboratory experiment includes dense matter (a plastic plug) that explodes, expansion and cooling to produce energetic, flowing plasma, and the production of shock waves in lower-density exterior matter. For the instability experiments, C foam was used as the low-density matter, to allow a clear view of the contact surface by x-ray radiography. The plastic plug contained a 200 µm deep opaque layer in the middle, so that the measurement of the structures would not be confused by edge effects. Instabilities at the contact surface were seeded by imposing a 4-µm peak-to-valley, 100 µm wavelength ripple on the surface of the foam.

We obtained images of the evolution of this surface either by using a gated framing camera or by using a short-pulse backlighter. The images show the development of structures as small as the resolution of the instrument (10 µm). We analyzed the data by defining an interface corresponding to a constant optical depth and then Fourier transforming the interface location. This provides evidence of instability growth and strongly nonlinear behavior. These results will be presented and discussed.

1. R.P. Drake, et al. Phys. Rev. Lett. 81, 2068 (1998).
2. R.P. Drake, et al., Phys. Plasmas, May (2000)

Work supported by the U.S. Department of Energy both directly and through the Lawrence Livermore National Laboratory

Laser-Driven Burnthrough Experiments on OMEGA

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Abstract

Burnthrough [1] experiments are conducted on spherically imploding capsules containing a buried Si-doped signature layer to study the Rayleigh–Taylor (RT) hydrodynamic instability in direct-drive implosions. The targets are irradiated by the 60-beam OMEGA laser system with shaped pulses having peak intensities of 6 x 10^{14} W/cm^2, and time-resolved x-ray spectroscopy is used to determine the onset of the Si K-shell emissions. In recent experiments the burnthrough electron temperature was determined to be ~750 eV from the measured line ratios of Si K-shell transitions [2]. The burnthrough electron temperature is used in the postprocessor model to define the burnthrough time. Since the measured electron temperature is higher than the previously used temperature of 200 eV [1], the burnthrough time is now simulated by taking into consideration both the RT growth of the spikes and the ablation of the material from the tip of the spikes to the ~750-eV isotherm. The model also includes imprint spectra obtained from two-dimensional simulations. Results from the model are compared with experimental burnthrough times.

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[1] D. K. Bradley, J. A. Delettrez, and C. P. Verdon, Phys. Rev. Lett., 68, 2774 (1992); J. Delettrez, D. K. Bradley, and C. P. Verdon, Phys. Plasmas 1, 2342 (1994).

[2] S. P. Regan et al., "Spectroscopic Analysis of Electron Temperature in Laser-Driven Burnthrough Experiments," presented at the Atomic Processes in Plasmas Conference, Reno, NV 19–23 March, 2000.

Prefer oral session.

Two-Dimensional Simulations of Cryogenic Deuterium Foil Acceleration for NIF Instability Experiments

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Abstract

Two-dimensional simulations using the Eulerian code *SAGE* are presented for proposed stability experiments on the National Ignition Facility (NIF). The basic scenario involves the acceleration of a directly driven cryogenic deuterium foil of 200- to 500-μm thickness through a distance of ~1.5 mm in order to explore the Rayleigh–Taylor instability from the linear growth phase to the saturated growth regime. A ring of four NIF clusters, each containing four beams, is assumed, with the angle of incidence preferably 23.5°. Within each cluster, each beam may be given a different pointing to optimize the drive uniformity over the full range of motion. All beams have the same temporal shape and are modeled using 3-D ray tracing.

The simulations are used to look for 2-D effects, including the geometric distortion of the foil and the possibility of heat conduction to the rear through the region between the accelerated foil and the unaccelerated target. Variations in parameters including the target thickness and the laser spot size, spatial profile, temporal pulse shape, and beam pointing are considered in order to optimize the design and produce a target with a uniformly accelerated central portion. Comparisons with 1-D simulations are included.

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.

Prefer oral session.

Results of Two-Dimensional Simulations of Implosions of DD-filled CH Shell Targets on the OMEGA Laser

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Abstract

Over the past two years several implosion experiments were carried out on the 60-beam OMEGA laser in which DD-filled CH shells (some with a CHTi layer imbedded) were irradiated with various laser pulse shapes and smoothing conditions. Target CH-shell thicknesses varied from 20 μm to 27 μm with DD-fill variations from 3 to 20 atm, sometimes mixed with ^{3}He. Two pulse shapes—a 1-ns square pulse and a 2.5-ns pulse with a 10% 1-ns foot—with and without SSD provide several levels of laser imprint. Diagnostics measured neutron yields, fuel ion temperatures, fuel ρR, and shell ρR. Simulations for some of these experimental conditions were carried out with the 2-D hydrocode *ORCHID*. Two types of laser illumination nonuniformities are included in these simulations: the single-beam nonuniformity and the nonuniformity caused by the power imbalance between beams, mostly in low-order modes. The effect of each type of nonuniformity on target performance is discussed. Results are compared with the experimental results. The degradation of target performance due to laser nonuniformity is analyzed by comparing the 2-D results with those of 1-D 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.

Prefer oral session.

One-Dimensional Simulation of the Effects of Unstable Mix on Neutron and Charged-Particle Spectra from Laser-Driven Implosion Experiments

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Abstract

The effects of Rayleigh–Taylor flow in recent laser-driven implosion experiments are simulated in one dimension by the hydrocode *LILAC*. Mix is modeled as a diffusive transport process affecting material constituents, thermal energy, and turbulent mix-motion energy within a growing mix region whose boundaries are derived from a saturable, linear multimode model of the Rayleigh–Taylor instability. The linear growth rates and the feedthrough coupling between perturbations of different unstable interfaces are obtained analytically in terms of the one-dimensional fluid profiles. Mode evolution proceeds according to equations applicable to all phases of acceleration and the effects of geometrically converging, compressible flow are taken into account. Simulated mix-diagnostic signals include time-resolved energy spectra of neutrons from core fuel and/or embedded deuterium shell layers and the energy spectra of charged primary and secondary products of nuclear reactions. The mix modeling within *LILAC* allows the effects of the fuel–pusher mix on burn history, neutron source temperature, and charged-particle energy spectra to be characterized and identified in data from implosion experiments.

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.

Prefer oral session.

Status of the Los Alamos ICF high convergence implosion campaigns at the Omega laser facility

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J.D. Colvin, S.M. Pollaine and R.E. Turner, *Lawrence Livermore National Laboratory, Livermore, CA*

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The Inertial Confinement Fusion Program has as its goal, ignition and burn of a mixture of hydrogen isotopes, usually deuterium and tritium (DT). In order to do this successfully the fuel must be heated to a fusion temperature and compressed to a fuel thickness great enough to trap alpha particles from the burn. This allows the fuel to self-heat and raise the temperature high enough to burn the fuel efficiently. To accomplish all this at the energies that will be available at the National Ignition Facility (NIF) being constructed at the Lawrence Livermore National Laboratory, targets must be designed to reach a convergence ratio of about 30-35. The convergence ratio (CR) is defined as the ratio of the initial target radius, where the drive radiation is applied, to the final radius of the compressed fuel. Reaching this high convergence with good performance is one of the last major goals required for successfully obtaining ignition at the NIF. In order to successfully reach high convergence, we have been testing two types of targets, single- and double-shell designs. A single-shell design is the mainline target for reaching ignition, but it requires a frozen fuel layer, which is difficult and expensive to produce. A simpler double-shell design can use high-pressure gaseous fuel inside an inner shell that is strong enough to hold the pressure. The double-shell design is less efficient, but advantageous in simplicity of fabrication as well as simplicity of the laser pulse shape.

Experimental results from recent ICF high convergence implosions at the Omega laser are presented. Results from both single shell and double shell implosion experiments will be discussed. Promising results from the reduced absorption double shell design, which follows 1-D radiatively driven hydrodynamics simulations in the high convergence range will be discussed. In order to understand the performance of high convergence single-shell targets better, we have designed new diagnostic techniques to determine the mixing of dopant shell material into the fuel. Recent Omega experiments which look at imaging and spectroscopy of a titanium or chlorine doped shell are discussed. If the dopant material mixes into the central fuel region, it will get hotter than without mixing. This can be detected with X-ray imaging and spectroscopy; and the imaging may tell us the spatial distribution of the mixing. Hydrodynamic simulations have been done for these high convergence targets and we show comparison of experimental data with the simulations. The designs achieve convergence ratio of 10 to 30, by varying the amount of deuterium gas fill in the central region.

[X] Oral session preferred

High-convergence indirect-drive implosions on OMEGA in the absence of argon fuel-dopant

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Recent experimental results of high-convergence indirectly–driven implosions in cylindrical hohlraums have shown a factor-of-two-to-three discrepancy between observed and simulated primary neutron yields. However, moderate convergence implosions (•10) have repeatedly shown good agreement between predicted and observed neutron yields. A number of scenarios are possible which could help explain the discrepancy at higher convergence. These candidate sources of yield degradation include target fabrication imperfections, laser power imbalance, and underestimating surface roughness-induced instability. Another possible explanation is a shortcoming in our modeling of the behavior of the argon-dopant in the capsule fuel near peak burn. LANL has previously reported discrepancies in their high-convergence implosion series with tetrahedral hohlraums between the Ar and no-Ar cases where unexpectedly large yield degradation was observed in the presence of argon.* In our series of high-convergence implosions at LLNL we have routinely used between 0.05 and 0.1 atm Ar dopant in the fuel, regardless of the deuterium fill. Thus, the lower convergence implosions at 50 atm DD fill have relatively less atomic concentration of Ar and are expected to be less sensitive to a possible error in our modeling of Ar-dopant compared with the higher convergence implosions (10 atm DD fill). Intrigued by the results of the LANL experiments, we are conducting an experimental effort to address whether the presence of Ar is a significant source of anomalous yield degradation in high-convergence implosions in cylindrical hohlraums. We report on these results and provide an update on our high-convergence implosion database.

* Jon Wallace, private communication (1999).

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

Scaled Targets for the National Ignition Facility*

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L. J. Suter, and A. B. Langdon
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In the start-up phase of the National Ignition Facility (NIF), currently under construction at Lawrence Livermore National Laboratory (LLNL), it is likely that there will be a time during which it is useful to do experiments with 96 of the eventual 192 laser beams. These will provide a total power of ~300 TW and energy ~900 kJ. Scaled-down versions of the standard Scale 1.0 NIF ignition targets are being designed to determine what experiments can be performed during this phase. These targets utilize mixed material hohlraum walls to maximize the energy delivered to the capsule. Viewfactor calculations indicate acceptable symmetry with 96 beams and the high-albedo hohlraum wall.

At Scale 0.6, using 140 TW of laser power at energy 355 kJ, a target has been designed that is hydrodynamically similar to the Scale 1.0 design. This target has a polyimide ablator doped with germanium, and has Rayleigh-Taylor (RT) growth during both the acceleration and the deceleration phases similar to the Scale 1.0 NIF target. By varying the dopant concentration, the RT growth in simulations can be made very similar to that of the full scale, or more unstable, or less unstable. Experiments with these targets should allow detailed verification of the RT modeling in the full-scale ignition targets. Hot spot formation is also replicated very well. At both Scale 1.0 and Scale 0.6, the hot central gas conductivity heats about ten times its own mass to form the hot spot.

The plasma density is slightly higher than at Scale 1.0, perhaps because of closure of the laser entrance hole (LEH); the electron temperature is slightly lower than at Scale 1.0, probably because the spot size at best focus is larger in this design. Preliminary analyses suggest that at Scale 0.6, backscatter and filamentation gains are marginally nonlinear. Hence, plasma simulations (currently underway) and experiments, that study the effects of spatial and temporal laser beam smoothing, are also of interest at this scale.

A target with a beryllium ablator doped with 0.9% copper has also been designed at Scale 0.9. This design uses 250 TW and 900 kJ, and yields 10.7 MJ of energy, ***provided all*** components of the experiment (laser, target, etc.) operate at the upper limits of current expectations, including untested mixed-material wall. Assessments of the Rayleigh-Taylor growth and of the laser-plasma interactions at this scale are currently underway, and will be presented along with the Scale 0.6 analyses.

Prefer Oral Session

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

Exploring the upper limits of NIF multi-keV source efficiency

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Lawrence Livermore National Laboratory

Previous theoretical studies, supported by experiment, indicate that NIF will be able to efficiently produce multi-keV x-rays using underdense sources. That work was limited to pulse lengths ~2ns and powers of 60TW. Here we present theoretical studies that examine the scaling of targets irradiated with longer pulses (up to 6ns) and at higher powers (up to 700TW). Our simulations of the highest power sources indicate remarkably high instantaneous multi-keV efficiencies. For example we calculate that an ~7mm diameter Be container, filled with .01g/cc of germanium, and irradiated at 300TW for 6ns, will radiate ~30% of the absorbed laser energy as K-shell x-rays (~10keV). The peak, instantaneous conversion efficiency approaches 50%. We show why these high outputs are plausible and discuss the ways in which such targets are pushing the boundaries in several areas of physics.

Work performed under the auspices of the United States Department of Energy, by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48

Perfer Oral

INVITED TALK 2

Hydrodynamic Instabilities from the Beginning to the End

Riccardo Betti
Laboratory for Laser Energetics
University of Rochester

Tuesday, May 23rd, 2000
7:30 PM

Alexander Velikovich, Chair

Hydrodynamic instabilities from the beginning to the end

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Abstract

In inertial confinement fusion implosions, hydrodynamic instabilities develop through three stages: seeding, acceleration phase and deceleration-phase. We present a comprehensive review of the instability theory through all three stages with emphasis on the less known aspects of the theory such as the rear surface perturbation feedout and the deceleration phase growth rates. The feedout problem in an accelerated planar foil has a simple analytic solution that is compared to the results of numerical simulations as well as to the latest experiments carried out at LLE. The deceleration phase is studied both theoretically and numerically for the model problem of a decelerated planar foil compressing a low-density shocked material against a rigid wall. Though quite different from the ICF case of an imploding spherical shell, the planar problem presents many similarities. Furthermore, the planar theory of the deceleration phase can be easily tested experimentally by compressing a "sandwich" target consisting of two planar foils of different masses confining a low-density foam. The lighter foil can be accelerated by direct laser irradiation, while the heavy one plays the role of the rigid wall. From the theoretical standpoint, the deceleration-phase instability of a planar foil presents several interesting features. First, the initial rear-surface perturbation growth is not exponential because multiple shock reflections from the rigid wall induce successive Richtmyer–Meshkov instabilities with a linear growth. As the foil decelerates, the linear growth is followed by an exponential growth (the RT phase). However, because of the finite ablation velocity and density-gradient scale length on the inner foil surface, the growth rates are reduced with respect to the classical value. Furthermore, the rapid density increase of the decelerating foil leads to an additional reduction of the perturbation growth as the mass under the rippled inner surface must remain constant.

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POSTER SESSION 2

Tuesday, May 23rd, 2000
8:30 to 11 PM

Simulation of Laser Plasma Filamentation Using Adaptive Mesh Refinement

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We describe an approach for using adaptive mesh refinement (AMR) in the simulation of laser plasma filamentation. The ability to locally adapt the computational grid in such calculations enables the use of fine grids in highly filamented regions of the plasma with coarser gridding in regions of low or no light intensity. Computational efficiency is therefore enhanced by reducing execution time and memory requirements

In our model, the plasma motion is described by a system of fluid equations expressing conservation of mass, momentum and total energy. The system is discretized using a second-order Godunov method. The forward light propagation is modeled using a factored Helmholtz equation, and is discretized using Fourier transformation to diagonalize the transverse pseudodifferential operator as is currently done in the pF3D code. Since the use of FFTs limits the applicability of AMR, we also consider a paraxial approximation that facilitates the use of local finite differences.

We employ a block-structured AMR approach in which the computational domain consists of a hierarchy of refinement levels, each of which is a disjoint union of rectangular patches. The integration of the coupled plasma fluid and light systems is accomplished through the coordinated integration of the respective models on each refinement level with periodic synchronization across levels. The location of the refined grids changes dynamically during the calculation based on user-prescribed criteria on the plasma and/or light variables. Parallel processing is exploited by distributing the grid patches on each refinement level across processors. Implementation of the algorithm is facilitated by the use of the SAMRAI (Structured Adaptive Mesh Refinement Applications Infrastructure) system, which is a C++ class library that supports the development of structured AMR algorithms. We will present some preliminary results obtained by our research code ALPS (Adaptive Laser Plasma Simulator) that demonstrate the adaptive speedup obtained by our algorithm relative to equivalent uniform grid calculations.

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

3D PIC simulations of the Weibel instability and the nonlinear structure of the self-generated magnetic field

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The Weibel instability is a fundamental mechanism to understand the transport of electron beams through plasmas and the generation of quasi-static magnetic fields by anisotropic distribution functions. Furthermore, 2D particle-in-cell (PIC) simulations have shown that in the nonlinear regime of the instability strong filamentation of the driving beam also occurs. In this paper, we present results from 3D and 2D OSIRIS PIC runs. Our simulations show that in 3D the lifetime of the density cavities is much shorter than in 2D. Stronger particle heating is also observed in 3D. The structure of the self-generated magnetic field is examined in detail. Estimates of the energy transferred to the magnetic field are compared with the numerical results. Generation of helicity domains is demonstrated

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Relativistic Focusing and Ponderomotive Channeling of Intense Laser Beams in Plasmas*

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The ponderomotive force associated with an intense laser beam expels electrons radially and can lead to cavitation in plasma. Relativistic effects as well as ponderomotive expulsion of electrons modify the refractive index. An envelope equation for the laser spot size is derived, using the source dependent expansion method with Laguerre-Gaussian eigenfunctions, and reduced to quadrature. The envelope equation is valid for arbitrary laser intensity within the long pulse, quasi-static approximation and neglects instabilities. Solutions of the envelope equation are discussed in terms of an effective potential for the laser spot size. An analytical expression for the effective potential is given. The solutions are compared with previously obtained results neglecting ponderomotive channeling as well as with simulations.

*Work supported by DoE & ONR

Poster

Simulation of absolute emission from Nike targets

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We used the 1D, 2-temperature version of the NRL code FAST1D[1] to compute the absolute outgoing flux from the front (toward the laser) surface of some Nike planar targets. These results are compared directly (without post-processing) to absolute measurements (see posters by Weaver *et al*, and by Deniz *et al*). The purpose of this comparison is to check the validity of FAST1D as a tool for the design of targets using radiation to preheat the ablator[2]. The code solves the hydrodynamic equations of compressible flow in conservation form using the explicit Flux Corrected Transport (FCT) finite-volume method[3], with a sliding zone Eulerian formulation. The radiation energy source and sink terms are computed at each timestep by an efficient multigroup variable Eddington-factor diffusion package. The groups are carefully chosen for each target to ensure proper resolution of the resulting time integrated spectra. Opacities are computed in LTE with the STA code[4], and non LTE effects are incorporated with Busquet's model[5, 6]. The laser intensity time-profile was taken in each case from the experimental files. The massive targets consisted of plastic (CH), Al, W and Au. The agreement with measurements ranges from a factor of 2 for high Z to a factor of 5 for CH. Considering that the computations are planar 1D- i.e no provision is made for temperature gradients in the target plane-, the simplicity of the non LTE model, and the difficulty of the experiment, this agreement is quite satisfactory. This work is supported by the USDOE under a contract with the Naval Research Laboratory.

[1] J. H. Gardner, A. J. Schmitt, J. P. Dahlburg, C. J. Pawley, S. E. Bodner, S. P. Obenschain, V. Serlin and Y. Aglitskiy, *Phys. Plasmas,* **5**, 1935 (1998).

[2] D. G. Colombant, S. E. Bodner, A. J. Schmitt, M. Klapisch, J. H. Gardner, Y. Aglitskiy, A. V. Deniz, S. P. Obenschain, C. J. Pawley, V. Serlin and J. L. Weaver, *Phys. Plasmas,* **7**, to be published(2000).

[3] J. P. Boris and D. L. Book, *J. Comp. Phys.,* **11**, 38(1973).

[4] A. Bar-Shalom, J. Oreg, M. Klapisch and T. Lehecka, *Phys. Rev. E,* **59**, 3512 (1999), and references therein..

[5] M. Busquet, *Phys. Fluids B,* **5**, 4191 (1993).

[6] M. Klapisch, A. Bar-Shalom, J. Oreg and D. Colombant, *Phys. Plasmas,* **5**, 1919 (1998)

Time Resolved, Absolutely Calibrated Observations of Soft X-rays with the Transmission Grating Spectrometer at the Nike Laser Facility

J. L. Weaver,[1] G. Holland,[2] U. Feldman,[3] J. F. Seely,[3] C. M. Brown,[3] V. Serlin,[4] A. V. Deniz,[5] M. Klapisch,[6] A. Mostovych,[4] D. Colombant,[4] S. Obenschain[4]

A new transmission grating spectrometer has been commissioned at the Nike laser facility to provide absolutely calibrated, time-resolved spectra in the wavelength range from 10 to 150 Å. Currently, the system has measured the spatially integrated soft x-ray flux for various target materials (CH, BN, Kapton, Au, and W) with different laser powers and laser spot sizes. This new spectrometer is distinguished from previous transmission grating instruments by its use of two 2500 l/mm transmission gratings with two separate detector systems: a soft x-ray streak camera and a detector system that combines absolutely calibrated Si photodiodes and a CCD camera with a phosphor scintillator. The photodiodes provide modest temporal resolution (~1 ns), high sensitivity over discrete wavelength bands ($\Delta\lambda = 6.2$ Å), and an absolutely calibrated responsivity. The CCD camera is used to determine the location of each photodiode and the relative (time-integrated) intensity distribution over the photodiode array. The spectrometer components have been calibrated at the National Synchrotron Light Source at Brookhaven National Laboratory. The transmission grating spectrometer complements a set of filtered photodiodes also in use at Nike to measure the soft x-ray flux.

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Absolute Soft X-ray Emission Measurements and Calculations on the Nike Laser

A. V. Deniz, SAIC, J. L. Weaver, NRC/NRL Research Associate, M. Klapisch, ARTEP, D. G. Colombant, Plasma Physics Division, NRL, G. Holland, SFA, J. Seely, U. Feldman, C. Brown, Space Sciences Division, NRL A. N. Mostovych, S. P. Obenschain, Plasma Physics Division, NRL.

Soft x-ray emission from a thin, high-Z layer on the laser side of a fusion pellet can be used to tailor the adiabat of a laser-driven foil or pellet, and thus control the Rayleigh-Taylor (RT) instability. The x-rays heat the ablator enough to reduce the RT growth, while controlling the adiabat. This concept has been used in direct-drive, high-gain pellet designs by Colombant and Bodner[1,2]. We have begun an effort to verify the soft x-ray emission calculated by the simulations.

In our initial set of experiments, we measured the absolute soft x-ray emission from the front surface of a KrF (248 nm) laser-illuminated CH, Al, Au, or W flat target. The laser intensity is $\sim 5 \times 10^{12}$ W/cm^2 with a 4 ns flat-top pulse shape. We have fielded two types of diagnostics: transmission grating spectrometers, and filtered photodiodes with grazing incidence mirrors (see the poster by J. L. Weaver *et al*). We will present measurements with several laser power levels and target materials. We will compare these with calculations (see the poster by D. G. Colombant and M. Klapisch), and also discuss effects which affect the comparison, such as finite size and spatial profile of the laser illumination, spatial profile of the emission, and opacity of low-temperature plasma (from the laser prepulse or off-profile intensity hitting the target).

[1]D. G. Colombant, S. E. Bodner, A. J. Schmitt, M. Klapisch, J. H. Gardner, Y. Aglitskiy, A. V. Deniz, S. P. Obenschain, C. J. Pawley, V. Serlin and J. L. Weaver, *Phys. Plasmas*, **7**, to be published (2000).

[2]S. E. Bodner, D. G. Colombant, A. J. Schmitt and M. Klapisch, *Phys. Plasmas*, **7**, to be published (2000).

Prefer poster presentation.

X-Ray spectromicroscopy investigations of fast ions and hot electrons in plasmas, heated by nanosecond laser radiation with different wavelengths.

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By means of space resolved X-ray spectroscopy we have investigated the generation of fast (up to MeV) ions for various laser installations with different flux densities (10^{12} -10^{14} W/cm^2) and laser wavelengths (λ=308 nm, 800 nm,1.06 μm, 10.6 μm). The implementation of our spectroscopically determined data into the generally accepted scaling relation diagrams with the axes $q\lambda^2$ and E_{ion}, where q is the laser flux density, λ the laser wavelength and E_{ion} the fast ion energy showed a large scatter by orders of magnitude. The simultaneous use of mass spectrometry showed reasonable agreement for both methods of measurements. Non-Maxwellian X-ray spectroscopy enabled us for the first time to investigate the generation of fast ions and hot electrons by means of space resolved spectroscopy in plasma areas, where the interaction with the laser beam takes place.

Using spherically bent crystals for obtaining high-resolution, large-field, monochromatic X-ray backlighting imaging for wide range of Bragg angles.

T. A. Pikuz[a], A. Ya. Faenov[a], M. Fraenkel[b], A. Zigler[b], F. Flora[c], S.Bollanti[c], P.Di Lazzaro[c], T. Letardi[c], A. Grilli[d], L.Palladino[e], G. Tomassetti[e], A. Reale[e], L. Reale[e], A. Scafati[e], T. Limongi[e], F. Bonfigli[f], L. Alainelli[g], M. Sanchez del Rio[g],

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Abstract

The new advantages of well-known combination of a laser-produced X-ray plasma source and spherically bent crystal for the soft X-ray region backlighting scheme were experimentally demonstrated and theoretically modelling by ray-tracing package SHADOW. The X-ray source was produced by heating radiation of Ti:Sa laser (120fs, 3-5 mJ, laser flux density 10^{16} W/cm^2) or XeCl laser (1-1.3 J, 10 ns, laser flux density 10^{13} W/cm^2) with repetition 10 Hz at different solid targets (Mg, Fe, Ni, Dy, BaF_2). X-ray source spot size on the target was well localised both spatially (~20 μm) and temporally (1 ps – 10 ns, depend of used laser) and is spectrally tunable in a relatively wide range (6-19 Å). High quality monochromatic ($\delta\lambda/\lambda \sim 10^{-5}$-$10^{-3}$) images with high spatial resolution (up to ~4 μm) and in a large field of view (few mm) were obtained for different wavelengths using the same spherically bent crystal. It was demonstrated at first time that the spherically bent crystals can be sufficiently used for obtaining high-resolution, large-field, monochromatic images in a wide range of Bragg angles (θ = 40-90°); thus spherically bent crystals are universal for very wide wavelength selection, what is very important for many applications. Obtained experimental results were independently confirmed by ray-tracing modelling for different radius of crystal curvatures, Bragg angles and linear magnification of images.

Target designs of table-top X-ray lasers

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Utilizing different approaches in achieving of population inversion in X-ray region and methods of plasma creation we succeeded recently to scale X-ray lasers from Nova laser dimensions down to the size of laboratory optical table. Short-lasting burst of gain provided by transient inversion collisional scheme at ultrashort pulse laser heating allowed drastically reduce requirements for laser driver energy [1,2]. At present time LLNL and several other laboratories in the world have been successfully developing this approach. With 1 ps CPA COMET laser at LLNL delivering approximately 5-7 J of energy the lasing in the range 119-326 A was demonstrated. Anomalously high gain ~60 cm^{-1} was reported [3]. X-ray laser intensity was driven up to saturation in the recent experiments [3].

The work was performed with tight interaction of numerical and real experiments. The modeling has revealed that with previous relatively simple laser target designs only 5% of CPA laser energy have been utilized at the optimal for lasing electron densities. Methods of improvement of efficiency and as a consequence the ways of driving lasing wavelengths shorter have been discussed. We will present the numerical modeling results of ongoing experiments activities for achieving sub-100A table-top X-ray lasers.

The pulse duration of X-ray lasers for elements Z~45 has been determined in the range ~4-8 ps. We discuss also the possibilities of substantial shortening of pulse duration of transient X-ray lasers which has been important for some applications.

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

1. P.Nickles et al, PRL, Vol.78(14), p.2748, 1997
2. J.Dunn et al, PRL, Vol.80, No.13, p. 2825, 1998
3. J.Dunn et al, PRL, 2000 (in press)

Inelastic electron-ion collisions and plasma heating by inverse bremsstrahlung

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The problem of electron-ion (e-i) collisions in an intense high-frequency field has been recently examined by Fraiman et al. [1] . Their finding of a population of electrons which undergo correlated collisions due to repeated scattering on an ion in the oscillating field of the laser has been confirmed in calculations of the transport cross-section. We have also found that in a strong electromagnetic field dominant fraction of electrons contributing to the e-i cross-section undergoes large angle scattering, thus violating the basic approximation of plasma kinetic theory leading to Fokker-Planck like collision operators.

We have implemented the modified transport cross-sections into particle code and studied evolution of an electron distribution function. Modifications to the heating rates have been examined and compared with old models based on the Born approximation to the e-i scattering process.

Particle code runs in the presence of electron-electron collisions have shown existence of Maxwellian tails in addition to well known modifications of the bulk of the electron distribution function [2] due to inverse bremsstrahlung absorption. We have examined the effect of these tails on the Langmuir wave damping and Thomson scattering spectra in high-Z plasmas.

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DRACO— A Multidimensional Hydrocode for ICF

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Abstract

A program to develop a new multidimensional code is underway at LLE. *DRACO* is an Arbitrary Lagrange-Eulerian (ALE) code designed to run in one, two, and three dimensions in cartesian, cylindrical, and spherical geometries. The code includes normal-incidence laser energy deposition, flux-limited Spitzer thermal conduction, multigroup radiation transport, mixed-material equation of state using *SESAME* or Wisconsin tables, and interface tracking in two dimensions. *DRACO* has been tested on a variety of problems involving the growth of instabilities. Recent emphasis has been on simulations of burnthrough experiments and comparisons between two and three dimensions for Richtmeyer–Meshkoff growth rates through an extension of the material-tracking techniques to three dimensions. This paper will present some of the tests on *DRACO*, show results from the burnthrough simulations, and address instability growth in two and three dimensions.

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.

Prefer poster session.

Numerical modeling of heating and compression of spherical shell targets with a low-density coating using a two-beam laser

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We present the results of two-dimensional numerical simulations of heating and compression of spherical shell targets with a low-density coating («blanket») using two beams of a powerfull Nd-laser with energy 100 kJ and pulse duration of 3 ns. This type of target design is discussed in [1].

The distribution of laser flux was $q(r,t)=q_1(t)*q_2(r)$, where $q_1(t)$, right-angled triangle, and 1) $q_2(r)=C/\sqrt{(1-r^2/R_f^2+0.0001)}$, 2) $q_2(r)=C/\exp(r^2/R_f^2)$, R_f,C- parameters.

The shell target was filled with a DT gas with initial density of 0.1-1 mg/cm^3 and targets with DT-ice layer at inner side of working shell. The shell thickness varied from $\Delta=R_0-R_1=10$ to 40 µm. Inner radius was $R_1=0.9$ mm. Outer layer (»low-density blanket») had the density 2 mglcm^3 and outer radius $R_f= 1.54$ mm. The numerical simulations were performed using our 2D Lagrange code «ATLANT_C» [2]. We have calculated the compressed fuel parameters and neutron yields from such targets.

The report presents the results for 3 types of laser targets:

1) a spherical «working shell» ($\rho=1$ g/cm^3) with thickness 10-40 µm and outer low-density blanket at $R_0<r<R_f$,

2) a shell with a ring of the density of $\rho=1$ g/cm^3 located at the equator at $r> R_0$ («Saturn ring»). The other target parameters were the same as in 1),

3) outer surface of the working shell with a «relief»: $R=R_0+a*\cos\theta$, where a=3-5 µm. The other target parameters were the same as in 1),

The variants 2) and 3) modeled the hydrodynamic compensation effect of non-uniformities of laser energy deposition in targets [3,4]. Our numerical calculations show that it is possible to reach high compressed fuel parameters (density ≥ 50 g/cm^3, temperature ≥ 5 keV) in such target designs.

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2P13

Further progress towards high-coupling efficiency, high yield NIF capsules

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This paper discusses recent developments in our ongoing exploration of the limits of NIF capsule coupling.

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

Prefer poster

Implosion target surrogacy studies on Omega for the National Ignition Facility: backlit foamballs and thinshells[†]

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Several symmetry diagnostic techniques in indirectly-driven cylindrical hohlraums have been developed over the past several years for eventual application to the National Ignition Facility (NIF). These methods include symmetry implosion capsules,[1] backlit aerogel foamballs,[2] reemission balls,[3] and backlit thinshells.[4] Recent attention has focussed on the backlit thinshells as a promising means for detecting higher-order Legendre flux asymmetries, e.g., P6 and P8, which are predicted to be important sources of performance degradation on the NIF at levels greater than 1%.[4] A key property of backlit thinshells is the strong amplification of modal flux asymmetry imprinting with shell convergence. Provided coupling with lower-order modes is weak, a higher-order shell distortion will be representative of an imposed higher-order flux asymmetry. A simple analytic model is presented which explores the degree of linearity of the shell response to an imposed flux asymmetry. Using a rocket model, the family of incompressible thinshell implosions can be described in terms of a single dimensionless

$$P_A \cong a(\varepsilon;t)\cdot\frac{\mu_0 r_0^2}{r^2(\varepsilon;t)}\,e^{v(\varepsilon;t)/v_{ex}} \qquad (1)$$

parameter $\varepsilon=v_{ex}t_0/r_0$, where v_{ex} is the exhaust velocity, $t_0=m_0/(\mathrm{d}m/\mathrm{d}t)$ is an areal mass loss timescale and r_0 is the initial shell radius. An expression is derived relating the equilibrium acceleration history $a(\varepsilon;t)$ to the ablation pressure P_A:

where v is the shell speed, and μ_0 is the initial shell areal density. Except near t=0 the dependence of P_A on the acceleration is implicitly nonlinear through Eq. (1). The degree of nonlinearity versus time is investigated for parameter regimes of experimental interest, i.e., a prescribed value of ε. Given a measured shell trajectory, the ablation pressure history can be constructed from Eq. (1) and compared with the simulated ablation pressure history. A related procedure has been demonstrated previously for foamball experiments on Omega.[5] By definition, a legitimate surrogate target must have a pressure asymmetry history which roughly mimics the simulated ablation pressure asymmetry seen by a NIF capsule. Depending on the composition of the surrogate target, the capsule blowoff environment may alter the hohlraum environment to the point of significantly affecting the flux asymmetry seen at the ablation front. The degree of surrogacy of backlit foamball targets and thinshell capsules will be assessed and compared.

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

30th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

Design of hydrodynamically driven, radiative-precursor shock experiments

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Many astrophysical systems, including for example supernova remnants and jets, produce radiative-precursor shock waves. In a radiative-precursor shock, radiation from the shock ionizes and heats the medium ahead of it. The simulation of such systems requires that one treat both the emission and the absorption of the radiation, in contrast to some simpler astrophysical problems that involve only radiation cooling. This motivates our design of experiments in which a hydrodynamic system produces a radiative-precursor shock, both as a direct demonstration of the phenomenon and as a test case for astrophysical simulation codes. An important goal of this effort is to produce an experiment that can be modeled without needing to implement laser absorption physics, itself a source of problems, into the astrophysical code.

In this poster, we will describe our design of such experiments, and will show some diagnostic test results if they are available. The experimental design is based on a past experiment[1,2] that used the Nova laser facility to simulate young supernova remnants (SNRs). Analogous to an SNR, the laboratory experiment includes dense matter (a plastic plug) that explodes, expansion and cooling to produce energetic, flowing plasma, and the production of shock waves in lower-density (aerogel) exterior matter. For the new experiment, the components and the laser-irradiation conditions are chosen so that the driven shock will produce an observable radiative precursor. Astrophysical modeling will begin with the properties of the shocked plastic layer, after the end of the laser pulse but before the shock emerges from the plastic. If available, modeling results will also be shown.

1. R.P. Drake, et al, Phys. Rev. Lett. 81, 2068 (1998).
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Work supported by the U.S. Department of Energy both directly and through the Lawrence Livermore National Laboratory

Observation of Stimulated Brillouin Scattering in Single Hot Spot Laser Plasma Interaction Experiments

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Abstract

We present experimental observations of stimulated Brillouin scattering (SBS) from recent single hot spot (SHS) laser-plasma experiments conducted on the TRIDENT laser at Los Alamos National Laboratory (LANL). These experiments are unique in that a near diffraction-limited interaction beam is passed through a quasi-homogeneous plasma. The intensity profile of the SHS interaction beam has the characteristic size of a single speckle found in large diameter, high-intensity laser beams. Thus, these experiments measure the effect of a single speckle, or hot spot, rather than the effect of many interacting speckles. The experimental setup is described. Results are correlated for various target materials, electron densities, and interaction beam intensities. Trends are plotted and conclusions are drawn from the observations. Future experiments involving the SHS interaction beam are outlined.

Poster presentation preferred

Numerical Simulations of the SSD Smoothed Laser Beam Filamentation and Forward Stimulated Brillouin Scattering in Plasmas

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Abstract

In previous papers [1, 2] we studied analytically the one-dimensional spatiotemporal evolution of near-forward stimulated Brillouin scattering (FSBS) in different regimes. As an expansion of this analysis we have developed a code that solves the paraxial light wave equation in conjunction with the ion-acoustic wave equation in two-dimensional Cartesian geometry. The forward-scattered light from an SSD-smoothed laser beam is studied as it propagates through homogeneous plasma. The bandwidth corresponding to the 3-GHz SSD modulation frequency on OMEGA gives rise to the possibility of the forward SBS, which leads to energy transfer between speckles. The growth rate of the FSBS is higher than that of the beamlets filamentation [3], which leads to reduced efficiency of SSD on this frequency.

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.

[1] C. J. McKinstrie, J. S. Li and A. V. Kanaev, Phys. Plasmas **4**, 4227 (1997).
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[3] R.W. Short, 29th Annual Anomalous Absorption Conference, Monterey CA, June 14–18th (1999).

Prefer poster session.

Speckle statistics in self-focusing smoothed laser beams

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The statistics of smoothed laser beams before interacting with a plasma is characterized by the transverse speckle size (width w), the average laser intensity $\langle I \rangle$, and the intensity of the most intense speckle $I_{\max}$. If the power $P(\propto I)$ of speckles with $I \leq I_{\max}$ is beyond the critical power P_c, a smoothed laser beam is subject to self-focusing (SF). In particular, when average-intensity speckles are close to or beyond the SF threshold, strong nonlinear interaction with the plasma leads to a breakup into smaller spatial structures together with enhanced angular spreading and large temporal bandwidth. This effect has been observed in simulations [A. Schmitt, B.B. Afeyan, Phys. Fluids 5, 504 (1998), A. Maximov et al. Proceedings of the 1st IFSA, Bordeaux 1999] and has received the name of "self-induced smoothing" (SIF). It corresponds to an improved spatial and temporal smoothing due to the succesively smaller speckle sizes and the diminishing contrast.

We have carried out simulations using two codes, with and without the restriction to the paraxial approximation for the light propagation. We studied in detail the speckle statistics. Both the number of speckles in the interaction volume and the shape of the speckle distribution function change in time due to breakup, preferentially in the rear part of the interaction volume. While the speckle size of the incident smoothed beam was homogeneous, a broader population of speckle sizes appears due to self-induced smoothing. However, the simulations show that the abundance of speckles scales inversely with the average value of the speckle volume. Particular attention is payed to the dynamics and an eventual state of the speckle distribution function depending on the above mentioned parameters.

30th Anomalous Absorption Conference

Modeling of the Competition of Stimulated Raman and Brillouin Scatter in LULI Multiple Beam Experiments

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Multiple laser beam experiments with CH target foils at the LULI facility [Baldis, *et al.*, Phys. Rev. Lett. **77**, 2957 (1996)] demonstrate anti-correlation of stimulated Brillouin and Raman backscatter (SBS and SRS). Detailed Thomson scattering diagnostics show that SBS always precedes SRS, that secondary electron plasma waves can accompany SRS appropriate to the Langmuir Decay Instability (LDI), and that with multiple interaction laser beams the SBS direct backscatter signal in the primary laser beam is reduced while the SRS backscatter signal is enhanced and onsets earlier in time. Analysis and numerical calculations are presented that evaluate the influences of local pump depletion in laser hot spots due to SBS, of mode coupling of SBS and LDI ion waves, and of optical mixing of secondary and primary laser beams on the competition of SBS and SRS. The calculations take into account simple models of the laser beam hot spot intensity probability distributions and assess whether ponderomotive and thermal self-focusing are significant. Within the limits set by the assumptions of the model, the calculations quantify the effectiveness of local pump depletion, ion wave mode coupling, and optical mixing in affecting the LULI observations.

*This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory through the Institute for Laser Science and Applications under Contract No. W-7405-ENG-48.

POSTER

P6 and P8 modes in NIF hohlraums*

Steve Pollaine, David Bradley, Otto Landen, Peter Amendt, Ogden Jones,
Russell Wallace, Gail Glendinning, Robert Turner, and Larry Suter
Lawrence Livermore National Laboratory

We are now running an experimental campaign on the OMEGA laser at LLE, Rochester, to detect and correct P6 and P8 flux asymmetry inside scale 2 to 3 vacuum hohlraums that approximate the conditions of a NIF hohlraum during the foot of the NIF drive. We need to diagnose P6 and P8 to within 1% for ignition on NIF. The linearity and sensitivity of thin imploding shells to flux asymmetry should make it possible to achieve this degree of accuracy. These experiments use a point projection backlighter with 4.7 KeV x rays that projects images of thin Ge-doped shells with a resolution of 30 microns. Distortions in the limb of the capsule from drive asymmetries can be measured to an accuracy of 2 microns. We present preliminary results from this campaign.

*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.

Diffusion of light in a smoothing mirror laser

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A new method is proposed for calculating the divergence of a smoothing mirror laser [1]. The results show that the distribution of light inside the smoothing mirror laser satisfies the diffusion equation. The angular distribution of an output energy is described by the Bessel function of order zero.

[1] S. L. Popyrin, I. V. Sokolov, A. V. Yurkin, Optics Commun. **164**, 297 (1999)

Prefer poster session

Wednesday, May 24th, 2000

8:30 AM to 12:10 PM	**Oral Session 3** **Ultra Intense, Short Laser Pulse Interactions** ***S. P. Hatchett, Chair***
7-11 PM	**Banquet**

ORAL SESSION 3

ULTRA INTENSE, SHORT LASER PULSE INTERACTIONS

Stephen P. Hatchett II, Chair

Wednesday, May 24th, 2000
8:30 AM

Powerful Subpicosecond Beam Propagation in High Density Microcapillary Plasmas

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Abstract

We will present results on the laser beam propagation through the high density plasma in microcapillaries at the conditions close to those for soft x-ray laser gain generation. We will discuss the laser beam propagation as a function of laser and plasma parameters. We have found that absorption of the laser beam is a very sensitive function of the microcapillary diameter: as the diameter decreases, the absorption rapidly increases. Also, by increasing the prepulse energy, which creates the initial plasma (preplasma) in the microcapillary, the absorption increases. Both of these effects are practically the same for LiF and B_2O_3 microcapillaries. The influence of the "main" laser pulse (pumping pulse) on the plasma transmission (absorption) depends on the pulse duration and intensity. At certain delay of "injection" of an ultra-high power subpicosecond pulse, it rapidly ionizes preplasma without any significant change of its temperature. Therefore after the laser pulse, plasma transmission is rapidly restored to the same transmission as before the pulse. In the case of a nsec type laser pulse, preplasma is ionized due to the heating process, hence the change of the plasma transmission is a much longer lasting process. We have also found that increasing subpicosecond laser intensity above certain value could lead to increase the length of its propagation, which has very important implications for gain saturation and the development of much shorter wavelength x-ray lasers.

*For Oral Presentation

Ultrafast neutron generation by Coulomb explosions of deuterium clusters

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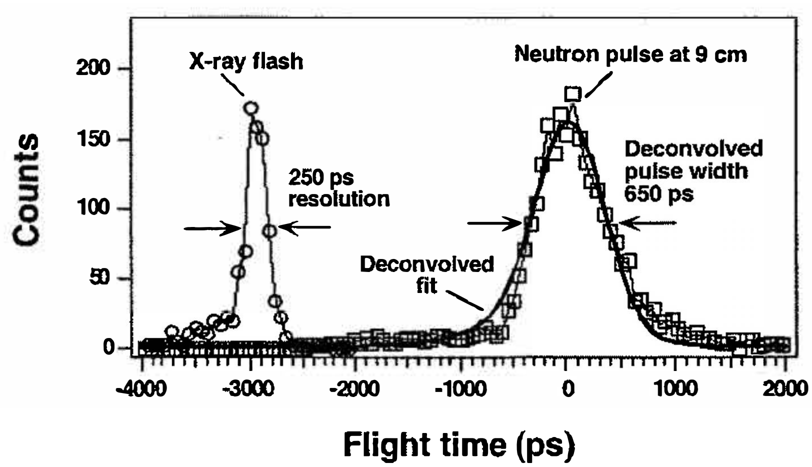
It has been shown that when clusters of deuterium atoms are irradiated with intense, femtosecond laser pulses, conditions can be created which are sufficient to fuse deuterium atoms, producing DD (2.45 MeV) fusion neutrons. While high Z clusters exhibit a "plasma-like" behavior, the space charge forces in small to moderately sized deuterium clusters (< 10 nm diameter) are not sufficient to confine the electrons to the cluster body. If the strong laser field can expel the electrons on a time scale before the cluster ions begin to move, the deuterium ions will be ejected with substantial kinetic energy via a Coulomb explosion. Measurements have shown that plasmas with mutli-keV ions are formed when deuterium clusters are irradiated at intensity around 10^{17} W/cm^2. These high ion energies, coupled with modest average ion density (>10^{19} cm^{-3}), produce conditions for fusion in the inertially confined plasma. Recently, we have observed the production of DD fusion neutrons in these deuterium cluster plasmas, with a yield of >10^4 neutrons/shot using 100 mJ, 35 fs laser pulses.

The nature of this interaction suggests that the neutron pulse width should be very short. We will present data showing the measured pulse width at different distances from the target (9 cm shown in figure below). Extrapolating back to the source, the pulse width is expected to be <500 ps. This has possible applications in the study of the dynamics of neutron damage. We will also present data on the dynamics of the Coulomb explosion, measuring the neutron yield scaling with cluster size. The physics surrounding the laser cluster coupling and cluster Coulomb explosion will be discussed. In addition, we will discuss the prospects for scaling this experiment to higher neutron yields.



Computational relativistic hydrodynamics as applied for simulations of strong laser pulses and relativistic cumulative jets.

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Relativistic computational hydrodynamics is usually believed to be applicable only for astrophysical simulations. The applications for more vital problems of high density energy physics have not been considered so far.

There are some reasons in favor of the development of mathematical models, which are based on the governed equations of the relativistic hydrodynamics, for studying the super-bright laser pulse interaction with a plasma. First, the codes, which are now commonly applied for these purposes, use the approximation of collision-less plasma and this approximation fails as applied for comparatively long pulses. Second, if the thermal photons are in equilibrium with plasma electrons, then the electron-photon collision frequency rapidly increases with the temperature, because the photon density is $\sim T^3$. So, under the circumstances, the model of relativistic hydrodynamics coupled with the Maxwell equations for both laser and plasma electromagnetic fields seems to be not less reasonable than the commonly used ones.

Using this model we consider the problem of relativistic cumulative jet formation. In a frame of reference, moving with the laser pulse group velocity, the electrons can not penetrate to the high-intensity core of the laser pulse, so that the electron fluid flows around the pulse core. As the result the standard flow geometry for cumulative jet formation arises behind the pulse, since the axially convergent hydrodynamic flow produces a jet that rapidly moves along the axis (see [1] for a theory of cumulative jet). Such a jet is similar to one present in the scheme of flow around a plate in an ideal fluid, proposed by Efros (see [1]).

To develop a method for simulations of the relativistic electro-hydro-dynamic flows we proposed a model equation of state for a gas with a relativistic Maxwellian distribution function [2], constructed an exact Riemann solver for such an equation of state and developed a method of constructing a numerical scheme based upon Lorenz (or Galilean) invariance of the governed equations [3]. Relativistic jet propagation with Lorenz factor $\gamma = 10$ and relativistic Richtmyer-Meshkov instability were simulated as the test 1-Fluid problems.

[1].M.A.Lavrent'ev and B.V.Shabat, *Problems of Hydrodynamics and Their Mathematical Models* (in Russian). Nauka, Moscow, 1973. [2] I.V.Sokolov, H.M.Zhang and J.I.Sakai. Submitted to Astrophys J. [3] I.V.Sokolov, E.V.Timofeev, J.I.Sakai and K.Takayama. Journ. Shock Waves. 1999. V.9. P.115.

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Recent topics on the fast ignitor research at ILE, Osaka University

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Using two ultra-intense lasers, the 100TW PWM Laser and the 60TW GMII Short Pulse Laser both at the ILE, Osaka, we are performing the fast ignitor and related laser-plasma experiments as well as the theoretical approaches. The former supplies 60J on target in 600 fs at 1.053 μm wavelength and synchronizes to the GEKKO 12 smoothed green beams. The latter supplies 25J in 450fs, which synchronizes to a long pulse CPA beam.

So far, we have found the super penetration of the intense laser into overdense region both for plain and spherical targets. It occurs only when the laser is focused at a point close to but somewhat far, that is, about the Rayleigh length far, from the critical surface. Figure 1 shows a 2-D Plasma-Particle Simulation of the 100TW laser penetration above 2nc plasma.

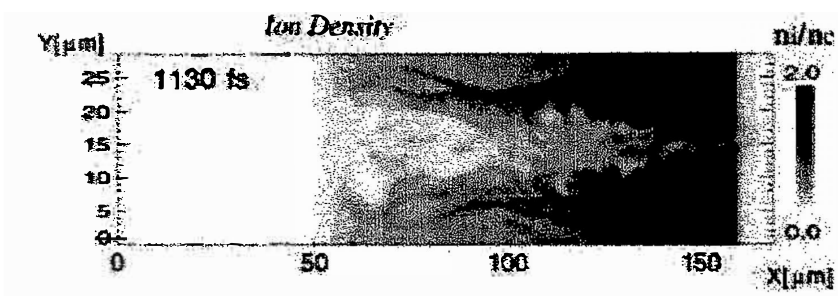

FIG.1. 2-D Plasma-Particle Simulation of the 100TW laser penetration above 2nc plasma.

Kα experiment indicates that more than 20 % of the laser energy is converted into hot electrons in the preformed plasma. The hot electrons then transport through the solid target to the rear surface, making a virtual cathode to extract and accelerate ions. We have observed thus generated 10 MeV protons.

In an underdense plasma, the forward Raman instability drives a relativistic plasma wave, of which the longitudinal field is over 150 GV/m.

Now we start to up-grade the 100TW PWM laser to the PW laser in order to supply 500J on target in 500fs, synchronizing to the GEKKO XII green beams. The beam size expands from present 20 cm to 50 cm in diameter. A pair of 1-m gratings compresses the pulse width and an off-axial parabola focuses it onto target with F number 7. We expect the laser illumination makes the imploded high density plasma temperature twice and the neutron yield more than ten times. The PW laser will complete in the next spring.

Experimental and numerical studies on fast electron transport in relativistic laser-solid interaction

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Simulations of ultraintense laser pulse-generated fast electron transport into solid-density matter are performed via a novel 3D numerical code (PÂRIS) where both electromagnetic and collisional effects are taken into account, according to a hybrid scheme first employed by Davies *et al*[1]. The code models self-consistently the response of the medium to the beam injection, with locally varying ionization rate and electrical resistivity as functions of collisional and Joule heating. A variety of instabilities are seen to take place ranging from filamentation and coalescence to hollowing and hosing. Eventually, the ability of the fast electrons to heat solid-density matter along a collimated region is demonstrated. This heating is shown to be essentially due to the ohmic dissipation of the return current.
These numerical results are of prime relevance to explain the current fast ignitor-related experimental studies at LULI and elsewhere[2]. The latest measurements of the fast electron-induced processes arising at the target back-surface are also presented.

[1]J. Davies *et al.*, Phys. Rev. E **56**, 7193 (1997)
[2]L. Gremillet *et al.*, Phys. Rev. Lett. **83**, 5015 (1999) ; M. Borghesi *et al.*, Phys. Rev. Lett. **83**, 4309 (1999)

Oral presentation preferred

On the generation of multi-MeV electrons and positrons using fs-laser pulses

C. Gahn[a], G. D. Tsakiris[a], G. Pretzler[a], C. Delfin[d], A. Pukhov[a], V. K. Tripathi[c], P. Thirolf[b], C.-G. Wahlström[d], J. Meyer-ter-Vehn[a], D. Habs[b], and K. J. Witte[a]
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We present experimental investigations of the *multi-MeV electron production* concomitant to the relativistic self-channeling of a laser pulse in a high-density gas jet. Using the ATLAS laser system at Max-Planck-Institut für Quantenoptik (130 fs, 2 TW) and a novel multi-channel electron spectrometer [1], we have performed systematic measurements in which the dependence on the plasma electron density ($3x10^{19}$ – $6x10^{20}$ cm^{-3}) and the laser intensity ($1x10^{18}$ – $6x10^{18}$ W/cm^2) was studied.

The thus obtained angularly resolved and absolutely calibrated electron spectra are closely reproduced by three-dimensional Particle-in-Cell simulations. A detailed analysis indicates that for the cases investigated the dominant electron acceleration mechanism is *direct laser acceleration* at the channel betatron resonance [3]. The dynamics of this new mechanism has been studied with the help of a fully relativistic 3-D single particle code, supported by a theoretical model [4]. It turns out that the electron motion in the self-generated static fields of the channel resembles the motion in a magnetic wiggler. At resonance between bounce frequency and Doppler shifted laser frequency, the electron experiences a large momentum gain in parallel direction to the laser beam.

Finally, measurements on the first table-top laser produced *positrons* will be shown. By inserting a high-Z material into the electron beam, we could detect a signal due to positrons which when scaled to the full solid angle represents 10^6 positrons per shot.

[1] C. Gahn *et al.*, Rev. Sci. Instrum. **71** (2000)
[2] C. Gahn *et al.*, Phys. Rev. Lett. **83**, 4772 (1999)
[3] A. Pukhov and J. Meyer-ter-Vehn, in Proc. First Int. Conf. on Inertial Fusion Science and Applications, Bordeaux, Sept 1999, ed. C. Labaune (to appear)
[4] G. D. Tsakiris *et al.*, accepted for publication in Phys. Plasmas (2000)

oral presentation preferred

For submission to the Anomalous Absorption Conference, May 21, 1999

Multi-Species Ion Acceleration in Ultra-Intense Laser-Plasma Interactions.

S. C. Wilks, T. Cowan, M. Key, W. L. Kruer, A. B. Langdon, A. Mackinnon, and M. Roth

Lawrence Livermore National Laboratory

We discuss various ion acceleration mechanisms when an ultra-intense laser ($I\lambda^2 > 10^{19}$ W-μm^2/cm^2) is incident onto a thin solid foil. Using 1 and 2-D PIC simulations of a carbon-hydrogen mixture on the surface of the target (representing the monolayer), we present the first multi-species simulations of ion blow-off driven by relativistic electrons. We find that significant structure is generated in the proton energy spectra, a feature not previously understood. The physical mechanisms causing these features will be discussed in detail. In particular, we discuss the energy transfer from electrons to ions, the directionality of the various ion species, and the dependence of the ion energy on (1) electron energy, (2) density gradient scale lengths, and (3) geometry. We find that a maximum proton energy of ~100 MeV protons is not unreasonable, with monoenergetic features near 25 MeV. Comparison with experimental results will be presented.

Prefer Oral.

Detailed Study of Raman Instabilities and Electron Acceleration in the Self-Modulated Laser Wake Field Accelerator.

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Z. Najmudin, B. Walton
Imperial College, London, UK

P. Mora, A. Solodov
Centre de Physique Théorique, CNRS-Ecole Polytechnique, 91128 Palaiseau, France

The interaction of a 10 Hz laser pulse with a gas jet has been studied experimentally over a wide range of laser intensity (10^{17} to 2×10^{19} W/cm^2 with laser pulse durations from 35 fs to 6 ps) and plasma density (1.5×10^{18} to 1.5×10^{20} cm^{-3}). Using chirped laser pulses, Raman instabilities have been studied through forward (0°), side (30°) and backward (180°) Raman scattering spectra. The temporal dynamics of these instabilities could be retrieved from the time-frequency equivalence of a chirped laser pulse. Backward Raman scattering was found to occur very rapidly at the beginning of the pulse while forward and side scattering occurred at the end of the pulse. To explain these results, a simple temporal model was developed showing that for long pulses ($\tau > 1$ ps), the forward Raman instability is saturated by the modulational instability. The sign of the chirp did not seem to have any effects on Raman growths and on the number of accelerated electrons.

Detailed measurements of electron beam spectra, charge and profile have been performed. A total electron beam charge of 8 nC has been measured. The maximum electron energy (E_{MAX}) was found to increase when the density was decreased, demonstrating that electrons are accelerated by relativistic plasma waves. E_{MAX} was also found to increase with laser intensity.

Mutual Interaction of Photon Beams in a Plasma: Braided Lights

C. Ren, R. G. Hemker, R. Fonseca, B. J. Duda and W. B. Mori

University of California, Los Angeles

Light beams do not interact in vacuum. However, in a plasma there is a self-interaction as is obvious from the well known self-focusing mechanisms. This naturally leads to the question, is there a mutual interaction between two (or more) light beams in a nonlinear optical medium, such as a plasma? We show using a variational principle method, that the relativistic mass nonlinearity causes an effective attractive force between two Gaussian laser beams in a plasma. This force will cause two Gaussian beams to spiral around each other if the beams enter the plasma with some angular momentum about their effective center of mass. Furthermore, if they enter the plasma with no angular momentum they periodically pass through each other. Both the rotation period and the oscillation period are proportional to the Rayleigh length. The spiral orbits are stable if the ratio of orbit diameter to laser spot size $(d/W)^2<2$. Three dimensional particle-in-cell simulations using OSIRIS have confirmed these analytical solutions. The simulations show that the actual solutions lead to the light beams braiding around each other. While we have concentrated on the relativistic mass nonlinearity the conclusions should apply to any nonlinearity and the results also have direct relevance to the interaction of individual filaments and speckles.

This work is supported by DOE under Contract Nos. DE-FG03-98DP00211 and DE-FG03-92ER40727, by NSF under Grant No. DMS 9722121 and by the ILSA at LLNL under contract No. W-7405-ENG-48. RAF acknowledges the financial support of Gulbenkian Foundation and FCT(Portugal).

Short Intense Laser Pulses in Plasmas

P. Sprangle, B. Hafizi[1], J. Penano[2], R.F. Hubbard and D. Gordon[3]
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Naval Research Laboratory
Washington DC 20375

The dynamics of short intense laser pulses in plasmas can be very different from that of long pulses. For example, when the pulse length is short compared to the plasma wavelength the Raman instability is not excited since a plasma wave is not generated. In addition, the relativistic modulation and filamentation instability are greatly modified. Relativistic effects also modify the refractive index and lead to self phase modulation. Self phase modulation induces a frequency chirp along the pulse while anomalous group velocity dispersion causes the front of the pulse to have a smaller group velocity than the back. This variation in group velocity along the pulse results in longitudinal compression and intensity enhancement. The frequency chirp along the pulse can be substantial, approaching 100%, and is predominately towards lower frequencies. The longitudinal compression of the pulse and corresponding increase in laser intensity can be substantial. An intense laser pulse can also undergo a relativistic filamentation instability that leads to the transverse break-up of the pulse. The nonlinear evolution of the various short pulse instabilities is analyzed numerically using a fully nonlinear cold fluid model and compared with PIC simulations.

1. Icarus Research, Inc. P.O. Box 30780, Bethesda, MD 20824

2. LET Corporation, 4431 MacArthur Blvd., Washington, DC 20007

3. NRC Post Doc.

Supported by DOE and ONR

Oral Session

Thursday, May 25th, 2000

8:30 to 11:50 AM	**Oral Session 4** **Laser Plasma Interactions** *M. Casanova, Chair*
7:30 to 8:30 PM	**Invited Talk 3** **An overview of fusion enabling technology with emphasis on inertial fusion energy** *C. C. Baker*
8:30 to 11 PM	**Poster Session 3**

ORAL SESSION 4

LASER PLASMA INTERACTIONS

Michel Casanova, Chair

Thursday, May 25th, 2000
8:30 AM

Interplay of Raman and Compton Scattering in Laser Plasma Interaction

Chuan S. Liu , ToshihiroTaguchi [1] and Vipin Tripathi [2]

Institute for Plasma Research , University of Maryland

We studied the nonlinear interaction and evolution of Raman and Compton Scattering instabilities of a high power laser beam in Plasmas with an electromagnetic, relativistic simulation. Both interactions in the underdense region of the plasma and at the quarter critical density are analyzed. In the case of medium high power pump where the oscillatory velocity is 0.1 c, the pump depletion is not significant; Raman scattering is saturated by the bulk electron trapping and the corresponding damping of the plasma wave. But the scattered EM wave persists by the continued feeding of electrons in the ponderomotive well due to the Compton scattering. The resulting electron acceleration and current generation would produce return current. This current can be unstable to the excitation of ion acoustic wave, which then terminates the Raman scattering, with the appearance of Brillouin scattering. With higher power pump where oscillatory velocity is 0.26 c – 0.4 c, significant pump depletion is observed with corresponding electron energy increase and ion momentum increase. Saturation of the Raman instability occurs when there is an equipartition of energy between the electromagnetic field and the electrons. Subsequent heating by Compton process can continue the transfer of EM wave energy to electrons at a slower rate. Ion quasi mode can also be very important as its frequency and growth rate can exceed the ion plasma frequency. At quarter critical density, Raman is very efficient in the electron acceleration and 80% of the pump energy can be carried by fast electrons in few hundreds plasma periods.

[1] Permanent address: Setsunan university, Osaka, Japan
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Abstract of the oral presentation at the 30 th anomalous absorption conference

30th Anomalous Absorption Conference – Sheraton Fontainebleau, Ocean City, MD-
21-26 May 2000

Experimental observation of secondary waves produced in the non-linear evolution of stimulated Raman scattering.

S. Depierreux[1], C. Labaune[1], H.A. Baldis[2], J. Fuchs[1], D. Pesme[3],

V. T. Tikhonchuk[1], S. Hüller[3], G. Laval[3]

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The main issue regarding Stimulated Raman scattering (SRS) (the decay of the incident laser into an electromagnetic wave and an electron plasma wave (EPW)) in the context of inertial confinement fusion (ICF) experiments is the identification and understanding of its saturation mechanisms. Indeed, when the instability develops either via the absolute regime or the convective one with large regions available for the spatial amplification, the daughter waves can reach very high levels. In these situations which are likely to occur with the megajoule-scale facilities, linear theory of SRS will fail and SRS behavior will be dominated by saturation mechanisms. Theoretical work and numerical simulations demonstrate that the Langmuir decay instability (LDI) which is the decay of the primary SRS Langmuir wave into another Langmuir wave and an ion acoustic wave (IAW), may act efficiently to saturate the SRS instability via the introduction of an additional damping term on the primary EPWs.

We will present Thomson scattering measurements of the secondary ion acoustic and electron plasma waves associated with the LDI of SRS-driven EPWs. The experiments have been designed to study the interaction between a 1.053 μm pump and a well-characterized preformed plasma using the six-beams laser facility at LULI. Two spectrometers coupled with streak cameras were used to analyse the Thomson scattered light of the 3 ω probe beam from both EPWs and IAWs. These measurements were resolved in time, space, wavelength and wave-number. The frequency and wave-number spectra of the secondary IAWs are measured to be peaked at values matching the resonance conditions with the SRS and LDI instabilities whereas their localization and timing are observed to be coincident with the SRS activity. The LDI cascade have been resolved thanks to the high spectral resolution of the diagnostic. The amplitude of the secondary waves and the SRS reflectivity were measured over a large range of laser intensities allowing a connection between SRS and LDI evolutions.

Oral preferred

30^{th} Annual Anomalous Absorption Conference
Sheraton Fontaineblau, Ocean City, Maryand
21-26 May, 2000

Optical Mixing Controlled Stimulated Scattering Instabilities: Demonstration of Large SBBS and SRBS Reflectivity Reduction in Specific Temporal and Spectral Windows

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D. S. MONTGOMERY[3], R. KIRKWOOD,[4], J. HAMMER,[4],
A. J. SCHMITT[5], S. REGAN[6], D. D. MEYERHOFER[6] AND W. SEKA[6]

[1] Polymath Research Inc., Pleasanton, CA
[2] University of Californa, Berkeley, CA
[3] Los Alamos National Laboratory, Los Alamos, NM
[4] Lawrence Livermore National Laboratory, Livermore, CA
[5] Naval Research Laboratory, Washington, DC
[6] Laboratory for Laser Energetics, Rochester, NY

We report on experiments conduxted on the Omega laser facility at LLE. In these experiments, we measured the effects of a large amplitude ion acoustic wave (IAW), generated by the optical mixing of two high intensity laser beams, a pump and a probe, on the stimulated Raman and Brillouin backscattering of the pump. Detailed analyses of our temporally and spectrally resolved data on SRBS and SBBS of the pump beam and the transmission of the probe beam reveal that there are specific temporal and spectral windows in which the backscattering reflectivities are most dramatically reduced. Two ways to examine the data are 1) to compare cases when a resonant IAW was created at the Mach -1 surface to cases where the focusing was at the Mach +1 surface, with the same pump and probe intensities, where no resonant wave would have been created, and 2) to compare cases at the Mach -1 surface to each other when the probe intensity is small and large. We will show the results of both types of comparisons in order to make the case that the reduction in backscattering levels should have been caused by the creation of an IAW disturbance at the resonant layer at Mach -1.

Our long term goal is to find the most efficient ways to generate large enough (EPW and IAW) disturbances in the plasma so as to control backscattering levels of SRS and SBS throughout the plasma.

*This work is performed under the auspices of the U. S. Department of Energy under the grant DE-FG03-99SF21787. The work by LLNL employees was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48, while that of LLE employees 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. LANL and NRL staff acknowledge the support of their respective laboratories and their DOE contracts.

PREFER ORAL SESSION

Power transfer between smoothed laser beams

A. B. Langdon, R. L. Berger, B. I. Cohen, C. D. Decker, D. E. Hinkel, R. K. Kirkwood, C. H. Still, and E. A. Williams

Lawrence Livermore National Laboratory
Livermore, CA 94550, USA

Theory and experiment have demonstrated that power transfer can occur between beams in the inner and outer cones of NIF. The coupling mechanism is stimulated forward Brillouin scatter, made resonant by Doppler shifts in the plasma jet flowing out of the laser entrance hole in hohlraum targets. Like beam deflection, this power transfer could degrade the symmetry of x-ray drive on the capsule. This effect may constrain target design, and place additional requirements on the NIF laser, e. g. to provide a frequency separation between the inner and outer cones in order to detune the resonance.

Here we consider laser beams smoothed by phase plates and spectral dispersion, which are spatially and temporally modulated. In addition to understanding intrinsically interesting physics, our goal is to establish the scaling of power transfer for application to conditions in NIF ignition targets derived from LASNEX modeling.

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

Prefer oral session

Laser plasma interactions using green (2ω) light.

E. A. Williams, R. L. Berger, A. B. Langdon and C. H. Still

Lawrence Livermore National Laboratories,
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It is well established that laser plasma interactions, potentially deleterious to achieving inertial confinement fusion, such as filamentation, beam spray, beam bending and stimulated Raman and Brillouin backscatter increase with laser wavelength.
The laser intensity I, typically enters in the combination $I\lambda^2$ and densities as n/n_c, where $n_c \sim \lambda^{-2}$ is the critical density. Largely for this reason current generation large lasers (eg Nova, Omega) primarily have operated with blue (3ω) light. However, NIF, because of glass damage limitations at 3ω, may have more power and energy available at the second harmonic. In addition, doubling crystals have a larger band-pass than triplers, allowing the use of larger SSD bandwidth for beam smoothing. Coupled with ignition target designs that use larger spot-sizes, there may be a favorable tradeoff to the use of 2ω light at lower intensity.
We show simulations using the code F3D, which couples paraxial light propagation to fluid plasma models, and examine the instability scalings with laser wavelength and smoothing bandwidth to assess this trade-off.

Preferred format: Oral

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

Exploring New Interaction Regimes and Options for NIF

William L. Kruer

Naval Postgraduate School Monterey, Ca.
and
Lawrence Livermore National Laboratory Livermore, Ca.

Given the challenges involved both in building NIF and in achieving its ignition goals, it is clearly important to vigorously explore new interaction regimes and control mechanisms to provide additional options for success. For example, operation of NIF with .53μm light[1] would considerably relax constraints on the laser due to damage thresholds and allow the use of larger bandwidth. Even with .35μm light, accessing a wider range of irradiation and plasma conditions would allow more options for target designs and greater flexibility to deal with Mother Nature's inevitable surprises. This is especially important[2] given the complexities in the extrapolation of the interaction physics to NIF's larger plasmas, multiple crossing beams, and highly shaped pulses and the need for excellent temporal and spatial control of the laser deposition for ignition targets. Recent work[3] has indeed indicated that some more strongly–driven interaction regimes are possible. Some ongoing work on these regimes, on the search for new control mechanisms, and on novel features of ignition-scale hohlraums is discussed.

1. E.M Campbell, D. Eimerl, W.L. Kruer, S. Weber, and C.P. Verdon, Comments Plasma Phys. Cont. Fusion 18,201 (1997)
2. W.L Kruer, "Wave Particle Interaction and Turbulence Issues and Opportunities in Inertial Fusion", invited presentation, 1999 Fusion Summer Study, Snowmass, Co. July 1999
3. W.L Kruer *et.al.*, Plasma Phys. Cont. Fusion 41,1 (1999), and references therein

This work was performed under the auspices of the United States Department of Energy by the University of California Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Prefer Oral Presentation

Return Current Instability and its Effect on the Thomson Scattering Spectra in Laser Produced Plasmas*

W. Rozmus, V. Bychenkov[a], A. V. Brantov[a], S. Glenzer[b], K. Estabrook[b], H. A. Baldis[b]

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[b] *Lawrence Livermore National Laboratory, Livermore, California.*

Linear theory of the return current instability which is excited due to localized plasma heating in a laser hot spot is examined within the framework of the nonlocal transport theory. In plasmas where the size of a hot spot is comparable with the electron mean free path nonlocal thermal effects reduce the growth rate of the instability, increase the threshold and modify angular distribution of the ion acoustic waves.

A perturbed electron distribution function due to the heat flow and a return current of cold electrons has been used in calculations of the Thomson scattering cross section. In stable plasmas such a perturbation results in asymmetry of ion acoustic peaks which is observed in experiments.

Our analysis also includes a model of laser light absorption and plasma heating. Comparison with experimental measurements allows identification of the threshold conditions for the ion wave instability and the regime of anomalous absorption. We have examined a theoretical model of laser light absorption in the presence of enhanced ion acoustic fluctuations.

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

Optical and X-Ray Signatures from the Two-Plasmon-Decay Instability on OMEGA

C. Stoeckl, V. Yu. Glebov, D. D. Meyerhofer, W. Seka, B. Yaakobi, and J. D. Zuegel

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Abstract

Laser–plasma instabilities producing suprathermal electrons are potentially dangerous for direct-drive inertial confinement fusion. These energetic electrons can preheat the fuel and prevent compression of the capsule to the requisite conditions for ignition.

On OMEGA the predominant mechanism to produce suprathermal electrons is the two-plasmon decay instability. Its optical signature, the $3\omega/2$ emission, correlates in both time and power with the hard x-ray radiation generated by the interaction of the hot electrons with the target. Using the signals from time resolved detectors in an energy range from 10 keV to 500 keV, this paper will present measurements of the temperature of the hot electrons, and the amount of laser energy coupled to suprathermal electrons and to the target.

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.

Prefer oral session.

Ion Sound Wave Stability Analysis

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* *P. N. Lebedev Physics Institute, Russian Academy of Science,*
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Abstract

We have investigated the effect of fluid and kinetic[1] nonlinearities of an ion sound wave (ISW) driven by an external ponderomotive potential in one and two spatial dimensions. In order to assess the respective roles of the fluid and of the kinetic nonlinearities, we have compared the results of ion-PIC and nonlinear fluid simulations for various frequency detuning, amplitude, and localization of the ponderomotive potential. These simulations have shown the possibility of transfer of the ISW energy towards longer wavelengths. We have investigated analytically the stability of a driven, coherent ISW, in which we have accounted for weak harmonic generation, wave dispersion and damping. In the case where the driver frequency corresponds to the linear ISW dispersion relation, two branches of instability – modulational and decay – are found in 2-D. The 1-D limit is found to be degenerate, the decay instability growth rate vanishing exactly in this limit. However the decay instability can be restored if the driver frequency is shifted from the linear resonance. These results suggest that the ISW instability could have an important effect on SBS.

1. B. I. Cohen, B. F. Lasinski, A. B. Langdon, and E. A. Williams, Phys. Plasmas 4, 956 (1997).

INVITED TALK 3

An Overview of Fusion Enabling Technology with Emphasis on Inertial Fusion Energy

Charles C. Baker
Virtual Laboratory for Technology
University of California/San Diego

Thursday, May 25th, 2000
7:30 PM

Yefim Aglitskiy, Chair

An Overview of Fusion Enabling Technology With Emphasis on Inertial Fusion Energy

Charles C. Baker
University of California, San Diego

A comprehensive enabling technology program is being carried out in the U.S. in support of magnetic (MFE) and inertial (IFE) fusion energy concepts. An overview of current activities will be presented with an emphasis on inertial fusion energy technology. This will include chamber and target technology for IFE as well as associated work on reactor design studies, advanced low-activation materials, and MFE chamber technology. This work is coordinated for the U.S. Department of Energy by a Virtual Laboratory for Technology

POSTER SESSION 3

Thursday, May 25th, 2000
8:30 to 11 PM

The Influence of Electron Viscosity on Ion Heating in Shock-Heated, Moderate Atomic Number, Plasmas

K. G. Whitney*, J. W. Thornhill, and A. L. Velikovich
Plasma Physics Division
Naval Research Laboratory, Washington D.C., 20375

Generally, artificial viscosity is used in computer codes to minimize the number of zones needed to model strongly driven hydrodynamic flows. In plasmas, artificial viscosity is commonly employed for ions only. It depends on (and influences) the velocity profile in the plasma and acts as a seed for compressive heating of the ions. Consequently, much higher ion than electron temperatures are generated in plasma compression calculations employing such viscosities. However, in highly ionizable plasmas, real (classical) electron viscosity can greatly exceed real ion viscosity under plasma conditions where the ion temperature does not greatly exceed the electron temperature. For example, for ionization states of six or more, electron viscosity begins to increasingly dominate over ion viscosity when electron and ion temperatures are equal. However, how this electron viscosity influences the hydrodynamics of moderate atomic number (Z) plasmas is complicated by the ionization and x-ray emission dynamics of the plasma, which act as a drag on the electron temperature. In this talk, a comparison will be made of the ion temperature behavior in the neighborhood of a shock front in the presence of electron viscosity for both analytic and computer treatments of this problem. The analytic calculation, which treats a steady-state shock, is for a totally ionized titanium plasma and shows significant reductions in the ion temperature when electron viscosity is included in the calculation. The computer calculations that are discussed are for the full heating dynamics of shock-driven moderate-Z plasmas. They demonstrate how compressive heating can be channeled more directly into x-rays when electrons receive their rightful share of the artificial viscosity heating.
Work supported by DTRA and Sandia National Laboratories
* Berkeley Scholars, Inc.

Time resolved x-ray spectra from laser-generated high density plasmas

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Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany

We present time resolved x-ray spectra of C, F, Na and Al, generated by focusing frequency doubled 150fs ATLAS laser pulses on solid targets at 10Hz repetition rate. Intensities of about 10^{17}W/cm^2 averaged over 10μm diameter are achieved on the target surface. Prepulse formation is strongly suppressed due to an outstanding contrast ratio of 10^{10} at 2ns and 10^6 at 1ps before the laser pulse maximum. Therefore, the laser pulses interact with a steep density gradient and energy is coupled very efficiently to the solid target. Electron temperatures of 300eV and electron densities close to 10^{24}cm^{-3}, corresponding to solid state, are generated this way in case of Al as target material [1].
For time resolved measurements we use a new ultra fast x-ray streak camera providing an outstanding time resolution of 0.8ps. In combination with a semiconductor based laser triggering system we were able to accumulate thousands of laser shots, thereby improving the signal to noise ratio substantially, while maintaining a high time resolution of 1.7ps.
By means of a transmission grating (5000lp/mm) we observed time resolved spectra in the range of 0 to 50Å covering the hydrogen- and helium-like K-shell resonance lines of the investigated materials. A general trend of longer emission times with increasing wavelength, respectively decreasing atomic number is clearly observed. Ly-α lines generally show shorter durations than He-α lines. The FWHM duration of all investigated resonance lines was observed in the range of 2-4ps.
For modelling the time resolved emission we used the hydro code MULTI-fs [2], post processed with the atomic FLY-code. Simulation results show very good agreement with experimental data concerning pulse profile and absolute duration of the different target elements

[1] A. Saemann et al., Phys. Rev. Lett. 82, 4843 (1999)
[2] K. Eidmann et al., accepted for publication in Phys. Rev. E

Poster presentation is preferred for this contribution

High-resolution X-ray Radiography using X Pinches

T.A. Shelkovenko*, S.A. Pikuz*, D.B. Sinars, K.M. Chandler, D.A. Hammer.
Laboratory of Plasma Studies, Cornell University, Ithaca, NY 14853

An X pinch is a variant of a Z pinch that is made using 2 (or more) fine wires (typically 5-50 microns in diameter), which cross and touch at a single point (forming an "X" shape.) Using a pulsed power device, large currents are sent through the wires in a very short time. During the resulting wire explosion, one or more short (~1 ns or less), intense bursts of x rays are emitted from a region that can be sub-micron in diameter. The spectral bandwidth of the x-ray radiation is also very wide.

We present several schemes using X pinches as bright sources for imaging dense objects with short lifetimes. By varying the wire material, driver current, and the experimental setup it is possible to obtain a wide variety of x-ray source parameters: source sizes from 1 micron to 1 mm, x-ray burst durations from <100 ps to 10 ns, and line or continuum radiation sources in the 1-20 keV spectral band. With the proper choice of X-pinch parameters, the X pinch can be used for point-projection shadow radiography, capturing the image directly onto film with micron-scale resolution. This scheme has been used to study the fast evolution of the dense cores of exploding wires, as well as wire arrays. The dynamics of the dense plasma near the cross-point of the X pinch have also been directly observed using other X pinches. The structures in the X pinch cross-point have been observed with 1-2 micron spatial and 0.05 ns spatial resolution. We also present a scheme using x-ray focusing elements to produce monochromatic x-ray radiation from the X pinch source. This is useful for imaging objects that also produce radiation, such as hot plasmas.

This research was supported by the Sandia National Laboratories Pulsed Power Sciences Division and a Department of Energy Grant No. DE-FG02-98ER54496.

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Smoothing mirror and the effect of light beam self-symmetrization in laser beams with the experimental demonstration *in situ*.

A. V. Yurkin, S. L. Popyrin, and I. V. Sokolov

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The scheme of a modeless laser was proposed by Ewart [1]. There is no longitudinal mode structure in this optical device. In this work, we investigate the laser scheme similar in part to that mentioned above. To obtain a smooth laser beam, we apply smoothing mirrors proposed in [2]. The smoothing mirror consists of many non-parallel semi-transparent planes inclined relative to the axis so there is no longitudinal mode structure in this optical device. In the smoothing mirror cavity the reflected light rays are inclined at various angles in different areas of laser active medium [3]. As a result, light mixing and multiple scattering take place in this cavity, improving the homogeneity and self-symmetrization of the laser beam.

The geometric optical properties of the plane-plane cavity and the smoothing mirror cavity are compared. The threshold pumping energy of the smoothing mirror cavity is experimentally measured. Actually the smoothing mirror cavity consists of many cavities of different types, which are bound with each other.

We demonstrate experimentally that the laser beam splits each time after the reflection from this mirror in a great number of interfering beams which are axially symmetrical with regard to each other. The formation of spatial patterns takes place after the reflection of laser beam from the smoothing mirror in our linear case. Qualitatively the smoothing effect is demonstrated *at the poster* using a laser pointer and the sample of the mirror.

Similar patterns were given in [4] for nonlinear optical systems.

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Numerical Study of Deceleration-Phase Rayleigh–Taylor Instability

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Abstract

Typical ICF targets consist of a solid DT shell filled with DT gas. It is well known that the inner surface of the shell is Rayleigh–Taylor unstable during the final phase of the implosion when the shell is being decelerated by the large central pressure. During the deceleration phase, the inner-surface nonuniformities grow rapidly, causing the mixing of the cold-shell material with the hot central plasma and quenching of the hot-spot ignition process.

We have found that mass ablation on the inner surface of the shell plays an important role in stabilizing short-wavelength modes during the deceleration phase. The ablation process is induced by the heat flux leaving the hot spot and deposited on the shell's inner surface.

Two-dimensional planar and spherical codes have been developed to study the linear phase of the instability. The single-mode growth rate is compared with the theoretical predictions based on the large Froude number model of Ref. [1]. It is shown that the mass ablation through the inner-shell surface combined with the finite density gradient scale length significantly reduces the R–T growth rate and suppresses short-wavelength modes.

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.

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Prefer poster session.

Mitigation of Laser Imprint in Direct-Drive using Tailored Density Targets

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In a previous work [1], we have shown that density tailoring can reduce the laser imprint generated by early time lateral non-uniformity in the laser illumination. Tailoring of initial density profiles in laser targets inverts the acceleration of the ablation front at early time. Due to the tailored density gradient, mass perturbations oscillate at a higher frequency and at lower amplitude than merely due to the "rocket effect" caused by mass ablation [2]. This was demonstrated analytically and numerically for planar geometry. In the present work, we discuss the efficiency of this stabilization method for a spherical geometry, under more realistic pellet-design constraints. We show that this mitigation of early time laser imprint results reduced perturbations throughout acceleration and compression.

Work sponsored by US DOE.

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Prefer Poster Presentation

Abstract for 30th Anomalous Absorption Conference
21-26 May 2000, Ocean City, Maryland

LA-UR-00-1164 Revised

Observation of Compressible Plasma Mix in Cylindrically Convergent Implosions

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An understanding of hydrodynamic mix in convergent geometry will be of key importance in the development of a robust ignition/burn capability on NIF, LMJ and future pulsed power machines. Much work has been done in understanding the growth of mix in planar geometry (from the linear to the turbulent phase), whilst high convergence implosions have demonstrated a shortfall in our ability to predict the behavior of highly unstable systems. To help address this problem we have made use of the OMEGA laser facility at the University of Rochester to investigate directly the mix evolution in a convergent geometry, compressible plasma regime.

The experiments comprise a plastic cylindrical shell imploded by direct laser irradiation. The cylindrical shell surrounds a lower density plastic foam which provides sufficient back pressure to allow the implosion to stagnate at a sufficiently high radius to permit quantitative radiographic diagnosis of the interface evolution near turnaround. The laser illumination is relatively constant over the central region of the cylinder, where marker layers are placed to isolate hydrodynamic behavior. The susceptibility to mix of the shell-foam interface is varied by choosing a different density material for the inner shell surface (thus varying the Atwood number). Early experiments concentrated on a target design that underwent significant acceleration during the laser pulse, leading to dominance of Rayleigh-Taylor growth from the ablation surface. Subsequent experiments (January 2000) used a modified target design which minimized the acceleration period and decoupled the inner interface from the laser-plasma interaction, allowing the study of shock-induced Richtmyer-Meshkov growth during the coasting phase, and Rayleigh-Taylor growth during the stagnation phase. The experimental results will be described along with calculational predictions using various radiation hydrodynamics codes and turbulent mix models.

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Status of the LANL ICF double-shell implosion campaign

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Abstract

Experimental observations of ICF implosions using capsules with two concentric shells separated by a low density region (double-shells) are reported. Historically behavior of such capsule designs has been poor but several recent capsule designs have shown significant improvements over the historical behavior. These new designs attempt to mitigate the effect of asymmetric Au M-band radiation in the 2-2.5 keV energy range generated by the 60 laser spots on the wall of tetrahedral hohlraums at the Omega laser. While both new designs have shown promise experimentally, the best performing design, called the reduced absorption double-shell, has been shown to closely follow one dimensional (1D) radiatively driven hydrodynamics simulations in the convergence ratio range 25.5 –38. The reduced absorption design reduces the amount of M-band absorbed by the inner capsule by removing more than 80% of the glass from it, and thus making it much less sensitive to any existing asymmetry by removing the absorption of that asymmetric component of the drive by a large amount. This capsule design has achieved over 50% of the unperturbed 1D calculated yield at a convergence ratio (CR) of 25.5, and ranges over 30-60% for convergence ratios in the 25.5 – 38 range, with no apparent correlation between reduced YOC and increased CR, as in the case of all other indirect drive ICF capsule implosions to date, regardless of capsule design. A second, reduced transmission, design in which the M-band is mostly absorbed in the outer shell has also seen significant improvement relative to the historical double shell database, but the results have been erratic. In both designs some shots have shown that with severe outer capsule defects the yield can be significantly hurt, but the reduced absorption design seems quite insensitive to defects in the outer shell. The range of CR where YOC remains near 50% in the reduced absorption design covers that of a double-shell design for an ignition capsule at the National Ignition Facility. Imploded core images, data plots of YOC vs. CR, and detailed pictorial images of the shells and construction process will be shown.

[X] poster session preferred

LASER DRIVEN HYDRODYNAMIC INSTABILITIES IN THE SOLID STATE AND SENSITIVITY TO NATURE OF FLOW

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A laser driven planar target (CHBr/metal) can be shocked and compressed below the melt temperature of the metal to study hydrodynamic instabilities in the solid state [1, 2]. Similar experiments [3] have been carried out with high explosives (H. E.) : a metal plate was accelerated under the action of gaseous detonation products generated by a plane wave generator.
The latter experiments have shown that the growth of the Rayleigh-Taylor Instability in solids is smaller than in fluids. In many cases the elastic-plastic model provides a satisfactory description of this behavior [4]. For a moderate stress level and when the perturbation initial amplitude is small enough, the system stays in the elastic strain region. This leads to an unstable flow when the perturbation wavelength is greater than the elastic cut off wavelength, and to a stable flow in the opposite case. However, when the perturbation initial amplitude is large enough, a transition to the plastic strain region occurs and the flow becomes unstable even if the perturbation wavelength is smaller than the elastic cut off wavelength.
In the first part of this work we discuss the amplitude dependent plastic transition in numerical simulations of H.E. experiments.
The second part of this work is devoted to numerical simulations of a laser target. In such a system, the stress level is high enough to lead to a plastic unperturbed flow which is unstable for any perturbation. An elasto-plastic viscosity [5] proportional to the yield strength and inversely proportional to the modulus of the deviatoric strain rate tensor is used to describe the properties of the flow. The elastic cut off wavelength is replaced by a plastic attenuation wavelength.

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30th ANNUAL ANOMALOUS ABSORPTION CONFERENCE

Modeling of hohlraum stagnation pressure in a supernova remnant simulation experiment

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Some detailed analysis of an experiment[1,2] that used the Nova laser facility to simulate young supernova remnants (SNRs) is presented. Analogous to an SNR, the laboratory experiment includes dense matter (a plastic plug) that explodes, expansion and cooling to produce energetic, flowing plasma, and the production of shock waves in lower-density (aerogel) exterior matter. The structures are diagnosed by x-ray radiography. The data show that the hohlraum provided energy for the explosion in two ways: first, by the generation of x-rays which produced a radiation pulse and second, by imparting an additional impulse, which is attributed to stagnation pressure.

The stagnation pressure creates a second shock, which overtakes the forward shock. The interaction of these shocks produces a reshock of the contact surface, which becomes turbulent at later times. The position of the contact surface is modeled with the HYADES radiation hydrodynamics code, a 1-D, Lagrangian code, run with greybody transport. The range of second shock properties allowed by the data, and their implications for the turbulence, will be discussed.

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PLASMA CHANNEL FORMATION IN A HIGH-DENSITY GAS PUFF TARGET IRRADIATED WITH A NANOSECOND LASER PULSE.

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Experiment was performed at the Institute of Optoelectronics, Warsaw using a Nd:glass laser system producing 1 ns pulses with energy up to 10 J. The laser pulses were focused onto a high-density gas puff target created by pulsed injection of gas through a nozzle of the fast, high-pressure electromagnetic valve [1]. Numerical simulations of the interaction of nanosecond laser pulses with a gas puff target were performed using the 2D magnetohydrodynamic code MAG [2] with the gasdynamical description of the plasma motion.

To consider the plasma formation two different cases of gas densities have been analyzed: 1) gas with density higher than critical density for the given laser parameters and 2) low-density gas with the density below critical value. In the first case the laser focus point was placed at a distance of 0.2-mm from the nozzle output, for the second case - at 1-mm. The dynamics of plasma formation is quite different for these two cases. As for the first case the gas density exceeds critical value, the length of laser absorption is limited and small region of hot plasma is formed. For the second case, extensive region is heated at full length of the gas puff - from laser beam falling edge to an opposite edge of gas As a result the approximately uniform plasma column along laser axis is formed. In the case of higher density the plasma dynamics process is more complex. A narrow plasma channel along the focus axis is formed. Such plasma configuration was observed in experiments with higher density of gas, when a plasma with the critical density was formed.

Acknowledgments:

The research was partially supported by the State Committee for Scientific Research of Poland under the grant No 2 P03B 093 16 and the ISTC Project 525.

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30^{th} Annual Anomalous Absorption Conference
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21-26 May, 2000

Discrete Wavelet Transforms Multi-resolution Analysis and Tackling Physics on Disparate Scales

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A new set of tools developed at PRI will be described which are used to analyze multi-dimensional dynamic fields in their phase space or configuration-scale space. Both toy problem and 2D MHD simulation results will be shown analyzed using these tools. Particular emphasis will be placed on choice of wavelet families and filter lengths balancing accuracy concerns with ease of use and computational complexity. Wigner function techniques will be employed to make the optimal choices based on pattern recognition criteria in addition to least square error minimization schemes, among others.

Adaptive Wavelet techniques to solve the PDEs and IDEs of plasma physics will also be described including ways of tackling the double phase space of plasma kinetic theory (Vlasov, Fokker-Planck, etc.). Asymptotic techniques of mapping the Vlasov equation to an x-space equation in analogy with the correspondence between the Liouville eq. and Schrodinger's equation in quantum mechanics will also be explored. Methods of deriving reduced plasma kinetic descriptions will be shown which may help diminish the computational complexity of some problems of interest to laser-plasma interactions, fast Z-pinch dynamics and related plasma phenomena.

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3P13

Laser-plasma interaction studies for the LIL facility

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The LIL facility (Ligne d'Intégration Laser) which will be completed in 2001, at CEA/CESTA, Bordeaux (France) is a prototype of the LMJ laser. In 2002, one of the 60 LMJ quadruplets (30kJ) will be available on the LIL and the first campaign using this facility concerns laser-plasma interaction. We are designing hohlraum targets for this campaign. Our first results will be presented.

We further need routine interaction tools to analyse the LIL experimental data and to get safety margins in the context of target design. On the one hand, our post-processor PIRANAH will be improved to include saturation mechanisms. On the other hand, we are developing an interaction code using a full nonlinear hydrodynamic model in planar geometry. The laser propagation is given by a paraxial wave equation and the plasma response is obtained from a two-temperature Eulerian hydrodynamic model with adaptive mesh refinement (AMR). As a first step, this code is used to study filamentation and its consequences on the beam propagation. We will discuss this code and we will give our first results.

δf Simulations of Nonclassical Drive and Transport of Electrons in LPI.

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The δf method with evolving background, developed for carrying out transport time scale simulations of near-Maxwellian distributions [1], has been applied for studying nonclassical heat transport of electrons. In a first stage, the relaxation of small amplitude temperature perturbations in the linear regime was considered [2], and results were successfully benchmarked against the equivalent nonlocal hydrodynamic approach [3]. The code has now been extended to include fully nonlinear spatial and temporal gradients of the background plasma. In parallel, a one-dimensional finite difference code, similar to Reference 4, has been developed for benchmarking the nonlinear δf simulations, as well as to enable a fair assessment of the advantages/disadvantages of these two different numerical techniques. We shall report on first results of such comparisons. Considerations on the self-consistent implementation of the laser driven microinstabilities (Raman scattering) to these transport calculations may also be presented.

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⟶ Poster preferred.

Raman Forward Scattering by broadband radiation sources

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We consider the excitation of relativistic plasma waves by incoherent radiation sources via Raman Forward Scattering (RFS). Photon kinetic theory is employed to recover the standard growth rates for the different forward instabilities driven by a monochromatic intense photon beam. The physical mechanisms included in the photon kinetic theory are illustrated with a 1D photon kinetic simulation of relativistic self-phase modulation. The photon susceptibility is calculated for different exact analytical models of broad spectrum photon beams with finite angular spread. The RFS growth rates are determined for parameters relevant for high brightness x-ray sources (either from laboratory laser-plasma interactions, z-pinches, or astrophysical sources such as supernovae, GRBs), for intense radio/microwave sources (from AGNs and pulsars), and laser beams (from RPPs or with ISI). Our results show that moderate angular spread does not suppress RFS driven by intense photon beams.

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30th Anomalous Conference – Ocean City, MD - May 21-26 2000

Self-induced plasma smoothing of an intense laser beam propagating in underdense plasmas

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Experiments have been conducted at LULI in the interaction of an intense (mean average intensity up to 10^{14} W/cm^2) long (600 ps FWHM) randomized (RPP) laser beam at λ=1.053 μm with underdense, well-characterized plasmas from a CH exploded foil (top electron density at the time of the interaction is varied between 0.2 and $0.7\times n_c$). They deal with the coherence properties of the forward scattered light after propagation through the plasma.

At the highest intensity, the beam initial aperture is found widely broadened and its bandwidth increases from <0.1 Å to more than 10 Å. Near-field images of the transmitted beam exhibit a strong contrast reduction of the random incident speckle pattern, from 1 to ~0.3, with a dynamical behavior of the transmitted speckles. Such spatial and temporal smoothing imposed upon the beam via the coupling with the plasma is induced only at high intensity and increase with increasing density. When we use additional polarization smoothing onto the intense beam, both the spray and the increased bandwidth are reduced.

This self-induced plasma smoothing (SIPS) is interpreted, in agreement with recent numerical simulations [V. Eliseev *et al.*, Phys. Plasmas **4**, 4333 (1997); A. Schmitt and B. Afeyan, Phys. Plasmas **5**, 503 (1999)], as due to the interplay between randomly deflected filaments (by dynamical filamentation) and strongly driven stimulated Brillouin forward scattering.

By increasing the laser beam incoherence, SIPS is theoretically expected to significantly reduce further growth of the stimulated scattering instabilities. It has therefore to be taken into account in order to determine the proper smoothing strategies for the future megajoule-scale laser facilities (LMJ and NIF).

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory, through the Institute for Laser Science and Applications, under contract No. W-7405-Eng-48.

poster preferred

Variational Principle Approach to the Study of Whole-Beam, Short-Pulse Laser-Plasma Interactions, and the effects of dispersion.

B.J. Duda, and W.B. Mori, University of California at Los Angeles.

Over the past few years we have developed a variational principle approach for describing the evolution of short pulse lasers [1]. The starting point is an action integral whose Euler-Lagrange equations recover the model equations. In its simplest form the action can be thought of as $S = \int d\tau d\psi d^2 x_\perp L(a, a^*, \phi)$, where α is the complex envelope of the laser's vector potential and ϕ is the scaler potential of the plasma. Substituting trial functions for α and ϕ, and performing the $\int dx_\perp$ integration provides a reduced action whose Euler-Lagrange equations give envelope equations for the parameters of the trial functions. We will present recent results using the variational principle with the inclusion of the effects of dispersion. We will present recent results using the variational principle with the inclusion of the effects of dispersion, which allows for the coupling between the whole-beam instabilities and Forward Raman Scattering. We will also present simplified differential equations for the dispersive whole-beam modes.

Work supported by grants DOE DE-FG03-98DP00211, DOE DE-FG03-92ER40727, NSF DMS-9722121, and LLNL W-7405-ENG-48.

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Seeding of the Forward Raman Instability via Raman Backscatter and Ionization Effects

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The self-modulated laser wakefield accelerator (SMLWFA) relies on the forward Raman instability to generate the large amplitude electron plasma wave which is used to accelerate particles. The field patterns produced by the instability can vary greatly depending on the nature of the seed. The seed for forward Raman is the wakefield driven by the laser pulse, which is typically at least tens of plasma periods in duration. The amplitude of this wakefield can be anomalously large for at least two reasons. First, the rapid growth of Raman backscatter can deplete the laser pulse in localized regions, leading to an enhanced ponderomotive impulse. This has been observed previously in PIC simulations [1]. Second, laser energy can bunch near the ionization front, again leading to an enhanced ponderomotive impulse. The importance of ionization in this regard has been suggested by experimental results [2]. We present both fully explicit PIC simulations and PIC simulations using a ponderomotive guiding center algorithm to illustrate these seeding mechanisms and their relative importance. Since the ponderomotive guiding center model does not include backward propagating radiation, comparison with the fully explicit model offers a new way of evaluating the importance of backscatter.

Work supported by DOE and ONR

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Poster

Propagation of intense short laser pulses in a plasma.

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The propagation of intense laser pulses with durations, τ_0, on the order of a plasma period, τ_p, are examined using a numerical simulation. The simulation solves propagation equations derived using the quasi-static approximation but which are otherwise valid for arbitrarily large laser intensities. The simulation includes the effects of group velocity dispersion, self-phase modulation, and forward Raman scattering. For intense short pulses with $|\mathbf{a}| > 1$ and $\tau_0 \leq \tau_p$, where $\mathbf{a} = e\mathbf{A}/m_e c^2$ is the normalized vector potential of the pulse, the forward Raman instability is not excited and pulse compression proceeds via the relativistic modulation instability. Significant pulse compression and intensity gain are observed. This process is accompanied by spectral broadening with frequency shifts of the order of the laser frequency. The interplay between forward Raman and modulation instabilities in longer pulses (i.e., $\tau_0 >> \tau_p$) is also examined. The Raman instability can give rise to structures at the plasma wavelength which are prone to further steepening from the modulation instability.

Supported by DOE and ONR.

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Poster Session

Proton Acceleration by Virtual Cathode on the Rear Surface of the Ultra-Intense Laser illuminated Plastics

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We have illuminated a 60TW laser on a CH plain target and have measured the energy and angular distribution of protons, emitted from the rear surface. The GEKKO MII CPA laser, used here, is at the ILE, Osaka University, producing 25J at 1.053 μm with 0.45ps pulse length. 68% of the beam energy is focused to the spot size of 25 μm using an f/3.8 off axial parabolic mirror on a C_8H_8 target. The target was positioned at 40° to the axis of laser propagation for p-polarization. The intensity on target was (5.5 }0.3)x10^{18}W/cm^2. The main to prepulse intensity ratio is 10^{-3}.

The CR-39 film stacks analyzed not only the angular distribution of MeV protons, but also their energy spectrum. The proton emissions show ring structures coaxial to the target normal axis and the ring diameter is proportional to the square root of the proton energy. The energy spectrum shows an exponential feature with a cut off around 10 MeV. Using 5 μm thick target, we have estimated the total protons to be 1.8x10^9 and the temperature to be 3.2 MeV. The temperature and yield decrease, as increasing the thickness from 5 to 100μm. The temperature decrease does not agree with that predicted from the case the protons generate at the front surface and loose their energy on the path in the solid to the rear surface. It is hence likely that the protons generate at the rear surface, where the hot electrons make a virtual cathode, accelerating the protons.

The coaxial structure of proton rings suggests us the existence of an azimuthal magnetic field generated by the hot electron currents to the target normal from front to rear side. The fact that the proton ring diameter is proportional to the square root of the proton energy gave us the product of the azimuthal magnetic field and the acceleration distance to be 120~100 MG-μm.

We will also discuss on the s-polarized beam illuminations.

Friday, May 26th, 2000

8:30 to 11:10 AM	**Oral Session 5** **Diagnostics and Spectroscopy** ***D. Colombant, Chair***
11:10 AM	**Conference ends**

ORAL SESSION 5

DIAGNOSTICS AND SPECTROSCOPY

Denis Colombant, Chair

Friday, May 26th, 2000
8:30 AM

Development and Characterization of a K_α X-ray Source for Time-Resolved Diffraction

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Sub-ps sources of K_α x-rays produced by ultrafast laser-solid interactions offer the possibility of temporally resolving shock propagation in solid crystals through time resolved Bragg diffraction. Previously acoustic waves have been time-resolved in this manner and shock waves have also been characterized by dynamic diffraction of x-rays produced by large scale, single shot lasers. We are currently working to extend the shock wave characterization technique to K_α sources driven by high repetition rate short pulses lasers, a goal which requires high efficiency K_α production to enable single shot diagnosis. We report on the characterization and optimization of a Ti K_α source driven by a 150mJ, 35fs laser (λ=820nm). By maximizing the K_α yield through a Ti foil target, we measure a laser-to-xray efficiency of $>10^{-5}$. We observe a striking conversion efficiency dependence on low intensity ns-scale prepulses in the laser ($\sim 10^8$ W/cm^2). We have also conducted a series of studies to ascertain the effect of thin CH and Al overlayers on the K_α yield and have found that they can have a dramatic effect under certain pre-pulse conditions. Progress toward a time-resolved shock in aluminum crystals will be presented.

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

Oral Session Requested

Aluminum K-shell emission of laser-generated hot plasma at solid density in high spectral and sub-ps time resolution

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For coupling laser energy efficiently to solid targets, we focused frequency doubled 150fs laser pulses from the ATLAS system on a flat aluminum surface. Focal intensities in the range of $2 \cdot 10^{17}$W/cm^2 averaged over 10μm diameter are generated this way at 10Hz repetition rate. Prepulse formation is strongly suppressed due to an outstanding contrast ratio of 10^{10} at 2ns and 10^6 at 1ps before the laser pulse maximum. Emission from the expanding plasma at lower density can be removed from the detected spectral range by a thin surface layer of carbon as tamper material on the aluminum target.
A von Hamos spectrometer (PET) coupled to an x-ray film is used for time integrated detection of aluminum K-shell emission in high spectral resolution at 6-8.4Å. In addition, time resolved spectra have been measured for comprehensive analysis of the plasma dynamics in the spectral range of 7-8.4Å. We developed a new setup to couple a conical crystal spectrometer (Mica) to an ultra fast x-ray streak camera, providing an outstanding time resolution of 0.8ps. In combination with a semiconductor based laser triggering system we could accumulate large numbers of laser shots for substantially improving the signal to noise ratio, while maintaining the time resolution in the sub-ps range.
Spectra emitted from low density plasma are detected as reference by splitting the laser pulse into two successive pulses. The first pulse is thereby creating an expanding low density plasma, absorbing the second pulse. Using high contrast laser pulses, dense plasma conditions are preserved, leading to strongly merged spectra as a consequence of Stark broadening effects. Resonance lines are clearly red shifted due to plasma polarization, corresponding well with predicted lineshifts based on quantum mechanical impact theory. Experimental spectra are analysed and compared to simulations, using detailed line broadening, atomic kinetics and radiation transport calculations. From spectral characteristics, an electron temperature of 300eV and an electron density close to 10^{24}cm^{-3}, corresponding to solid state, can be deduced for the emitting plasma condition [1]. FWHM durations of 1-3ps for resonance lines and their satellites have been observed. Finally we present clear evidence of time resolved line narrowing and shifting at high density plasma condition.

[1] A. Saemann et al., Phys. Rev. Lett. 82, 4843 (1999)

Oral presentation is preferred for this contribution.

Temporal, spatial, and spectral parameters the x-ray emission produced by X pinches

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Recent experimental investigations using a variety of different diagnostics demonstrate that the bright x-ray sources that occur during the implosion process of an X pinch have a very small size and lifetime. The temporal duration and shape of the x-ray bursts emitted from an X pinch were directly measured in the 1.5-6 keV band using a set of fast diamond PCDs and a 10 Gs/s digitizing oscilloscope. The x-ray burst duration measured using the PCDs was less than 250 ns, the temporal resolution limit of that diagnostic system. Using a Kentech x-ray streak camera, x-ray burst durations less than 100 ps were measured for continuum radiation with energies greater than 4 keV. The sizes of the x-ray sources were measured using a 5-micron pinhole and a Bragg-Fresnel lens. These measurements indicate that the x-ray sources were often less than a few microns in diameter. Spectral measurements of the x-ray source parameters were measured using: (a) a convex spectrograph using a mica or KAP crystal and (b) a spectrograph based on a spherically bent mica crystal (FSSR [1]). Two classes of x-ray sources appear to exist in X pinches, sometimes even within the same X pinch. The first is a "high-temperature" source with a spot size near 5-10 microns, and the second is a "high-density" source with a size less than 1 micron.

The X pinch is a unique physical object useful as a bright point source of x-ray radiation for spectroscopic, radiographic, and diagnostic testing applications. For applications requiring a monochromatic x-ray source, it is possible to use X pinches with spherically bent crystals to produce the desired wavelength.

This research was supported by the Sandia National Laboratories Pulsed Power Sciences Division and a Department of Energy Grant No. DE-FG02-98ER54496.

[1] Y.U. Skobelev, T.A. Pikuz, S.A. Pikuz et al, JETP **81**, 692 (1995).

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Direct spectroscopic observation of multicharged MeV ions in plasma, heated by intense femtosecond laser radiation.

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Experimental and theoretical investigations of multicharged ions acceleration by an intense femtosecond laser radiation in wide (10^{17} - $4 \cdot 10^{18}$W/cm^2) laser flux density range will be presented. With the help of Focusing Spectrometers with Spatial Resolution (FSSR-1,2D) we have observed evidence of the emission of energetic He- and H-like ions in fluorine more than 1 MeV produced via the optical field ionization (OFI) from solid target irradiated by intense I=(1-4) $\cdot 10^{18}$ W/cm^2 (UHI-10 laser facility, 60 fs, λ=800 nm), obliquely incident p-polarized pulse laser. The measured blue wing of He_α, He_β and Ly_α lines of fluorine shows a feature of the Doppler-shifted spectrum due to the self-similar ion expansion dominated by superthermal electrons with the temperature T_h ~100-400 keV. Using a collisional particle-in-cell simulation, which incorporates the nonlocal-thermodynamic-equilibrium ionization including OFI, it were obtained the plasma temperature, line shapes, hot electron spectra and maximal energy of accelerated ions, which agree well with those determined from experimental hot electrons and ions spectra. The red wing of ion spectra gives the temperature of bulk plasma electrons. By using simultaneously 3 FSSR spectrometers it were also obtained X-ray spectra with 3D spatial distribution for He_α - K_α lines of Al, Ca and Cu targets. Such spectra clear show that the size of emission zone of Ka radiation on the target surface in 2-5 times large, than the size of emission zone of Hea lines and their satellites. At the same time the size of all lines emission in the direction of laser-plasma expansion were equal. Interpretation of such effect will be presented.

A powerful source of thermonucear neutrons on the basis of a KrF laser

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The feasibility of designing a driver on the basis of a KrF-laser producing composite radiation pulses with duration of about 100 ns for target acceleration and compression and 10-20 ps for fusion reaction initiation is analyzed.

The efficiency of the pumping power conversion is about 10-15% for long laser pulse. It is about 5% for a train of short pulses. As a result, it would be possible to create the KrF-laser module with output energies $E_1 \approx$ 300-400 kJ in long pulse and $E_2 \approx$10-30 kJ in short pulse.

We present the results of a 2D numerical study of DT fuel compression in conical targets. It has been shown that it is possible to compress fuel up to 5-10 g/cm^3 and reach neutron yield $\geq 10^{16}$, using a KrF-laser with energy 300 kJ in a long pulse and 20kJ in a short pulse.

The development of such a neutron source would be of interest for fission-fusion reactor and various applied problems.

We discuss the opportunity to use the "GARPUN"-facility (Lebedev Phys. Institute, Moscow) for studying stable acceleration of thin foils into cylindrical and conical channels and hydrodynamic instability development.

X-ray imaging diagnostics for the inertial confinement fusion experiments.

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We report on our continued development of the advanced x-ray plasma diagnostics based on spherically curved crystals. The diagnostics include x-ray spectroscopy with 1D spatial resolution, 2D monochromatic self-imaging and backlighting and can be extended to the x-ray collimating and 2D absorption and emission spectroscopy. The system is currently used, but not limited to diagnostics of the targets ablatively accelerated by the NRL Nike KrF laser.

Spherically curved quartz crystal (2d=6.68703 Å, R=200 mm) has been used to produce monochromatic backlit images with the He-like Si resonance line (1865 eV) as the source of radiation. The spatial resolution of the X-ray optical system is 1.7 μm in selected places and 2-3 μm over a larger area. Another quartz crystal (2d=8.5099 Å, R=200mm) with the H-like Mg resonance line (1473 eV) has been used for backlit imaging with higher contrast. Spherically curved mica (2d=9.969 Å in the second order of reflection, R=200mm) has been used for backlighting of the low-density foam cryotargets with the backlighter energy of 1.26 keV.

Time resolution is obtained with the help of a four-strip x-ray framing camera. Time resolved, 20x magnified, backlit monochromatic images of CH planar targets driven by the Nike facility have been obtained with spatial resolution of 2.5 μm in selected places and 5 μm over the focal spot of the Nike laser. A second crystal with a separate backlighter has been added to the imaging system. This makes it possible to use of all four strips of the framing camera. As a result we have four monochromatic "snapshots" of developing instabilities.

We are currently exploring the enhancement of this technique to the higher and lower x-ray energies. A progress in high energy (4.5 keV) backlighting that has been made in cooperation with the LLNL will be reported.

Multi-Kilovolt X-ray Driven Ablation and Closure of 5 µm and 10 µm Pinholes during Point-Projection Backlit Imaging*

A. B. Bullock, O.L.Landen, and D.K. Bradley,
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Pinhole-assisted point-projection backlighting with 5 µm and 10 µm pinholes placed a small distance of order 1mm away from the backlighter produces images with large field of view and high resolution. Pinholes placed closely to high-power backlighter sources can vaporize and close due to x-ray driven ablation, thereby limiting the usefulness of this method. A study of streaked 1-D backlit imaging of 25 µm W wires using the OMEGA laser is presented. The pinhole closure timescale for 10um pinholes placed 0.45 mm and 1 mm distant from the backlighter is 1.3 ns and 2.2 ns, respectively. Observed reduction in effective pinhole size and 1-D image resolution due to X-ray drive pinhole closure will also be shown.

*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.

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Corrigenda

Oral talk **1O5** has been moved to **4O3**
Oral talk **1O6** has been moved to **4O1**
Oral talk **1O9** has been moved to **4O10**
Oral talk **1O10** has been moved to **1O6**
Oral talk **4O1** has been moved to **1O9**
Oral talk **4O3** has been moved to **1O5**
Poster **2P17** has been moved to **1O10**
A new poster (see the abstract below) has been substituted for **2P17**
Posters **1P15** and **3P11** have been canceled

30th Annual Anomalous Absorption Conference
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Wall Losses of Soft X Rays in a Confined Hohlraum Geometry

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We have investigated wall losses in cylindrical hohlraums by comparing radiation temperature measurements from hohlraums heated with long laser pulses of 3.5 ns with predictions of a radiation budget analysis. The latter predicts an apparent conversion efficiency of laser power into soft x rays of >100% if wall losses are estimated using a slab like limit. This result indicates that wall losses in a confined hohlraum geometry might be reduced compared to the slab limit. To measure this effect, we shot scale-1 hohlraums at the OMEGA laser facility with a 3.5 ns long square heater pulse and measured the radiation temperatures through the laser entrance hole. Hole closure effects late in the heating phase of the hohlraums have been addressed by imaging soft x-rays at 450 eV and 900 eV emitted through the laser entrance holes. We will compare the experimental data with model predictions taking into account that the absorbed laser power in the experiments is reduced by laser scattering losses by stimulated Brillouin and Raman scattering.

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