48th Anomalous Absorption Conference

July 8th-13th, 2018   Bar Harbor, Maine

Organizing Committee

J. Bates, M. Karasik, J. Weaver

U. S. Naval Research Laboratory

Washington, DC

Conference Support

Jenifer Schimmenti

Strategic Analysis, Inc.

Arlington, VA

Sunday July 8th

6:00 - 10:00 PM	Registration
8:00 - 10:00 PM	Welcome Reception

Monday July 9th

Welcome/Opening Remarks

8:30 - 8:50 AM	Conference Organizing Committee

Oral Session	Session Chair:		Strozzi, LLNL	
8:50 - 9:10 AM	MO1	Winjum	UCLA	*Influence of magnetic fields on nonlinear electron plasma waves and kinetic stimulated Raman scattering*
9:10 - 9:30 AM	MO2	Palastro	LLE	*Resonant absorption of a broadband laser pulse*
9:30 - 9:50 AM	MO3	Wen	UCLA	*Simulations of stimulated Raman scattering for speckled laser with temporal bandwidth*
9:50 - 10:10 AM	MO4	Yan	Univ. Sci. & Tech. China	*Laser-plasma instabilities at large-angle oblique laser incidence*

10:10 - 10:30 AM	Coffee Break

Oral Session	Session Chair:		Albright, LANL	
10:30 - 10:50 AM	MO5	Molvig	LANL/MIT	*Theory of laser driven ablation*
10:50 - 11:10 AM	MO6	Sauppe	LANL	*Effects of double shell joint morphology and capsule size on implosion performance*
11:10 - 11:30 AM	MO7	Schmitt	LANL	*2-Dimensional simulations of the Revolver direct-drive multi-shell ignition concept*
11:30 - 11:50 AM	MO8	Wan	LANL	*Experimental investigation of hydrodynamic instability inhibition in a material gradient*
11:50 - 12:10 PM	MO9	Ho	LLNL	*High-yield implosions via radiation trapping and high rR*

Evening Invited Talk	Session Chair:		Casanova, CEA	
7:00 - 7:40 PM	MI1	Michel	LLNL	*Mitigation of SBS and associated optics damage in NIF experiments*

Evening Poster Session				
8:00 - 10:00 PM	MP1	Chan	NRL	*Nike laser-target facility and diagnostic systems*
	MP2	Tsung	UCLA	*Controlling laser plasma instabilities via bandwidth*
	MP3	Davies	LLE	*Picosecond-resolved collective Thomson scattering in underdense collisional plasmas*
	MP4	Manheimer	RSI	*A new model for alpha transport and deposition*
	MP5	Weis	SNL	*Advances in laser pre-heat modeling for MagLIF*
	MP6	Mori	UCLA	*The particle-in-cell and kinetic simulation software center*
	MP7	Myers	NRL	*Development of an argon fluoride laser for inertial confinement fusion*
	MP8	Cao	LLE	*Fluid modeling on three dimensional two plasma decay instability using FLAME-MD*

Tuesday July 10th

Oral Session	Session Chair:		Tsung, UCLA	
8:30 - 8:50 AM	TO1	Froula	LLE	*Plasma physics and broadband lasers - A path to an expanded inertial confinement fusion design space*
8:50 - 9:10 AM	TO2	Poole	LLNL	*Time resolved study of plasma amplifier for beam combination on NIF*
9:10 - 9:30 AM	TO3	Edgell	LLE	*Analysis of unabsorbed light beamlet images on OMEGA*
9:30 - 9:50 AM	TO4	Ralph	LLNL	*Crossed Beam Energy Transfer in "mid" fill hohlraums on the NIF*
9:50 - 10:10 AM	TO5	Hansen	LLE	*Plasma characterization for the OMEGA laser-plasma interaction platform*

10:10 - 10:30 AM	Coffee Break

Oral Session	Session Chair:		M. Schmitt, LANL	
10:30 - 10:50 AM	TO6	Albright	LANL	*The MARBLE campaign - understanding the interplay between heterogeneous mix and thermonuclear burn*
10:50 - 11:10 AM	TO7	Yin	LANL	*Plasma kinetic effects on interfacial mix and burn rates in multi-spatial dimensions*
11:10 - 11:30 AM	TO8	Li	UCSD	*Particle-in-cell simulations of laser plasma instabilities and hot electron generation in shock ignition regime*
11:30 - 11:50 AM	TO9	Luedtke	UT, Austin/LANL	*Photon jets for QED particle-in-cell laser-plasma simulations*
11:50 - 12:10 PM	TO10	Ren	LLE	*Laser-plasma instabilities in long-scale-length plasmas in shock ignition*

Evening Invited Talk	Session Chair:		A. J. Schmitt, NRL	
7:00 - 7:40 PM	TI1	Geissel	SNL	*3-Phase pulse shaping for laser pre-heat in Mag-LIF*

Evening Poster Session				
8:00 - 10:00 PM	TP1	Kehne	NRL	*Capabilities of the Nike laser for HEDP experiments*
	TP2	Ludwig	LLNL	*Design of a high-bandwidth probe laser for LPI and plasma photonics experiments*
	TP3	Schmitt	NRL	*Triangulated raytracing in spherically-gridded plasmas*
	TP4	Vold	LANL	*Further examination of multi-species plasma ion transport: results in 1-D ICF configurations*
	TP5	Berger	LLNL	*Multidimensional simulations of Brillouin amplification experiments*
	TP6	Rosculp	LANL	*Simulation of magnetically driven HEDP/ICF experiments with a Lagrangian/ALE Code*
	TP7	Bates	NRL	*Suppressing cross beam energy transfer in direct drive laser-fusion targets using stimulated rotational Raman scattering*
	TP8	Scheiner	LANL	*The role of incidence angle in the laser ablation of ICF targets*

Wednesday July 11th

Oral Session	Session Chair:		Geissel, SNL	
8:30 - 8:50 AM	WO1	Weis	SNL	*Advances in laser pre-heat modeling for MagLIF*
8:50 - 9:10 AM	WO2	Strozzi	LLNL	*Design of magnetized, room-temperature capsule implosions for NIF*
9:10 - 9:30 AM	WO3	Zhao	Tsinghua Univ.	*Measuring CH-Au interface in gas-filled hohlraum using Thomson scattering on SG-III prototype*
9:30 - 9:50 AM	WO4	Zimmerman	LLNL	*Factors which determine the magnitude of the Nernst effect in spherical and cylindrical implosions*
9:50 - 10:10 AM	WO5	Roycroft	LANL	*Ion beam driven isochoric heating on Texas Petawatt*

10:10 - 10:30 AM	Coffee Break

Oral Session	Session Chair:		Froula, LLE	
10:30 - 10:50 AM	WO6	Sary	CEA	*Comprehensive Zakharov-type modeling of parametric instabilities in the corona of direct-drive targets*
10:50 - 11:10 AM	WO7	Solodov	LLE	*Hot-electron generation and preheat in direct-drive experiments at the National Ignition Facility*

11:10 - 11:30 AM	WO8	Seaton	Univ. of Warwick	*Laser-plasma instabilities at ignition-scale: particle-in-cell simulations of shock ignition*
11:30 - 11:50 AM	WO9	Zhang	UCSD	*The generation of collimated moderate temperature electron beam in shock ignition-relevant planar target experiments on OMEGA-EP*
11:50 - 12:10 PM	WO10	Kagan	LANL	*Inference of the electron temperature in spherical implosions from x-ray spectra*
Conference Banquet				
6:00 - 8:00 PM	Post-banquet speaker			Dr. Robert C. Bayer, Director of Lobster Institute, Univ. of Maine: *Lobsters 101*

Thursday July 12th

Oral Session	Session Chair:		Kagan, LANL	
8:30 - 8:50 AM	RO1	Anderson	LANL	*A fully-conserving, adaptive, multi-scale algorithm with arbitrary temporal integration for the multi-species Vlasov-Ampere system*
8:50 - 9:10 AM	RO2	Keenan	LANL	*Unraveling the kinetic structure of multi-ion collisional plasma shocks*
9:10 - 9:30 AM	RO3	Wilson	LANL	*Assessing xRAGE predictive capability using the high-energy density physics validation suite*
9:30 - 9:50 AM	RO4	Manheimer	RSI	*Krook and Fokker Planck models for calculation nonlocal transport in a laser fusion target plasma*
9:50 - 10:10 AM	RO5	Farmer	LLNL	*Electron heat transport in beryllium sphere on Omega*
10:10 - 10:30 AM	Coffee Break			
Oral Session	Session Chair:		Rosenberg, LLE	
10:30 - 10:50 AM	RO6	Berger	LLNL	*The scaling of stimulated backscatter from BigFoot hohlraums with laser power and energy: practical backscatter reduction options*
10:50 - 11:10 AM	RO7	Liu	UMD	*Nonlinear transition to absolute Raman backscattering instability with trapped electrons - a theory for inflation of Raman reflectivity*
11:10 - 11:30 AM	RO8	Maximov	LLE	*Modeling of stimulated Raman scattering in inhomogeneous plasmas for conditions relevant to the National Ignition Facility*
11:30 - 11:50 AM	RO9	Chapman	LLNL	*Modeling optics damage patterns at the NIF caused by light backscattered from targets*
11:50 - 12:10 PM	Business Meeting			
Evening Invited Talk	Session Chair:		Michel, LLNL	
7:00 - 7:40 PM	RI1	Rosenberg	LLE	*Planar laser-plasma interaction experiments at the direct-drive ignition-relevant scale lengths at the National Ignition Facility*
Evening Poster Session				
8:00 - 10:00 PM	RP1	Casanova	CEA	*Modeling the propagation of a nanosecond smoothed laser beam in a multi-millimeter underdense plasma*
	RP2	Poole	LLNL	*Plasma instability enhancement for generating high fluence, high energy x-ray sources*
	RP3	Simakov	LANL	*Plasma ion stratification by weak planar shocks*
	RP4	Oh	NRL	*Progress on plasma profile measurements for the Nike experiments*
	RP5	Stark	LANL	*Laser-ion acceleration in the transparency regime*
	RP6	Weaver	NRL	*CBET studies in long scale-lengths plasmas at the Nike laser*
	RP7	Miller	UCLA	*Recent OSIRIS development for improved high-energy-density plasma simulations*

Friday July 13th

Oral Session	Session Chair:		Hu, LLE	
8:30 - 8:50 AM	FO1	Karasiev	LLE	*Density functional theory methods for transport and optical properties: application to warm dense silicon*
8:50 - 9:10 AM	FO2	Lee	NRL	*Radiative and atomic properties of C and CH plasmas under warm dense conditions*
9:10 - 9:30 AM	FO3	Patel	LLNL	*The role of NLTE atomics kinetics in radiation hydrodynamics modeling of ICF targets*
9:30 - 9:50 AM	FO4	Karasik	NRL	*Imprint mitigation with high-Z coating on Omega EP and NIF imprint experiments*
9:50 - 10:10 AM	Coffee Break			
Oral Session	Session Chair:		Weaver, NRL	
10:10 - 10:30 AM	FO5	Belyaev	LLNL	*Energy-conserving model of laser propagation and heating in subcritical foam*
10:30 - 10:50 AM	FO6	Hu	LLE	*Mitigating laser-imprint effects in direct-drive implosions on OMEGA with low-density foam layers*
10:50 - 11:10 AM	FO7	Langer	LLNL	*HYDRA simulations of laser-heated foams*
11:10 - 11:30 AM	FO8	Johns	LANL	*Analysis of radiation flow experiments in Ti-doped foams on OMEGA*
11:30 - 11:50 AM	FO9	Dhakal	LANL	*Effects of thermal conductivity of liquid layer in NIF wetted foam experiments*

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Influence of magnetic fields on nonlinear electron plasma waves and kinetic stimulated Raman scattering*

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Nonlinear electron plasma waves propagating perpendicular to magnetic fields can be damped due to the fact that trapped electrons (those moving near the phase velocity of the wave) in an average sense all get accelerated perpendicularly across the wave front, continually extracting energy from it[1,2]. We present particle-in-cell simulations of externally driven electron plasma waves showing how the initial damping of the wave, the evolution of the wave after several bounces, and its long time evolution after many bounce times are all effected by even weak magnetic fields ($\omega_c/\omega_p \ll 1$). We use these results to inform our simulations of backward stimulated Raman scattering (SRS) in which small normalized magnetic fields applied perpendicularly to a light wave can significantly modify SRS evolution in the kinetic regime. The presence of the magnetic field increases the threshold for kinetic inflation and decreases the amount of reflectivity when SRS is driven significantly above threshold.

[1] R. Z. Sagdeev and V. D. Shapiro, "*Influence of transverse magnetic field on Landau damping,*" JETP Lett. **17**, 279 (1973).
[2] J. M. Dawson et al., "*Damping of large-amplitude plasma waves propagating perpendicular to the magnetic field,*" Phys. Rev. Lett. **50**, 1455 (1983).

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July 8-13, 2018

Resonant absorption of a broadband laser pulse*

J. P. Palastro, J. G. Shaw, R. K. Follett, A. Colaïtis, I. V. Igumenshchev, V. N. Goncharov, and D. H. Froula
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Optical parametric amplifiers create high power, broad bandwidth infrared light. As a driver for inertial confinement fusion, these amplifiers present a trade-off: The bandwidth provides temporal incoherence, which can suppress laser–plasma instabilities, but precludes high efficiency conversion to the third harmonic, where laser–plasma interactions tend to be weaker. In resonance absorption, for instance, the fraction of laser energy converted to plasma waves and hot electrons increases with wavelength. We present calculations and simulations exploring the effect of bandwidth on resonant absorption. While linear calculations predict that bandwidth has little effect on electron heating, simulations, including the coupling to ion acoustic waves, show that bandwidth can increase or decrease the heating depending on the stage of the nonlinearity.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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 abstract.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
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Simulations of stimulated Raman scattering for speckled lasers with temporal bandwidth*

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Large-scale multi-dimensional particle-in-cell (PIC) simulations have been performed with parameters relevant to initial confinement fusion (ICF) experiments. Stimulated Raman scattering (SRS) has been studied with more realistic laser profiles by including laser speckles without and with temporal beam smoothing such as induced spatial incoherence (ISI) and smoothing by spatial dispersion (SSD), and Spike Train of Uneven Duration and Delay (STUD pulses). Simulation results show that SRS can be greatly reduced with laser bandwidth comparable to the temporal growth rate of the instability. Kinetic effects such as "inflation" have been found to be important for SRS even with high (6 THz) laser bandwidth in two dimensions.

* Work supported by NSF ACI 133983 and DOE DE-NA0002953

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Bar Harbor, Maine
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Laser Plasma Instabilities at Large-Angle Oblique Laser Incidence*

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In inertial confinement fusion, laser plasma instabilities (LPI) is a critical concern due to its impact on the laser coupling efficiency and the fuel preheating risk it may cause. When a laser is obliquely incident at a large angle with respect to the plasma density gradient, the turning-point density where it gets reflected can be lowered to near the quarter-critical-density region where stimulated Raman scattering (SRS) and Two plasmon decay (TPD) can be excited. We find that the LPI thresholds are reduced due to the field swelling near the turning-point density. The linear theory for TPD growths is developed and in good agreement with fluid simulations using FLAME-MD. Both the fluid simulations and the PIC simulations using OSIRIS show that TPD can be enhanced significantly when the angle is close to 60º. The PIC simulations show that different types of LPI become dominant for different incident angles, causing different nonlinear features and hot electron spectra.

*This work is supported by Science Challenge Project, No. TZ2016005, by Strategic Priority Research Program of the Chinese Academy of Science (Grant No. XDB16), and by the US DOE under Grant No. DE-SC0012316

48th Annual Anomalous Absorption Conference
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Theory of laser driven ablation*

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An asymptotic theory of laser driven ablation is presented. The theory is appropriate for directly driven implosions at intensities below any LPI thresholds, as proposed, for example, in the Revolver ignition design[1]. This puts the problem in the realm of the well understood physics: laser absorption via inverse Bremsstrahlung and heat flow from local electron heat conduction. The theory connects an outer region non-stationary, super-sonic rarefaction wave with a stationary, sub-sonic inner region flow. This configuration, in qualitative form, is well understood, but the detailed physics that accounts for much of the observed behavior in simulations and experiments has been a mystery. What are the conditions required for a stable sonic transition point? What is the sonic point density?

What is the length (in time) of the initial transient that establishes the quasi-steady flow?

What is the life time of the ablative drive (that decays as the coronal mass accumulates)? What causes the observed separation of electron and ion temperatures that increases with distance along the flow? And, finally, what is the mass ablation rate? And what is the ablation pressure? The theory presented in this paper gives answers to all of these questions and semi-analytic predictions of the parameters. The key advance of the theory comes from determining the conditions for the creation of a stable sonic transition point. A primary condition is that the sonic point coincide with the peak in the laser energy deposition profile. This condition determines the sonic point density. For example, we find that a stable sonic transition point cannot form until the sonic density is less than 8/9th critical, $\rho_s < 8/9\ \rho_c$. The sonic density time dependence is predicted by the theory, giving both the time of the initial transient and the lifetime for sustaining a quasi-steady ablative drive. Electron and ion temperature gradients do not separately vanish at the sonic point but cancel to make an effective net temperature gradient that is zero and allows the sonic transition. A positive electron temperature gradient that persists at the sonic point has the effect of reducing the net energy deposited into the rarefaction zone. This makes for the correct balance of power needed into the electrons to maintain a near isothermal flow in the corona. Detailed comparison with observations is forthcoming. *Research in this presentation was supported by the Laboratory Directed Research and Development Program of Los Alamos National Laboratory under project number XWPL.

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[1] *Kim Molvig, Mark J. Schmitt, B. J. Albright, E. S. Dodd, N. M. Hoffman, G. H. McCall, and S. D. Ramsey, Low fuel convergence path to direct-drive fusion ignition, Phys. Rev. Lett.* ***116****, 255003 (2016).*

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Effects of Double Shell Joint Morphology and Capsule Size on Implosion Performance*

J. P. Sauppe, S. H. Batha, P. A. Bradley, T. Cardenas, E. S. Dodd, F. Fierro, B. M. Haines, J. L. Kline, E. N. Loomis, E. C. Merritt, D. S. Montgomery, S. Palaniyappan, R. B. Randolph, R. F. Sacks, W. C. Wan, D. C. Wilson
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Double shell[2] target assembly requires an equatorial joint where two hemispheres are mated to form the outer shell. Experimental radiographs from recent sub-scale double shell shots at the National Ignition Facility (NIF) demonstrate that the joint morphology significantly impacts the implosion dynamics, and simulations show that the joint feature is a major factor in yield degradation. Consequently, understanding and mitigating the joint perturbation is important for improving double shell performance.

We discuss simulations of the double shell joint feature using xRAGE,[3] an Eulerian radiation-hydrodynamics code with adaptive mesh refinement well suited to modeling fine-scale engineering features. Post-shot simulations of the recent sub-scale (1.0 MJ laser energy) NIF experiments are presented, and synthetic radiographs of the joint feature are compared to the experimental data. Target metrology indicates the outer gap in these targets is roughly 5 um wide and 13 um deep, while the inner gap is 5 um wide and 22 um deep, but current plans are to reduce this further in future targets. Exploratory simulations at full-scale (1.8 MJ laser energy) are performed for a nominal capsule in a cylindrical hohlraum as well as scaled up variants designed for the novel rugby hohlraum.[4] Burn-off stagnation pressures, fall-line performance, and predicted yields are computed and compared, and the effects of joint morphology and changes in radiation drive are investigated. Several different inner shell materials are considered in order to best image shape transfer during shell collisions. Preliminary designs for a hydro-growth radiography[5] (HGR) platform to directly image the joint feature are discussed.

[2] P. Amendt et al., "*Assessing the prospects for achieving double-shell ignition on the National Ignition Facility using vacuum hohlraums*," Physics of Plasmas **14** 056312 (2007).
[3] B. M. Haines et al., "*High-resolution modeling of indirectly driven high-convergence layered inertial confinement fusion capsule implosions*," Physics of Plasmas **24** 052701 (2017).
[4] M. Vandenboomgaerde et al., *"Prolate-spheroid ("rugby-shaped") hohlraum for inertial confinement fusion,"* Physical Review Letters **99.6** 065004 (2007).
[5] V. A. Smalyuk et al., *"Measurements of an ablator-gas atomic mix in indirectly driven implosions at the National Ignition Facility,"* Physical Review Letters **112.2** 025002 (2014).

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2-Dimensional simulations of the Revolver direct-drive multi-shell ignition concept*

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The Revolver concept[1] employs several unique design features to attempt to obtain ignition using the current National Ignition Facility (NIF) laser system. Direct laser drive of a large 6 mm diameter outer beryllium shell maximizes laser drive energy conversion to target inward kinetic energy at low intensity ($3x10^{14}$ W/cm^2) while simultaneously minimizing any nonlinear drive non-uniformities and target coupling inefficiencies caused by laser-plasma instabilities. The relatively short laser drive time of 6.5 ns allows the energy to couple to the target before the plasma critical density radius shrinks significantly, thereby eliminating the need for laser zooming of the imploding target. The Revolver triple-shell concept is studied using 2D Hydra simulations of both an idealized multi-cone symmetric direct-drive (SDD) configuration followed by the asymmetric drive from the existing NIF multi-cone polar direct drive (PDD) configuration. Mode amplitude growth from the outer shell into the intermediate copper shell and finally into the inner gold shell is examined. Drive uniformity metrics are proposed for achieving multi-megajoule yields on the current NIF. Target design enhancements to mitigate drive non-uniformities are examined for their efficacy against both laser pointing errors and shot-to-shot laser beam power variations. A preliminary overview of recent Omega experimental results showing excellent hydro-coupling efficiencies (>90%) and mitigation of cross-beam energy transfer using low laser drive intensities and small beam-to-capsule ratios will be shown. Future proposed experiments on both Omega and NIF will be discussed.

* Research in this presentation was supported by the Laboratory Directed Research and Development Program of Los Alamos National Laboratory under project number XWPL.

[1]Kim Molvig, Mark J. Schmitt, B. J. Albright, E. S. Dodd, N. M. Hoffman, G. H. McCall, and S. D. Ramsey, *Low fuel convergence path to direct-drive fusion ignition*, Phys. Rev. Lett. **116**, 255003 (2016).

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Experimental investigation of hydrodynamic instability inhibition in a material gradient*

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Hydrodynamic instabilities are a significant degradation mechanism in Inertial Confinement Fusion (ICF) experiments; these instabilities contribute to asymmetries in the implosion dynamics and an undesired intermixing of species at material interfaces. Historically, hydrodynamic instabilities have been of particular concern in the design of double-shell capsule implosions due to the large Atwood numbers at the interfaces of the inner-shell.[1] We present simulations, radiographic data, and a preliminary analysis of a recent experiment in which we studied the inhibition of hydrodynamic instabilities by comparing the growth of seed perturbations in graded-density and tampered foils.

The Atwood number is a dimensionless expression of the density ratio between two fluids that approaches 1 when the density ratio is large, or 0 when the density ratio is small. Two of the most problematic instabilities in ICF, the Rayleigh-Taylor (RT) instability and the Richtmyer-Meshkov (RM) instability, grow more quickly at interfaces where the Atwood number is large. Analytic and computational models suggest that the growth rate of the RT and RM instabilities are significantly reduced in the presence of a density gradient.[2] These models do not, however, consider the complex effects of mixed opacities or equations of state that may arise from mixed-species density gradients. We utilized the RAGE[3] code to develop an experimental platform to measure instability growth in material-gradient foils. A halfraum is used to accelerate an Al ablator that collides with either a pure Zr foil, a Zr foil that has been tampered with a layer of Be, or a foil that consists of a linear material gradient of Be to Zr. The relative growth of precision-machined seed perturbations is inferred from on-axis x-ray radiography.

*Supported under the U. S. Department of Energy by the Los Alamos National Security, LLC under contract DE-AC52-06NA25396.

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[1] P. Amendt et al., "*Assessing the prospects for achieving double-shell ignition on the National Ignition Facility using vacuum hohlraums*," Physics of Plasmas **14** 056312 (2007).
[2] D.H. Munro, "*Analytic solutions for Rayleigh-Taylor growth rates in smooth density gradients*," Physical Review A **38** 1433-1445 (1988).
[3] B.M. Haines et al., "*High-resolution modeling of indirectly driven high-convergence layered inertial confinement fusion capsule implosions,*" Physics of Plasmas **24** 052701 (2017).

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High-yield implosions via radiation trapping and high ρR

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Placing a thin layer of mid- or high-Z material (e.g. Mo or W) at the inner surface of the ablator for reducing the implosion velocity and hotspot temperature thresholds for ignition is well known.[1-5] This is because this thin layer can reduce Bremsstrahlung radiation lost from the hotspot as well as improving the confinement by increasing the ρR of the assembled configuration. The problem with the thin layer is that it forms an unstable interface during the acceleration phase and this is the paramount concern for this type of implosion configuration. However, recent advances in target fabrication enable the doping of the inner region of Be ablators with mid- or high-Z material in such a way that the dopant concentration is decreasing toward the outer region of the ablator. This allows us to demonstrate substantially reduced Rayleigh-Taylor growth during the acceleration phase and high yield using high-resolution 2D simulations. Two types of capsule configurations — with DT gas only and with a DT ice layer, their performance and robustness, and their trajectories in $\rho r - T$ space will be presented. Simulation results show that reduced RT growths does not cause shell breakup and confirm that Bremsstrahlung radiation loss from the hotspot is reduced. They also reveal that the onset of propagated burn starts at a lower hotspot temperature in comparison with conventional ICF capsules. Furthermore, the yield of DT-gas only capsules can be considerably higher than that of conventional low-Z ablator configurations.

*This work is performed under auspices of U.S. DOE by LLNL under 15-ERD-058 and contract DE-AC52-07NA27344

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Mitigation of SBS and associated optics damage in NIF experiments*

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Stimulated Brillouin scattering (SBS) can lead to high levels of back-scattered laser energy in inertial confinement fusion (ICF) experiments on the National Ignition Facility (NIF). In addition to its impact on laser-target coupling and drive symmetry, SBS can also constrain experiments on NIF due to its potential to damage laser transport mirrors as the scattered light travels back upstream through the laser chain. Recent indirect-drive ICF designs have experienced a resurgence of SBS on the outer cones of NIF beams. This is attributed to the lower gas-fill used in these hohlraums,that allows the formation of a large volume of gold filling up the hohlraum (the “gold bubble”) that is prone to SBS growth. The experiment designs also have less reliance on crossed-beam energy transfer (CBET) to tune the implosion symmetry by transferring power to the inner cones, leading to increased power on the outer cones beams. Risk of optics damage due to SBS restricts the design space of most of these recent platforms and must be considered for operation of NIF at higher power and energy.

In this talk, we will review our recent efforts to understand and mitigate both SBS and the resulting optics damage. Mitigation strategies have been developed and tested in simulations using the code pF3D coupled to crossed-beam energy transfer calculations; these include laser-based LPI control (higher laser bandwidth, multi-wavelength upgrade, or optimized phase plate design), target optimization (e.g. changing the hohlraum wall composition to increase ion wave damping and reduce SBS), and facility protection against SBS scattered light. We will present the estimated impact of these mitigations on current ICF platform performance, and on scaled designs at higher laser energy.

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Nike Laser-Target Facility and Diagnostics Systems*

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The Nike laser-target facility is a 56-beam krypton fluoride system that can deliver 2 to 3 kJ of laser energy at 248 nm onto targets inside a two meter diameter vacuum chamber. Nike is used to study the physics and technology issues related to laser direct-drive ICF fusion, including hydrodynamic and laser-plasma instabilities, material behavior at extreme pressures, and optical and x-ray diagnostics for laser-heated targets.

We will discuss current laser and target experimental diagnostics systems fielded on the Nike target chamber, including:

- high-resolution curved-crystal x-ray streak imaging for target hydrodynamic instabilities and x-ray spectroscopy
- 5th harmonic grid image reflectometer and shadowgraphy for target plasma density
- 1D / 2D visar imaging of shock propagation through transparent targets
- absolutely calibrated, time-resolved soft x-ray and visible photo-detection for LPI and Raman studies
- neutron detectors for laser-accelerated target impact studies
- visible streak imaging of target rear shock breakout

We will also describe the status and plans for an experiment to impose multi-THz bandwidths on a frequency doubled Nd: glass laser using Stimulated Rotational Raman Scattering (SRRS) bandwidth in diatomic gases. The goal is to generate sufficient bandwidth to mitigate laser plasma instabilities.

*This work conducted under the auspices of DOE/NNSA.

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Controlling Laser Plasma Instabilities via Bandwidth*

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We have performed a series of 2+1/2D particle-in-cell simulations using the code OSIRIS to study the effects of laser plasma interactions in the presence of temporal and spatial incoherence under conditions relevant to current and future experiments on the NIKE laser. Our simulations show that, for sufficiently large bandwidth (where the bandwidth is comparable to the linear growth time), the saturation level, the distribution of hot electrons, and the laser coupling, can be effected by the addition of temporal bandwidths. Higher order effects and the importance of e-i collisions will also be investigated and reported.

*Prefer Poster
*This work is supported by DOE, NNSA and NSF.

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Bar Harbor, Maine
July 8-13, 2018

Picosecond-resolved collective Thomson scattering in underdense collisional plasmas*

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Thomson scattering spectra from collisional electron plasma waves were measured in an underdense (~10^{19}/cm) H_2 plasma irradiated by a 60-ps, 1053-nm laser pulse with an intensity of 2×10^{14} W/cm^2. The picosecond-resolved spectra were obtained with a novel pulse-front–tilt-compensated streaked optical spectrometer. The Thomson spectra have been compared to a collisionless Thomson scattering model, a Bhatnagar–Gross–Krook model, and an exact solution of the Landau kinetic equation that includes collision integrals.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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 abstract.

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Bar Harbor, Maine
July 8-13, 2018

A new model for alpha transport and deposition*

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Consultant to NRL through RSI Corporation

Alpha particle heating in a laser fusion target is generally treated with a flux limited diffusion model (1,2). Since 3.5 MeV alpha particles, for perhaps 95% of their energy deposition, travel in straight-line orbits and deposit their energy in electrons, it is unclear how valid a diffusion model can be, even with a flux limit. Recently an ion-alpha Fokker Planck model has been developed (3). This model treats alphas in a laser implosion with a flux limited diffusion model until just before burn, and then switches to Fokker Planck. It found lower gains, as the alphas spread out spatially more than the flux limited diffusion model predicted.

This paper develops a new and different theory for 3.5 MeV alpha particles based on straight-line orbits. It is simple to implement in a laser hydro code. Once the electron temperature increases to ~10 keV, one could either continue with the straight-line model, or switch to an ion-alpha Fokker Planck model as in Ref (3). In fact according to this theory and Ref. (3), one could accurately shift to the Fokker Planck model considerably later in the implosion than is the case for flux limited diffusion model.

*This work was supported by DoE NNSA and ONR

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Bar Harbor, Maine
July 8-13, 2018

Advances in Laser Pre-Heat Modeling for MagLIF*

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Magnetized Liner Inertial Fusion (MagLIF) requires preheating of the fusion fuel with the 532 nm Z-Beamlet laser (ZBL). Introduction of beam smoothing and modifications to the temporal structure of the laser pulse have improved the predictive performance of magneto-hydrodynamics codes, such as HYDRA, that are used to design MagLIF experiments performed on the Z-machine at Sandia National Laboratories. This success is made possible by laser-only experiments in the Pecos target chamber that are used to benchmark 2D and 3D HYDRA simulations of laser preheat. In the absence of significant LPI, the benchmarked simulations provide estimates of deposited energy in the fuel (deuterium) and plastic window (1.7 um of polyimide) as well as the potential for a given laser pulse shape to introduce mix of the window into the fusion fuel.

Currently, until Pecos is upgraded, HYDRA is primarily relied upon to assess the impact of the axial magnetic field present in MagLIF (~ 10 T). The HYDRA MHD package now includes most of the relevant physics and terms required to assess magnetic field effects, such as anisotropic thermal conduction, the Nernst and Ettingshausen thermo-electric terms, and Biermann term for self-generated fields. The influence of Hall physics is a focus of future simulation work. Generally, the strength of the magnetic field does not strongly affect the total energy deposited in the fuel, but strongly influences the distribution of energy through thermal conduction inhibition.

Despite the leap from un-magnetized to magnetized preheat, results of integrated MagLIF calculations using the benchmarked laser calculations compare favorably with experiments on the Z-machine and indicate significant increase in preheat energy as compared to previous experiments utilizing an unsmoothed laser. Current design efforts are focused on continuing to increase the fuel density while necessarily increasing the preheat energy, all the while, maintaining a low LPI environment.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

The Particle-in-Cell and Kinetic Simulation Software Center*

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The UCLA Particle-in-Cell and Kinetic Simulation Software Center (PICKSC) aims to support an international community of PIC and plasma kinetic software developers, users, and educators; to increase the use of this software for accelerating the rate of scientific discovery; and to be a repository of knowledge and history for PIC. We discuss progress towards making available and documenting illustrative open-source software programs and distinct production programs; developing and comparing different PIC algorithms; coordinating the development of resources for the educational use of kinetic software; and the outcomes of our first sponsored OSIRIS users workshop. We also welcome input and discussion from anyone interested in using or developing kinetic software, in obtaining access to our codes, in collaborating, in sharing their own software, or in commenting on how PICKSC can better serve the community.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Development of an argon fluoride laser for inertial confinement fusion*

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The U.S. Naval Research Laboratory is converting the repetitively pulsed Electra krypton fluoride (KrF) laser system to an electron-beam pumped argon fluoride (ArF) laser. Operating at 193 nm, ArF has the potential of being the most efficient excimer laser and is a good candidate for driving inertial confinement fusion (ICF) targets. The shorter wavelength increases energy coupling to the target due to increased absorption at higher density and reduction of laser-plasma instabilities (from both smaller wavelength and a cooler plasma). Shorter wavelength also increases hydrodynamic efficiency, due to the higher ablative pressure. Thus, the attributes of the ArF laser are attractive for an ICF driver.

Here we report on measurements of the small signal gain, non-saturable absorption, and saturation intensity of ArF as a function of gas pressure in an electron-beam pumped amplifier. These measurements allow an evaluation of the intrinsic efficiency as function of energy deposition in the gas. The data also, in conjunction with the NRL-developed ArF kinetics code Orestes, can be used to design modifications of the electron-beam amplifier for optimal output. These modifications include reducing the height of the electron-beam emitter to increase current density and using a higher transparency support structure for the pressure foil to achieve higher electron-beam deposition in the ArF gas mixture. Our program goals are to evaluate the laser performance as a function of pressure, electron-beam deposition, and gas composition; advance the NRL ArF kinetics code to be a reliable and predictive tool for designing large scale electron-beam pumped ArF lasers; and develop the required electron-beam technologies to fabricate large scale ArF lasers.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Fluid modeling on three dimensional two plasmon decay instability using FLAME-MD*

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Comprehensive simulations of laser plasma instabilities over large spatial and temporal scales in an ICF plasma is important to target design but challenging to perform. Fluid models can be a good candidate for their lower computational cost compared to particle-in-cell models. We continue to improve our 3D fluid code FLAME-MD based on the fluid-like equations[1]. FLAME-MD is designed to be able to simulate all types of LPIs including the stimulated Raman scattering (SRS), the stimulated Brillouin scattering (SBS), and the two-plasmon decay instability (TPD) simultaneously with a self-consistent laser propagation – pump depletion model. Each type of LPI can be switched on and off for a better understanding with physical mechanisms able to be isolated. Now the SRS and TPD modules have been largely completed and benchmarked with previous codes LTS[2] and Glints[3]. The laser-polarization effect on TPD is simulated for ICF relevant parameters using FLAME-MD. It is found that TPD with a circular-polarized laser has much lower growth rates than that with a linear-polarized laser given the same Poynting-flux of the two lasers, indicating a likely advantage using CP lasers as the ICF driver.

*This work is supported by the US DOE under Grant No. DE-SC0012316, and by China Science Challenge Project, No. TZ2016005.

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Tuesday July 10th

Oral Session	Session Chair:		Tsung, UCLA	
8:30 - 8:50 AM	TO1	Froula	LLE	*Plasma physics and broadband lasers - A path to an expanded inertial confinement fusion design space*
8:50 - 9:10 AM	TO2	Poole	LLNL	*Time resolved study of plasma amplifier for beam combination on NIF*
9:10 - 9:30 AM	TO3	Edgell	LLE	*Analysis of unabsorbed light beamlet images on OMEGA*
9:30 - 9:50 AM	TO4	Ralph	LLNL	*Crossed Beam Energy Transfer in "mid" fill hohlraums on the NIF*
9:50 - 10:10 AM	TO5	Hansen	LLE	*Plasma characterization for the OMEGA laser-plasma interaction platform*
10:10 - 10:30 AM	Coffee Break			
Oral Session	Session Chair:		M. Schmitt, LANL	
10:30 - 10:50 AM	TO6	Albright	LANL	*The MARBLE campaign - understanding the interplay between heterogeneous mix and thermonuclear burn*
10:50 - 11:10 AM	TO7	Yin	LANL	*Plasma kinetic effects on interfacial mix and burn rates in multi-spatial dimensions*
11:10 - 11:30 AM	TO8	Li	UCSD	*Particle-in-cell simulations of laser plasma instabilities and hot electron generation in shock ignition regime*
11:30 - 11:50 AM	TO9	Luedtke	UT, Austin/LANL	*Photon jets for QED particle-in-cell laser-plasma simulations*
11:50 - 12:10 PM	TO10	Ren	LLE	*Laser-plasma instabilities in long-scale-length plasmas in shock ignition*
Evening Invited Talk	Session Chair:		A. J. Schmitt, NRL	
7:00 - 7:40 PM	TI1	Geissel	SNL	*3-Phase pulse shaping for laser pre-heat in Mag-LIF*
Evening Poster Session				
8:00 - 10:00 PM	TP1	Kehne	NRL	*Capabilities of the Nike laser for HEDP experiments*
	TP2	Ludwig	LLNL	*Design of a high-bandwidth probe laser for LPI and plasma photonics experiments*
	TP3	Schmitt	NRL	*Triangulated raytracing in spherically-gridded plasmas*
	TP4	Vold	LANL	*Further examination of multi-species plasma ion transport: results in 1-D ICF configurations*
	TP5	Berger	LLNL	*Multidimensional simulations of Brillouin amplification experiments*
	TP6	Rosculp	LANL	*Simulation of magnetically driven HEDP/ICF experiments with a Lagrangian/ALE Code*
	TP7	Bates	NRL	*Suppressing cross beam energy transfer in direct drive laser-fusion targets using stimulated rotational Raman scattering*
	TP8	Scheiner	LANL	*The role of incidence angle in the laser ablation of ICF targets*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Plasma physics and broadband lasers—A path to an expanded inertial confinement fusion design space*

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To expand the inertial confinement fusion (ICF) design space, innovative laser–plasma instability (LPI) mitigation services are required. The Laboratory for Laser Energetics is developing advanced diagnostics, focused LPI experiments, and a broadband laser to expand the LPI understanding. To study the dynamics of both electron plasma and ion acoustic waves, a target platform has been developed on OMEGA that enables interactions between frequency-shifted laser beams. When the frequency shift between the beams is small ($\delta\lambda/\lambda$ ~1%), the beat wave will drive ion-acoustic waves. When the frequency shift between beams is large ($\delta\lambda/\lambda$ ~50%), the beat wave will drive electron plasma waves. This platform will provide detailed studies of ion-acoustic and electron plasma waves driven by multiple laser beams with ICF-relevant laser beam conditions (e.g., phase plates, smoothing by spectral dispersion, polarization smoothing, etc.). A broadband laser beam ($\delta\omega/\omega$ ~ 10%) is planned to be implemented on this platform to investigate the effects of bandwidth on LPI and determine the level of bandwidth required to mitigate LPI in ICF plasmas. The high-bandwidth beam will use laser technologies that will enable various spectral formats to be tested.

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Time resolved study of plasma amplifier for beam combination on NIF*

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Recent work at the National Ignition Facility (NIF) has demonstrated a plasma-based optic that combines the energy and fluence of many laser beams into a single bright beam, thus creating a new capability for designing future high energy density physics experiments. The technique uses the Cross Beam Energy Transfer (CBET) process and shows that a plasma can combine pulses to produce a single beam that emerges with energy and fluence beyond that of any inputs, to be delivered then to a range of possible experimental targets requiring compact, high energy laser delivery.

The initial beam combiner campaign[1,2] utilized up to 8 pump beams to produce a directed pulse of light, and more recent shots have scaled up to 20 pump beams resulting in a record ~8 ± 1.7 kJ of energy in the 1 ns duration seed pulse, a 10x increase from the original seed beam. The resulting self-generated plasma diffractive optic is far more damage resistant than existing solid state optics and is consequently capable of producing much higher single beam fluence and radiance than solid state refractive or reflective optics can.

A summary of the recent campaign results and simulations at higher pump power will be presented, as well as a study of the temporal characteristics of seed amplification within the 1 ns pulse.

*This work conducted under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

[1] R. K. Kirkwood *et al.* Nature Physics **14**, 80-84 (2017).
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Analysis of unabsorbed light beamlet images on OMEGA*

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When unabsorbed light from an OMEGA implosion is imaged, a distinct spot is observed for every laser beam. Each spot is, in essence, the end point of a beamlet of light that originates from different regions of each beam's profile and follows a path determined by refraction. The intensity of each spot depends on the absorption and cross-beam energy transfer (CBET) the beamlet experiences along its path. The beamlets diagnostic uses a Wollaston prism and an etalon time-delay prism to simultaneously record gated images for both *s* and *p* polarizations of the unabsorbed light from two separate times during the implosion. This diagnostic has provided the first evidence of polarization rotation caused by CBET during direct-drive implosions.

The beamlets diagnostics lends itself to several possible measurements that could prove very beneficial to the understanding of absorption, including the effects of CBET and its mitigation during inertial confinement fusion direct-drive implosions. In a perfectly symmetric implosion, all beamlets at the same radius in the image would have the same intensity. Variations in intensity of these beamlets directly correlate to nonuniformity in the absorption or CBET over the target. Since the position of the beamlet spots depends on refraction through the coronal plasma, the radial density scale length may be inferred from the spot locations and compared to hydrocode predictions. Additional beamlets diagnostics would give measurements of the unabsorbed light from multiple locations in the beam profile for each beam. This would be particularly useful for verifying CBET mitigation by wavelength separation using the upcoming TOP9 wavelength variable beam on OMEGA.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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 abstract.

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Bar Harbor, Maine
July 8-13, 2018

Crossed Beam Energy Transfer in "Mid" Fill Hohlraums on the NIF*

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Maximizing the hohlraum x-ray drive on inertial confinement fusion capsules remains a key aim at NIF. The NIF laser presently produces a maximum energy of approximately 1.9 MJ of 351 nm (3ω) laser light in 192 beams with plans to increase the energy to greater than 2 MJ in the near future. The typical hohlraum is a helium filled, gold coated, depleted uranium can with two laser entrance holes (LEHs), one at either end of the can. The beams on the NIF can be divided into inner and outer. The geometry of the NIF is such that the inner beams are incident near the waist of the hohlraum producing x-rays that drive the capsule located at the center of the hohlraum from the equator, while outer beams deposit their energy near the LEHs producing x-rays that drive the capsule from the poles. Balancing the x-ray drive from the pole and the waist is essential to produce round implosions. Since the high foot campaign demonstrated alpha heating for the first time on the NIF, new designs have avoided using crossed beam energy transfer (CBET) to balance the x-ray drive because of the added complication and risk of laser plasma interactions. The designs have instead opted for altering the experiment geometry such as changing the ratio of the capsule diameter to the hohlraum diameter or changing to beam pointing. In addition, new designs use a lower helium fill density of 0.6 mg/cc to reduce hot electron production and stimulated Raman Backscattering[1] (SRS) compared to the 1.6 mg/cc used in the high foot campaign. Here we present measurements and simulations that demonstrate a good understanding of CBET throughout the laser pulse when using a 0.6 mg/cc He fill. Additionally, we present experimental results showing that hot electrons production and inner beam SRS levels remain low even with post CBET powers exceeding 4 TW/beam. Measurements also show that although measured Stimulated Brillouin Scattering (SBS) levels were high with multiple beamline optics damaged by the >1 kJ backscatter, the required level of CBET for round implosions is shown to be lower and well outside the damaging range. These results indicate a window wherein the size of the capsule could be increased to absorb more hohlraum radiation.

* This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

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July 8-13, 2018

Plasma characterization for the OMEGA laser−plasma interaction platform*

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A supersonic gas-jet system has been developed on OMEGA to provide uniform plasmas for focused laser–plasma instability studies. A ~2-mm-diam volume of gas was heated by ten 351-nm, 200-J, 500-ps heater beams that used phase plates to generate uniform ~500-μm-diam laser spots in the gas. The plasma conditions were characterized using spatial and temporally resolved optical Thomson scattering. A uniform ~1-mm-scale plasma plateau $\left(\sim 1\% n/n_c^{3\omega}\right)$ was measured with an electron temperature of 800 eV. This work is in preparation for the activation of a new laser–plasma interaction platform on OMEGA, which will include a wavelength tunable UV beam ($\Delta\lambda_{3\omega}$ ~ 3.5 nm) and complementary transmitted-beam diagnostics. This platform facilitates the study of ion and electron waves in plasma conditions relevant to inertial confinement fusion conditions.

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48th Annual Anomalous Absorption Conference
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July 8-13, 2018

The MARBLE campaign - understanding the interplay between heterogeneous mix and thermonuclear burn*

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MARBLE[1] is a unique separated reactants campaign on the NIF that seeks to investigate the effects of heterogeneous mix on thermonuclear burn. The goal of MARBLE is to obtain data that can be used to validate models, such as the probability distribution function (PDF) burn model[2], of thermonuclear burn in heterogeneous media. MARBLE uses Si-doped plastic capsules filled with deuterated plastic foam and cryogenic hydrogen-tritium gas fills. Embedded in the foam are "macro-pores," engineered voids in the foam of known sizes and locations, which allow for control of the level of heterogeneity prior to hydrodynamic mixing. In MARBLE implosions, the ratio of DT to DD neutron yield is measured, from which the level to which the material has mixed atomically can be obtained. The MARBLE campaign has successfully completed a one shock platform development mini-campaign on the NIF that demonstrated the ability to field and diagnose thermonuclear burn in engineered foam capsules. A new mini-campaign has begun with a two-shock implosion design that is expected to have higher levels of turbulent mix and lower levels of fuel preheat. Initial tuning shots have exhibited superior implosion symmetry. Initial results from this mini-campaign will be discussed.

*Work performed under the auspices of the U.S. Department of Energy by the Los Alamos National Security, LLC Los Alamos National Laboratory under contract DEAC52-06NA25396.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Plasma kinetic effects on interfacial mix and burn rates in multi-spatial dimensions*

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Mixing at interfaces in dense plasma media is a problem central to inertial confinement fusion (ICF) and high energy density laboratory experiments. In this work, particle-in-cell VPIC[3] simulations in one- and higher-spatial dimensions (2D and 3D) with a binary collision model are used to explore kinetic effects arising during the mixing of unmagnetized plasma media. In 1D, comparisons[4] are made to the results of recent analytic theory in the small Knudsen number limit[5]. For both short and long timescales, mixing at interfaces leads to persistent, bulk, hydrodynamic features in the center of mass flow profiles. This behavior arises as a result of the diffusion process and conservation of momentum. In other words, interfacial mixing inevitably generates modifications to the bulk hydrodynamics, a result that has not been examined extensively in prior studies. These conclusions are drawn from VPIC results together with simulations from the RAGE code[6] with a new implementation of diffusion and viscosity from theory[3] and a novel implicit Vlasov-Fokker-Planck (iFP) code[7]. The applicability of the 1D ambipolarity criterion (from which theoretical plasma transport models have been derived) was evaluated in 2D and 3D VPIC simulations of a plasma interface with a sinusoidal perturbation. The 1D ambipolarity condition is found to remain valid in 2D and 3D simulations, as electrons and ions still flow together as required by $\boldsymbol{J}=0$. The simulations show that in higher dimensions the kinetic behavior of sinusoidally perturbed interfaces together with the associated hydrodynamic flows act to flatten high wavenumber perturbations and enhance the rates of mix. Such dynamics have been shown to inhibit the growth of instabilities such as the Rayleigh-Taylor instability, leading to fundamental differences in the dynamics of mixing in plasma media. Finally, under plasma conditions relevant to MARBLE separated-reactants experiments, finite Knudsen-number, kinetic modifications to the thermonuclear burn rates are observed.

* Work performed under the auspices of the U.S. DOE by the Los Alamos National Security, LLC Los Alamos National Laboratory and supported by the LDRD, ASC, and Experimental Sciences programs.

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Bar Harbor, Maine
July 8-13, 2018

Particle-in-cell simulations of laser plasma instabilities and hot electron generation in shock ignition regime*

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Experiments[1] conducted on the OMEGA EP laser facility with high-intensity, multi-kJ UV laser (1×10^{16} W/cm^2, 1.25 kJ, 1 ns) interacting with a long scalelength keV corona plasma have shown strongly directional hot electrons with moderate temperature (~45 keV), which is favorable for electron assisted shock ignition. To understand the underlying physics, we have performed 2-dimensional particle-in-cell (PIC) simulations with a long density range (0.01~0.3n_c) using the OSIRIS code to study the laser plasma instabilities (LPI) and resultant hot electron generation in the experiments. We aimed at investigating the hot electron energy fraction, temperature and angular distribution and the corresponding LPI behaviors and contributions. The simulation results show that SBS reflects significant amount of laser energy in the region with density below 0.1n_c, and this amount decreases if a laser speckle is used instead of plane wave laser. The hot electrons are mainly generated by TPD near the n_c/4 surface with half angle of 30 degrees and temperature of 40 keV, which agree very well with the experiments. The major mechanism of generating hot electrons changes to SRS if the laser is directly injected at 0.14n_c instead of 0.01n_c, suggesting the importance of modeling LPI below 0.1n_c. More details of the simulation results will be presented in the meeting.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Photon Jets from QED Particle-in-Cell Laser-Plasma Simulations*

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The goals of discovering quantum radiation dynamics in high-intensity laser-plasma interactions and engineering new laser-driven high-energy particle sources both require accurate and robust predictions. We introduce a new "jet" observable to describe quantitatively a characteristic dipole pattern of high-energy photon emission that results when the laser pulse bores through the target, forming a channel that enhances the laser field. We establish that the phenomenon is robust by showing that the dipole pattern gradually switches on as a function of target density, and with no need for wavelength scale structure in the target, as used in previous work.[1] The observable is robust to experimentally-motivated perturbations including a preplasma and non-normal laser target angle. We analyze statistical uncertainties and compare results from two particle-in-cell codes.[2,3] We offer quantitative guidance for the design of experiments and detectors, setting the stage to use photon emission to interpret dynamics during high intensity laser-plasma experiments.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Laser-plasma instabilities in long-scale-length plasmas in shock ignition*

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We review some of our recent Particle-in-Cell (PIC) and fluid simulations of laser plasma instabilities (LPI) and hot electron generation in shock ignition in the regime of long density scale length.[1,2,3] Issues to be discussed include intermittency induced by mode-coupling via Langmuir wave decay instability (LDI) and laser pump depletion; the role of convective modes; and comparison with existing experimental data[4]. The results show that LPI may severely limit the laser energy reaching the quarter-critical surface.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

3-Phase Pulse Shaping for Laser Pre-Heat in MagLIF*

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The laser-driven pre-heating of deuterium gas for Magnetized Liner Inertial Fusion (MagLIF) is studied in stand-alone experiments at the PECOS target area with Sandia's Z-Beamlet laser facility. The target area is a surrogacy test-bed for new pulse shapes and target configurations. Hydrodynamic simulations provide suggestions for incremental improvements that are verified and quantified through backscatter measurements and calorimetric shadowgraphy. The latter uses strobed snap-shots of the propagating blast wave in the fuel and interprets the time- and depth-dependent radii as a measure of deposited energy.

The implementation of deuterium as fill gas, replacing the previously used helium surrogate, revealed significant differences between gas species with respect to both backscatter efficiency and energy deposition profile. To improve laser heating with respect to both observables, and to minimize gas contamination from upstreaming material of the laser-entrance-hole window (LEH), an advanced laser pulse shape was developed. The new laser pulse shape consists of an early pre-pulse (t = -20 ns, phase 1), that has been co-injected by a separate laser, followed by a 'foot' of low intensity (t ~ -2 ns, phase 2) to reheat the previously disassembled LEH material, and a final 4-5ns long main pulse (phase 3). The new 3-phase pulse shape provides better laser-target coupling with low backscatter and proved to reduce LEH mix in integrated MagLIF experiments dramatically. The observed reduction of backscatter and the improved propagation into the gas also enable the use of 1.05 mg/cc gas fills instead of the previous standard fill of 0.7 mg/cc. Gas fills of 1.4 mg/cc will be tested later in the year. The latest iteration of the 3-phase pulse shape, using a 1.1 mm phase plate for focus conditioning and a 1.05 mg/cc target fill, contributed to producing the highest neutron yield on integrated MagLIF experiments to date.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Capabilities of the Nike Laser for HEDP Experiments*

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The Nike Laser[1] at the Naval Research Laboratory is a krypton fluoride laser capable of delivering 2-3 kJ of 248 nm radiation in 44 overlapped beams onto planar targets. Twelve beams serve as backlighter diagnostic beams. Capabilities of the laser have been extended over the past several years. Focal zooming[2], the ability to change on-target beam size in time, has been implemented on Nike. This feature allows wide flexibility in creation of pulse shapes and intensities on target and is currently being employed in experiments. The inherent bandwidth of the Nike Laser has been measured as 1.0 THz, 0.7 ps coherence time[3]. Bandwidth control (0.3 THz to 2.7 THz) via etalons previously implemented on the main beams has now been extended to the backlighters, being useful for beam-beam interaction experiments. Long path (up to 5 meters) high intensity beam experiments have allowed the study of Stimulated Rotational Raman Scattering (SRRS) with extensive diagnostics, including, pulse shape, energy, spectrum (time-integrated and time-resolved), far-field and near-field profiles both before, within, and after the interaction region. Controlled generation of SRRS is a potential means to generate wide bandwidth with the goal of suppressing deleterious Laser Plasma Interactions. The capabilities of the Nike Laser and results of the SRRS experiments are presented.

*This work supported by the US Department of Energy.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Design of a high-bandwidth probe laser for LPI and plasma photonics experiments*

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Pump-probe laser-plasma experiments have recently demonstrated that the refractive index of a laser-plasma system could be arbitrarily modified, enabling the design of plasma-based optical elements such as polarizers and Pockels cells[1,2]. In this presentation, we will present a new design for a probe laser with high, tunable bandwidth, to be built at the optical science laboratory (OSL) laser at LLNL. The goal is to achieve single-shot probing of plasma photonics structures. Our design is a variation on smoothing by spectral dispersion (SSD). In this study we are varying several key parameters (e.g. modulation frequency, modulation depth, color-cycling and angular dispersion) while keeping the bandwidth fixed, and look at the impact on laser-plasma interactions for single-shot probing of plasma photonics structures, and mitigation of LPI in ICF experiments.

* This work was supported by the LLNL-LDRD Program under Project No. 45020/81435.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Triangulated raytracing in spherically-gridded plasmas*

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Laser power deposition in hydrocodes using conventional raytracing techniques is numerically noisy. This noise is due to the discrete representation the rays provide of the propagating laser light, as opposed to a more physical wave/EM-field model.[1] The computational advantages of raytracing – lower computer memory requirements along with the straightforward handling of reflections or turning points usually outweigh these problems. However, this noise can easily mask the physical imprinting of an optically smoothed laser -- to calculate laser imprint with raytracing, one needs effective techniques to reduce this noise.

Common techniques to reduce ray-tracing noise invoke combinations of: (i) numerical smoothing of the deposited power, (ii) increasing the number of rays, and (iii) careful non-random placement of the initial rays[2] . In the new approach taken here, we calculate power deposition by considering the rays to be connected together via a triangulation established in the lens plane. As these triangles propagate through the plasma, they sweep out the entire deposition volume; the deposited power is calculated by integrating the swept triangles (prisms) over the plasma grid. This reduces the need for more rays and also allows other relevant quantities carried by the ray (e.g., the phase, amplitude, and ***k*** of the light field) to be interpolated from the connected rays.

We have applied this approach to a designing a raytracing module for the 3D orthogonal spherical-grid hydrocodes Aster and FAST3D. We show our current results and discuss the strategies, pitfalls and optimizations involved in using triangulated distributions on non-Cartesian grids.

* Work supported by US DoE/NNSA.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Further examination of multi-species plasma ion transport: results in 1-D ICF configurations

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We examine simulations of 1D ICF implosions reported recently [1] using a fully self-consistent multi-species plasma ion transport model [2-3] implemented in the Eulerian AMR radiation hydro code, Rage. Initial 1D tests compare well to binary mix problems [4,5] and to a planar isothermal and isobaric mix problem with 4 ion species, a D-T fuel and a plastic shell of C-H [6]. The test problem examined in the present work is a modification of a 1D spherical Omega experiment originally with Ar impurity doped deuterium fuel in a plastic shell [7]. Three case are compared; 1, DT fuel with CH plastic shell alone, 2, adding a 1% Ar impurity to the fuel region, and 3, adding a 1% Ar impurity to the shell region, coupling the transport of the 5 ion species, D, T, Ar, C, H. Mixing profiles for the four ion case, D-T and C-H seen here in 1D ICF geometry at several times are compared to ion profiles in the planar self-similar isobaric result reported in [6]. We examine ion profiles prior to shock convergence when the ion temperature gradient in the shock front dominates ion separation, and ion profiles show the expected signature of depletion of the heavier ion species. During later convergence and at maximum density compression, fuel-shell mixing and ion stratification are apparent. The carbon in the plastic is the least mobile ion relative to the Lagrange frame, while hydrogen in the shell penetrates to the center in all cases. The Ar impurity initially in the fuel is relatively mobile, while Ar initially in the shell remains tightly coupled with the carbon and does not penetrate to the center. Results are considered in the context of ICF experiments, which have demonstrated 'anomalous yields' compared to single fluid simulations. Difficulties in distinguishing plasma ion transport from numerical diffusion in 2D or 3D simulations as previously discussed [5] are addressed as a final point.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Multidimensional Simulations of Brillouin Amplification Experiments*

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Amplification of an intense, short-pulse laser beam in a plasma by extracting energy from a long pulse laser beam via Raman or Brillouin scattering has been studied extensively with theory and simulations for nearly 20 years. Recent experiments at LULI with the ELFIE laser facility have demonstrated nearly 25% conversion of the 9 Joules incident in a 1.7ps FWHM pulse with intensity of 4 x 10^{16} W/cm^2 at a wavelength, λ= 1058 nm via Brillouin amplification. The seed beam, incident at a 165^o angle to the pump beam, had a pulse length of 0.55ps. The plasma, created by a third beam, had a maximum density of ~0.05 n_c where n_c is the critical density for 1058 nm light. The plasma density profile was Gaussian with FWHM length of ~750 μm along the laser propagation direction. The temperature was ~100 eV.

The 3D wave propagation code, pF3D, was used to simulate this amplification process with the experimental pump and seed energies, correct angle between the pump and seed, and realistic density and temperature profiles. Optimization of the energy exchange was studied experimentally by varying the seed energy and time delay between the pump and seed pulses. A set of simulations varying the seed energy and pump-seed delay showed very good agreement with the overall behavior of the amplification and energy exchange as a function of these parameters, and reasonable agreement for the value of the measured seed energy gain. Both spontaneous stimulated Raman and spontaneous and seeded Brillouin scattering reach nonlinear levels. The role of nonlinearity of the plasma waves will be discussed.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Simulation of Magnetically Driven HEDP/ICF Experiments with a Lagrangian/ALE Code[1]

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Magnetic drive has recently received a great deal of attention in the context of high energy density physics (HDEP) as well as inertial confinement fusion (ICF). Here, stored electrical energy in converted into mega-Gauss level magnetic fields that accelerate a conductor that, in turn, drives materials to HEDP regimes or compresses fusion fuel. Most prevalent are cylindrical Z-pinch configurations where a pulsed, axial current generates an azimuthal field via Lorentz forces. The system may or may not be complemented by a static axial field to aid in confinement. Another configuration utilizes a planar geometry for either shocked or quasi-isentropic loading. In order to study the performance of these emerging designs, sophisticated computational tools are required. At the very least, a single-fluid, resistive, magneto-hydrodynamics (MHD) model must be implemented. Shown here are recent developments and applications of the Lagrangian/ALE FLAG code to such problems. Through verification test problems, an explicit, ideal MHD algorithm is shown to be second order on smooth test problems and first-order on problems involving shock discontinuities. The operator-split, implicit, resistive diffusion algorithm is shown to be second-order on arbitrary polyhedral/polygonal meshes. Finally, results of simulation of relevant Z-pinch and planer configurations for HEDP and ICF applications are shown.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
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Suppressing cross-beam energy transfer in direct-drive laser-fusion targets using stimulated rotational Raman scattering*

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Cross-beam energy transfer (CBET) is a significant energy-loss mechanism in directly drive inertial-confinement-fusion (ICF) schemes. Simulations with the wave-based code LPSE [1] have demonstrated that a laser bandwidth of 5 THz (corresponding to a normalized bandwidth of 0.6% at a laser wavelength of 351 nm) is sufficient to suppress CBET under realistic plasma conditions [2]. Although such a bandwidth is beyond that presently available with contemporary lasers used for ICF, it could likely be achieved by passing high-power "narrowband" light through diatomic gas cells and relying on stimulated rotational Raman scattering (SRRS) to augment the spectrum of illuminating radiation with additional discrete-wavelength components [3]. Here, we report on recent LPSE simulations modeling the four principal Stokes lines generated by SRRS in air [4] and assess their utility for CBET suppression in ICF targets. We also briefly discuss the efficacy of using a single discrete separation of laser wavelengths (*i.e.*, laser "detuning") to mitigate CBET --- an approach that was employed in recent polar-direct-drive experiments performed on the National Ignition Facility [5].

[1] J.F. Myatt *et al*., Phys. Plasmas **24**, 056308 (2017).
[2] J.W. Bates *et al*., *to appear in* Phys. Rev. E, Rapid Communications (2018).
[3] N. Bloembergen, *Nonlinear Optics* (World Scientific Publishing, Singapore, 1996).
[4] Y. Lin, T.J. Kessler and G.N. Lawrence, Appl. Optics **33**, 4781 (1994). [5] J. A. Marozas *et al*., Phys. Rev. Lett. **120**, 085001 (2018).

*This work was conducted under the auspices of the U.S. Department of Energy.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

The role of incidence angle in the laser ablation of ICF targets*

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The effect of the laser beam incidence angle on the mass ablation rate and ablation pressure of inertial confinement fusion (ICF) targets is explored using an idealized planar model. NIF, in its current configuration, has it's 192 laser beams clustered within 50 degrees of the poles of its target chamber. Therefore, non-normal incidence angles are encountered in all direct drive ICF experiments currently being planned for and carried out at the National Ignition Facility (NIF). The formulation of a design of a polar direct drive (PDD) scheme presents a significant challenge to achieving the uniform implosion that is needed to achieve ignition. In this work, a modified version of the textbook model of laser ablation [Manheimer et al. Phys. Fluids 25, 1644 (1982)] is used to illustrate that the mass ablation rate and ablation pressure scale with the 4/3 and 2/3 power of the cosine of laser incidence angle. This result implies that a uniform shell mass and velocity cannot be simultaneously obtained when beams intercept the target with a variety of incidence angles. However, with the correct intensity variations, uniform dynamic pressure can be achieved approximately. Additionally, the conduction zone length is found to increase with increasing incidence angle, resulting in decreased laser imprint. Predictions of the scaling of imprint efficiency are made using a laser imprint model [Goncharov et al. Phys. Plasmas 7, 2062 (2000)] and are found to be in good agreement with prior experimental measurements.

*This work was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20180051DR.

Wednesday July 11th

Oral Session	Session Chair:		Geissel, SNL	
8:30 - 8:50 AM	WO1	Weis	SNL	*Advances in laser pre-heat modeling for MagLIF*
8:50 - 9:10 AM	WO2	Strozzi	LLNL	*Design of magnetized, room-temperature capsule implosions for NIF*
9:10 - 9:30 AM	WO3	Zhao	Tsinghua Univ.	*Measuring CH-Au interface in gas-filled hohlraum using Thomson scattering on SG-III prototype*
9:30 - 9:50 AM	WO4	Zimmerman	LLNL	*Factors which determine the magnitude of the Nernst effect in spherical and cylindrical implosions*
9:50 - 10:10 AM	WO5	Roycroft	LANL	*Ion beam driven isochoric heating on Texas Petawatt*
10:10 - 10:30 AM	Coffee Break			
Oral Session	Session Chair:		Froula, LLE	
10:30 - 10:50 AM	WO6	Sary	CEA	*Comprehensive Zakharov-type modeling of parametric instabilities in the corona of direct-drive targets*
10:50 - 11:10 AM	WO7	Solodov	LLE	*Hot-electron generation and preheat in direct-drive experiments at the National Ignition Facility*
11:10 - 11:30 AM	WO8	Seaton	Univ. of Warwick	*Laser-plasma instabilities at ignition-scale: particle-in-cell simulations of shock ignition*
11:30 - 11:50 AM	WO9	Zhang	UCSD	*The generation of collimated moderate temperature electron beam in shock ignition-relevant planar target experiments on OMEGA-EP*
11:50 - 12:10 PM	WO10	Kagan	LANL	*Inference of the electron temperature in spherical implosions from x-ray spectra*
Conference Banquet				
6:00 - 8:00 PM	Post-banquet speaker			Dr. Robert C. Bayer, Director of Lobster Institute, Univ. of Maine: *Lobsters 101*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Advances in Laser Pre-Heat Modeling for MagLIF*

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Magnetized Liner Inertial Fusion (MagLIF) requires preheating of the fusion fuel with the 532 nm Z-Beamlet laser (ZBL). Introduction of beam smoothing and modifications to the temporal structure of the laser pulse have improved the predictive performance of magneto-hydrodynamics codes, such as HYDRA, that are used to design MagLIF experiments performed on the Z-machine at Sandia National Laboratories. This success is made possible by laser-only experiments in the Pecos target chamber that are used to benchmark 2D and 3D HYDRA simulations of laser preheat. In the absence of significant LPI, the benchmarked simulations provide estimates of deposited energy in the fuel (deuterium) and plastic window (1.7 um of polyimide) as well as the potential for a given laser pulse shape to introduce mix of the window into the fusion fuel.

Currently, until Pecos is upgraded, HYDRA is primarily relied upon to assess the impact of the axial magnetic field present in MagLIF (~ 10 T). The HYDRA MHD package now includes most of the relevant physics and terms required to assess magnetic field effects, such as anisotropic thermal conduction, the Nernst and Ettingshausen thermo-electric terms, and Biermann term for self-generated fields. The influence of Hall physics is a focus of future simulation work. Generally, the strength of the magnetic field does not strongly affect the total energy deposited in the fuel, but strongly influences the distribution of energy through thermal conduction inhibition.

Despite the leap from un-magnetized to magnetized preheat, results of integrated MagLIF calculations using the benchmarked laser calculations compare favorably with experiments on the Z-machine and indicate significant increase in preheat energy as compared to previous experiments utilizing an unsmoothed laser. Current design efforts are focused on continuing to increase the fuel density while necessarily increasing the preheat energy, all the while, maintaining a low LPI environment.

*Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Design of Magnetized, Room-Temperature Capsule Implosions for NIF*

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We present designs of indirectly-driven, gas-filled (no DT layer) capsule implosions for the National Ignition Facility, with an imposed magnetic field. The goals are to demonstrate:

- Improved capsule performance with the field due to reduced electron thermal conduction (alpha confinement is less significant without a DT layer)
- Good agreement with MHD-radiation-hydrodynamic modeling
- Adequate hohlraum performance (e.g. x-ray drive and backscatter) vs. no field

A pulsed-power field generator is being developed for NIF, which should magnetize a volume ~ 3 cm^3 to ~ 30 Tesla. There are plans to conduct the first target experiments in late 2018 or early 2019. This system will work with targets fielded from the TANDM, which can only support room-temperature ("warm") operation. We therefore consider warm hohlraum experiments that build on an established methodology[1]. The main difference from cryogenic targets is using a large molecule (e.g. C_5H_{12}) for the hohlraum fill gas, to avoid high hohlraum-window pressure.

We show modeling with the HYDRA code, which extends earlier hohlraum modeling with imposed field[2] by including self-generated "Biermann battery" fields and the Nernst effect. These suggest a 30 T axial field could potentially double the nuclear yield of an HDC capsule filled with D-He3 gas, and driven with a laser pulse and hohlraum similar to the NIF "bigfoot" and HDC platforms. This is in line with prior work[3,4] showing ~ 20 T axial field could almost double the yield of cryogenic gas-filled HDC capsules.

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[1] J. E. Ralph, D. Strozzi, T. Ma, et al., "*Experimental room temperature hohlraum performance study on the National Ignition Facility,*" Phys. Plasmas **23**, 122707 (2016).
[2] D. J. Strozzi, L. J. Perkins, et al., "*Imposed magnetic field and hot electron propagation in inertial fusion hohlraums*," J. Plasma Phys. **81**, 475810603 (2015).
[3] D. D. Ho et al., APS Div. Plasma Phys. (2016).
[4] L. J. Perkins, unpublished.

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Bar Harbor, Maine
July 8-13, 2018

Measuring CH-Au interface in gas-filled hohlraum using Thomson scattering on SG-III prototype

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An experiment was conducted on the SG-III prototype laser facility[1] to measure the plasma conditions in pentane-gas-filled gold hohlraum using Thomson scattering. What interests us most is the region where the expanding gold-bubble interacts with the filling gas. The experiment is designed to be a quasi-2D experimental configuration, with 7 drive-beams (800J/3ω/2ns per beam) heating the hohlraum in a single ring. The probe beam (90J/4ω/3ns) enters the hohlraum through a hole on its waist, and the scattered light is collected at an angle of 90°. The time-resolved plasma conditions are measured 400 μm off the hohlraum wall. Both ion-resonant feature and red-shifted electron-resonant feature of Thomson-scattered light were supposed to be measured, but the electron feature was not detected due to high background.

In the measured ion feature, the transition from scattering from CH to scattering from Au is clearly resolved. Plasma parameters are obtained by fitting the ion feature with a theoretical form factor, with electron density given by radiation-hydrodynamic simulation (LARED code[2]). A discrepancy is observed in flow velocity and electron temperature between experiment and 2D-simulation, indicating that the impact of the probe beam on the gold-bubble and 3D-effects are not negligible.

A post-simulation was done to evaluate the influence of the probe beam on the plasma conditions, and the result shows, when considering probe-beam heating, (1) the CH/Au interface moves much faster, (2) the electron density inside the gold bubble decreases significantly, and (3) a density increase occurred at the CH/Au interface. For comparison, Thomson-scattering spectra are reconstructed based on plasma conditions given by simulation, with time-dependent absorption taken into account. All the above effects can be reflected in the reconstructed spectra, which is in agreement with experimental results.

[1] *T. Gong et al., Rev. Sci. Instrum.* ***86****, 023501 (2015).*
[2] *W. Pei, Commun. Comput. Phys.* ***2****, 255 (2007).*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Factors which determine the magnitude of the Nernst effect in spherical and cylindrical implosions

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In magnetized spherical implosions, maintaining the B-field amplification from spherical convergence close to that obtainable from the ideal flux frozen condition (i.e. $\propto r^2$) is important since high field is required to effectively trap the DT-generated alphas so that the fraction of alpha kinetic energy deposited inside of the hotspot is increased. Consequently, the implosion requirements for hotspot ignition can be relaxed. However, the Nernst effect can potentially reduce the compressed field as observed in simulations for cylindrical implosions (MagLif).[1] But the Nernst effect is not prominent in all our high-resolution 2D simulations of spherical implosions with high initial seed fields (e.g. > 30 T). The reduction of the B field by the Nernst effect can be made less effective by any of the following three factors. (1) the B field is aligned to the direction of ∇T_e; (2) the Hall parameter ($\omega_{ce}\tau_{ei}$) is either << 1 or >> 1; (3) the implosion time scale is too short for the Nernst effect to develop. Analysis of our simulation results for spherical implosion indicates that (1) and (2) are not the cause for the Nernst effect to be ineffective. We find that the short implosion time scale in spherical implosions does not allow sufficient time for Nernst effect to play a significant role. In contrast, the implosion time for MagLif is an order of magnitude longer than that for typical ICF spherical implosions for hotspot ignition. Furthermore, the maximum compressed field in MagLif is an order of magnitude less than that in spherical implosions (i.e., 3000 T vs > 30,000 T) and therefore, the change in ΔBB relatively to the compressed field is also higher in MagLif. The effect of magnetic diffusion on field compression will also be discussed.

Reference:

(1) S. A. Slutz *et al*., Phys. Plasmas 17, 056303 (2010).

*This work is performed under auspices of U.S. DOE by LLNL under 15-ERD-058 and contract DE-AC52-07NA27344

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Ion Beam Driven Isochoric Heating on Texas Petawatt*

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Isochoric heating of solids and foams to warm dense matter (1-100 eV) conditions is relevant to the study of equation of state as well as laboratory astrophysics. In a series of experiments at the Texas Petawatt Laser Facility, we have built a platform using the petawatt laser to generate large numbers of intermediate energy (1-20 MeV) protons via TNSA off of 5 μm gold foils. In contrast with previous campaigns[1], we are using the f/40 beamline of the Texas Petawatt, softly focusing the laser to a large focal spot (60-70 μm), in order to produce higher numbers of lower energy protons.

This work presents results of experiments in which aluminum foils (7-10 μm) and carbon foams (100 μm, 60mg/cc) are heated using this ion beam. We shoot the petawatt laser pulse at a 5 μm gold foil target, and subsequently the ion beam heats a secondary target. The brightness temperature and heating over time of the secondary target is measured by a streaked optical pyrometer, which images the rear surface of the secondary target. We have observed peak brightness temperatures from 1-20eV. The pyrometer has a temporal resolution of 3ps; it can therefore see that the heating time (~20ps) is indeed fast enough to be isochoric.

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[1] *S. Feldman, et al. Phys. Rev E,* ***95****, 031201 (2017)*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Comprehensive Zakharov-type modeling of parametric instabilities in the corona of direct-drive targets

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Direct-drive laser plasma interaction scenarios involving many overlapping laser beams span a broad range of characteristic spatial scales, from long scale-length density gradients down to the narrowly spaced wavelength-sized speckles[1]. Limited computational capabilities have so far restrained modeling efforts to either costly PIC simulations[2], often performed on modest spatiotemporal scales, or to strongly simplified models. We intend to bridge this gap by developing a 2D mesoscale reduced description that both retains the main physical processes at speckle level and accurately accounts for collective multi-speckle phenomena on a few tens of ps timescale.

To this end, we have worked out a Zakharov based model that simultaneously describes SRS, SBS, TPD, and secondary decays in the fluid approximation. A kinetic quasilinear-type[3] extension of the model is planned for the near future. In this work, the reduced fluid model is applied to the case of an intense ($2 \times 10^{16}\ \mathrm{W \cdot cm^{-2}}$), isolated, two wavelength wide Gaussian speckle immersed in a typical direct-drive exponential density profile. Two situations are studied depending on whether the speckle is focused at $0.2\ n_c$ or $0.24\ n_c$, and our results are compared with PIC simulations in the same conditions.

Strong cavitation activity is expected especially in the $0.24\ n_c$ case due to the beating on speckle axis of SRS and TPD-generated Langmuir waves (LWs). In PIC simulations, several clearly separated electrostatic cavities develop before merging into a single density depression along the speckle axis once LWs have burned out. At this stage, only weak electron and ion deviations from Maxwellian distributions are observed. Yet, Zakharov equations are already notoriously incapable of properly describing the collapse arrest of high-energy-density cavities[4,5], thus quickly leading to non-physical plasma density depressions. Instead of resorting to an *ad hoc* damping rate at small scales[4], we draw on Ref. [5], where it is shown that transit-time Landau damping of trapped LW packets provides a potential saturation mechanism during late cavity evolution stages. The application of this damping mechanism to our reduced model is explained and its consequences on LWs and cavity remnants are described and compared to PIC simulation results. The effect of the subsequent lower density filament on resonant Landau damping is also discussed, in relation to ulterior excitation of TPD and SRS in the speckle. This situation is compared with that in the $0.2\ n_c$ speckle.

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[1] A. Le Cain et al., Phys. Plasmas **18**, 082711 (2011)

[2] L. Yin et al., PRL **108**, 245004 (2012)

[3] J. Myatt et al., Phys. Plasmas **20**, 052705 (2013)

[4] D. Russel et al. PRL **8**, 838 (1986)

[5] P.A. Robinson Phys. Fluids B **3**, 545 (1991)

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Hot-electron generation and preheat in direct-drive experiments at the National Ignition Facility*

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Laser–plasma instabilities, such as stimulated Raman scattering and two-plasmon decay, can degrade the performance of direct-drive inertial confinement fusion implosions by generating hot electrons that preheat the target. To assess the extent of hot electron generation at ignition scales and conditions, planar and spherical target experiments at the National Ignition Facility have been designed using the radiation–hydrodynamic codes *DRACO* and *LILAC*. Planar-target experiments, with $T_e \sim 4$ to 5 keV and density gradient scale lengths of $L_n \sim 600$ μm, exhibited hot-electron temperatures ranging from ~45 to 60 keV and conversion efficiencies from ~0.5 to 3% as the laser intensity at the quarter critical surface increased from ~6 to 15×10^{14} W/cm^2. Spherical, multilayer target experiments will be fielded in September 2018. The target will consist of an outer plastic ablator and an inner Ge-doped plastic layer (payload). The difference in hard x-ray signals between the mass-equivalent plastic and multilayer implosions and the Ge Kα emission will be used to infer the hot-electron energy deposition in the payload. The experiments will demonstrate how the divergence of hot electrons and the extent to which they slow down in the ablator reduce the preheat. The effects of preheat on direct-drive ignition designs will also be evaluated.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Laser-plasma Instabilities at Ignition-Scale: Particle-in-Cell Simulations of Shock-Ignition

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Over the last decade shock ignition (SI) has emerged as a promising approach to high gain direct-drive ICF. One of the key issues facing the scheme is how the behavior of laser-plasma instabilities (LPIs) during the high-intensity igniter 'spike' will affect it, particularly with regard to hot electron preheat. Experimental work has been performed with sub-scale targets and laser energies below those thought necessary to achieve ignition. With the construction of megajoule-class laser facilities such as the NIF and LMJ, it is now feasible for SI experiments to take place with ignition-scale targets for which the coronal temperature and density scale-length will be significantly larger.

We have recently performed 2D particle-in-cell simulations under three separate sets of conditions, moving from the small-scale parameters investigated to date (L_n~150μm, T_e~2keV) through to ignition-scale (L_n~600μm, T_e~5keV). We discuss how the behavior of LPIs varies through this transition and also illustrate the effect of laser speckle profiles on the dynamics. Additionally we present the resulting hot-electron distributions and an analysis of scattered light.

This work was funded by the EPSRC and CCPP. We are grateful for computing resources provided by the Archer, Cirrus and Athena supercomputing facilities, with which this work was performed.

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Bar Harbor, Maine
July 8-13, 2018

The Generation of Collimated Moderate Temperature Electron Beam in Shock Ignition-Relevant Planar Target Experiments on OMEGA-EP*

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Understanding of laser-plasma instability (LPI) and the resultant hot electrons is critical for the validity of the shock ignition (SI) scheme. We have conducted a series of experiments on OMEGA-EP to characterize the hot electrons and LPIs from the interaction of kilo-joule infrared (IR) and ultraviolet (UV) lasers with long-scalelength keV plasmas at SI-relevant high laser intensities (10^{16} W/cm^2). The hot electrons were found to have 45 – 90 keV moderate temperatures with 2.0 – 3.5% energy conversion efficiencies. The hot electron beam divergence was less than 22°, which was indicated by the measured hot electrons induced Cu Kα spot size. These hot electrons can be generated by both two plasmon decay (TPD) and stimulated Raman scattering (SRS) according to the Particle-in-Cell (PIC) simulations. [1] The existence of strong SRS is also confirmed by the observed plasma density perturbation. The time resolved spectrum of the SRS light shows pump depletion in the low-density plasma (0.01 n_c – 0.20 n_c) during the first 0.5 ns of the UV spike pulse. The observed directional and moderate temperature hot electrons are encouraging for the electron-assisted SI. Details of the experiments and comparisons with the PIC simulations will be presented.

*This work conducted under the auspices of U.S. DOE NNSA under the NLUF program with award number DE-NA0002730, DE-NA0003600 and DOE Office of Science under the HEDLP program with award number DE-SC0014666.

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[6] *Jun Li et. al., "Particle-in-cell simulations of laser plasma instabilities and hot electron generation in shock ignition regime", This Conference.*

48th Annual Anomalous Absorption Conference
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July 8-13, 2018

Inference of the electron temperature in spherical implosions from X-ray spectra*

G. Kagan[7], O. L. Landen[2], D. Svyatskiy[1], P. Hakel[1], C. J. McDevitt[1], H. Sio[3], N. V. Kabadi[3], R. A. Simpson[3], M. Gatu-Johnson[3], J. A. Frenje[3], R. D. Petrasso[3], R. C. Shah[4], M. J. Rosenberg[4], R. Epstein[4], S. P. Regan[4], T. R. Joshi[1], T. E. Weber[1], H. G. Rinderknecht[2], D. Thorn[2], M. Schneider[2], D. Bradley[2] and J. Kilkenny[2]

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In principle, information about the electron temperature in spherical implosions is carried by the radiation from the hot-spot. In practice, the emitted photons can be reabsorbed on their way to detectors, complicating the interpretation of the data. The current consensus is therefore that the successful diagnostic should operate with the harder part of the spectrum, i.e. with photon energies $\hbar\omega$ greater than 15 keV, for which the imploded capsule is transparent. Two main approaches are being considered, which are based on measuring, respectively, line emission from a high-Z dopant such as krypton or spectral continuum of 15 keV $< \hbar\omega <$ 30 keV from electrons scattering off the D and T ions.

However, both types of the hard X-ray emission are due to suprathermal free electrons. Their mean-free-path is much larger than that of thermal electrons and their distribution thus likely deviates from Maxwellian even if the bulk plasma is close to equilibrium. We present the first study of the X-ray emission from the hot-spot with the kinetic modifications to the electron distribution accounted for. We demonstrate qualitatively new features in the emission spectrum brought about by these modifications and then discuss their practical implications. In particular, we show that inferring the electron temperature as if the emitting electrons are Maxwellian gives a lower value than the actual one[1].

*This work is supported by the Laboratory Directed Research and Development program under the auspices of the U.S. Dept. of Energy by the Los Alamos National Security, LLC, Los Alamos National Laboratory under Contract No. DE-AC52-06NA25396.

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[7] *G. Kagan, O. L. Landen, D. Svyatskiy, H. Sio, N. V. Kabadi, R. A. Simpson, M. Gatu-Johnson, J. A. Frenje, R. D. Petrasso, R. C. Shah, T. R. Joshi, P. Hakel, T. E. Weber, H. G. Rinderknecht, D. Thorn, M. Schneider, D. Bradley and J. Kilkenny "Inference of the electron temperature in ICF implosions from the hard Xray spectra continuum", arXiv:1710.01343 (https://arxiv.org/abs/1710.01343)*

Thursday July 12th

Oral Session	Session Chair:		Kagan, LANL	
8:30 - 8:50 AM	RO1	Anderson	LANL	*A fully-conserving, adaptive, multi-scale algorithm with arbitrary temporal integration for the multi-species Vlasov-Ampere system*
8:50 - 9:10 AM	RO2	Keenan	LANL	*Unraveling the kinetic structure of multi-ion collisional plasma shocks*
9:10 - 9:30 AM	RO3	Wilson	LANL	*Assessing xRAGE predictive capability using the high-energy density physics validation suite*
9:30 - 9:50 AM	RO4	Manheimer	RSI	*Krook and Fokker Planck models for calculation nonlocal transport in a laser fusion target plasma*
9:50 - 10:10 AM	RO5	Farmer	LLNL	*Electron heat transport in beryllium sphere on Omega*
10:10 - 10:30 AM	Coffee Break			
Oral Session	Session Chair:		Rosenberg, LLE	
10:30 - 10:50 AM	RO6	Berger	LLNL	*The scaling of stimulated backscatter from BigFoot hohlraums with laser power and energy: practical backscatter reduction options*
10:50 - 11:10 AM	RO7	Liu	UMD	*Nonlinear transition to absolute Raman backscattering instability with trapped electrons - a theory for inflation of Raman reflectivity*
11:10 - 11:30 AM	RO8	Maximov	LLE	*Modeling of stimulated Raman scattering in inhomogeneous plasmas for conditions relevant to the National Ignition Facility*
11:30 - 11:50 AM	RO9	Chapman	LLNL	*Modeling optics damage patterns at the NIF caused by light backscattered from targets*
11:50 - 12:10 PM	Business Meeting			
Evening Invited Talk	Session Chair:		Michel, LLNL	
7:00 - 7:40 PM	RI1	Rosenberg	LLE	*Planar laser-plasma interaction experiments at the direct-drive ignition-relevant scale lengths at the National Ignition Facility*
Evening Poster Session				
8:00 - 10:00 PM	RP1	Casanova	CEA	*Modeling the propagation of a nanosecond smoothed laser beam in a multi-millimeter underdense plasma*
	RP2	Poole	LLNL	*Plasma instability enhancement for generating high fluence, high energy x-ray sources*
	RP3	Simakov	LANL	*Plasma ion stratification by weak planar shocks*
	RP4	Oh	NRL	*Progress on plasma profile measurements for the Nike experiments*
	RP5	Stark	LANL	*Laser-ion acceleration in the transparency regime*
	RP6	Weaver	NRL	*CBET studies in long scale-lengths plasmas at the Nike laser*
	RP7	Miller	UCLA	*Recent OSIRIS development for improved high-energy-density plasma simulations*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

A fully-conserving, adaptive, multi-scale algorithm with arbitrary temporal integration for the multi-species Vlasov-Ampère system*

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We discuss the addition of a fully kinetic electron capability into the 1D-2V iFP Vlasov Fokker-Planck code.[1] Irrelevant fast timescales, such as the electron plasma frequency, are stepped over via an appropriately preconditioned HOLO approach.[2] To enforce conservation of mass, momentum, and energy, the proposed algorithm utilizes pseudooperators in an approach similar to that of Taitano & Chacón.[3] However, unlike this earlier study, which utilizes a symplectic Crank-Nicolson-type scheme to conserve energy, our approach is fully conserving for an *arbitrary* temporal integration scheme. This is a critical development, allowing integrators of any order – implicit or explicit – to be used, with arbitrary time-centering of the right-hand-side quantities. To demonstrate the effectiveness of the approach, we present simulation results for several canonical collisionless kinetic problems, including the ion acoustic shockwave where the inverse plasma frequency is a very stiff timescale. The results show that mass (and charge), momentum, and energy can all be conserved to well below the convergence tolerance of the solver, clearly demonstrating the promise of this scheme for application to complex multiscale kinetic plasma systems.

*This work was supported by the Thermonuclear Burn Initiative of the Advanced Simulation and Computing Program using resources provided by the Institutional Computing Program at Los Alamos National Laboratory, and was performed under the auspices of the National Nuclear Security Administration of the U.S. Department of Energy at Los Alamos National Laboratory, managed by LANLS, LLC under contract DE-AC52-06NA25396.

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[1] W. T. Taitano, L. Chacón, and A. N. Simakov, *"An adaptive, implicit, conservative, 1D-2V multi-species Vlasov-Fokker-Planck multi-scale solver in planar geometry,"* arXiv:1709.04502v1 (2017) preprint submitted to J. Comp. Phys.

[2] L. Chacón *et al.*, "*Multiscale high-order/low-order (HOLO) algorithms and applications*," J. Comp. Phys. **330**, 21 (2017)

[3] W. T.. Taitano and L. Chacón, *"Charge-and-energy conserving moment-based accelerator for a multispecies Vlasov-Fokker-Planck-Ampère sytem, part I: Collisionless aspects,"* J. Comp. Phys. **284**, 718 (2015)

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Unraveling the Kinetic Structure of Multi-Ion Collisional Plasma Shocks*

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Strong collisional shocks in multi-ion plasmas are featured in many high-energy-density environments, including Inertial Confinement Fusion (ICF) implosions. Shock-driven ion-species stratification (e.g., relative concentration modification, and temperature separation) is a critically important effect, since many recent ICF experiments have evaded explanation by standard, single-fluid, radiation-hydrodynamic (rad-hydro) numerical simulations, and shock-driven fuel stratification likely contributes to this discrepancy. Yet, despite their apparent importance, basic structural features of multi-ion plasma shocks remain poorly understood, inviting contradictory claims in the literature.[1] Using a Vlasov-Fokker-Planck code (iFP[2]), as well as direct comparisons to multi-ion hydrodynamic simulations and semi-analytic predictions, we quantify the ion stratification by planar shocks as a function of Mach number, relative species concentration, and ion mass/charge ratios for two-ion plasmas; and resolve several controversies along the way. In particular, for strong shocks, we find that the structure of the ion temperature separation has a nearly universal character across ion mass and charge ratios. Additionally, we find that the shock fronts are enriched with the lighter ion species and the enrichment scales as M^4 for $M >> 1$.

*This work was supported by the Los Alamos National Laboratory LDRD Program, and used resources provided by the Los Alamos National Laboratory Institutional Computing Program. Work performed under the auspices of the U.S. Department of Energy National Nuclear Security Administration under Contract No. DE-AC52-06NA25396.

[1] Compare, for example, M. S. Greywall, Phys. Fluids **18**, 1439 (1975) and C. Bellei *et al.*, Phys. Rev. E **90**, 013101 (2014), which substantially disagree on the dependence of the ion shock width vs. Mach number. We resolved this controversy in Keenan *et al.*, Phys. Rev. E **96**, 053203.
[2] W. T. Taitano *et al.*, J. Comp. Phys. **297**, 357 (2015); *ibid.* **318**, 391 (2016); *ibid.* **339**, 453 (2017).

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Assessing xRAGE Predictive Capability using the High Energy Density Physics Validation Suite*

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Inertial confinement fusion (ICF) physics include poorly understood physics processes, *e.g.* instability growth and turbulent mixing, non-local thermal electron conduction, NLTE opacity, ion physics, and non-linear laser-plasma instabilities (NLPI). Strong coupling between these processes complicates the validation of high-energy density physics (HEDP) multiphysics codes. LANL is developing a high-energy density physics validation suite (HEDP-VS) consisting of verification, code comparison, and validation over a spectrum of HEDP-relevant physics, metrics, and validation experiments.

In this work, we use the HEDP-VS to assess predictive capabilities of LANL's multiphysics hydrodynamics code, xRAGE coupled with the LLE laser package Mazinisin. We follow the ASME V&V Standard for Computational Fluid Dynamics and Heat Transfer (ASME V&V 20) to quantify the laser package validation uncertainty.

A systematic error is observed in the predicted scattered laser energy and propagates into all validation metrics (*i.e.* absorbed laser energy and ablation front position and velocity with time) using the default implementation of xRAGE and Mazinisin. The validation comparison error is consistently larger than the validation uncertainty, indicating a systematic model form error (*i.e.* missing physics). We suggest cross-beam energy transfer (CBET), one of many unmodeled laser-plasma interactions from the laser system, is a significant source of the missing physics. *High priority should be placed on updating the laser package to include CBET predictive capability.*

Other significant sources of uncertainty include early time LPI during the first picket and non-local heat conduction.

* This work was performed at Los Alamos, funded by the US Department of Energy

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Krook and Fokker Planck models for calculating nonlocal transport in a laser fusion target plasma

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In direct drive laser fusion, nonlocal transport of the more energetic electrons can have at least two potentially important effects. First, the most energetic electrons, furthest out on the tail of the distribution function can cause preheat of the fuel deep inside the target. Second the nonlocal deposition of less energetic electrons can spread out the ablation layer, possibly having a stabilizing effect on the Rayleigh Taylor instability. This talk treats two different methods of modeling nonlocal transport. For about 20 years, these phenomena have been treated with a Krook model for the electron collisions. However different versions have given different results, especially as regards preheat. We analyze the various reasons for discrepancies, and derive a simple formula to evaluate preheat, a formula which can be used as a simple check on the fluid simulation if a Krook model is used. We then offer, for the first time, a steady state, nonlocal method of using the Fokker Planck equation to calculate the deposition for a given flux of energetic electrons, initially localized near a particular spatial region. These energetic electrons may be produced either by an instability, or simply by the tail of a thermal distribution in the hot region of the plasma. As for the case of the Krook model, we derive a simple analytic estimate for the preheat which can be used to check on and confirm a fluid simulation. Regarding ablation surface broadening, the two models are not very different; but regarding preheat, the Fokker Planck model gives orders of magnitude less. This is a very optimistic result for direct drive laser fusion.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Electron heat transport in a beryllium sphere on Omega*

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Electron heat transport in ICF experiments is important in setting the hohlraum plasma conditions, which determine laser-beam propagation in the underdense plasma. However, modeling electron heat transport in an integrated ICF environment is challenging. For that reason, simple tests of heat transport models are invaluable for guiding further effort towards a predictive model. In an effort to field a simple experimental test of heat transport models, a hollow beryllium sphere was irradiated on the Omega laser facility, and Thomson scattering was used to assess the plasma densities and temperatures near the surface of the sphere. In using a low-Z material like beryllium, energy coupled into x-rays from the target is largely negligible, removing deficiencies in atomic physics models as a source of disagreement between modeling and experiment. However, unmodeled cross-beam energy transfer can also cause disagreement. The experimental data is discussed, and modeling of the experiment using both radiation-hydrodynamics and Fokker-Planck codes is compared to the measurements.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

The scaling of stimulated backscatter from BigFoot hohlraums with laser power and energy: practical backscatter reduction options*

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The "BigFoot" design uses a high pressure first shock with its associated high implosion velocity, short implosion time, and high fuel adiabat. Neutron yields as high as $2x10^{16}$ have been achieved with laser energies ~2 MJ and peak power ~490 TW in low gas fill hohlraums and laser pulse durations less than 7 ns.[1] Once the total power reaches its maximum, the fraction of total power on each cone is held constant until it is turned off. This design simplicity makes the study of laser plasma instabilities (essentially stimulated Brillouin scattering [SBS] of the 50^o cone of beams) on this platform particularly attractive. Here, we will show the measured dependence of the SBS on laser power, energy, and pulse length for hohlraums of radius 5.4 and 6.0 mm. Furthermore, using the plasma conditions from the Lasnex simulations used to design the experiment with the as-shot laser pulse shapes, we have simulated successfully with pF3D the backscatter SBS power for a large number of BigFoot shots. That success has given us the confidence to propose several options for reducing SBS. The most effective are to transfer power from the 50^o to the 44^o beams by adding a frequency difference between these cones, to use a Ta2O5 liner on the hohlraum wall, and to repoint some 50^o beams toward TCC.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52--07NA27344.

[1] C. A. Thomas, Bull. Am. Phys. Soc. **61**,18 (2016); D. T. Casey *et al.*, Phys. Plas **25**, 056308 (2018).

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Nonlinear Transition to Absolute Raman Backscattering Instability with trapped electrons –a theory for Inflation of Raman Reflectivity

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We present a theory of nonlinear transition from convective to absolute instability of Stimulated Raman Backscattering by plasma wave with substantial trapped electrons. The trapped electrons can modify the electron distribution to reduce the threshold of the absolute instability by reducing the damping rate of the plasma wave. A consequence of the absolute instability is to cause greatly enhanced reflectivity by Raman backscattering. This theory accounts well the observation in LPI experiments with Trident laser system.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Modeling of stimulated Raman scattering in inhomogeneous plasmas for conditions relevant to the National Ignition Facility*

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Stimulated Raman scattering (SRS) has been one of the major laser–plasma interaction (LPI) processes since the beginning of the research on laser-driven inertial confinement fusion (ICF). The two main consequences of the SRS instability for ICF target performance are the scattering of laser light to the lower-density region and the generation of fast electrons by the SRS-driven electron plasma waves. Both of these SRS effects have played a prominent role in the experiments at the National Ignition Facility (NIF) because of the large density scale length of the order of few hundred microns, so that the SRS threshold is well exceeded at NIF laser intensities.[1]

To model SRS in large regions of plasma, the time-enveloped equations for the plasma waves and the Raman light waves has been added to the system of LPI equations in the laser-plasma simulation environment (*LPSE*) platform.[2] The new code can model SRS in inhomogeneous plasmas with a wide range of plasma densities. An important effect has been observed in the *LPSE* SRS simulations and confirmed in the theoretical SRS analysis in inhomogeneous plasmas: the coupling of backscattered and forward-scattered SRS waves with same wavelength via plasma-wave resonances at different plasma densities. The new version of *LPSE* takes into account the coupling of SRS-driven plasma waves and light waves to low-frequency waves, and can model the interplay between SRS and crossbeam energy transfer.[2]

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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 abstract.

[1] J. F. Myatt et al., "Multiple-beam laser–plasma interactions in inertial confinement fusion," Phys. Plasmas **21**, 055501 (2014).
[2] J. F. Myatt et al., "A wave-based model for cross-beam energy transfer in direct-drive inertial confinement fusion," Phys. Plasmas **24**, 056308 (2017).

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Modeling optics damage patterns at the NIF caused by light backscattered from targets*

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High-power laser facilities are often restricted in operations by the risk of damage to expensive optics due to the backscattering of laser light from the intended target. A portion of this backscattered light retraces the optical path of the laser light and at sufficient fluence may damage (burn) optical apparatus in the beam line. Here, the observed cumulative burn pattern on laser transport mirrors at the National Ignition Facility (NIF) due to both stimulated Raman and Brillouin scattering is explained using detailed simulations using the code pF3D. Our methodology involves using an image of a phase plate installed at the NIF to provide the laser input to a three-dimensional simulation of laser-plasma interaction into targets typical of those fielded at the NIF. Light scattered in our simulations is then followed back to the final aperture of the beam line, back through the phase plate, and to a mirror where damage if present typically occurs. Our methodology is applicable to other laser facilities and understanding of the burn pattern (distribution, modulation depth) may lead to phase plate designs that limit damage throughout the optics assembly of high-powered laser facilities.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Planar laser–plasma interaction experiments at direct-drive ignition-relevant scale lengths at the National Ignition Facility*

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Experiments at the National Ignition Facility have probed laser–plasma interactions (LPI's) and hot-electron production at scale lengths relevant to direct-drive ignition.[1] The irradiation on one side of planar slabs generated a plasma at the quarter-critical surface with predicted density scale lengths of L_n ~ 500 to 700 μm, electron temperatures of T_e ~ 4 to 5 keV, and overlapped laser intensities of I ~ 6 to 15×10^{14} W/cm^2. For CH targets, the fraction of laser energy converted to hot electrons increases from ~1% to ~3% as the laser intensity at quarter-critical increases from ~6 to 15×10^{14} W/cm^2, while the hot electron temperature is nearly constant around 45 to 60 keV. Initial experiments using Si targets have demonstrated a reduction in hot electrons relative to a CH target, with the onset intensity for hot-electron production increasing from around 4×10^{14} W/cm^2 in CH to around 6×10^{14} W/cm^2 in Si. Only a sharp red-shifted feature is observed around $\omega/2$, along with significant stimulated Raman scattering (SRS), including sidescattering, at lower densities, suggesting that SRS dominates hot-electron production, unlike in shorter-scalelength plasmas on OMEGA that are dominated by two-plasmon decay (TPD). This difference in regime is explained based on absolute SRS and TPD threshold considerations. Subsequent measurements of $3\omega/2$ emission have revealed evidence of TPD, although the contribution of TPD to hot-electron generation is still under study. Upcoming experiments will diagnose hot-electron coupling to an implosion, which will determine the need for hot-electron preheat mitigation strategies for direct-drive ignition.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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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[1] M. J. Rosenberg *et al.*, "*Origins and Scaling of Hot-Electron Preheat in Ignition-Scale Direct-Drive Inertial Confinement Fusion Experiments,*" Phys. Rev. Lett. **120**, 055001 (2018)

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Modeling the propagation of a nanosecond smoothed laser beam in a multi-millimeter underdense plasma

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In the context of inertial confinement fusion (ICF), laser-plasma interaction (LPI) refers mainly to the study of ponderomotively driven phenomena, which affects the laser propagation and the subsequent laser energy deposition. Due to the multi-millimeter size of the target and the nanosecond duration of the irradiation involved in ICF experiments, the numerical modeling of LPI usually does not capture the complex speckle dynamics of a smoothed laser beam in production codes.

Hence, aiming at improving our modeling of LMJ/NIF/OMEGA-type laser beams, we will show that a modified refraction index can be introduced in classical ray-tracing schemes in order to capture several mechanisms involved in the speckle dynamics. We will also address the feasibility of including thermal and ponderomotive self-focusing on the speckle scale in ray-tracing schemes.[2,3,4, 5] We conclude by making comparisons with fluid-based envelope codes (HERA) and kinetic simulations (CALDER).

Prefer Poster Session

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[2] *R. D. Jones, W. C. Mead, S. V. Coggeshall, C. H. Aldrich, J. L. Norton, G. D. Pollak and J. M. Wallace, "Self-focusing and filamentation of laser light in high Z plasmas," Phys. Fluids* ***31****, 1249 (1988).*
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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Plasma instability enhancement for generating high fluence, high energy x-ray sources*

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X-ray source development on high power laser facilities aims to mimic high fluence xray environments for national security and materials testing applications[6]. While current NIF efforts can produce large x-ray yield (~10 kJ) with photon energy near 20 keV from K-shell emission of Mo and Ag, extending these techniques to higher Z materials (and therefore higher line emission energy) requires plasma conditions not available to even NIF drivers. Other methods have similar difficult achieving ~10 J/cm^2 x-ray fluence at non-destructive standoff distances to test large samples, such that there is a critical gap in high fluence sources for 30-100 keV energies.

An alternative x-ray source optimizes bremsstrahlung emission through plasma instability enhancement. Instabilities like Stimulated Raman Scattering and Two Plasmon Decay can accelerate electrons via Landau damping that prematurely heat fusion capsules and are therefore most commonly minimized. However, optimizing the output of these hot electrons can yield the desired 30+ keV x-ray energies via bremsstrahlung in high-Z hohlraum walls in numbers sufficient for high radiation environment physics.

Experiments on Omega and NIF and supporting simulations will be presented demonstrating control over laser plasma interactions via target and laser details to select both the x-ray spectral details and time of emission, as well as a 10x increase in yield over typical Omega setups and the most efficient 50 keV x-ray source to date on NIF.

*This work conducted under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

[6] *M. May et al. Phys. of Plasmas **25**, 056302 (2018).*

Plasma ion stratification by weak planar shocks*

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We derive fluid equations for describing steady-state planar shocks of a moderate strength (0<M-1~1 with M the shock Mach number) propagating through an unmagnetized quasineutral collisional plasma comprising two separate ion species. In addition to the standard fluid quantities, such as the total mass density, mass-flow velocity, and electron and average ion temperatures, the equations describe shock stratification in terms of variations in the relative concentrations and temperatures of the two ion species along the shock propagation direction. We have solved these equations analytically for weak shocks[7] (0<M-1<<1), with the results depending on M, ratios of the ion masses and charges, and the upstream mass fraction of one of the ion species. These analytical results are instrumental for gaining understanding in the behavior of weak shocks, and they have been used[8] to verify kinetic simulations of shocks in multi-ion plasmas.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Progress on plasma profile measurements for the Nike experiments*

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The grid image refractometer (GIR)[9,10] at the Nike krypton fluoride laser (λ = 248 nm) facility of NRL was previously implemented with UV probe rays (λ = 263 nm) and demonstrated its capability of simultaneous measurements of spatial profiles of electron density (n_e) and temperature (T_e) in the underdense coronal region of the plasma. Using a self-consistent inversion algorithm developed for the strongly refracted probe rays, GIR probed electron densities up to 4×10^{21} cm^{-3} in a plasma with the density scale length of 120 μm.[2] This instrument was recently upgraded with a 5th harmonic probe laser (λ = 213 nm) to explore a deeper coronal region and has been deployed to diagnose various plasmas produced by the Nike laser. We have performed the GIR measurements on plasmas produced from CH targets for laser plasma instability research, Si targets in comparison with X-ray imaging spectroscopic measurements, and high-Z coated CH targets heated by the low-level prepulse of Nike. Observed plasma properties will be presented and discussed with other standard target diagnostics of Nike.

*Work supported by DoE/NNSA.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Laser-ion acceleration in the transparency regime*

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A particle-in-cell study of laser-ion acceleration mechanisms in the transparency regime illustrates how two-dimensional (2D) S and P simulations (laser polarization in and out of the simulation plane, respectively) capture different physics characterizing these systems, visible in their entirety in often cost-prohibitive three-dimensional (3D) simulations.[11] The artificial longitudinal electron heating in 2D-P exaggerates the effectiveness of targetnormal sheath acceleration (TNSA) into its dominant acceleration mechanism throughout the laser-plasma interaction, whereas 2D-S and 3D both have sizable populations accelerated through a combination of mechanisms. We perform a target length scan to optimize the peak ion energies in both 2D-S and 3D, and tracer analysis allows us to isolate the acceleration into stages of TNSA, hole boring (HB), and break-out afterburner (BOA) acceleration.[12] Of particular significance is that 3D simulations, unlike 2D-S, do not show a pronounced HB acceleration phase. Eliminating the transverse laser spot size effects by performing a plane wave simulation, we isolate the dynamics behind the BOA mechanism with greater confidence. Specifically, supplemented by FFT analysis, we match the post-transparency BOA acceleration with a wave-particle resonance with a high-amplitude low-frequency electrostatic wave of increasing phase velocity, consistent with that predicted by the Buneman instability. We show that relativistic ion flows, plasma density and velocity gradients, and a weak transverse magnetic field alter the growth rate and breadth of unstable wave numbers for this instability.[3]

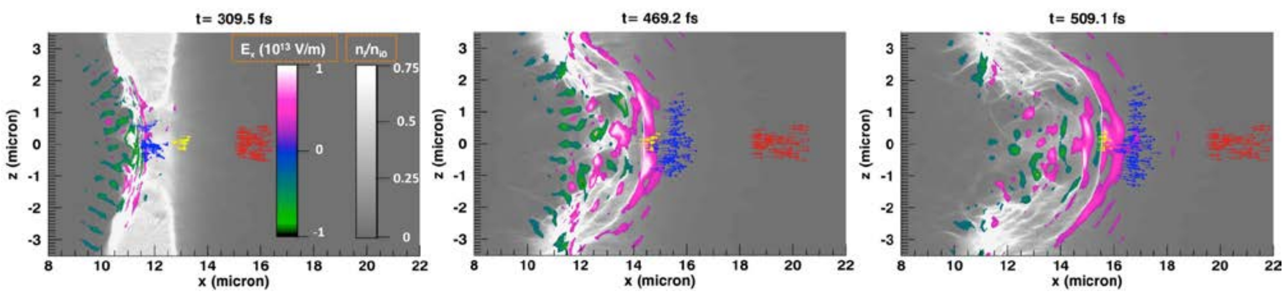

Figure: Three different snapshots of the longitudinal electric field E_x and the ion density n_i from a 2D-S simulation of a laser penetrating a $10n_{cr}$ carbon target. Red, blue, and yellow vectors represent a sample of TNSA-accelerated, HB-accelerated, and BOA accelerated ions, respectively.

* This work was supported by the LANL Directed Research and Development Program.

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48th Annual Anomalous Absorption Conference
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July 8-13, 2018

CBET Studies in Long Scale-length Plasmas at the Nike Laser*

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Studies of laser plasma instabilities (LPI) at the Nike laser have mainly used short pulses, small focal spots, and solid plastic (CH) targets that have yielded maximum gradient scale-lengths below 200 microns. The current experimental effort aims to produce larger volume plasmas with 5-10x reduction in the density and velocity gradients as a platform for SBS, SRS, and TPD studies. The recent campaign has concentrated on the effects of wavelength shifting and bandwidth changes on CBET in low density (5-15 mg/cm^3) CH foam targets. This poster will discuss the development of this new LPI target platform based on modelling with the LPSE code developed at LLE and experimental observations. The presentation will also discuss alternative target schemes (e.g. exploding foils) and improvements to the LPI diagnostic suite and laser operations; for example, a new set of etalons has been used to simultaneously shift both the main beams and the backlighter beams. Upgrades to the scattered light spectrometers in general use for LPI studies will also be presented.

*Work supported by DoE/NNSA

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Recent OSIRIS development for improved high-energy-density plasma simulations*

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OSIRIS is a parallelized, fully relativistic, explicit particle-in-cell (PIC) code using a finite-difference field solver combined with a rigorous charge-conserving current deposit that is used to study the nonlinear optics of plasmas (NLOP), intense laser and beam plasma interactions—including laser-solid interactions and plasma-based acceleration—and plasma astrophysics. Some studies of NLOP where relativistic plasmas and beams move along the grid, such as stimulated Raman scattering (SRS) and plasma-based acceleration, are very sensitive to noise and numerical instabilities. Recent developments in OSIRIS include implementing a Boris correction—including a multigrid Poisson solver—combined with a direct current deposit to provide a low-noise alternative to the charge-conserving current deposit. In addition, the Boris correction may allow for the use of higher-order stencils in the field solver to limit the numerical Cerenkov instability (NCI). These features are used to investigate threshold-level SRS simulations; the instability onset and behavior are compared for the two current deposit schemes. Examples of SRS will also be presented. Finally, single-node performance of large parallel simulations can be improved by grouping field and particle data close together in memory with tiling.[i,ii] This has been implemented in OSIRIS by dividing the simulation on each node into a patchwork of small tiles which are processed using OpenMP parallelism. Preliminary timings of OSIRIS on the Intel Xeon Phi processor family with and without tiling will be presented.

*This work conducted under the auspices of the DOE and NSF.

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Friday July 13th

Oral Session	Session Chair:		Hu, LLE	
8:30 - 8:50 AM	FO1	Karasiev	LLE	*Density functional theory methods for transport and optical properties: application to warm dense silicon*
8:50 - 9:10 AM	FO2	Lee	NRL	*Radiative and atomic properties of C and CH plasmas under warm dense conditions*
9:10 - 9:30 AM	FO3	Patel	LLNL	*The role of NLTE atomics kinetics in radiation hydrodynamics modeling of ICF targets*
9:30 - 9:50 AM	FO4	Karasik	NRL	*Imprint mitigation with high-Z coating on Omega EP and NIF imprint experiments*
9:50 - 10:10 AM	Coffee Break			
Oral Session	Session Chair:		Weaver, NRL	
10:10 - 10:30 AM	FO5	Belyaev	LLNL	*Energy-conserving model of laser propagation and heating in subcritical foam*
10:30 - 10:50 AM	FO6	Hu	LLE	*Mitigating laser-imprint effects in direct-drive implosions on OMEGA with low-density foam layers*
10:50 - 11:10 AM	FO7	Langer	LLNL	*HYDRA simulations of laser-heated foams*
11:10 - 11:30 AM	FO8	Johns	LANL	*Analysis of radiation flow experiments in Ti-doped foams on OMEGA*
11:30 - 11:50 AM	FO9	Dhakal	LANL	*Effects of thermal conductivity of liquid layer in NIF wetted foam experiments*

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Density functional theory methods for transport and optical properties: Application to warm dense silicon*

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Accurate knowledge of equation of state, transport, and optical properties of matter in a wide range of material densities across temperature regimes is of growing importance in many areas of research such as planetary science, astrophysics, and inertial confinement fusion. First-principles methods based on density functional theory (DFT) take into account quantum effects that are essential for warm dense matter (WDM). Nevertheless, the potential for predictive DFT calculations of WDM depends crucially upon having an exchange-correlation (XC) free-energy functional accurate across temperature regimes.

In this talk, we will report on some details of the formal developments of new XC free-energy functional that bridges low-temperature (ground-state) and high-temperature (plasma) limits[1] and therefore takes into account the XC thermal effects. Transport properties (thermal and electrical conductivity, dielectric function, index of refraction, reflectivity, absorption, and opacity) of warm dense silicon are calculated within the Kubo-Greenwood formulation with use of the thermal XC functional and the all-electron projector augmented wave (PAW) data set transferable to extreme conditions. All-electron PAW is required to calculate x-ray absorption near edge structure (XANES) spectra.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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 abstract. This research used resources of the National Energy Research Scientific Computing Center, a DOE Office of Science User Facility supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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48th Annual Anomalous Absorption Conference
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July 8-13, 2018

Radiative and atomic properties of C and CH plasmas under warm dense conditions*

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A super-transition-array (STA) self-consistent method under the local thermodynamics equilibrium (LTE) condition has been employed to examine the radiative atomic properties such as emissivities, opacities, and the average ionization Z* of warm dense C as well as CH plasmas with coupling constant Γ varying from 0.02 to 2.0. The quantitative quality of the STA calculations is evaluated by comparing with other available theoretical calculations as well as experimental measurements. It is found that, in general, the STA computed emissivities, opacities and Z* for carbon and CH are in good agreement with other theoretical and experimental data. In comparison with other theoretical calculations, for C plasma, we find that the STA has essentially reproduced the emissivities, opacities and Z* results obtained using detailed-level accounting and detailed-configuration accounting methods [1]. For CH plasma, we find that the STA computed opacities agree with the results obtained using the first principle quantum molecular dynamics code of LLE and ATOMIC code of Los Alamos [2] down to plasma temperature of about 20 eV. In comparison with experimental measurements, the X-ray scattering diagnostic of the blast wave from planar carbon foam using the Omega laser inferred Z* to be about 2.0 to 4.0 in the shock and rarefaction regions, and the plasma temperature to be between 20 and 40 eV [3]; STA computed Z* largely agrees with the experimental values in the shocked region but underestimates the ionization balance in the rarefaction region. The finding is consistent with the atomic collisional radiative equilibrium simulations. In addition, we further predict the Z* for CH to be about 1.0 to 2.4 in the same temperature range as for the C plasma.

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*This work is made possible under the auspices of the DOE/NNSA.

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July 8-13, 2018

The role of NLTE atomic kinetics in radiation hydrodynamics modeling of ICF targets *

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A multi-year effort to understand NLTE atomic kinetics impacts on the modeling of ICF targets will be reviewed. Since previous hohlraum modeling significantly underreported energetics discrepancies, this study starts with 1D/2D hohlraum models designed to meet *a priori* convergence criteria for the primary simulation outputs. Post-shot simulations using the new models provide quantitative assessments of physics sensitivities in the modeling of the NLTE wall plasma as well as NLTE ablator material. In addition to identifying NLTE parameters that significantly impact energetics observables, the study reveals sensitivity variations between different hohlraum configurations (e.g. hohlraum gas fill) and suggests that Au-He mix may explain some of the variations. This work continues to help motivate and assess improvements in the underlying DCA atomic physics models, and some results obtained using the most recent (2018) generation of models will also be presented.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Imprint mitigation with high-Z coatings on Omega EP and NIF imprint experiments

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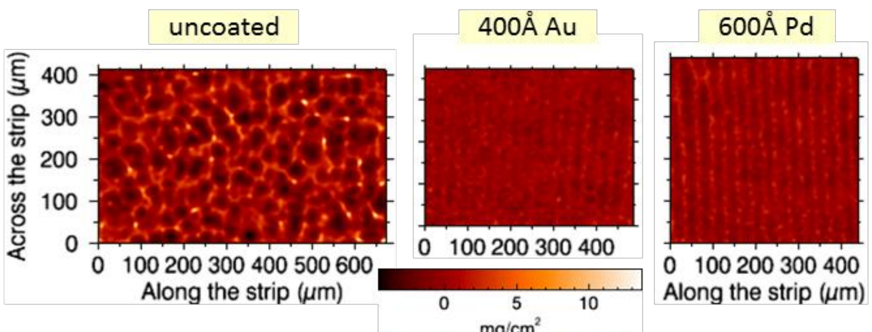
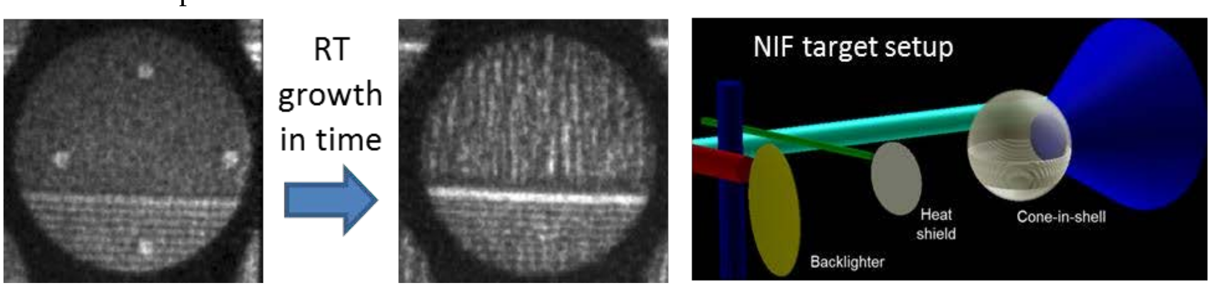
M. Hohenberger, *LLNL, Livermore, CA*

The order-of-magnitude laser imprint reduction technique using direct-indirect hybrid drive with high-Z coatings pioneered[1,2] on the Nike KrF laser ($\lambda = 248$ nm) at NRL has now been applied to a frequency-tripled Nd:glass (351 nm) NIF-like beam of Omega EP laser. We find that in order for the imprint mitigation to be most effective, the coating needs to be pre-expanded to ~100 µm scale length. This pre-expansion allows the initial soft x-ray ablation to be smoothed by the increased distance between laser absorption and the ablation surface. On Nike, a low-intensity, highly smooth prepulse heats and preexpands the low thermal mass metallic coating. This is difficult to achieve using Omega EP beams because of harmonic conversion and lack of SSD. In order to improve longer spatial scale imprint reduction there, we have introduced a means of pre-expanding the high-Z coating to similar length scale using a soft x-ray prepulse.



Areal mass non-uniformity on EP with pre-imposed 30µm ripple and x-ray prepulse

Our experiments on the NIF aim to measure laser imprint in an ignition-scale, multibeam direct-drive geometry in order to benchmark the simulations and assess the need for imprint mitigation there. We will present results of our recent measurements there.



Work supported by the US Department of Energy/NNSA.

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July 8-13, 2018

Energy-conserving model of laser propagation and heating in a subcritical foam*

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We develop an energy-conserving model for laser propagation and heating in a subcritical foam (homogeneous ne/nc < 1). Our model parametrizes the absorbed energy per unit mass during explosive expansion of foam elements illuminated by a laser. This scaling is expressed in terms of experimental parameters as well as the properties of the foam. We create a simple 1D numerical model for laser propagation and heating that incorporates our energy-conserving model of foam element expansion. We apply this model to data collected from an experiment on the Janus laser facility at LLNL which directed a 527 nm, 2 ns laser pulse with a peak intensity of 3E14 W/cm^2 at a target of 2 mg/cm^3 SiO_2 foam. Radiation hydrodynamical simulations modeling the foam as a homogeneous plasma found that the heat front propagated through the foam target ~20% faster than in the experiment. An even larger discrepancy was found between the backscattered SBS intensity modeled with pF3D (~60% of incident) vs. that observed in the experiment (~5% of incident). The energy-conserving model of foam element expansion can explain the discrepancy between experiment and simulations.

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48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

Mitigating laser-imprint effects in direct-drive implosions on OMEGA with low-density foam layers*

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Low-density and low-/mid-*Z* foams have been previously proposed to mitigate laser imprint for direct-drive inertial-confinement fusion (ICF). For foam densities above the critical density of the driven laser, the mechanism of laser-imprint mitigation relies on both the quick formation of the conduction zone, the increased laser ablation, and the increase of density-scale-length at ablation surface in foams. Experimental demonstration of this concept has been limited to planar-target geometry so far. To the best of our knowledge, the impact of foams on improving spherical implosion performance has not been explored, even in radiation–hydrodynamics simulations. To examine the viability of using foam layers to mitigate laser-imprint effects in direct-drive ICF implosions on OMEGA, we have performed a series of 2-D *DRACO* simulations with the state-of-the-art nonlocal and cross-beam energy transfer models. The simulation results indicate that a 40-μm-thick foam layer with a density of $\rho \approx 40$ mg/cm^3 on D_2-filled warm CH capsule can significantly improve the low-adiabat ($\alpha \approx 3$) implosion performance. In comparison with the no-foam case, an increase of neutron yield by a factor of 4 to 8 and the recovery of 1-D compression ρR are expected for a foam surface roughness of $\sigma_{rms} \leq 0.5$ μm. In this talk, we will present these simulation results and discuss the plan for experimental demonstrations of such a laser-imprint mitigation strategy with foam layers.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, 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.

48th Annual Anomalous Absorption Conference
Bar Harbor, Maine
July 8-13, 2018

HYDRA Simulations of Laser Heated Foams*

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Traditional hohlraum designs are limited to helium and neon for the fill gas. Solid coatings can be placed at the laser entrance hole to control LEH closure and on the hohlraum wall to hold back the expanding gold bubble. Foams are an intriguing alternative for these purposes because of their wide range of possible densities and materials.

Experiments on the Janus laser found that the rate at which the ionization front propagates through the heated foam is slower than in HYDRA simulations that treated the target as a gas at the average density of the foam. A more accurate and detailed understanding of foams is needed before they can be effectively used as part of a hohlraum target design.

This paper describes preliminary HYDRA simulations of laser heating of foams created using additive manufacturing (e.g. 3D printers). AM foams can be doped with a variety of elements, made with a range of average densities, and shaped to fit inside a hohlraum. Colleagues are simulating natural foams such as aerogels. AM foams are constructed of alternating planes of filaments at 90 degrees to each other and are reminiscent of a cabin constructed of (notchless) Lincoln Logs.

Our simulations resolve individual filaments in the foam. The extremely regular structure of an AM foam reduces the computational cost by allowing us to take advantage of symmetries. This talk discusses 2D simulations with 4 and 8 filaments one after another in the laser direction. The rate at which the ionization front penetrates the foam initially has jumps due to the discrete filaments, but fairly quickly moves into a quasi-steady flow. The average density of these foams produces a plasma that is above the critical density.

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Bar Harbor, Maine
July 8-13, 2018

Analysis of radiation flow experiments in Ti-doped foams on OMEGA*

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We will present analysis of recent experiments developing a platform for studying the evolution of supersonic to subsonic radiation flow on OMEGA. Supersonic radiation flow and its transition to the subsonic regime is observed in astrophysical systems; but quantifying the propagation of supersonic radiatively driven heat fronts is challenging due to the need for exacting target tolerances[1] and detailed knowledge of equation of state and opacity of the material through which the radiation flows. Simultaneous measurements of spatial temperature distribution (dT/dx) and heat front position are required. We have developed a platform using x-ray absorption spectroscopy and radiography together to obtain dT/dx for the supersonic phase and dρ/dx for hydrodynamics in the subsonic phase. We use K-shell 1s-2p and 1s-3p x-ray absorption spectra of Ti-doped targets to infer temperature from the ionization balance of the dopant, which is sensitive to T_e changes as small as 2eV. We measure the evolution of the hydrodynamic motion in the subsonic phase as the variation in density with position using radiography. Both measurements provide the position of the heat front. Previous experiments[2] using absorption spectroscopy of chlorinated foams measured heat front arrival but would not be suited to higher temperatures at NIF, where radiation flow experiments may be conducted in a diffusive regime[3]. In our case, custom opacity tables in the LANL OPLIB format[4] enable spectroscopic analysis of the ionization balance of the titanium dopant to infer temperature using PrismSPECT. Results from this analysis showing dT/dx and dρ/dx profiles for several times during the evolution of the radiation flow will be discussed. Experimental uncertainty includes changes in temperature 3-5eV and density changes across 20 μm along the direction of propagation. Spatial temperature and density profiles serve as vital metrics for comparison to radiation transport models of supersonic and subsonic radiation flow.

*Work conducted at Los Alamos National Lab under contract DE-AC52-06NA2536

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48th Annual Anomalous Absorption Conference
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Effects of thermal conductivity of liquid layer in NIF wetted foam experiments

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Numerical simulation of inertial confinement fusion (ICF) capsule implosion experiments require many plasma parameters corresponding to different materials and their mixtures for a broad range of densities and temperatures. Thermal conduction is the primary mechanism of energy loss from capsule since for low Z materials such as DT, radiative energy loss is negligible. The determination of accurate thermal conductivity of ICF relevant materials is thus important. In traditional ICF simulations, analytic models such as Spitzer or Lee-More models have been extensively used. First principle calculations have shown that these analytic models tend to underestimate electron thermal conductivity at warm dense plasma regime for ICF related materials. Tabular EOS data, such as SESAME tables, are not available for all materials. In this talk, we numerically investigate the effects of electron heat conductivity of CH+DT liquid layer[1] to the final implosion results for NIF wetted foam experiment. We found that electron heat conductivity affects the initial hot spot formation as well as its evolution. In principle, we can adjust the conductivity of liquid layer by varying the density of CH matrix or adding a dopant to the liquid layer. This could provide a new mechanism for adjusting hot spot size without appealing to shock timing. We also found that using first principle based QMD fitted conductivity model[2] yields better agreement with experimental results.

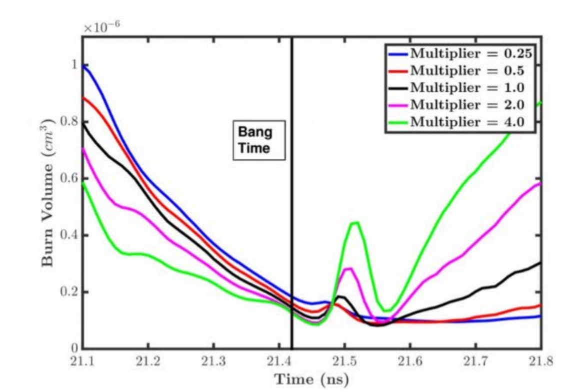

Fig. Evolution of hot spot corresponding to different conductivity multipliers in liquid layer

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