52nd Annual Anomalous Absorption Conference

June 9-14, 2024

The Big Sky Resort, Big Sky, MT

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June 9th–14th, 2024

52nd Anomalous Absorption Conference Agenda

Monday, June 10, 2024 in the Talus Room of the Summit Hotel

7:00am-8:15am	**Breakfast in the Huntley Dining Room**	
Welcome and Oral Sessions 1 & 2 in the Talus Room of the Summit Hotel		
8:15am	**Introduction/Welcome**	**Mark Schmitt**
Time	**Session 1: Inertial Confinement Fusion**	**Chair: Dustin Froula**
8:30	(**Invited**) *A path towards experimentally validated implosion designs for future inertial confinement fusion facilities*	Follett, Russ *LLE*
9:00	*First inertial confinement fusion implosions using low gas-filled hohlraums on the Laser Mega Joule facility*	Lafon, Marion *CEA*
9:20	*Multi-MJ target designs for Inertial Fusion Energy*	Christopherson, Alison, *Xcimer Energy*
9:40	*Integrated radiation-magneto-hydrodynamic simulations of magnetized burning plasmas*	Djordjevic, Blagoje, *LLNL*
10:00	*Shape evolution of imploding shocks and shells and its effects on burn wave propagation in magnetized ICF for high yield*	Ho, Darwin, *LLNL*
10:20am	**Coffee Break**	
	Session 2: Laser-Plasma Interactions	**Chair: Frank Tsung**
10:40	(**Invited**) *Experimental Evidence of the Effect of a Moderate External Magnetic Field on Stimulated Raman Scattering*	Winjum, Ben *UCLA*
11:10	*Laser-plasma interaction considerations for an enhanced yield capability at the National Ignition Facility*	Chapman, Tom, *LLNL*
11:30	*Exploration of cross-beam energy transfer mitigation constraints and chamber geometry designs for ignition-scale direct-drive ICF*	Colaitis, Arnaud, *LLE*
11:50	*Statistical theory of the broadband two plasmon decay instability*	Ruskov, Rusko, *Oxford*
12:10	*Machine learning for laser backscatter at the National Ignition Facility*	Kur, Eugene, *LLNL*
12:30	**Lunch in the Huntley Dining Room**	

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A path towards experimentally validated implosion designs for future inertial confinement fusion facilities*

R. K. Follett, A. Colaitis, I. V. Igumenshchev, V. Gopalaswamy, D. Cao, V. N. Goncharov, D. N. Polsin, R. Betti, J. P. Palastro, T. J. B. Collins, D. H. Froula, C. Stoeckl, J. P. Knauer, V. Yu. Glebov, C. J. Forrest, L. Cuervorst, A. S. Joglekar, W. Trickey, R. C. Shah, R. Nora[†] and D. Turnbull

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The achievement of ignition in the laboratory has renewed interest in defining the requirements for a future high-gain inertial-confinement fusion (ICF) facility. This requires a design paradigm that relies less on empirical evidence than the approaches commonly used at current facilities but still leverages the enhanced predictive capability that can be obtained with simulations that are validated against experimental data. We develop a hierarchical approach where 3-D radiation hydrodynamic simulations and experimental measurements are used to train physics-based 3-D degradation models in 1-D simulations allowing for accurate predictions over the entire OMEGA database.

* This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0004144.

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First inertial confinement fusion implosions using low gas-filled hohlraums on the Laser Mega Joule facility

M. Lafon [1], S. Depierreux [1], S. Laffite [1], S. Liberatore [1], P-E. Masson-Laborde [1], R. Riquier [1], V. Tassin [1], R. Botrel [2], T. Caillaud [3], R. Capdessus [1], Q. Cauvet [1], P. Dupré [3], L. Le Deroff [3], J. Trela [1], and J-L. Willien [1]
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The inertial confinement fusion (ICF) platform in the indirect-drive configuration on the Laser Mega Joule (LMJ) facility has been considerably extended since the first fusion experiments performed in 2019 [1]. The LMJ facility is now capable of delivering up to 270 kJ of UV energy on target using eighty beams evenly distributed among four rings allowing for a symmetric irradiation inside a hohlraum for the first time.

Here, we report on recent experimental progress on the first indirect-drive implosion campaigns carried out over the past three years to achieve an ablative compression regime using this unprecedented irradiation configuration. In those experiments, D_2-filled silicon-doped plastic capsules were imploded using low gas-filled rugby-shaped, elliptical and cylindrical gold hohlraums using 2-shocks and drooping pulses. The commissioning of new plasma diagnostics has allowed observing X-ray images of the hot spot emission for the first time on LMJ.

Integrated 2D and 3D simulations using the radiation hydrodynamics code TROLL [2] are performed to investigate the experimental results including neutron yield, radiation temperature, implosion symmetry and X-ray images of the stagnating hot spot as well as the gold wall motion inside the holhraum. We also report on significantly different levels of measured backscattered energy and cross-beam energy transfer between inner and outer beams for the three hohlraum shapes. Finally, we show how these results will guide the future designs for the inertial confinement fusion campaigns on LMJ in the upcoming years.

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[1] S. Liberatore *et al*, "*First indirect drive inertial confinement fusion campaign at Laser Mega Joule*", Phys. of Plasmas **30** 122707 (2023).
[2] E. Lefebvre *et al*, "*Development and validation of the TROLL radiation-hydrodynamics code for 3D hohlraum calculations*", Nucl. Fusion **59** 032010 (2019).

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Multi-MJ target designs for Inertial Fusion Energy

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In laser driven inertial confinement fusion (ICF), a spherical capsule filled with deuterium and tritium (DT) is accelerated inward by direct irradiation of the laser energy (direct drive) or by X-rays generated from the laser interacting with the hohlraum (indirect drive). At stagnation, the fuel is compressed to ~ 100-200 x its initial density and has been heated to temperatures larger than ~ 10 keV. The DT atoms fuse to produce a 3.6 MeV alpha particle and a 14.1 MeV neutron. On December 5, 2022, the National Ignition Facility (NIF) achieved “breakeven” for the first time, where 2.6 MJ of fusion energy output were generated from 2 MJ of laser energy input. This represented a significant milestone after 50 years of research. The goal of the emerging inertial fusion energy (IFE) community is to commercialize ICF for the purpose of creating a fusion pilot plant (FPP) and eventually, a first of a kind (FOAK) GW nuclear reactor.
Xcimer Energy Inc is designing a novel class of low cost, high energy (~10 MJ) laser systems enabled by the development of gas optics. This is a huge step forward given the present inability of solid optics to survive large beam fluences. The chamber design is based on the well-studied HYLIFE concept which uses molten eutectic salt to collect the radiation from the target output, serving as a coolant, Tritium breeder, and a shield for the chamber wall. The target containing the DT fuel must survive injection into the chamber, irradiation from two sides, and achieve gains >100-150 (the requirements for which depend on repetition rate and wall plug efficiency). For a target concept to be viable and credible, it also must exhibit robustness to the Rayleigh Taylor instability which severely limited the performance of early NIF experiments predicted to achieve high yields. In this presentation, we discuss the target design opportunities that are enabled by high energy lasers for producing robust implosions that are both high gain and hydrodynamically stable.

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Integrated radiation-magneto-hydrodynamic simulations of magnetized burning plasmas*

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Considering recent breakthroughs[1] in inertial confinement fusion (ICF), first achieving ignition conditions in National Ignition Facility (NIF) shot N210808 and then laser energy breakeven in N221204, modeling efforts have been investigating the effect of imposed magnetic fields on integrated simulations of igniting systems. Previous NIF experiments have shown fusion yield and hotspot temperature to increase in magnetized gas-filled capsules[2] in line with expected scalings[3]. We use the 2D radiation-magneto-hydrodynamics code Lasnex, including its multi-ion species[4] and cross-beam energy transfer (CBET)[5] models, within the Lasnex Hohlraum Template (LHT) ICF common model[6]. Simulations are tuned to approximate data from unmagnetized experiments: the laser power vs. time is modified to match shock velocities and nuclear bangtime, the CBET saturation clamp and cone fraction are chosen to match the P2 Legendre mode of the hotspot self-emission, and mix models for hotspot degradation to match yield[7].

Investigated here is the effect of axial imposed fields up to 100 Tesla on the fusion output of historically best performing ICF shots, specifically N180128 (record BigFoot shot), N210808, and N221204. The main effect is increased hotspot temperature due to magnetic insulation, as electron heat flow is constrained perpendicular to the magnetic field and alpha particle trajectories transition to gyro-orbits. Magnetic fields must be fastidiously applied however as magnetic pressure can resist the implosion and fields can decrease the propagation speed of the burn wave[8,9]. In conclusion it is found that magnetization can increase ion temperature by 30% and neutron yield by 3x, e.g., 9.5 keV to 13 keV and 1.5 MJ to 4.3 MJ for N210808 at B_0 = 70 T.

*This work was conducted under the auspices of the U.S. Department of Energy by LLNL under contract DE-AC52-07NA27344 and Laboratory Directed Research and Development project 23-ERD-025.

[1] H. Abu-Shawareb, et al., Phys. Rev. Lett. 129, 075001 (2022) and 132, 065102 (2024)
[2] J. D. Moody, et al., Phys. Rev. Lett. 129, 195002 (2022)
[3] C. A. Walsh, et al., Phys. Plasmas 29, 042301 (2022)
[4] D. P. Higginson, et al., Phys. Plasmas 29, 072714 (2022)
[5] D. J. Strozzi, et al., Phys. Rev. Lett. 118, 025002 (2017)
[6] D. J. Strozzi, et al., Phys. Plasmas, submitted (2024)
[7] B. Bachmann, et al., Phys. Plasmas, 30, 052704 (2023)
[8] I. R. Lindemuth and R. C. Kirkpatrick, Nuclear Fusion 23, 263 (1983)
[9] R. D. Jones and W. C. Mead, Nuclear Fusion 26, 127 (1986)

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SHAPE EVOLUTION OF IMPLODING SHOCKS AND SHELLS AND ITS EFFECT ON BURN WAVE PROPAGATIONS IN MAGNETIZED ICF FOR HIGH YIELD*

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Spherically symmetric shocks imploding in the imposed B field always evolve into an ellipsoidal shape. After bouncing from the center, the outgoing shock front induces an asymmetric radial velocity field, which is further enhanced by the oblate shape of the imploding shell in late time. This radial velocity field delays the impediment of burn wave propagation by the flux-compressed B field, and this effect is the determining factor in the feasibility of achieving high yields in magnetized implosions. For intermediate-strength shocks and strong shocks, the ellipsoidal shape is caused by the faster magnetosonic shock speed perpendicular to the B field[1] and by the slowing-down of the shock by electron thermal conduction along the direction of the field,[2] respectively. After the shock bounces from the center, an asymmetric radial velocity field with components perpendicular to the field directed outward and components along the field directed inward is developed. This radial velocity field is further enhanced in late time as the spherical imploding shell evolves into an oblate shape with the long axis perpendicular to the field because of the magnetic pressure inside the shell. This asymmetric velocity field expands the plasma in the central region of the hotspot along the perpendicular direction and limits the strength of the compressed B field. Thus, the B field in the central region is weak enough to allow burn wave propagation while strong enough to enhance the energy deposition of the alpha particles into the hotspot. The imploding shock and the shell are spherical in the hypothetical magnetized situation where the $\mathbf{J}\times\mathbf{B}$ force is absent. The compressed B field in the central hotspot region can then be strong enough to impede the propagation of burn waves, and the thermonuclear yield is substantially reduced. Simulations of the magnetized N210808 with the $\mathbf{J}\times\mathbf{B}$ force show that the B field amplifies the yield if the imposed field is $\lesssim$ 60T, while without this force, the B field does not enhance the yield because a strong central B field impedes the burn wave propagation.

[1]D. D.-M. Ho, L. J. Perkins, G. B. Zimmerman, B. G. Logan, S. Hawkins, and M. A. Rhodes, 56th Annual Meeting of the APS Divison of Plasma Physics, BO7.00002 (2014); http://meetings.aps.org/link/BAPS.2014.DPP.BO7.2

[2]D. Ho, G. Zimmerman, A. Velikovich, R. Kulsrud, J. Moody, J. Harte, and A. Kritcher, 63rd Annual Meeting of the APS Division of Plasma Physics, UO04.00010, (2021).

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. DE-AC52-07NA27344.

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Experimental Evidence of the Effect of a Moderate External Magnetic Field on Stimulated Raman Scattering*

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Laser-plasma instabilities (LPI) such as stimulated Raman scattering (SRS) play a detrimental role in inertial confinement fusion (ICF) by degrading energy coupling to the target and generating hot electrons that threaten to preheat the fuel. However, numerical studies have shown that SRS can be mitigated in the kinetic regime ($k\lambda_{De}$ > ~0.3) by moderate external magnetic fields.[1] Such magnetic fields are now being explored for a range of uses in ICF and laboratory astrophysics experiments, opening up opportunities to explore their effects on LPI. We present results from an OMEGA-EP experiment that investigated the effect of a magnetic field on SRS. A 22-T magnetic field was imposed on a gas jet plasma with a MIFEDS coil, and a novel three-picket interaction beam was used to explore SRS reflectivity for several plasma densities within single shots. The time-resolved backscattered light shows that SRS was mitigated by the external 22-T magnetic field in the kinetic regime ($k\lambda_{De}$ ~ 0.3) and at a density of n_e/n_{cr} ~ 0.10. Intriguingly, we also found an unexpected enhancement of SRS reflectivity at lower density ($n_e/n_{cr} < 0.08$). The enhancement is likely due to the evolution of bulk plasma properties, and we discuss our further simulation and theoretical work to scan SRS dynamics for a variety of electron temperatures, electron densities, and laser intensities.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Numbers DE-NA0003842 and DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority.

[1] B. J. Winjum, F. S. Tsung, and W. B. Mori, "Mitigation of stimulated Raman scattering in the kinetic regime by external magnetic fields," Phys. Rev. E **98**, 043208 (2018).

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Laser-plasma interaction considerations for an enhanced yield capability at the National Ignition Facility*

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An enhanced yield capability (EYC) provided by an upgraded laser at the National Ignition Facility (NIF) is being proposed with the goal of fielding indirect inertial confinement fusion implosions driven by laser energies in excess of 2.6 MJ. Using a target hydroscaled up by a factor of 1.09 from current igniting Hybrid E designs[1,2], we present the first experiments specifically designed to study EYC-relevant physics with a focus on exploring laser-plasma interaction in the EYC regime. Key data collected include light from stimulated Brillouin and Raman scattering and x-ray images of the beam spots on the wall provided by the use of deliberately thin hohlraum walls. These results are discussed in the context of past measurements at the NIF in similar designs at the currently igniting scale (scale 1.0) as well as designs throughout the history of NIF operations.

[1] The Indirect Drive ICF collaboration, Phys. Rev. Lett. **132**, 065102 (2024)
[2] A. L. Kritcher *et al.*, Phys. Rev. E **109**, 025204 (2024)

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52–07NA27344

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Exploration of cross-beam energy transfer mitigation constraints and chamber geometry designs for ignition-scale direct-drive ICF*

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The compression of direct-drive inertial confinement fusion (ICF) targets is strongly impacted by cross-beam energy transfer (CBET), a laser-plasma instability that limits ablation pressure by redirecting laser energy outward and that is projected to be mitigated by laser bandwidth. Here, we explore various CBET mitigation constraints to guide the design of future ICF facilities. First, we find that the flat, Gaussian, and Lorentzian spectral shapes have similar CBET mitigation properties, and a flat shape with nine spectral lines is a good surrogate for what can be obtained with other spectral shapes. Then, we conduct a comprehensive study across energy scales and ignition designs. 3D hydrodynamic simulations are used to derive an analytical model for the expected CBET mitigation as a function of laser and plasma parameters. From this model, we study the bandwidth requirements of conventional and shock ignition designs across four different energy scales and find that they require between 0.5 and ~3% relative bandwidth. In steady state, we find that the bandwidth required to mitigate 85% of CBET scales as $(R_b/R_c)^{2.15}$ $L_n^{-0.58}$ $I^{0.7}$, where L_n is the density scale length, R_b/R_c is the ratio of the beam radius to critical radius, and I the laser intensity. In the case of a driver using many monochromatic beamlets, we find that 10 beamlets per port is required, with diminishing returns above 20. Finally, we study different beam port layouts suited for direct-drive. We find that these do not influence CBET mitigation for the configurations we have chosen (>48 beam ports). Focusing on designs using ~80 beam ports, we find that different layouts behave differently in terms of stability to systematic low-mode error sources such as beam pointing error, target positioning error and beam balance error. Notably, optimum designs differ depending on assumed error sources of 0% (ideal case) or 1% (more realistic case).

*This work was granted access to the HPC resources of TGCC under the Allocation Nos. 2021-A0120513397 and 2022-A0130513772 made by GENCI. The software used in this work was developed in part at the University of Rochester's Laboratory for Laser Energetics. This material is based on work supported by the Department of Energy National Nuclear Security Administration under Award No. DE-NA0004144, the University of Rochester, the New York State Energy Research and Development Authority, and Office of Fusion Energy IFE-COLoR Hub under Award No. DE-SC0024863.

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Statistical theory of the broadband two plasmon decay instability

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Broad-bandwidth laser technology has attracted considerable interest for its high potential impact on direct-drive ICF. Large enough laser bandwidth is expected to lead to substantial suppression of the deleterious parametric instabilities occurring in the coronal plasma, thereby unlocking the ablation pressures required for IFE-relevant gains. Therefore, detailed understanding of the effects of laser bandwidth on the various instabilities is paramount. From a theoretical point of view the complications arise from the fact that such a problem can be statistically nonlinear and statistically inhomogeneous, even in a uniform plasma during the linear stage of the instability. Recent techniques developed to tackle similar problems in a magnetic confinement as well as geophysical contexts, are applied to the two plasmon decay instability. We derive a dispersion relation for it valid under laser fields with arbitrary power spectra. When investing the effects of temporal incoherence, growth rates are shown to be more sensitive to the laser spectral shape, rather than the coherence time. Laser bandwidth is also seen to broaden the range of plasma waves generated by two plasmon decay, making the absolute ($k \to 0$) modes accessible in regions further away from the quarter critical density[†].

[†]R.T. Ruskov, R. Bingham, L. O. Silva, M. Harper, R. Aboushelbaya, J. F. Myatt and P. A. Norreys, "Statistical theory of the broadband two plasmon decay instability", under consideration at the Journal of Plasma Physics, arXiv preprint: arXiv:2404.17384 (2024).

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Machine learning for laser backscatter at the National Ignition Facility*

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Recent success at the National Ignition Facility (NIF) has motivated pushing the laser and hohlraum to conditions where laser light can scatter back out of the hohlraum and damage laser optics or reduce drive efficiency and symmetry control. Understanding trends in backscatter with limited data using machine learning (ML) models is important as we push the designs and laser to higher fusion yields.

In this talk, we consider backscatter produced by stimulated Brillouin and Raman scatter (SBS and SRS) during laser propagation in the hohlraum. While such backscatter has little impact on overall energetics in modern hohlraums[1], we show that it can still have significant impacts on implosion shape: HYDRA[2] simulations of Hybrid-E[3] experiments had Legendre mode P2/P0 decreased by 20-35% as inner cone SBS on the rise to peak power caused the implosions to become significantly more oblate.

Such considerations led us to develop an ML-powered automated backscatter analysis tool. The tool corrects and combines SBS and SRS data across multiple diagnostics (drive diagnostics, DrDs[4], and the full aperture backscatter station, FABS[5]), inferring smooth non-negative backscatter signals on all beams. We show how the tool accurately quantifies uncertainty from systematic errors, DrD debiasing, FABS rescaling, diagnostic noise, and uncertainty in the inference model. Such analysis takes just minutes per shot, with little-to-no input from the user, producing backscatter-subtracted laser input files for use in HYDRA simulations, along with various backscatter energy and power summaries. We highlight how these results are utilized by various modeling efforts, and close with a discussion of ongoing work to produce a predictive backscatter model.

* 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] H. Abu-Shawareb, et al. (Indirect Drive ICF Collaboration), *Phys. Rev. Lett.* **129**, 075001 (2022)
[2] M. M. Marinak, et al., *Phys. Plasmas* **8**, 2275 (2001)
[3] A. B. Zylstra et al., *Nature* **601**, 542 (2022)
[4] B. J. MacGowan No. LLNL-CONF-777549. 2019.
[5] D. E. Bower, et al. *Review of scientific instruments* 75.10 (2004): 4177-4179.

7:00pm	**Plenary Session I in the Talus Room of the Summit Hotel** *In Memory of Harvey A. Rose: Honoring His Science and Impact on Laser-Plasma Interactions*	Rozmus, Wojciech (*Univ. of Alberta*), Michel, Pierre (*LLNL*), Montgomery, David (*LANL*)
8:00pm	**Poster Session I in the Gallatin Ballroom (see end of this file)**	

Monday Poster Session I: Laser plasma interactions **8:00pm in the Gallatin Ballroom**

1	Carleton, Daniel	*U Alberta*	Ray tracing model of side scattering instabilities in laser produced plasmas
2	Leal, Luis	*LLNL*	HYDRA simulations modeling magnetized CBET gas-jet experiments at OMEGA
3	Moloney, Philip	*Imperial*	Modelling Cross-Beam Energy Transfer in Magnetized Direct-Drive Implosions
4	Moody, John	*LLNL*	Thomson scattering from a magnetized CBET experiment
6	Shi, Yuan	*UC-Boulder*	Status of the magnetized cross beam energy transfer
7	Sinclair, Mitchell	*UCLA*	Does the WKB approximation predict the Amplification Length of the B-SRS instability in a Density Gradient Plasma?
8	Thomas, Izzy	*UCSD*	Nonlinear evolution of helical plasma waves
9	Tsung, Frank	*UCLA*	Particle-in-cell simulations high-frequency hybrid instability (HFHI) dominated rescattering relevant to inertial fusion energy (IFE)
10	Weichman, Kale	*LLE*	Challenges and progress in kinetic modeling of broadband laser-plasma interaction with WarpX
11	Sutcliffe, Graeme	*LLNL*	Investigation of late-time nonlinear evolution of ion-Weibel filaments
12	Lemos, Nuno	*LLNL*	Quantifying laser wave length shifts from forward stimulated Brillouin scattering at the laser entrance holes of a hohlraum
13	Attiyah, Danny	*UC-Irvine*	Spatio-Temporal Light Springs: An Exotic State of Light to Explore Novel Laser-Plasma Interactions
14	Chase, Sarah	*UCLA*	Exchange of angular momentum in stimulated Raman scattering interactions
15	Bruulsema, Colin	*LLNL*	Backscatter dependence on $\delta\lambda$ in low gas fill ICF

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In Memory of Harvey A. Rose: Honoring His Science and Impact on Laser-Plasma Interactions

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Harvey Rose has been a leading theorist working in statistical physics, plasma physics, and laser-plasma interactions (LPI). For almost five decades, his innovative ideas have shaped research directions and provided a basis for both experimental and theoretical explorations into laser fusion physics. His significant contributions in areas such as strong Langmuir turbulence, trapped particle dynamics, laser beam bending in flowing plasmas, stimulated Brillouin and Raman scattering (SBS & SRS) in speckled laser beams and “electron acoustic waves” have left a lasting mark on the field of LPI physics. To commemorate Harvey’s recent passing, brief summaries of some of his collaborative work will be given by three well known LPI scientists.

Pierre will begin by providing an introduction to Harvey’s groundbreaking work on the statistics of speckles and backscatter in optically-smoothed laser beams. After publishing the first analysis of speckle statistics as local intensity maxima, Harvey followed up with the first analytical model of full beam backscatter reflectivity using an “independent hot spots” model. These two studies initiated decades-long research efforts from LPI researchers around the world.

David will continue by recounting his great fortune and pleasure to interact with Harvey beginning in 1989 during the National Academy of Sciences ICF Program Review that continued more closely in the early 1990’s on the Nova laser, followed by experiments from the Trident, Omega, and NIF laser facilities. He will first review experiments which validated Harvey’s critical onset intensity for SBS in speckled laser beams, whereby the convective gain diverges at some average intensity and SBS saturates above that intensity. Next, experimental results on flow-induced beam steering, which were first inspired by Nova gas-filled hohlraum experiments, and later validated and tested further on Nova, Trident, and more recently on NIF will be discussed. Finally, David will give an overview of past experiments on Trident, first inspired by Harvey’s Vlasov trapping model of driven electron plasma waves, which predicted a so-called “electron acoustic wave”, later observed in experiments by others worldwide. He will conclude with some personal thoughts of working with Harvey over many years.

Wojciech will round out the seminar by recounting efforts he had with Harvey on the topics of strong Langmuir turbulence, trapped particle dynamics, and laser beam bending in flowing plasmas. He will reflect on Harvey's generosity in sharing his insights and offering advice on these and other topics that influenced him and countless others throughout Harvey’s remarkable career. The seminar will conclude with a tribute to Harvey’s profound scientific legacy and remembrance of the warmth of friendship he extended to many of us.

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Ray tracing model of side scattering instabilities in laser produced plasmas

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Side scattering instabilities, such as side scatter Raman and Brillouin can affect laser plasma coupling in inhomogeneous plasmas for pump intensities significantly below the absolute threshold [1]. A ray tracing program has been developed to calculate convective gain for arbitrary beam geometry and plasma profile. Numerical gain calculations have been used to evaluate the flux of emitted radiation and this has been compared with the bremsstrahlung sources of radiation measured in Thomson scattering experiments. Applications to pump-probe experiments in a crossed-beam geometry involving broadband lasers will be discussed.

In Thomson scattering experiments the intensity of the probe can reach intensities on the order of 10^{14} W/cm^2 motivating our examination of induced emission via Raman side scattering and comparison of the scattered signal with Thomson scattering radiation. We have analyzed inhomogeneous conditions of interpenetrating plasmas in the nonlinear stage of the saturated ion Weibel instability [2]. In the application of our ray tracing program, we calculated the side scatter Raman gain along the Thomson scattered rays.

The Fourth-Generation Laser for Ultra-Broadband Experiments (FLUX) at the Laboratory for Laser Energetics (LLE) enables a variety of broadband experiments. Interpreting the experimental results requires new simulation tools for broadband laser-plasma interactions. Application of the ray tracing program to pump-probe experiments with a broad-band laser will be demonstrated using a finite number of monochromatic waves in a crossed-beam geometry.

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HYDRA simulations modeling magnetized CBET gas-jet experiments at OMEGA*

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Recent experiments part of the MAGCBET campaign are seeking to characterize the effect of magnetization on Cross Beam Energy Transfer (CBET) using the gas-jet configuration driven by the OMEGA laser at LLE. We present 3D HYDRA[1] simulations of the plasma generated through the interaction gas jet and OMEGA laser system and compare plasma parameters to Thomson scattering measurements fit using the TSADAR[2] routine. We discuss the necessary simulation parameters to match the plasma parameters seen in experiments incorporating NLTE and DCA[3] atomics package. The trend in CBET from experiments with and without a magnetic field(~20T) is compared using the in-line CBET[4,5,6] package.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and by the LLNL-LDRD program under Project Number 23-ERD-025.

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Modelling Cross-Beam Energy Transfer in Magnetized Direct-Drive Implosions

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Magnetized inertial confinement fusion (ICF) is a scheme to relax the ignition requirement in the hotspot by reducing thermal-conduction losses and therefore potentially enhance the yields and robustness of implosions. Indirect-drive experiments have been carried out on the National Ignition Facility laser system that demonstrate enhanced fusion yields and ion temperatures [1]. Direct-drive experiments have also been carried out on the OMEGA laser facility which show that magnetization can significantly affect the shape of the implosion, leading to less efficient compression [2]. Cross-Beam Energy Transfer (CBET) is a laser-plasma instability that reduces coupled energy in OMEGA direct-drive experiments by roughly 20% and can effect the shape of stagnated states [3]. CBET scattering is also strongly affected by density and temperature asymmetries that feed out into the coronal plasma as these profiles affect the laser propagation and therefore the CBET resonances. Strong magnetic fields can directly alter the gain of LPIs, but magnetization can also affect the scattering indirectly in ICF implosions by modifying the thermal transport which alters the hydrodynamics and therefore the resonance region for the interaction [4].

In this work, we shall present simulations which demonstrate the effects of this indirect interplay between CBET and magnetization. By using the recently developed CBET model in the CHIMERA MHD code, we will present simulations of magnetized direct-drive exploding pusher experiments. The simulations show how increasing including an initial axial field enhances the in-flight coronal temperature asymmetries in the implosion which therefore modifies the CBET resonance region and ultimately changes the stagnated shape. Initial evidence suggests that including the effect of CBET in the laser modelling of magnetized implosions reduces the amplitude of the stagnation asymmetry, bringing simulations of these experiments into better agreement with experimental data.

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Thomson scattering from a magnetized CBET experiment*

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Recent experiments investigating magnetized implosions on the National Ignition Facility (NIF) [1] have raised important questions about the physics of magnetized high energy density (HED) plasmas. The implosion experiments apply a seed magnetic field of ~ 30 T to the hohlraum and capsule which reduces the electron thermal conduction losses and increases the temperature of the hot spot by an observed 40%. Magnetized cross-beam energy transfer (CBET) is a laser-plasma interaction physics process which is expected to be active in both magnetized indirect and direct drive implosions. The presence of the magnetic field can modify the plasma conditions in the CBET region and may introduce additional plasma modes which modify the beam-to-beam power transfer. We have performed experiments on the Omega laser to study magnetized CBET in several target geometries. In one experimental configuration we use a laser-coil to apply a 100 – 200 T B-field to an exploding foil Carbon plasma. Thomson scattering measurements in the magnetized plasma may show evidence of electron-cyclotron resonances due to the B-field. We show the experimental data and review the Thomson scattering predictions from magnetized plasma wave theory. In addition, we show that there may be additional modes resulting from the magnetic field which may be important to the beam-to-beam power transfer.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and by the LLNL-LDRD program under Project Number 23-ERD-025.

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Status of the magnetized cross beam energy transfer (MagCBET) campaign*

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In laser-driven magneto-inertial fusion concepts, laser-plasma interactions occur in a magnetized environment. In addition to changing plasma conditions, magnetization also intrinsically changes laser polarization and propagation, as well as nonlinear plasma responses. The MagCBET campaign at the OMEGA facility aims to measure the effects of magnetization on cross beam energy transfer (CBET), which controls the coupling and symmetry of implosions[1]. So far, two shot days have been conducted using two configurations. (1) In the gas-MIFEDS configuration, a laser-heated gas jet provides a plasma target, which is magnetized using a pair of MIFEDS coils[2] that provide ~20 T fields. After heater beams are turned off, a single OMEGA-60 beam is used as a CBET pump, and the wavelength tunable TOP9 beam is used as a CBET probe. Preliminary data suggests that magnetization decreases CBET at fixed laser drives, which is expected from the combined effects of increasing plasma temperature, decreasing nonlinear coupling, and misaligning laser polarizations. (2) In the foil-coil geometry, a laser heated carbon foil produces a plasma plume, and a laser driven coil[3] produces a magnetic field of ~100 T. In this configuration, two OMEGA-60 beams of equal wavelength are used as the CBET pump and probe. Resonance is achieved by unequal Doppler shifts of the two lasers in the plasma flow. Preliminary data suggests that turbulent magnetized jets are formed, in which CBET is observed. The stronger magnetic field in this configuration may enable observation of magnetized resonances away from the usual acoustic resonance.

* This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and by the LLNL-LDRD program under Project Number 23-ERD-025. Reviewed and released under LLNL-ABS-864150.

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Does the WKB approximation predict the Amplification Length of the B-SRS instability in a Density Gradient Plasma?

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We are investigating how effectively the Wentzel–Kramers–Brillouin (WKB) approximation predicts the interaction length of the Backwards-Stimulated Raman Scattering (B-SRS) instability in a density up-ramp plasma [1], [2].

The experiment uses a 2 ps FWHM (~60 laser cycles) CO_2 laser drive pulse with a normalized vector potential of a_0 of 0.4 – 1.2. We observe and diagnose the spectral amplitude of B-SRS via a custom made ZnSe long wavelength IR prism spectrometer that covers the spectral range from 9.2 – 14 μm. B-SRS is a three-wave process described by the matching conditions $\omega_o = \omega_s + \omega_{EPW}$ and $\boldsymbol{k_o} = \boldsymbol{k_s} + \boldsymbol{k_{EPW}}$ where a drive EM wave (ω_o, $\boldsymbol{k_o}$) first scatters from collective fluctuations in plasma at (ω_{EPW}, $\boldsymbol{k_{EPW}}$) to give an EM noise source (ω_s, $\boldsymbol{k_s}$). This noise source beats with the pump radiation and the resulting ponderomotive force reinforces the plasma noise which then scatters even more light, thus creating a feedback loop.

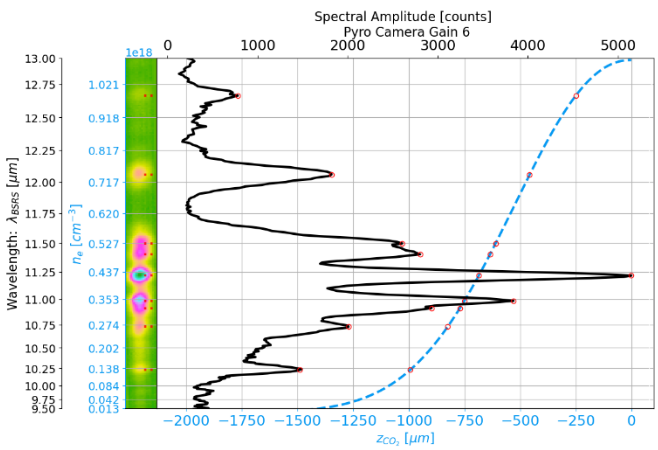

Figure 1: Experimental Spectrum of B-SRS. Individual peaks indicated with red circles.

When the B-SRS instability grows in a plasma with a density gradient, it locks at a density resonance, z_m, and the two daughter waves are amplified over a small region of space, the amplification length $2z_T$. This amplification length is given by , $\pm iz_T = \pm i\ 2\gamma\_o/\kappa'\sqrt{v_{g,s}v_{g,EPW}}$, where γ_o is the temporal growth rate, κ' is the derivative of the WKB dephasing term $\kappa(z) = k_{EPW}(z) - k_o(z) - k\_(z)$, and $v_{g,s}$ and $v_{g,EPW}$ are the group velocities of the scattered and plasma waves [2]. Using fully self-consistent PIC simulations we observe that the amplitude of the plasma wave peaks at the resonant point in the density ramp when an extremely weak counterpropagating seed is introduced and is driven at the matched resonance conditions to the upper/lower turning points, $\pm iz_T$. The width of this amplification length is then determined when the phase mismatch between this driven EPW, $k_{EPW}(z) \cong\ k_o(z_m) + k\_(z_m)$, and a self-support EPW becomes significant. Shown with these PIC simulations, we observe that k_{EPW} matches the wavenumber of the EM beat pattern and not that of a self-supported EPW, i.e. we see a quasi-single frequency and wavenumber across an amplification region. This quasi-single wave number amplification supports a discretize view of B-SRS, which correlates to the scattered wavelengths as observed from these short, but intense, amplified B-SRS spectra.

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Acknowledgement: This work was supported by the U.S. Department of Energy Grant Nos. DE-SC0010064 and DE-SC0014043 as well as NSF Grant No. 2003354 with experimental work conducted at the Accelerator Test Facility at Brookhaven National Laboratory, Upton, NY, 11973
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Nonlinear evolution of helical plasma waves*

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Electron plasma waves are inherent to several of the laser-plasma instabilities that inhibit the performance of inertial confinement fusion (ICF). When driven to large amplitudes, these waves can trap and accelerate a substantial population of electrons. The resulting modification to the electron distribution function produces a nonlinear frequency shift that allows for plasma wave self-action and, in some cases, enhanced instability growth. While these processes are relatively well understood for planar-like plasma waves, the three-dimensional topology of helical plasma waves offers an additional degree of freedom to control or mitigate the nonlinear evolution. More specifically, these waves feature an integer multiple l of azimuthal phase windings per period. Here, the nonlinear evolution of helical electron plasma waves is studied in ICF relevant plasma conditions using three-dimensional particle-in-cell simulations. To study these processes independently of a particular laser-plasma instability, the waves are resonantly excited using an external driving field. Preliminary results reveal the dependence of the trapped particle frequency shift and plasma wave self-action on the helical mode number l and show that the accelerated electrons generate an azimuthal magnetic field that persists well after the wave has damped.

*This work is conducted under the auspices of the Office of Fusion Energy Sciences under Award No. DE-SC0023423, the Department of Energy National Nuclear Security Administration under Award No. DE-NA0003856, and the National Energy Research Scientific Computing Center (NERSC), a Department of Energy Office of Science User Facility using NERSC award FES-ERCAP0027761.

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Particle-in-cell simulations high-frequency hybrid instability (HFHI) dominated rescattering relevant to inertial fusion energy (IFE)*

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In inertial fusion energy (IFE) plasmas, the scattered light from stimulates Raman scattering can undergo re-scatter and generate successively shorter wavelength electron plasma waves (EPWs) which can accelerate electrons to higher and higher energies [1]. However, in some advanced designs where the electron temperature is very high and in direct drive scenarios, laser plasma instabilities occurs above 0.11 nc. For these densities, the scattered light cannot rescatter in-place and must propagate down the density gradient to the quarter critical surface of the scattered light where it will undergo laser plasma instabilities near the quarter critical surface, where stimulated Raman (SRS), two-plasmon decay (TPD) and Raman sidescatter (SRSS)[2] all converge and higher dimensional effects are important even for plane wave lasers.

In this presentation, we will present a series of 1D simulations which identifies the parameter space where the primary scattering and the secondary rescattering processes can be observed, then we will demonstrate the competition between the various laser plasma instabilities near the quarter critical surface by performing two dimensional simulations with different polarizations. The 2D simulations will demonstrate the competition between SRS, TPD, and SRSS in the secondary rescattering region. Finally, we will discuss the importance of the relevance of these simulation results to future target designs and LPI experiments.

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Challenges and progress in kinetic modeling of broadband laser-plasma interaction with WarpX*

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The mitigation of laser-plasma instabilities is a key consideration in the development of the next generation of laser drivers for inertial confinement fusion and high energy density physics experiments. Temporal structuring of laser pulses using frequency bandwidth can disrupt the coherent growth of instabilities and offers a path towards instability mitigation. Kinetic plasma simulations are needed to fully assess the impact of bandwidth on instabilities including stimulated Raman scattering (SRS), two-plasmon decay, stimulated Brillouin scattering, and cross-beam energy transfer, and on other important processes such as non-local heat transport and hot electron preheat. However, particle-in-cell (PIC) simulations must overcome the computational challenges introduced by the multiscale nature of modeling experimentally relevant conditions. We will present a selection of these challenges to be addressed by the Kinetic IFE Simulations at Multiscale with Exascale Technologies (KISMET) collaboration, along with recent progress in modeling SRS with bandwidth using the PIC code WarpX.

* This material is based upon work supported by the KISMET collaboration, a project of the U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research and Office of High Energy Physics, Scientific Discovery through Advanced Computing (SciDAC) program. 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 using NERSC award FES-ERCAP0027617. This research used the open-source particle-in-cell code WarpX https://github.com/ECP-WarpX/WarpX, primarily funded by the US DOE Exascale Computing Project. Primary WarpX contributors are with LBNL, LLNL, CEA-LIDYL, SLAC, DESY, CERN, and TAE Technologies. We acknowledge all WarpX contributors.

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Investigation of late-time nonlinear evolution of ion-Weibel filaments

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The Biermann battery is thought to be the mechanism which generates the seed magnetic field in interstellar plasmas [1] after which turbulent dynamo must be invoked to explain how seed fields (~10^{-20} G) are amplified up to the observed levels (~10^{-6} G). The Weibel instability is another candidate for the generation of seed fields: PIC simulations [2] suggest that Weibel-generated fields might scale much more favorably for the long astrophysical length scales ($B \propto L^0$) than the Biermann-generated fields ($B \propto L^{-1}$). This possibility, however, requires a mechanism to explain how the Weibel fields might grow to larger length scales. Existing theory and simulations describing various details of Weibel filament mergers provide models that can be compared to data [3,4]: a model agnostic to the magnetic-reconnection microphysics [3] suggests that the long-term evolution of filaments progresses like $\lambda \propto t^2$, while a model invoking magnetic reconnection as the limiting factor in filament mergers [4] suggests that filament wavelengths should follow $\lambda \propto t^{1/2}$. Distinguishing these models requires linearly saturated ion Weibel filaments, which were demonstrated in an array of prior experiments at OMEGA [5-11] but did not cover later times where the largest difference between models exists. The experimental campaign described in this talk seeks to investigate this question by pushing measurements at OMEGA to later times and testing the dependence of the merger rate on Lundquist number to see if magnetic reconnection is indeed the limiting physical mechanism in nonlinear Weibel filament evolution.

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*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-864152

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Quantifying laser wave length shifts from forward stimulated Brillouin scattering at the laser entrance holes of a hohlraum*

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Recent results at the Omega Laser Facility [Turnbull et al., PRL **129**, 025001 (2022)] show that forward stimulated Brillouin scattering (FSBS) can red-shift laser beams by up to 0.5 Å at 3ω (=1.5 Å at 1ω) in inertial confinement fusion (ICF) relevant conditions (1 Å at 1ω => p_2 ~ 20 to 50 μm). At the National Ignition Facility (NIF), it is expected that the red-shift would vary by incident laser cone angle and it would be stronger on the outer cones since these are more intense. The different red-shifts by angle would therefore impart an effective wave length detuning ("Dl") between the inner and outer cones, where the outers would be more red-shifted than the inners. From past measurements of ICF hohlraums, we already have a grasp on how Dl affects cross-beam energy transfer (CBET) and how it impacts capsule implosion symmetry for some laser entrance hole (LEH) sizes and low gas fill density hohlraums, but the code predictions of the absolute values of p_2 don't agree with the experimental results (normally over-predicting CBET) without artificially limiting the maximum amplitude of ion waves driven during CBET. The question that we are trying to answer is could this discrepancy from model to experiment be caused by FSBS redshift at the LEH? With this experimental campaign we aim to answer this question by isolating the LEH contribution to FSBS by measuring the wave length shift caused by FSBS on a NIF beam. We developed and tested an experimental setup where we fire the upper hemisphere of NIF into a LEH assembly to create plasma conditions similar to those present early in peak power in low gas fill hohlraum experiments. In our configuration, an interaction beam crosses the LEH plasma, and hits a flat gold foil that specularly reflects the beam into FABS Q31B to measure the red shifted spectrum. A reference beam is used to decouple the wave length shifts caused by glint from the foil and FSBS in the LEH plasma.

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

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Spatio-Temporal Light Springs: An Exotic State of Light to Explore Novel Laser-Plasma Interactions*

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It is well known that light is capable of carrying both spin and orbital angular momentum (OAM). When two beams of different wavelengths and different OAM mode numbers are superimposed, an exotic state of light is generated. This superposition of 2-color, 2-OAM beams has been colloquially referred to as a "light spring" in reference to the unique property of having a 3-dimensional, spring-like intensity profile.

In this work, we investigate the interaction of light springs with under-dense plasma, and propose a novel method for generating relativistic strength light springs. We derive conditions such that the light spring both resonantly couples with the plasma and self-guides as it propagates through the plasma. Simulations conducted using FBPIC show angular momentum coupling between the light spring and plasma, generating magnetic fields on the order of 100's Tesla via the inverse Faraday effect driven by laser carrying less than 5TW of power.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344 and supported by the Natural Sciences and Engineering Research Council of Canada research grant number RGPIN-2019-05013. This work is also supported by the NSF under Grant No. PHY-1753165.

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Exchange of angular momentum in stimulated Raman scattering interactions*

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The growth of stimulated Raman scattering (SRS) depends on wave-wave and wave-particle interactions. pF3D simulations model SRS from the fluid approximation including nonlinear fluid effects such as pump depletion and linear kinetic effects, while OSIRIS particle-in-cell (PIC) simulations model full nonlinearities for both wave-wave and wave-particle interactions. A combination of pF3D and PIC simulations are used to study SRS behavior for a laser with orbital angular momentum (OAM). Conservation laws for action, energy, momentum, and angular momentum are derived from the envelope equations for SRS. pF3D simulations indicate that for similar power and intensity, lasers with OAM have lower SRS growth due to geometric effects. For pumps with OAM the saturated reflected light and plasma waves that grow from noise appear to develop near integer values of OAM. OSIRIS simulations are used to study nonlinear kinetic effects. Particles trapped in an electron plasma wave (EPW) affect its damping behavior. Single wavelength periodic OSIRIS simulations show how the electron distribution function is affected in the presence of the EPW with different degrees of OAM. The wave is excited by a short driving force, which can be viewed as ponderomotive force of two beating light waves with frequency and wavenumber differences that nearly satisfy the linear EPW dispersion relation. Comparison of the evolution of the plasma wave with different degrees of OAM will be presented. Fully 3D OSIRIS simulation results for the same parameters of some pF3D simulations will also be presented. These results indicate that inflation still occurs for pumps with OAM, but that the reflectivity is reduced.

*Work supported at UCLA under a LLNL subcontract B639330 and DOE HEDLP award DE-NA000413, and at LLNL which is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344. Simulations were carried out on computers at LLNL.

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Backscatter dependence on $\delta\lambda$ in low gas fill ICF

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In recent low gas fill ICF shots at NIF, backscatter for the inner cones into the beam ports is increasing, both for SRS and SBS, along with increases in the $\delta\lambda$ between the inner and outer cones. We can confirm this trend exists out to around three angstroms, and shots with up to six angstroms of $\delta\lambda$ do not show clear evidence of saturation as of yet.

There remains a large uncertainty on the total energy of the backscattered light. This is caused by discrepancies in the shape of the scattered light found in the 30 degree and 23 degree NBI images, as well as discrepancies between FABS and NBI. A likely source of these discrepancies is the damage to the spectralon plates in the NBI system. We outline the range of total backscatter energies and powers that could be occurring in ICF shots. We also show some test results from the NBI calibration prototype, which will remove the calibration uncertainties of the NBI when installed in NIF.

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

Tuesday, June 11, 2024

7:00am-8:30am **Breakfast in the Huntley Dining Room**

Oral Sessions 3 & 4 in the Talus Room of the Summit Hotel

Time	**Session 3: Laser effects & applications**	**Chair: Archis Joglekar**
8:30am	(**Invited**) *A Laser-Based 100 GeV Electron Plasma Accelerator*	Ludwig, Joshua, *LLNL*
9:00	*Review and Meta-analysis of Electron Temperatures from High-Intensity Laser-Solid Interactions*	Rusby, Dean, *LLNL*
9:20	*Multi-mJ THz Pulses from Picosecond Laser Irradiation of Wires*	Bruhaug, Gerrit, *LANL*
9:40	*Twisting High Intensity Lasers to Produce Extreme Magnetic Fields*	Longman, Andrew, *LLNL*
10:00	*How nonlocal heat transport impacts self-focusing and LPI in a laser speckle*	Belyaev, Mikhail, *LLNL*

10:20am **Coffee Break**

Time	**Session 4: Kinetics, PIC and Laser Absorption**	**Chair: Blake Wetherton**
10:40am	(**Invited**) *VPIC 2.0: Performance-Portable Particle-in-Cell for Present and Future Supercomputers*	Luedtke, Scott, *LANL*
11:10	*The role of plasma kinetics in neutron capture experiments on NIF*	Appelbe, Brian, *Imperial College*
11:30	*Short-time scaling of the laser-driven ablation front with 1D kinetic simulations*	Veauvy, Corentin, *CEA*
11:50	*General-Purpose Model of Laser Absorption for Radiation-Hydrodynamic Simulation*	Strozzi, David, *LLNL*
12:10	*Ionization lag in laser ionized mid-Z plasmas*	Milder, Avi, *LLE*

12:30pm **Lunch in the Huntley Dining Room**

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A Laser-Based 100 GeV Electron Plasma Accelerator

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We present the first explicit PIC simulations of a self-consistent, all optical LWFA that achieves 100 GeV energies in less than 7 meters with a single 312 J drive laser pulse. Inspired by the recent LWFA experiments by the University of Maryland[1] at the Colorado State University ALEPH laser facility that achieved 5 GeV in 20 cm with a 15 J laser, our result is made possible by using ionization injection, ramping the plasma density to beat the dephasing limit, and a unique plasma channel employing a channel-forming Bessel beam[2]. We find that maximum electron energy, length of plasma, and beam charge all scale with laser energy in a similar fashion to the Lu scaling.[3] Energetic muons enable radiography of massive structures that cannot be probed by other forms of radiation, due to their ability to penetrate deeply into matter. While these particles occur naturally at a relatively low flux in cosmic rays, they can be artificially generated via radiative processes by pointing an electron beam at a high-Z target. Laser Wakefield Accelerators (LWFA) can generate such electron beams over relatively small distances, because they achieve acceleration gradients of two-to-three orders of magnitude greater than conventional accelerators. Using simulated beam characteristics, we estimate muon production in a high-Z target material. We discuss implications of combining this accelerator with a high average power laser driver[4] on the possibility of a compact high-flux muon source.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, the Defense Advanced Research Projects Agency (DARPA) under the Muons for Science and Security (MuS2) Program, and was supported by the Livermore Computing (LC) Grand Challenge Program.

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Review and Meta-analysis of Electron Temperatures from High-Intensity Laser-Solid Interactions*

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When a high-intensity laser interacts with a solid-target, a high-energy, high-current electron beam is accelerated into the target, past the critical surface. One of the key properties of this hot-electron beam is the energy spectrum that can typically be characterized using a decaying exponential with a characteristic temperature. The hot-electron temperature is a key parameter that has been measured on numerous occasions experimentally and the subject of many simulation studies. This description of the electron energy distribution is convenient and simplifies analytical expressions for the generation/production of secondary particle sources, such as protons [1], x-rays [2] and positrons [3]. Here we have performed a comprehensive literature review of the electron temperature from both experimental and simulation studies, with many of the laser and target parameters used in each study [4]. This dataset allows us to develop new scaling laws that depend on the pulse duration and scale length and, when compared to the dataset, perform especially well against existing scaling laws.

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and funded by the LLNL LDRD program under tracking code 19-SI-002.

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Multi-mJ THz Pulses from Picosecond Laser Irradiation of Wires*

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High intensity (>10^{18} W/cm^2) laser–matter interactions have been found to be efficient (>0.1%) sources of terahertz (THz) radiation using a wide variety of solid targets irradiated by currently available lasers with picosecond-scale pulses[1,2]. We present the results of several years of study on ~1 mm scale wire targets irradiated by the ~12 J, ~0.7 ps Multi-Terawatt laser. Mult-angle THz measurements were performed, as well as electron and x-ray emission measurements. Wire length, radius, angle of irradiation, tip and body shape, and material were all varied as well as lase pulse length. The best performing targets generated multi-mJ THz pulses that were focused along the axis of the wire. A simple antenna model was developed to explain these results and was found to match well with the experimental results. These results will then be compared to other laser-solid-THz experiments and the potential utility of this wire-THz source discussed.

* This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856 and by the Department of Energy Fusion Energy Sciences under Award Number Award No. DE-SC0023239.

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Twisting High Intensity Lasers to Produce Extreme Magnetic Fields

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Recently, orbital angular momentum (OAM) beams have demonstrated at relativistic intensities at several high-power laser facilities around the world using off-axis spiral phase mirrors [1]. The additional angular momentum carried by OAM beams, even when linearly polarized, introduces a new control parameter in laser plasma interactions and has shown promise to introduce new and exciting phenomena not possible with a standard Gaussian beam [2].
Of particular interest is the relativistic inverse Faraday effect where laser angular momentum is absorbed by a plasma generating large axial magnetic fields colinear with the laser k vector [3]. Our recent work has demonstrated that magnetic fields on the order of 100's of Tesla, extending 100's of microns, and lasting on the order of 10 picoseconds can be generated with laser powers less than 5 terawatts [4]. In this work we will explore this phenomenon through theory, simulations, and present results from a recent campaign at the COMET laser at Lawrence Livermore National Laboratory in which we used a linearly polarized Laguerre Gaussian laser to drive magnetic fields for the first time in the laboratory. Experimental results will be compared and validated against theory and simulations.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344, LDRD 24-ERD-03, and supported by the Natural Sciences and Engineering Research Council of Canada (Grant No. RGPIN-2019-05013)

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How nonlocal heat transport impacts self-focusing and LPI in a laser speckle

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We present pF3D simulations of a Gaussian laser speckle in a plasma for a variety of compositions (He, Au, AuB, and Ta_2O_5). These simulations include heating due to inverse bremsstrahlung absorption, laser ponderomotive force, and *either* Spitzer-Härm or nonlocal electron heat transport. Nonlinear Spitzer-Härm heat transport is modeled via a fast explicit heat conduction algorithm[1]. Nonlocal effects are included by performing a convolution of the Spitzer-Härm heat flux in Fourier space with a delocalization kernel. We use a delocalization kernel given by the Epperlein model of nonlocal heat transport[2]. However, our conclusions generally apply to any model of nonlocal heat transport for which heat-conducting electrons are delocalized on a scale larger than the transverse dimension of the laser speckle.

We find that nonlocal heat transport lowers the filamentation threshold for high Z* materials (e.g. Au, AuB, and Ta_2O_5) under ICF conditions (ne/nc ~ 0.1, Te ~ 5 keV). However, the single speckle filamentation threshold in Au is still approximately a factor of two higher than the intensity of the brightest speckles encountered on the NIF during peak power.

We also find that self-focusing leads to a decrease in the speckle f# and an increase in intensity at the speckle waist. This is true even for intensities *below* the filamentation threshold. For our chosen plasma conditions, the intensity enhancement with nonlocal electron heat transport is approximately a factor of two in Au for a speckle intensity of 5E15 W/cm^2 in vacuum. This enhancement is also present with Spitzer-Härm heat transport but is substantially reduced.

Finally, we compare stimulated Brillouin scattering (SBS) in a laser speckle with Spitzer-Härm versus nonlocal electron heat transport. We find that the intensity enhancement with nonlocal heat transport substantially increases the gain per speckle, which has implications for LPI modeling of ICF experiments.

* This work was 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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VPIC 2.0: Performance-Portable Particle-in-Cell for Present and Future Supercomputers*

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VPIC is a high performance, portable, open source, general purpose, fully kinetic and relativistic particle-in-cell simulation code for modeling plasma phenomena such as magnetic reconnection, fusion, solar weather, and laser-plasma interactions in three dimensions using large numbers of particles. In this talk, we discuss the development of VPIC 2.0, report extensive performance results, and highlight features and areas of active development. Specifically, we show the work undertaken in adapting VPIC to exploit the portability-enabling Kokkos framework and highlight the enhancements to VPIC's modeling capabilities to achieve performance at exascale. We assess the achieved performance-portability trade-off through a suite of studies on nine different varieties of modern hardware, demonstrating good performance on CPU and GPU platforms with a single codebase. Our performance-portability study includes weak-scaling runs on three of the top ten TOP500 supercomputers and a comparison of low-level system performance of hardware from four different vendors. Lastly, we highlight improved documentation and user-friendly features.

*Work performed under the auspices of the U.S. DOE by Triad National Security, LLC, and Los Alamos National Laboratory. This work was supported by the LANL ASC, Experimental Sciences, and Laboratory Directed Research and Development programs. High-performance computing resources were provided by the ASC Advanced Technology Computing Campaign (ATCC), LANL's Institutional Computing program, Stony Brook Research Computing and Cyberinfrastructure (NSF #1927880), Purdue Research Computing, the Texas Advanced Computing Center, and NVIDIA. LA-UR-24-24544

The role of plasma kinetics in neutron capture experiments on NIF

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The NIF laser is capable of producing a laboratory environment consisting of a hot plasma and a large neutron flux. These features make it uniquely suitable for carrying out experiments to investigate interactions between Plasma Physics and Nuclear Physics. However, the success of such experiments relies on a detailed understanding of the plasma kinetic effects occurring in capsule implosions on the NIF. This presentation will highlight the challenges presented by these kinetic effects, solutions that have been developed to date and future directions for this emerging field of research.

A NIF Discovery Science experiment has recently been commissioned to measure the neutron capture cross section of Thulium 171 (Tm171), an isotope that plays an important role in the astrophysical *s* process that is responsible for producing approximately half the elemental abundances between iron and bismuth. In the plasma environment of stars in which the *s* process occurs, significant populations of nuclear excited states can exist, with the neutron capture cross section varying for each state. Conventional laboratory experiments e.g., using linear accelerators or spallation sources, can only measure cross sections of nuclei in the ground state. In contrast, NIF experiments can produce plasmas with ion temperatures of ~10 keV, which is sufficient to populate nuclear excited states of many nuclei, including Tm171, that participate in the *s* process.

Accurate measurement of the Tm171 neutron capture cross section on the NIF requires precise knowledge of (i) how the Tm171 isotopes, which are initially doped onto the inner surface of the capsule, mix with the neutron-producing deuterium plasma during the capsule implosion, and (ii) how this mix affects the neutron yield. These topics involve detailed modeling of the ion kinetic effects occurring during capsule implosions. Another key requirement is characterization of the ion and electron temperatures and densities at the locations in the capsule where neutron captures occur. This information is necessary for calculating the populations of nuclear excited states and for modelling processes, such as nuclear excitation by electron transfer and capture (NEET and NEEC), which can affect population rates. The presence of plasma kinetic effects, such as non-Maxwellian ion distributions generated by shocks in the implosion, can significantly alter these population rates. Post-processing of ion-kinetic simulations can be used to quantify these effects and accurately predict plasma-nuclear interactions in the NIF experiments.

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Short-time scaling of the laser-driven ablation front with 1D kinetic simulations

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Recently Inertial Confinement Fusion has been extensively studied as a carbon-free energy source. Direct-drive is a method aimed at achieving thermonuclear reaction conditions, and consists to compress a target of Deuterium Tritium until these conditions are reached. The surrounding surface layer of Carbon Hydrogen is heated with a hundred of laser beams, causing the expansion toward the vacuum and creating a shock into the undisturbed material by rocket effect. When the shock reaches the rear surface of the external layer, it sets the latter in motion. This flow regime, known as laser-driven ablation front, can be splitted into 3 zones. The laser propagation and energy deposition occurs in the plasma corona, where the electronic density (n_e) is below the critical density (n_{cr}). Then, the energy is carried by the electrons from the corona to the shock region in the conduction zone $n_e > n_{cr}$. The third region is the shock itself.
Presently, the only reliable tools to simulate a laser-ablation front at experimental scale (centimeter, nanosecond), are the hydrodynamic codes. Hydrodynamic codes need a heat flux closure which strongly affect the ablative flow. Finding or improving energy transport models to describe the ablation flow is crucial to have a consistent description of the ablation front.
For this purpose, we performed highly-resolved 1D laser-driven ablation front simulations with the kinetic code Smilei[1]. These simulations resolve the electron and ion distribution functions and capture the self-consistent evolution of the electron thermal transport together with the laser-ablation front. Important quantities such as the ablation pressure and mass ablation rate are expressed as a power law of the absorbed intensity and are compared against known scalings as in Ref. [2]. The electron distribution function anisotropy is characterized in the conduction zone. Our simulations confirm the non-locality of the heat flux and should be able to discriminate existing[3-4] and future non-local model in the hydrodynamic code TROLL[5].

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General-Purpose Model of Laser Absorption for Radiation-Hydrodynamic Simulation*

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Laser absorption is a key aspect of laser-produced plasmas. Radiation-hydrodynamic (rad-hydro) simulation requires an absorption model that is accurate over a wide range of conditions, from initial cold, dense matter to hot, fully-ionized plasma. We present a general-purpose absorption model, the heart of which is inverse-bremsstrahlung absorption and its free-free Gaunt factor G_{ff} (also referred to as the Coulomb logarithm). This follows recent work[1] which integrates Sommerfeld's quantum $G_{ff}[v]$, for one electron in the unscreened Coulomb potential of a point-charge ion, over the super-Gaussian electron distribution from the Langdon effect due to finite $Z^*(v_{osc}/v_{Te})^2$ (v_{osc} is the electron oscillation speed in the laser field, v_{Te} the thermal speed). An approximate treatment of dielectric screening is used – this is an ongoing research topic. This approach agrees well with recent absorption measurements at the OMEGA Laser[2].

This inverse bremsstrahlung model by itself is not valid for all relevant plasma and laser conditions. We therefore supplement it with models for finite v_{osc}/v_{Te} (the Silin effect), Fermi-Dirac statistics[3], and electron-neutral collisions for weak ionization. The goal is a model that robustly works over all conditions encountered in rad-hydro simulations, or at least behaves sensibly.

This model is being implemented in the LLNL rad-hydro codes Hydra and Lasnex. We apply it to hohlraum-driven ICF implosions on the National Ignition Facility (NIF), and compare the results to existing models in common use.

*Performed under the auspices of the US DoE by LLNL under Contract DE-AC52-07NA27344.

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[2] D. Turnbull et al., Phys. Rev. Lett. **130,** 145103 (2023) and Phys. Plasmas (submitted).
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Ionization lag in laser ionized mid-Z plasmas*

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Ionization dynamics of laser-produced plasmas play a pivotal role in comprehending phenomena in larger macroscopic systems, including thermal transport and plasma instabilities. Simulations using the Non-local Thermodynamic Equilibrium (NLTE) model Cretin, show when intense laser beams are used to produce and heat a mid-Z plasma, the rapidly changing conditions lead to a lag in ionization. The ionization state in these systems does not reach the steady state predictions even after the plasma conditions appear stable due to the rapid changes in plasma. The characteristic time for these plasmas to reach steady state ionization was found to be 1-2ns. Experimental measurements of the ionization state were performed using ion-acoustic wave Thomson scattering in argon-hydrogen plasmas where the mass difference produces two sets of ion-acoustic wave features. These measurements show the ionization state can remain below the steady state predictions over 2ns.

*This material is based upon work supported by the Department of Energy [National Nuclear Security Administration] University of Rochester "National Inertial Confinement Fusion Program" under Award Number(s) DE-NA0004144.

7:00pm **Plenary Session II in the Talus Room of the Summit Hotel**

Photochemically-induced acousto-optics in gases — Michel, Pierre, *LLNL*

8:00pm **Poster Session II in the Gallatin Ballroom (see end of this file)**

Tuesday Poster Session II: Rad-hydro, fields, ions, & electrons **8:00pm in the Gallatin Ballroom**

1	Lawrence, Yousef	*MIT*	Characterization of self-generated E and B Fields in the coronae of direct-drive implosions at OMEGA
2	Samulski, Camille	*LANL*	Hot-electron preheat effects on direct-drive Rayleigh-Taylor instability experiments at the NIF and Omega- EP
3	Velechovsky, Jan	*LANL*	Shock-Induced Material Separation in Heterogeneous Mixtures inside ICF Targets
4	Feinberg, Eli	*LANL*	Pre-shot assessment of the Xflows NIF experiment
5	Feltman, Jacob	*LANL*	Characterizing Radiation Hydrodynamics Through Lattices Using Mean Chord Length
6	Angus, Justin	*LLNL*	Energy-preserving coupling of explicit particle-in-cell with binary Monte Carlo collisions
7	Cao, Sida	*Stanford*	GeV Ion Acceleration with a Transverse Flying Focus
8	Huang, C.K.	*LANL*	Characterization of ion beams from solid targets driven by a 0.5kJ short-pulse laser
9	Obst-Huebl, Lieselotte	*LBL*	High energy density science and applications experiments at BELLA iP2
10	Seaton, Alex	*LANL*	Modelling electron-beam converter interactions in laser-driven X-ray radiography
11	Taitano, Will	*LANL*	DT-α Fusion Package in the Vlasov-Fokker-Planck Code, iFP
13	Crilly, Aidan	*Imperial*	Lagr-ADEPT: Lagrangian (AutoDifferentiable) Hydrodynamics for LDD simulations
14	Tubman, Ellie	*Imperial*	Proton radiography of electromagnetic fields from laser driven foils using imaging plates

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Photochemically-induced acousto-optics in gases*

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High-power lasers have applications ranging from particle acceleration to controlled thermonuclear fusion. Using large-scale optical elements is required in order to sustain the extreme fluences of these lasers; this dictates the size, and most of the cost, of these facilities, and also put limits on the maximum laser intensities that can be generated.
A new approach to this problem consists in creating optical elements made of gas instead of solid. Here, we show that a gas can be turned into a high-quality diffractive optics, able to manipulate lasers with fluences two to three orders of magnitude beyond what solids can sustain. To create such a gas optics, a spatially-modulated deep UV (200–300 nm) "imprint" laser is absorbed by a small fraction of ozone introduced in the gas; the UV absorption dissociates the ozone molecules, leading to localized heating of the surrounding gas via collisions and subsequent chemical reactions. The process is similar to the cycle of ozone in the earth's upper atmosphere. The resulting gas heating launches mixed acoustic/entropy waves in the gas, which imprint refractive index modulations—thus turning the gas into a diffractive optics, capable of manipulating high power lasers with diffraction efficiencies near 100%, as was recently demonstrated in separate experiments[1].
In this presentation, we will give a comprehensive physical description of the creation and operation of these gas optics[2]. Our theoretical and numerical analysis includes the physical chemistry of ozone dissociation and surrounding gas heating, the physics of the acoustic/entropy waves initiated by the modulated heating, and the diffraction properties of the resulting optics. Integrated calculations show good agreement with experiments, and suggest future directions for the application of these optical elements to high-power lasers.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and was funded by the Laboratory Research and Development Program at LLNL under Project Tracking Code No. 24-ERD-001.

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Characterization of self-generated E and B Fields in the coronae of direct-drive implosions at OMEGA*

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Self-generated electric and magnetic fields in direct-drive ICF implosions are caused by, for instance, plasma pressure gradients and the Biermann battery effect. These fields may affect the implosion by redirecting heat flows, seeding and amplifying hydrodynamic instabilities, and modifying hot electron transport. However, the precise nature of experimentally observed field structures is poorly understood. To determine the structure and effects of the fields, target normal sheath acceleration-based proton radiographs were obtained from exploding pusher implosion experiments conducted at OMEGA. We use the proton radiographs and reconstructions of the electric and magnetic fields from them, in concert with numerical simulations to assess potential field generation mechanisms in the corona.

*This work is supported in part by: NNSA Center of Excellence, DE-NA0003868
NNSA High-Energy-Density Laboratory Plasmas, DE-NA0004129, and NLUF No. DE-FG03-03SF22691.

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Hot-electron preheat effects on direct-drive Rayleigh-Taylor instability experiments at the NIF and Omega-EP*

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Hot-electron generation occurs at high laser intensity, such as those achievable at the National Ignition Facility (NIF). Hot-electron generation has the potential to cause unintended preheating of targets, thus producing unexpected results. Directly driven planar shock-tube experiments were performed at the NIF to study the blast-wave-driven Rayleigh-Taylor instability (RTI) in the presence of a background magnetic field. An intensity of ~3×10^{15} W/cm^2 was used to drive a shock strong enough to heat the plasma to high enough temperatures to significantly amplify the background magnetic field and reduce nonlinear RTI growth. X-ray radiographs of the interface showed total loss of the initial seed perturbation. The likely cause for this result has been identified as hot-electron-generated preheat. Additional experimental work at Omega-EP was performed at an intensity of ~$1.7\text{x}10^{15}$ W/cm^2 and supports hypothesis that hot-electron-generated preheat occurred on the NIF experiments. Computational work has been performed to explore the effects of varying levels of hot-electron induced preheating on targets and indicates that preheat temperatures achievable at the NIF could smooth out the machined perturbations in RTI experiments. These computational and experimental results suggest a conversion efficiency of laser energy into hot-electrons of ~10-20% in the NIF experiments.

*This work was supported by the Office of Science of the U.S. Department of Energy under Award No. DE-SC0020055 and US Department of Energy DE-SC0022319 by the Financial Assistance Program.
This abstract has been provided limited release by DC and is awaiting an identifier LA-UR-

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Shock-Induced Material Separation in Heterogeneous Mixtures inside ICF Targets

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Heterogeneous materials such as 3D-printed foams have many desired properties for Inertial Confinement Fusion (ICF) target design. Thanks to their extremely low mean density, they can be used to smoothen laser energy deposition for direct drive applications or simply as structural elements inside complex ICF targets such as double shells[1].

However, low-density foams in ICF targets lead to heterogeneous mixtures of a foam material with a background material, typically a fill gas. The characteristic wavelengths of these inhomogeneities ranging from 1 to 100 micrometers and corresponding homogenization times are large enough to affect the dynamics inside these targets. In addition to the homogenization time, another important property of such mixture is that materials of different densities get temporarily separated by shock waves compressing the target. When neglected in hydrodynamic simulations of targets with separated reactants, this material separation or "de-mixing" can result in inaccurate predictions of the target fusion yield.

We compare material de-mixing predicted by the state-of-the-art sub-grid mix models[2] to Direct Numerical Simulations (DNS) of simplified targets using Los Alamos National Laboratory (LANL) code xRAGE[3]. In particular, we investigate how the foam parameters such as a spectrum of characteristic wavelengths affect the amount of material de-mixing as well as the final homogenization time of the heterogeneous mixture under conditions relevant to the current ICF experiments investigating mixing phenomena[4].

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Pre-shot assessment of the Xflows NIF experiment*

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We present a computational study to characterize hohlraum performance and consequent radflow conditions for upcoming x-ray flow experiments on the NIF. The propagation of radiative heat fronts in HED experiments has long been a challenging topic to study. Experimental efforts in the past three decades have had success creating relevant data in this regime. However, it has been a challenge for multi-physics simulation tools to predict the behavior of these experiments accurately and unconditionally, a task which is essential to furthering our understanding of Inertial Confinement Fusion and astrophysical processes. The COAX campaign on the Omega-60 laser introduced a novel spectroscopic diagnostic to study radiation flows on Omega-60 by measuring temperature and charge state across the heat front.[1,2,3]. Xflows is the successor to COAX and is fielded at NIF to access higher temperature regimes with stronger shocks and supersonic flows[4]. Upcoming Xflows shots in July will include full physics shots with a near-supersonic radiative heat front in ~100 mg/cc aerogel foam driven by a gold hohlraum in a "T-raum" configuration. This work presents a computational study to predict the performance of the hohlraum and the effect of the driving x-ray radiation in the foam. Simulations show a spatially and temporally uniform hohlraum drive temperature of 280 eV which creates a heat front propagating at speeds peaked near 1000 km/s.

*Research presented in this presentation was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20220596ECR. This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). And by the U.S. Department of Energy NNSA Center of Excellence at the University of Michigan under cooperative agreement number DE-NA0003869.

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Characterizing Radiation Hydrodynamics Through Lattices Using Mean Chord Length*

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Studying radiation hydrodynamics from laser-driven hohlraums through lattice targets is a beneficial alternative to stochastic (random) media targets. Lattices provide a near exact initial condition for simulations of each target whereas stochastic media targets require prior characterization. Lattices also provide an anisotropic geometry to study radiation hydrodynamics. Radiation flow through these lattices, however, is difficult to directly simulate. The relative sizes of lattice and included diagnostic material requires fine resolution and thus unattainable computing power to directly simulate. Finding and adjudicating appropriate reduced two-dimensional models of three-dimensional lattices is critical for characterizing radiation hydrodynamics through these lattices. The mean chord length parameter is used as a closure term in some reduced models of the radiation transport equations (Levermore-Pomraning[1]) to simplify the calculation of radflow through stochastic media. Mean chord length is thus a relevant and intuitive parameter that can be used to find and adjudicate appropriate two-dimensional models of lattices. We present methods for calculating the approximate value of mean chord length for arbitrary and nonanalytical geometries, and we present the results of using this value as a comparing parameter between different geometric representations of lattices on simulations using the CASSIO radhydro code.

*This work was performed by the Los Alamos National Laboratory, operated by Triad National Security, LLC for the National Nuclear Security Administration (NSSA) of the U.S. Department of Energy (DOE) under Contract No. 89233218CNA000001.I

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Energy-preserving coupling of explicit particle-in-cell with binary Monte Carlo collisions*

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Binary Monte-Carlo collision (MCC) algorithms for Coulomb collisions are commonly used in particle-in-cell (PIC) simulations of plasmas to capture short-range collisional effects. However, for explicit PIC methods, coupling with MCC methods often results in a rapid artificial numerical heating of the plasma, even when the PIC and MCC models independently conserve energy well. Previous work[1] suggested that the root of this heating is that particles absorb artificial radiation that arises from the random motion of the particles owing to collisions in a numerical Bremsstrahlung-like process. However, we have found that this artificial numerical heating in explicit PIC-MCC simulations can be completely suppressed by appropriately centering the application of the collision operator in the particle advance. Several different ways to properly couple MCC with explicit PIC without enhanced numerical heating are presented. Numerical simulation results for a homogenous plasma and a collisional planar pinch problem are presented.

* Work supported by a US Department of Energy under contract DE-AC52-07NA27344.
LLNL-ABS-863974.

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GeV Ion Acceleration with a Transverse Flying Focus

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The extreme electric field generated in high-intensity laser-plasma interactions can efficiently accelerate ions to high energies more compactly than traditional radiofrequency accelerators due to a large acceleration gradient (~100 GeV/m). Despite this promise, it is challenging to accelerate ions in the laser wakefield due to their low charge-to-mass ratio. With recent advancements of pulse-shaping technologies[1-2], one can imagine adjusting the group velocity of a laser pulse to match the ion velocities, which makes laser wakefield acceleration of ions possible.

In this work[3], we demonstrate that ions can be efficiently accelerated to GeV energies in an underdense plasma with a transverse-flying-focus laser pulse. Analytic Hamiltonian analysis shows detailed acceleration dynamics and the conditions for efficient acceleration. This approach allows for compact high-repetition-rate production of high-energy ions and highlights the capability of more generalized spatio-temporal pulse shaping to address open problems in plasma physics.

This work was partially supported by NSF Grant PHY-2308641. The work of JPP is supported by the Office of Fusion Energy Sciences under Award Number DE-SC00215057, the University of Rochester, and the New York State Energy Research and Development Authority.

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Characterization of ion beams from solid targets driven by a 0.5kJ short-pulse laser*

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Energetic particles, including electrons, ions and secondary particles, are produced by directing an intense laser pulse at a target material. The laser-driven ion beam may find applications in inertial fusion or high-resolution images of both static and dynamic objects in next-generation radiography to probe materials and plasmas in extreme environments. To scale up ion beam production suitable for these applications, we have conducted experiments using a 0.5kJ sub-ps laser at the Omega-EP laser facility to characterize the laser-driven ion beam from a variety of solid targets, including CH/CD/Kapton sub-micron thin films, low-density CD foams and flat CH foil targets of micron-scale thickness, encompassing ion acceleration regimes including Target Normal Sheath Acceleration (TNSA), Radiation Pressure Acceleration (RPA) or Collisionless Shock Acceleration (CSA), and Relativistic Transparency (RT). Ion acceleration with/without Compound Parabolic Concentrator (CPC) cone have also been compared. We obtained beam spectra and spatial source profiles, and found that ~700-800nm foil target achieved the best ion yield among the targets tested. Preliminary static and dynamic radiography were also conducted using these laser-driven ion beams. The different characteristics of the ion beams produced from these targets will be summarized and compared with simulations and understandings/scaling from the literature.

* This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001).

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High energy density science and applications experiments at BELLA iP2*

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The high-intensity iP2 beamline at the BELLA PW laser system enables frontier capabilities in High Energy Density Science (HEDS), including accessing exciting new regimes of ion acceleration. This system provides a focal spot of ~3 μm diameter, resulting in on-target peak intensities of > 5×10^{21} W/cm^2. The high laser pulse repetition rate capability (up to 1 Hz), if paired with innovative, replenishable target systems, increases the particle flux for applications and allows for the collection of large data sets, enabling adequate statistical analysis of the results and the testing and integration of artificial intelligence and machine learning methods. An on-demand double plasma mirror is available to improve the amplified spontaneous emission (ASE) contrast of the laser pulse to <10^{-13} before target interaction. IP2's capabilities uniquely enabled a series of ongoing and scheduled experiments to study advanced ion acceleration mechanisms, investigate fundamental plasma processes relevant for inertial fusion energy (IFE) and strong-field QED, and develop innovative plasma-based technologies with societal benefits, such as in radiation therapy and qubit synthesis far from equilibrium. The iP2 beamline is accessible to users through LaserNetUS. In this poster we present examples of our ongoing research into laser proton beam applications and advanced ion acceleration regimes with near-critical density targets.

* This work was funded under the auspices of the U.S. Department of Energy (DOE) Office of Science (SC), Offices of Fusion Energy Science (FES), LaserNetUS, and High Energy Physics under contract number DE-AC02-05CH11231, and the Defense Advanced Research Projects Agency via Northrop Grumman Corporation. S. Hakimi was supported by the U.S. DOE FES Postdoctoral Research Program administered by the Oak Ridge Institute for Science and Education (ORISE) for the DOE. ORISE is managed by Oak Ridge Associated Universities (ORAU) under Contract No. DE-SC0014664. B. Stassel was supported by the U.S. DOE, SC, Office of Workforce Development for Teachers and Scientists, Office of Science Graduate Student Research (SCGSR) program, also administered by the ORISE. F. Condamine and G. Fauvel wish to acknowledge the support of the National Science Foundation (NSF) and the Czech Science Foundation (GACR) for funding on project number No. 22-42890L, and the National Science Foundation–Czech Science Foundation partnership (NSF Grant No. PHY-2206777).

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Modelling electron-beam converter interactions in laser-driven X-ray radiography*

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Short-pulse laser-plasma interactions provide a possible route to high-performance X-ray radiography. This scheme involves two main stages: the laser-target interaction which generates an electron beam with energies in the MeV range, and conversion of the electron beam to X-rays via bremsstrahlung. Here we focus on modelling of the latter process.

Modelling of the x-ray yield is conventionally achieved via Monte-Carlo particle transport simulations, using codes such as MCNP, GEANT4, and PENELOPE. However, it has been known for some time that electric fields generated within the electron-beam converter material may decelerate the electron beam and therefore reduce the x-ray yield, and this is not modelled by such codes.

In this presentation we discuss progress towards modelling the impact of the electric field via a new specialized Monte Carlo electron transport code. This incorporates electron transport algorithms from the PENELOPE Monte Carlo code, along with models for the heating and conductivity of the converter material.

*This work conducted under the auspices of the U.S. Department of Energy by Triad National Security, LLC, operator of the Los Alamos National Laboratory under Contract No. 89233218CNA000001, with support from the Laboratory Directed Research and Development (LDRD) Program

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DT-α Fusion Package in the Vlasov-Fokker-Planck Code, iFP*

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The iFP code is a 1D2V fully kinetic spherical implosion Vlasov-Fokker-Planck code designed to study kinetic effects in ICF capsules. The treatment of α-particles challenges grid-based codes like iFP due to the disparate energy scales involved between the helium ash (~10keV) and α-particles (3.5MeV). The challenge is visualized by considering a single-velocity space grid approach. As the fusion-born α-particles (3.5MeV) slow down against the electrons, the population in the velocity space with energies comparable to ash (~10keV) eventually appears as a delta function, imposing extreme grid requirements; refer to Figure 1. We address this multiscale challenge in the velocity space by developing a two-grid strategy, where the ash and α-particles are modeled on individual grids to deal with the scales separately; refer to Figure 2. When the α-particles slow down against electrons to energies comparable to the ash, a sinking function will transfer part of the distribution function to the ash grid, smoothing the velocity space structure out. Unlike previous similar works, our approach 1) does not rely on any asymptotic limiting arguments on the ratio of the energetic and thermal species, 2) conserves the mass, momentum, and energy of the original system, and 3) is consistent with the original PDE. We have implemented the new capability into the iFP code, and we will demonstrate the algorithm's numerical properties on a series of test problems, including a challenging spherical piston implosion problem representative of a layered cryo ICF capsule. The spherical implosion problem will act as a surrogate to study the impact of the kinetic mixing of DT-ice into the vapor region and the subsequent modification of hotspot and α-particle transport.

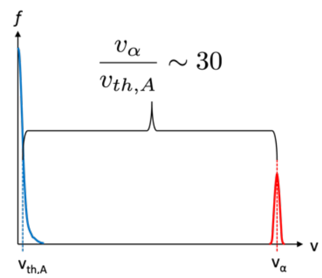

Figure 1: Illustration of velocity-space scale separation between ash (A) and α.

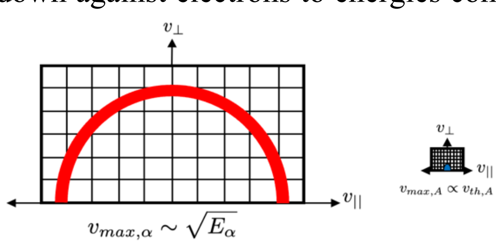

Figure 2: Illustration of the two-grid approach. The α-particles are modeled on a wider grid (left) than the ash (right).

**This work 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 Triad National Security, LLC under contract 89233218CNA000001.*

Lagr-ADEPT: Lagrangian (AutoDifferentiable) Hydrodynamics for LDD simulations

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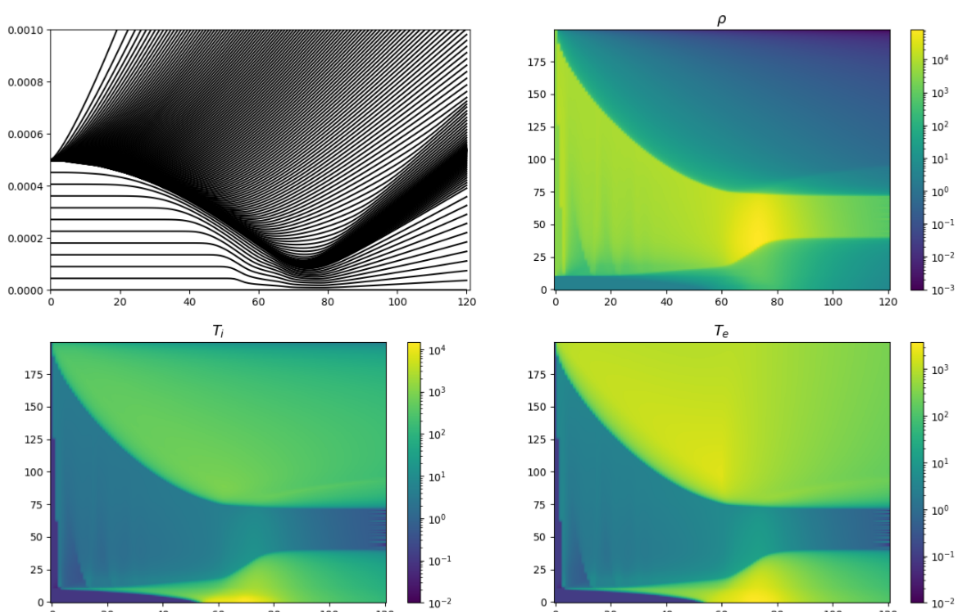
Automatic differentiation (AD) is a key enabling technology for machine learning applications. It allows for differentiable programming, where accurate gradient information can be computed for any computer program (roughly) automatically. In this poster, we discuss the ongoing development of a 1D Lagrangian hydrodynamics code for laser direct drive simulations, lagr-ADEPT. Because it is written in JAX, it is Pythonic, GPU-native, AD-enabled, and machine learning ready. The current physics capabilities are 1D Lagrangian hydrodynamics, Spitzer and SNB thermal conduction, ideal gas EoS and normally incident laser ray trace. We show examples of capsule simulations run using lagradept with different heat flow models, and showcase the ability to perform inverse design and uncertainty quantification using the AD-enabled gradient information.



* This material is based upon work supported by the Department of Energy Office of Fusion Energy under Award Numbers DE-SC0024863 and the Department of Energy [National Nuclear Security Administration] University of Rochester “National Inertial Confinement Fusion Program” under Award Number DE-NA0004144. 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 using NERSC award FES-ERCAP0026741.

52nd Annual Anomalous Absorption Conference
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Proton radiography of electromagnetic fields, from laser-driven foils, using imaging plates

E. R. Tubman[1], B. B. Pollock[2], C. A. Walsh[2], D. P. Higginson[2], M. Sherlock[2], D. Larson[2], J. S. Ross[2], M. P. Selwood[2], G. Swadling[2], M. J.-E. Manuel[3], M. Pokornik[4], K. Moczulski[5], P. Tzeferacos[5], H-S. Park[2] and G. D. Sutcliffe[2].
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A new detector design has been fielded on the Omega-60 laser facility using a DHe-3 backlighter capsule to radiograph a magnetized experiment[1]. DHe-3 capsules produce a low flux (~10^8 yield in 4π) of protons requiring detectors with close-to single-particle sensitivity to be employed. The new detector stack consisted of both imaging plate (IP) and CR-39 to detect 14.7 MeV protons where, historically, only CR-39[2] has been used. IP is sensitive to significant contributions in signal from both x-rays and protons so additional filtering has to be added to attenuate the x-rays. The signals and features observed from a single shot are detected by both IP and CR-39, giving confirmation that it is protons creating the signatures on the IP. A large benefit to this new stack design is that IP can be scanned and processed on much faster timescales than CR-39 allowing for prompt shot feedback.

Results from experiments investigating magnetised, collisionless shocks[3,4] as well as plasma bubbles being driven out into hohlraum-like gas fills have utilized this detector and results from these platforms will be presented. Electromagnetic field structures are measured within the plasma from various combinations of the modification of background magnetic fields, Weibel instabilities and self-generated Biermann fields. Comparisons between CR-39 and IP demonstrate the ability to resolve small-scale (~40 μm structures) using IP from these conditions.

* This work was performed under the auspices of the U.S. Department of Energy by LLNL under Contract DE-AC52-07NA27344. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

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[1] E. R. Tubman et al., "Demonstrating imaging plate detector stacks for proton radiography using exploding pusher capsules", NIM A **1060** (2024)
[2] C. K. Li et al., "Measuring E and B fields in Laser-produced plasmas with monoenergetic proton radiography", PRL **97** (2006)
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Wednesday, June 12, 2024

7:00am-8:30am	**Breakfast in the Huntley Dining Room**

Oral Sessions 5 & 6 in the Talus Room of the Summit Hotel

Time	Session 5: Laser effects	Chair: Alex Seaton
8:30am	(**Invited**) *Investigating the Dynamics of Short-Pulse Laser Beam Filamentation in Underdense Plasmas*	McMillen, Kyle, *LLE*
9:00	*Planar LPI experiments on the Laser Megajoule: first results*	Myatt, Jason, *Univ. of Alberta*
9:20	*Neural design of bandwidth schemes for mitigating the Two-Plasmon Decay instability*	Joglekar, Archis, *Ergodic, LLC*
9:40	*Gaining intuition on a SSD/RPP beam through accurate analytical modeling*	Debayle, Arnaud *CEA*
10:00	*Self-generated magnetic fields in the hot spot of direct-drive cryogenic implosions at OMEGA*	Bose, Arijit, *U. Delaware*
10:20	**Coffee Break**	
Time	**Session 6: Transport & complex target modeling**	**Chair: Rick Olson**
10:40am	(**Invited**) *A reduced kinetic method for investigating nonlocal ion heat transport*	Mitchell, Nic, *Imperial College*
11:10	*Electromagnetic Spokes in Laser-Solid Interactions*	Walsh, Chris, *LLNL*
11:30	*Nonlocal effects on Thermal Transport in MagLIF-Relevant Gaspipes on NIF*	Lau, Ryan, *Univ. of Colorado, Boulder*
11:50	*Estimating the Density and Temperature Profiles of Laser Preheated MagLIF Targets at NIF using Bremsstrahlung Emission*	Meyer, Henry, *LLNL*
12:10	*Modeling for a Planar Heterogeneous Ablation Experiment on OMEGA*	Wetherton, Blake, *LANL*
12:30	**Lunch in the Huntley Dining Room**	
1:15pm	**Business Meeting in the Talus Room of the Summit Hotel (All)**	**Dustin Froula**
6:00pm	**Banquet Reception in the Ballroom of the Huntley Hotel**	
7:00pm	**Banquet**	

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Investigating the Dynamics of Short-Pulse Laser Beam Filamentation in Underdense Plasmas*

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The filamentation instability results from the ponderomotive and thermal ejection of electrons from the high-intensity regions of a laser beam within a plasma. This process creates modulations in the plasma density and the refractive index that can lead to self-focusing and filamentation of the beam. The resulting intensified beam and modulated plasma can inhibit the propagation of the beam and limit the efficacy of laser-plasma interactions such as Thomson scattering[1], Raman amplification[2], and laser guiding structures[3]. We present experimental and simulation results investigating the growth rate of the filamentation instability. The experiment utilizes the joint operation of the OMEGA 60 and OMEGA EP laser systems at the University of Rochester's Laboratory for Laser Energetics. In our experiment, a 1ω short-pulse (1—100-ps) laser beam from OMEGA EP is coupled into a preheated plasma on the OMEGA 60 laser-plasma interaction platform. The resulting beam spray profile of the filamented short-pulse beam is recorded, while plasma parameters are determined via spatially-resolved Thomson scattering. We compare experimental results with 2D, axisymmetric simulations utilizing a paraxial electromagnetic wave solver coupled to a single-fluid nonlinear hydrodynamic solver. The simulations model the experiment based on the plasma condition retrieved from the Thomson scattering data and the transmitted nearfield measurements of a vacuum-propagated beam. By modifying the incident short-pulse beam pulse duration in the experiment and simulations, we limit the growth of the instability allowing us to connect the recorded beam spray to the underlying physics of filamentation at discrete steps in its temporal evolution.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Numbers DE-NA0004144 and DE-SC0021057.

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[1] A. M. Hansen et al., Physics of Plasmas 26, 103110 (2019).
[2] D. Haberberger et al., Physics of Plasmas 28, 062311 (2021).
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52nd Annual Anomalous Absorption Conference
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Planar LPI experiments on the Laser Megajoule: first results*

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†

Data has very recently been obtained from directly-driven planar target experiments on the Laser Megajoule (LMJ). The experiments were designed to closely approximate the planar laser plasma interaction (LPI) series of experiments carried out over the past several years on the National Ignition Facility (NIF)[1]. By taking advantage of the time-resolved and wide angular coverage of the diagnostics available on the LMJ[2], it is possible to accurately quantify the total amount of stimulated Raman scattering (SRS) produced.

An additional aim of the experiments, again taking advantage of the available diagnostics, radiation hydrodynamic modeling, and symmetry of the illumination, is to further isolate and quantify the respective contributions from the various SRS mechanisms of: single quad backscatter, single quad tangential side scatter, and multi-beam (cooperative) scattering.

The results will be compared with the NIF data set. While reproducibility with NIF was one goal of the experiments, the LMJ interaction conditions are not identical. Specifically, the LMJ quads are linearly polarized (NIF is polarization smoothed) and have smaller focal spots. Additionally, the single quad intensities on the LMJ experiments were higher for the same overlapped intensities. The consequences of these differences will be discussed.

*JFM acknowledges the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) (Funding Reference Nos. RGPIN-2018-05787 and RGPAS-2018-522497) and the Academic Access LMJ-PETAL award (CEA/DAM).

1 M.J. Rosenberg, A.A. Solodov, J.F. Myatt *et al.*, "*Origins and scaling of hot-electron preheat in ignition-scale direct-drive inertial confinement fusion,*" Phys. Rev. Lett. **120**, 055001 (2018).

2 V. Trauchessec, V. Drouet, C. Chollet, *et al.*, "*Time-resolved near backscatter imaging system on Laser Megajoule*," Rev. Sci. Instrum. **93**, 103519 (2022).

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Neural design of bandwidth schemes for mitigating the Two-Plasmon Decay instability*

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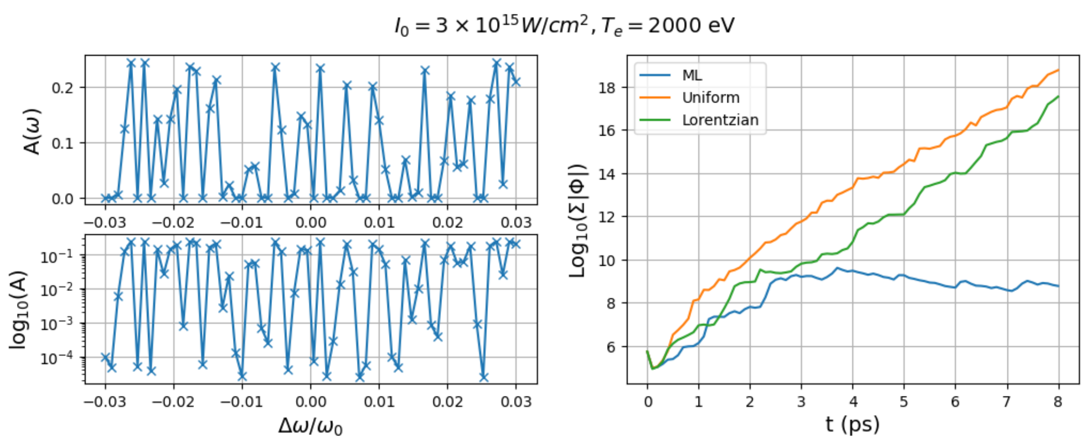
Previous work on the effects of bandwidth on TPD thresholds has quantified the increase in threshold as a function of $\Delta\omega$ where $\Delta\omega$ is discretized into a finite number of "lines" rather than a continuous distribution. Each of the finite number of lines has 2 free parameters depending on the $\Delta\omega_i$, the amplitude A_i and an initial phase shift φ_i. In the previous work, each of these were prescribed in a relatively simple but not necessarily optimal manner. Here, we show a method to optimize these. While gradient-free optimization is not tractable for this many parameters, gradient-based methods are well suited provided that fast and accurate gradients are available. We develop a GPU-native differentiable solver in JAX for the enveloped equations, ADEPT-LPSE, to acquire gradients of TPD simulations with respect to the bandwidth. Using a differentiable solver written in an ML-native framework enables us to train neural networks inline that give the optimal bandwidth parameters as a function of intensity, temperature, and scale length. With this functionality, we uncover bandwidth schema that dramatically reduce the TPD activity and often return the simulations to below the absolute instability threshold.



* This material is based upon work supported by the Department of Energy Office of Fusion Energy under Award Numbers DE-SC0024863 and the Department of Energy [National Nuclear Security Administration] University of Rochester "National Inertial Confinement Fusion Program" under Award Number DE-NA0004144. 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 using NERSC award FES-ERCAP0026741.

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Gaining intuition on a SSD/RPP beam through accurate analytical modeling

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Experiments carried out on NIF, LMJ and Omega use phase plates with smoothing by spectral dispersion (SSD) to improve laser beam propagation through plasmas and to reduce laser/plasma instabilities. Phase plates spread the laser intensity at focus over a large focal spot while producing small-scale inhomogeneities called speckles. SSD broadens the laser spectrum and renders these intensity inhomogeneities non-stationary over time-scale comparable with the (acoustic) plasma response.
Current in-line models of laser/plasma physics in ALE hydrodynamic codes neglect this laser beam smoothing technique and strong efforts are led to achieve this goal[1,2]. In another hand, dedicated hydrodynamic codes such as pf3d, LPSE or Hera, accurately simulate smoothed laser fields. The latter are usually modeled at the lens and propagated towards the entrance of the simulation box to obtain the boundary condition. While such methods provide a realistic laser field modeling, they greatly complicate the simulations interpretation as the laser fields are not analytical.
We developed analytical formula of the full field, near and far from focus, when using a random phase plate including SSD. The latter are used for both analytical modeling of wave mixing processes[2] and numerical modeling in the hydrodynamic code Hera and PIC code Smilei. This strategy aims at strengthening and facilitating the validation of current[2] and future theoretical models of wave mixing processes, as well as PIC Smilei and fluid Hera code comparisons using the same laser field. Different fine effects can be described such as spatial and temporal phase shifts, speckle anamorphosis due to quad splitting, and FM-AM effects. This approach can be extended to any new laser technology and particularly to next generation broadband lasers.

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[2] C. Ruyer et al., "*Backward stimulated Brillouin scattering spatial gain with polarization, spatial, and temporal beam smoothing techniques*", Phys. Plasmas, **30** 122102 (2023).

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Self-generated magnetic fields in the hot spot of direct-drive cryogenic implosions at OMEGA*

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This work reports that Biermann self-generated magnetic fields of ≈200-250 MG and Hall parameters of ≈2 are produced in the stagnation phase of direct-drive cryogenic implosions at OMEGA. The magnetic fields produce a drop of 2.4% in fusion yield and 1% in ion temperature. A quantitative estimate of the uncertainty in yield and ion temperature introduced due to hot-spot magnetic fields is essential, since direct measurements of the fields are not available. Reconstructed simulations of the 50 Gbar implosions, with all the stagnation measurements reproduced simultaneously by a combination of mid- and low-mode asymmetries as degradation mechanisms [A. Bose *et. al*., Phys. Rev. E 94, 011201 (2016)], are used to obtain the estimates. Magnetohydrodynamic solvers to model self-generated magnetic fields were incorporated into the deceleration phase code *DEC2D* for this purpose. The magnetic fields cause a decrease in yield due to the Righi-Leduc heat loss mechanism, which exceeds any benefits from heat flow suppression due to magnetization. It is important to note that both direct-drive OMEGA scale implosions and indirect-drive NIF scale implosions [C. A. Walsh *et. al*., Phys. Rev. Lett. 108, 165002 (2017)] produce similar estimates for the magnetic field strength and both show a decrease in fusion yield with the Right-Leduc transport as the loss mechanism. However, the yield degradation at OMEGA is small, and lower by ≈5x compared to indirect-drive NIF implosions where the self-generated fields have been estimated to make a 12% difference in yield.

*The work described herein was supported by a sub-award made by the Laboratory for Laser Energetics, University of Rochester, SUB00000056/GR530167/AWD00002510, under the Department of Energy, National Nuclear Security Administration grant number DE-NA0003856. The simulations reported in this paper were conducted using the high-performing cluster, Caviness, at the University of Delaware.

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A reduced kinetic method for investigating nonlocal ion heat transport

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A reduced kinetic method (RKM) with a first-principles collision operator is introduced in a 1D2V planar geometry and implemented in a computationally inexpensive code to investigate non-local ion heat transport in multi-species plasmas. The RKM successfully reproduces local results for multi-species ion systems and the important features expected to arise due to non-local effects on the heat flux are captured. In addition to this, novel features associated with multi-species, as opposed to single species, cases are found. Effects of non-locality on the heat flux are investigated in mass and charge symmetric and asymmetric ion mixtures with temperature, pressure, and concentration gradients. In particular, the enthalpy flux associated with diffusion is found to be insensitive to sharp pressure and concentration gradients, increasing its significance in comparison to the conductive heat flux driven by temperature gradients in non-local scenarios. The RKM code can be used for investigating other kinetic and non-local effects in a broader plasma physics context. Due to its relatively low computational cost it can also serve as a practical non-local ion heat flux closure in hydrodynamic simulations or as a training tool for machine learning surrogates.

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Electromagnetic Spokes in Laser-Solid Interactions*

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For more than 15 years proton radiography has been used to observe electromagnetic spokes protruding radially from th e center of a beam interacting with a solid target. Despite this phenomenon being observed across a large range of laser intensities and target materials, a rigorous explanation for these fields has been lacking.

This talk presents, for the first time, 3D MHD simulations that reproduce the spoke structure. To obtain these results, small-scale magnetic field loops are seeded in the laser absorption region. These loops are then reorganized by a combination of plasma and Nernst advection to form the eye-catching pattern observed in proton radiographs. In particular, it is the loops generated at the 'Nernst layer' that play an important role. The Nernst effect acts as an anchor, holding one side of the loop close to the foil, while plasma advection stretches the loop from the other end.

There are a number of feasible sources for the small-scale magnetic field loops. This talk will focus on laser speckles, as investigated through kinetic simulations.

Of course, the next question is 'what impact do these magnetic fields have on the plasma conditions and laser coupling?' There is some evidence from interferometry that the fields are imprinting a modulation onto the plasma density. Analysis of the 3D MHD simulations will attempt to shed light on this hypothesis, leading to a discussion of the ramifications of these formerly-anomalous electromagnetic fields on hohlraums and direct-drive ablation.

* This work was 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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Nonlocal effects on Thermal Transport in MagLIF-Relevant Gaspipes on NIF*

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We present simulations of heat flow relevant to gaspipe experiments on NIF to investigate kinetic effects on transport phenomena. These D2 and neopentane (C5H12) filled targets are used to study the laser preheat stage of a MagLIF scheme where an axial magnetic field is applied to the target [1]. Simulations were done with the radiation-MHD code Hydra[2] with a collision-dominated fluid model as well as the Schurtz[3] nonlocal electron conduction model. With nonlocal effects included the center of the gaspipe experienced increased temperatures due to inhibited radial heat flow and a faster laser propagation than without. Motivated for further study, we utilize Hydra to initialize plasma conditions for the Vlasov-Fokker-Planck K2 code[4]. We run until a quasi-steady state is reached and examine the impact of kinetic effects on heat transport. Although axial heat flow was well predicted by fluid models, the radial heat flow was found to be overpredicted by 150% in regions with the largest temperature gradient of D2 filled gaspipes. The Schurtz nonlocal electron conduction model was found to capture kinetic heat flow fairly well. Including self-generated magnetic fields further inhibits radial heat flow causing steeper radial temperature gradients.

*This work was 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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Estimating the Density and Temperature Profiles of Laser Preheated MagLIF Targets at NIF using Bremsstrahlung Emission

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Laser pre-heating is one of the key steps in the Magnetized Liner Inertial Fusion (MagLIF) concept for inertial confinement fusion ignition. Lasers can couple ignition relevant energy into the fuel, such that once compressed via a Z-pinch the MagLIF target can undergo nuclear fusion. Experiments at the National ignition Facility (NIF) are testing the accuracy of MagLIF target preheat models using gas-filled pipes and a single 351 nm laser quad to heat the gas. Bremsstrahlung emission from the laser heating is imaged by a gated x-ray detector (GXD) and analyzed to estimate the density and temperature of the laser-heated plasma. Our analysis creates a spatial map of the estimated density, temperature and pressure of the laser produced plasma, which gives an estimate of the energy coupled into the system. This has been performed in magnetized C_5H_{12} (neopentane) and un-magnetized D_2 filled targets and the results are compared to Hydra simulations. Until now these parameters could only be obtained through Hydra simulations, as experimental attempts using spectroscopy and optical Thomson scattering had produced data of limited value. This plasma emission model will help improve future simulations MagLIF experiments.

This work 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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Modeling for a Planar Heterogeneous Ablation Experiment on OMEGA*

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Ablation of heterogeneous material is not well understood and will play an important role in the implosion of targets such as the Polar Direct Drive- Wetted Foam (PDD-WF) concept[1] that employ advanced fabrication techniques. To this end, we have designed an experiment in a simplified planar configuration using the OMEGA cryo-platform which will drive a shock through the target by ablating a heterogeneous medium of two-photon-polymerization (2PP) 3D-printed lattice and liquid deuterium, where shock propagation speed and planarity of the shock structure relative to lattice morphology will be measured. To ensure that the measured shock is the result of the ablation of the heterogeneous material and not just the propagation of a shock from a uniform ablator being driven through a heterogeneous medium, a thin (~2 µm) high-density carbon front window and a laser pulse with a significant foot will be employed. Warm analog targets where SiO2 aerogel replaces the liquid deuterium will also be shot for increased throughput given longer cryogenic target turnaround times. Results of 2D and 3D xRAGE[2,3] simulations modelling the experimental setup for a range of lattice sizes and laser pulse shapes will be presented for both cold and warm targets, showing the perturbation of the shock front generated by the 2PP lattice and how the shock front heals after breakout into the pure deuterium (or aerogel) region. Shock differences will be analyzed relative to the case without any lattice to determine the fractional energy lost as a function of the heterogeneity of the propagation media.

*This work is supported by LANL LDRD project 20230034DR..

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[1] R. E. Olson, M. J. Schmitt, B. M. Haines, G. E. Kemp, C. B. Yeamans, B. E. Blue, D. W. Schmidt, A. Haid, M. Farrell, P. A. Bradley, H. F. Robey, and R. J. Leeper, "A polar direct drive liquid deuterium–tritium wetted foam target concept for inertial confinement fusion", Phys. Plasmas **28** 122704 (2021).

[2] M. Gittings, R. Weaver, M. Clover, T. Betlach, N. Byrne, R. Coker, E. Dendy, R. Hueckstaedt, K. New, W. R. Oakes, D. Ranta, and R. Stefan, "The RAGE radiation-hydrodynamic code." Comput. Sci. Discovery 1, 015005 (2008).

[3] B. Haines, C. H. Aldrich, J. Campbell, R. M. Rauenzahn, and C. A. Wingate, "High-resolution modeling of indirectly driven high-convergence layered inertial confinement fusion capsule implosions." Phys. Plasmas **24**, 052701 (2017).

Thursday, June 13, 2024

7:00am-8:30am **Breakfast in the Huntley Dining Room**

Oral Sessions 7 & 8 in the Talus Room of the Summit Hotel

Time	**Session 7: SBS, SRS & viscosity**	**Chair: Jason Myatt**
8:30am	(**Invited**) *Stimulated Brillouin Scattering in the Rare Gases in Deep UV*	Mironov, Andrey, *Xcimer Energy*
9:00	*Nonuniformity in direct-drive implosions on OMEGA induced by smoothing by spectral dispersion and polarization smoothing*	Edgell, Dana, *LLE*
9:20	*Mitigation study of absolute stimulated Raman scattering with 527 nm broadband driver*	Nguyen, Linh, *Focused Energy*
9:40	*Platform development for broadband laser mitigation of stimulated Raman scattering and two-plasmon–decay instabilities on OMEGA*	Solodov, Andrey, *LLE*
10:00	*Observing the transition to turbulence as an indirect method for validating plasma viscosity models*	Keenan, Brett, *LANL*
10:20	**Coffee Break**	
Time	**Session 8: Ignition concerns**	**Chair: Jose Milovich**
10:40am	(**Invited**) *Target gain greater than unity at the NIF and routes to even higher*	Casey, Dan, *LLNL*
11:10	*Characterizing the Effects of Drive Asymmetries, Component Offsets, and Joint Gaps in Double Shell Capsule Implosions.*	Sagert, Irina, *LANL*
11:30	*AI-enabled generative design of polymer AM targets*	Perumal, Vignesh, *CAMMINO*
11:50	*A KrF Laser Approach for High-Gain, High-TBR ICF Targets*	Holmes, Richard, *Innoven Energy*
12:10	*Computational studies of polar direct drive wetted foam ICF target implosions*	Olson, Rick, *LANL*
12:30	**Lunch in the Huntley Dining Room**	

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Stimulated Brillouin Scattering in the Rare Gases in Deep UV

A. E. Mironov[1,2], S.A. Messing[2], T.O. Reboli[2], C. Galloway[1], and J.G. Eden[1,2]
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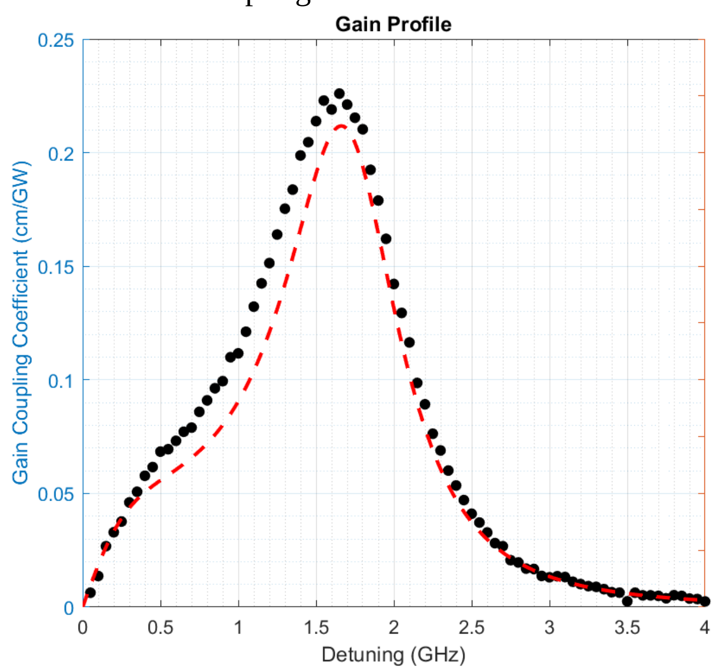
The demonstration of laser fusion scientific breakeven at the Lawrence Livermore National Laboratory (LLNL) in December of 2022 has spurred commercial and government efforts to pursue the realization of commercially viable power plants based on laser fusion energy (LFE). A leading candidate for the LFE optical driver is the krypton fluoride (KrF) laser at 248 nm, which was discovered in the mid-1970s and successfully produced multi-kJ output pulse energies in the 1980s.

Because temporal pulse compression and amplification by stimulated Brillouin scattering (SBS) undergirds several laser fusion optical driver concepts, we report the results of experiments in which SBS spectral profiles and absolute values of coupling coefficients have been measured in laser pump-probe experiments for several gases at 266 nm. Experiments were conducted with two Nd:YAG lasers operating on a single longitudinal mode and generating single pulse energies up to 50 mJ at the fourth harmonic. By thermally chirping the wavelength of the injection-seeding semiconductor laser in the probe, measurements could be made over the entire SBS spectral profile with a resolution of 50 MHz.



The figure on the right presents experimental data (black circles) acquired for krypton at a pressure of 6 atm and the dashed red line represents the spectral profile predicted by kinetic theory[1].

Experimental results will be presented for several rare gases and N_2, and the data will be compared to the predictions of both kinetic and hydrodynamic theory.

[1] V. S. Averbakh, A. I. Makarov, and V. I. Talanov, "Stimulated molecular scattering of light in gases at different pressures", Sov. J. Quantum Electron. 5, 1201 (1975).

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Nonuniformity in direct-drive implosions on OMEGA induced by smoothing by spectral dispersion and polarization smoothing*

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Cross-beam energy transfer (CBET) can severely degrade the implosion performance of direct-drive ignition experiments on OMEGA. Transfer of energy from incoming laser beams to outgoing scattered light can substantially reduce the total laser energy absorption. Simulations typically show a reduction in absorption from around 90% without CBET to 60% when CBET is modelled. The symmetry of implosions is also significantly compromised by CBET even with symmetric laser beams. The transfer of energy due to CBET redistributes the absorbed energy from low impact parameter regions of each beam profile to high impact parameter regions, increasing the absorbed energy and scattered light RMS variances. This variation is concentrated in spectral modes 6 and 10 due to the beam geometry.

Polarization smoothing using distributed polarization rotators (DPRs) and smoothing by spectral dispersion (SSD) have different angular dispersion orientations on each of OMEGA's laser beams breaking symmetry between the beams. The DPRs result in nearly linearly polarized regions on the edges of each beam profile, while the 2-D SSD bandwidth varies the beam wavelength across the beam profile. The polarization and wavelength dependances of CBET uniquely varies the energy exchange over each beam profile leading to larger asymmetries in absorption and scattered light distributions. The nonuniformity is spread over many spectral modes, including the lowest mode numbers.

Fully 3-D CBET modeling of the DPR-induced polarization and SSD bandwidth for each OMEGA beam is compared with measurements of the scattered light distribution. In particular, the predicted absorption ℓ=1 mode is compared to the experimentally observed systematic ℓ=1 mode of OMEGA implosions.

* This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority.

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Mitigation study of absolute stimulated Raman scattering with 527 nm broadband driver

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Laser plasma instabilities play a critical role in inertial confinement fusion. Among these instabilities, stimulated Raman scattering (SRS), or the resonant decay of an incident light into a scattered light and an electron plasma wave, inhibits the coupling of laser energy to the target plasma by diverting the laser energy into unwanted directions, and hinders the target compressibility by generating supra thermal electrons that prematurely heat the imploding fuel. To date, the most promising mitigation strategy for SRS involves the use of multiple overlapped beamlets with random phase plates and polarization smoothing to reduce the spatial coherence, and broad spectral bandwidths to reduce the temporal coherence. Here, we will present the mitigation study of absolute SRS with 527-nm broadband drivers for plasma conditions relevant to a preconceptual target design of an inertial fusion pilot plant at the company Focused Energy.

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Platform development for broadband laser mitigation of stimulated Raman scattering and two-plasmon–decay instabilities on OMEGA*

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Target preheat by superthermal electrons generated by stimulated Raman scattering and two-plasmon–decay instabilities is a potential concern for direct-drive inertial confinement fusion. The development of broadband laser technology can help suppress deleterious laser–plasma instabilities (LPIs). An experimental platform is being developed at the Omega Laser Facility to study LPI mitigation using the FLUX laser, which will be available in the second part of 2024 and have a frequency bandwidth of ~1.5%. FLUX beam interaction with a preformed coronal plasma, generated by nine OMEGA beams incident onto a planar or open-cone target, will be studied experimentally. Two-dimensional hydrodynamic DRACO simulations predict that coronal plasmas with a density scale length at the $n_c/4$ surface, ranging from 150 to 400 μm, will be available. We present DRACO simulations and the first experiments to utilize a narrow-bandwidth P9 interaction beam, which studied the regimes of LPI without mitigation. Simulations using the LPI code LPSE show advantages of small *f*-number optics to study the regimes of LPI relevant to direct-drive implosions.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0004144, the University of Rochester, and the New York State Energy Research and Development Authority.

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*Observing the transition to turbulence as an indirect method for validating plasma viscosity models**

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Turbulence is a ubiquitous phenomenon in neutral fluids. In contrast, collisional plasmas are subject to strong transport effects (which are anisotropic in the presence of strong magnetic fields), and the possibility of electromagnetic field generation (e.g., via the Biermann battery mechanism). Thus, plasma turbulence may differ markedly from its neutral counterpart. In fact, 2-D and 3-D xRAGE simulations of a plasma, flowing through a grid, indicate that the appearance of turbulent fluctuations is strongly dependent upon the plasma viscosity coefficient – owing largely to its $T^{5/2}$-dependence on temperature. To further elucidate plasma "grid turbulence", we have launched an experimental campaign on the Plasma Liner Experiment (PLX) platform at LANL. Leveraging Thomson scattering diagnostics, laser Schlieren/shadowgraphy, and Doppler spectroscopy, we aim to characterize the grid turbulence produced by a non-magnetized plasma jet interacting with a solid grid. The plasma jets are generated using a modified PLX gun setup. By carefully controlling the initial plasma conditions, thereby tuning the plasma viscosity coefficient (or, similarly, Reynolds number), we seek to observe the transition of the plasma from laminar-like flows to developed turbulence. As a side benefit, correspondence between the experimental results and xRAGE modeling – on the critical Reynolds number – would provide an indirect validation of the code's underlying plasma viscosity model. To achieve this, we require a predictive capability for determining the pre-grid plasma state, given a prescribed set of gun drive conditions (e.g., max. current). Here, we detail a simple analytical model – verified by comparisons with resistive MHD FLAG simulations – which roughly predicts the pre-jet plasma density (10^{-8} - 10^{-7} g/cc), temperature (1 eV - 100 eV), and flow velocity (~100 km/s). Additionally, we present some preliminary PLX results.

*Work performed under the auspices of the U.S. Department of Energy National Nuclear Security Administration under Contract No. 89233218CNA000001, and supported by the LANL LDRD ER program.

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Target gain greater than unity at the NIF and routes to even higher*

D. Casey[1] on behalf of the Indirect Drive ICF Collaboration

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Lawson's criterion has been exceeded[1] in Inertial Confinement Fusion (ICF) experiments at the National Ignition Facility (NIF) and target gain greater than unity (G>1) has been demonstrated.[2]

In recent experiments, increasing laser drive energies up to from 1.9 MJ to 2.2 MJ has successfully resulted in increased yield and target gain. Experiments to assess the variability of ignition experiments have shown a substantial sensitivity to hydrodynamic instabilities seeded by imperfections in the high-density-carbon (HDC) capsule and to low-mode asymmetries induced by the capsule and delivered laser imbalance. To achieve much higher gains, (G>>1) implosions require high enough areal density (>1.5 g/cm^2) to sufficiently confine the high pressure generated, while the thermonuclear burn wave consumes a substantial amount of deuterium-tritium DT-fuel (>>10%). Previous ignition experiments show evidence of substantially degraded compression and reduced areal density, compared with ideal simulations, and motivate efforts to understand and improve compression. One of the leading hypotheses for degraded compression is the growth of hydrodynamic instabilities during the implosion process, mixing hotter ablator material with the DT fuel and reducing its compressibility.

In this talk, we will review recent ignition experiments on the NIF including pushing toward higher laser drive energy and work toward achieving higher compression.

* This work was performed under the auspices of the U.S. Department of Energy by LLNS, LLC, under Contract No. DE-AC52- 07NA27344. LLNL-ABS- 864145.

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[1] H. Abu-Shawareb et al., PRL 129, 075001 (2022)
[2] H. Abu-Shawareb et al., PRL 132, 065102 (2024)

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Characterizing the Effects of Drive Asymmetries, Component Offsets, and Joint Gaps in Double Shell Capsule Implosions

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We present a numerical study of how double shell capsule deformations caused by drive asymmetries and fabrication imperfections affect implosion symmetry and neutron yield. The discussed capsules are composed of an aluminum ablator with a chromium inner shell. The latter encloses a carbon-deuterium foam ball that serves as fuel. Possible sources for inner shell deformation and yield degradation that are included in our studies are even-numbered low-mode asymmetries in the implosion drive, component offsets, and ablator joint gaps.

We find that for clean capsules, drive asymmetries are imprinted on the ablator and smoothly transferred to the inner shell during shell collision. The resulting deformation of the inner shell is more pronounced with larger fuel radius while the yield is inversely proportional with the amplitude of the drive asymmetry and varies by factors ≤ 4 in comparison to clean simulations. Capsule component offsets in the vertical direction and ablator thickness nonuniformity result in p1-type deformations of the imploding inner shell. Finally, joint gaps have the largest effect in deforming the ablator and inner shell and degrading yield. While small gap widths (1 μm) result in prolate inner shells, larger gap widths (4 μm) are found to cause an oblate deformation. More importantly, capsules with even a small outer gap experience a dramatic drop in yield.

This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). Release number LA-UR-24-24395.

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AI-enabled generative design of polymer AM targets*

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A principal cost driver in the IFE system is the target. Current designs will not be viable in a fusion energy system, and there is considerable effort to design targets that will be manufactured at scale with the requisite uniformity. Recent advances with wetted-foam targets show that they naturally develop a shell which makes them suitable for mass production.[1] These offer several advantages, including simplicity in target production (suitable for mass production for inertial fusion energy), absence of the fill tube (leading to a more-symmetric implosion), and lower sensitivity to both laser imprint and physics uncertainty in shock interaction. There are now many methods for making foam targets, although one stands out as not only scalable but also optimizable - 2 photon polymerization.[2] ML offers a route to change this paradigm by generating surrogate models that emulate the response surface of more computationally expensive models.

In this work, we present a gradient-based multidisciplinary design optimization technique that can be used to expedite exploration for ideal target design. The algorithm achieves computational efficiency by replacing standard finite element solvers with their ML surrogates having similar accuracy. These surrogates can capture scale transitions in a computationally inexpensive framework compared to hierarchical scale transition approaches using high-fidelity simulations. Further surrogates provide a means to rapidly calibrate models against experimental data (i.e. formal model calibration techniques), to quantify model form uncertainty, and to quantify parametric uncertainty. Extension of this approach to other fusion part design is also discussed.

*This work conducted under the auspices of the DOE-SBIR grant (DE-SC0024852) and the NMSBA assiastance program in collaboration with LANL.

[1] V. N. Goncharov, I. V. Igumenshchev, D. R. Harding, S. F. B. Morse, S. X. Hu, P. B. Radha, D. H. Froula, S. P. Regan, T. C. Sangster, and E. M. Campbell Novel Hot-Spot Ignition Designs for Inertial Confinement Fusion with Liquid-Deuterium-Tritium Spheres Phys. Rev. Lett. 125, 065001 (2020).
[2] Alex Haid, Neil Alexander, Mike Farrell, Rick Olson, Mark Schmitt, Brian Haines, Cliff Thomas, Elijah Kemp, Brent Blue, Mike Campbell Additive Manufacturing for Inertial Fusion Energy Target Production System White Paper (2022)

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A KrF Laser Approach for High-Gain, High-TBR ICF Targets

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Abstract:
KrF lasers can produce highly coherent light at relatively low cost and high efficiency. However, such lasers have a relatively low saturation intensity, which in turn requires a large-area, long-pulse laser to produce sufficient energy for laser fusion. The large area and long pulses are not consistent with a useful target laser profile for ICF targets. Nonlinear-optical means are proposed to compress the area and pulse duration to a useful laser profile. Detailed modeling supports the approach, which can achieve high fluence and excellent intensity uniformity on target. The design avoids laser damage threshold issues for almost all the optics. Competing nonlinear effects and remaining issues are discussed. Pulse energies in the 10-MJ regime can be produced with this approach and are attractive for targets that exhibit high gain and high tritium breeding ratio (TBR).

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Computational studies of polar direct drive wetted foam ICF target implosions*

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Wetted foam ICF targets employ a low-density 3D printed CH lattice to support a spherical shell of DT liquid[1]. Wetted foam ICF experiments[2] have shown that a mixed EOS must be used to accurately simulate the implosion results. This is largely due to the fact that a DT+CH mixed EOS is less compressible than pure DT. An important additional feature of the wetted foam approach to high gain ICF involves the delay of burn propagation caused by the presence of CH in the dense DT fuel layer at the time of ignition. These two features combine to limit the carbon concentration in the fuel layer and, hence, the density of the CH foam lattice. Three independent radiation-hydrodynamics codes – xRAGE, HYDRA, and LILAC -- using a variety of physics and burn models have been used to explore the limitations on the foam density.

The ability to control implosion convergence ratio is another key feature of the wetted foam ICF concept[2-3]. With a modest convergence ratio (CR~15), low mode perturbations might be tolerable and overall instability growth can be reduced[4]. In this presentation, results of 2D HYDRA simulations are used to explore the possibility of igniting a hot spot and propagating thermonuclear burn into a compressed wetted foam fuel layer using the existing polar direct drive capabilities of the National Ignition Facility.

*This work was supported by the Laboratory Directed Research and Development Program of Los Alamos National Laboratory under project number 20230034DR. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy (Contract No. 89233218CNA000001).

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[1]R. E. Olson *et al*., "A polar direct drive liquid deuterium-tritium wetted foam target concept for inertial confinement fusion," *Phys. Plasmas* 28, 122704 (2021).
[2]R. E. Olson *et al*., "First Liquid Layer Inertial Confinement Fusion Implosions at the National Ignition Facility," *Phys. Rev. Lett*. 117, 245001 (2016).
[3]A. B. Zylstra *et al*., "Variable convergence liquid layer implosions on the National Ignition Facility," *Phys. Plasmas* 25, 056304 (2018).
[4]B. M. Haines *et al*., "The effects of convergence ratio on the implosion behavior of DT layered inertial confinement fusion capsules," *Phys. Plasmas* 24, 072709 (2017).

7:00pm **Plenary Session III in the Talus Room of the Summit Hotel**

The road to the first liquid DT-filled double shell implosions at NIF — Loomis, Eric, *LANL*

8:00pm **Poster Session III in the Gallatin Ballroom (see end of this file)**

Thursday Poster Session III: Ablation, mix, implosions & high yield **8:00pm in the Gallatin Ballroom**

1	Farrell, Audrey	*UCLA*	Simultaneous Biermann battery and Weibel instability generated magnetic fields in near critical density plasmas
2	Huff, Maggie	*LANL*	Studying the fill tube interaction in double shell targets for inertial confinement fusion
3	Kuczek, John	*LANL*	Analysis of Tungsten Dopant on Simulated 1D/2D Implosions on the National Ignition Facility
4	Meaney, Kevin	*LANL*	Evolution of fusion ignition burn through ultrafast reaction history measurements
5	Milovich, Jose	*LLNL*	Development of an indirect-drive target producing 50 MJ of fusion energy for a prototype IFE power plant
6	Mohamed, Zaarah	*LANL*	Experimental design for planar experiments to characterize shock properties of wetted foams
7	Sauppe, Josh	*LANL*	Modeling of a Proposed Mitigation Mechanism for the Double Shell Ablator Joint
8	Schmitt, Mark	*LANL*	Simulation of polar direct drive wetted-foam capsule physics
9	Vold, Erik	*LANL*	Hydrodynamic versus Kinetic Mixing in ICF
10	Cheng, Baolian	*LANL*	Mode coupling and evolution in Rayleigh-Taylor instabilities and ICF applications
11	Wilks, Scott	*LLNL*	Simulations for Fast Ignition Studies

The road to first liquid DT-filled double shell implosions at NIF*

E.N. Loomis, D. Montgomery, P. Amendt[†], B.M. Haines, J.P. Sauppe, S. Palaniyappan, H. Robey, D.W. Schmidt, N. Christiansen, P. Keiter, E. Merritt, R. Sacks, M. Schmitt, D.J. Stark, Z. Mohamed, I. Sagert, W. Daughton, J. Kline, H. Xu[‡], A. Satsangi, J. Smidt
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The first liquid DT filled, laser indirect-drive double shell implosion was recently carried out at the National Ignition Facility (NIF). This achievement highlights the challenges and successes of research in the areas of theory, computation, target fabrication, and experimental fielding by many people for over 20 years. Indirect-drive double shell is just one type of design belonging to the larger multi-shell volume burn inertial confinement fusion (ICF) family. Their purpose is to achieve robust thermonuclear burn-up of DT fuel that volumetrically fills the region inside the inner most shell. In most multi-shell ICF designs, the inner most shell is made from high-atomic-number metal (e.g., Au, W, etc), which is a key design feature that can significantly reduce radiation losses compared to central hot spot designs while allowing them to reach high stagnation pressures at lower fuel convergence ratios. The placement of interior shells has required target fabrication advancements as well as novel designs for controlling dangerous hydrodynamic instability growth [1]. Coupling energy from the laser driver and transferring it to the inner shell in the form of kinetic energy is also of great importance and an active area of research for multi-shell platforms.

In this plenary we will first review the development of indirect and direct-drive [2,3], multi-shell research conducted over the last two decades. Following the review we will discuss current efforts at NIF to develop indirect-drive double shells. This research has been geared toward reducing modeling uncertainties in the following areas: 1) symmetry control and energy coupling to Al ablators, 2) Au L-shell preheating of metal inner shells, 3) control and mitigation of engineering features, 4) low-mode symmetry transfer between shells, and exploration of engineered density gradients to control inner shell hydrodynamic instabilities. Finally, we will present near term research including 2-shock pulse shaping for double shells, nuclear diagnostics for double shells, as well as first liquid fill DT data from NIF.

*This work conducted under the auspices of the National Nuclear Security Administration.

[1] J.L. Milovich, P. Amendt, M. Marinak, H. Robey, "Multi-mode short-wavelength perturbation growth studies for the National Ignition Facility double shell ignition target designs", Phys. Plasmas 11, 1552 (2004).
[2] S.X. Hu, R. Epstein et al., "Direct-drive double-shell implosion: A platform for burning-plasma physics studies", Phys. Rev. E 100, 063204 (2019).
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Simultaneous Biermann battery and Weibel instability generated magnetic fields in near critical density plasmas*

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The origin of magnetic fields in initially unmagnetized plasmas is important to our understanding of both astrophysical and laboratory plasmas. While many candidate mechanisms have been characterized in isolation in previous experiments, understanding how two particular mechanisms, the so-called Biermann battery effect and the Weibel instability, arise and compete with one another is particularly important, as both have been proposed as the source of seed fields that can be amplified by the galactic dynamo effect. Computational studies of scaled laser plasmas with temperature and density gradients as well as temperature anisotropy have shown that Weibel instability and Biermann battery generated magnetic fields can coexist in plasmas where the density and temperature gradient scale lengths are large compared to the skin depth c/ω_p. Using the Brookhaven National Laboratory Accelerator Test Facility's CO_2 laser allows us to ionize a near critical density plasma using a gas jet target, which has rather large electron temperature anisotropies and orthogonal temperature and density gradients. The former gives rise to the electron Weibel instability induced magnetic fields while the latter gives rise to a magnetic field due to the Biermann battery effect. These fields can be measured using a Faraday rotation diagnostic that measures the polarization rotation of a optical probe with sub ps temporal resolution using a fs Ti:Sapphire laser beam. By delaying the probe beam relative to CO_2, we can measure the temporal evolution of magnetic fields generated by these two mechanisms and explore the conditions in which either mechanism dominates.

*This material is based upon work supported by the National Science Foundation under Grant Nos. 2034835 and 2003354, and the U.S. Department of Energy under Grant Nos. DE-SC0010064 and DE-SC0014043.

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Studying the fill tube interaction in double shell targets for inertial confinement fusion

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One barrier to achieving uniform and efficient compression in inertial confinement fusion (ICF) capsules is the fill tube, which is the mechanism for delivering liquid fuel to the spherical capsule. The capsule is designed with two concentric shells, called double shells, with the purpose of maximizing the energy transfer from the laser drive to the outer shell and then from the outer shell to the inner shell, which compresses the fuel inside. The fill tube disrupts the symmetry of the concentric shells and leads to the propagation of instabilities, which then leads to less compression of the fuel, and less energy output. Upcoming OMEGA 60 experiments will investigate the effects of the bore hole (where the fill tube is inserted into the capsule), the fill tube wall thickness, and glue variations as they relate to the amount of aluminum jetting and disturbance in symmetry.

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Analysis of Tungsten Dopant on Simulated 1D/2D Implosions on the National Ignition Facility

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Inertial confinement fusion (ICF) research on the National Ignition Facility (NIF) has demonstrated energy gain through the x-ray driven implosion of spherical capsules filled with deuterium and tritium (DT) fuel[1]. Capsules consist of high-density carbon (HDC) ablators lined with DT ice surrounding low-density DT gas. ICF implosions are known to be hydrodynamically unstable, which amplifies deviations from spherical symmetry during the implosion process. Deviations from symmetry can interrupt or decrease the efficiency of hot spot formation[2], allow fuel to escape the hot spot, and cool the hot spot through the introduction of contaminant mass to the hot fuel region[3]. The stabilization of various hydrodynamic instabilities has been previously demonstrated in layered implosion experiments on NIF by increasing the ablation rate and hence ablative stabilization via changes to the pulse shape[4] and changes to the ablator material[5] as well as reducing the size of the fill tube[6].

Tungsten dopant is used in the HDC layer to block high energy x-rays from preheating the DT fuel. The amount of tungsten dopant in the HDC doped layer of the capsule also plays an important role in the evolution of hydrodynamic instabilities during the implosion. The level of dopant has to be designed carefully as more dopant will increase stability at the interface between the fuel and the capsule, but decrease the stability at the ablation front[7]. While fuel and ablative front instabilities are always present, the amount of tungsten dopant dictates which instability dominates the experiment. This study analyzes xRAGE[8] simulations of 1D and 2D high yield NIF implosions with increasing amounts of tungsten dopant. We compare the trade-offs between instabilities generated in the fuel due to preheat and instabilities generated at the ablative front with increasing dopant.

*Thank you to the HybridE team for providing data necessary to simulate these experiments. This work was performed by the Los Alamos National Laboratory, operated by Triad National Security, LLC for the National Nuclear Security Administration (NNSA) of U.S. Department of Energy (DOE) under Contract No. 89233218CNA000001.

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Evolution of fusion ignition burn through ultrafast reaction history measurements

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The NIF is now routinely making multi-MJ fusion yields, creating a burning, igniting plasma. With advanced diagnostic technology, the time evolution of the fusion can be measured at extreme time resolution (10 ps). With novel reaction history measurements, the transition between an igniting and non-igniting plasma has stark differences in the fusion evolution. The measurements are starting to be used to infer the fusion deposition rate, the explosion rate, and used with other measurements to estimate the hot spot trajectory through temperature and fuel areal density. These measurements can help inform the hot spot formation conditions which ultimately determine the capsule performance. The new measurements offer an unseen window into an extreme state of matter and offer many details of its evolution.

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Development of an indirect-drive target producing 50 MJ of fusion energy for a prototype IFE power plant*

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Recent experiments at the National Ignition Facility achieved the first demonstration in the laboratory of fusion energy output >2 times larger than the laser energy delivered to the target.[1] These results have initiated various efforts in the private sector to use inertial fusion energy (IFE) for commercial power generation. While the road ahead presents several challenges, it is clear that at a minimum, successful development will require target gains (G) well above the current results to greatly exceed the product of driver wall-plug and thermal efficiency $\eta \sim 0.1$ ($\eta G > 10$)[2]. Among several approaches under investigation (central hot-spot, fast, and shock ignition) to reach these desired gains, central hot-spot (CHS) ignition has been the most researched to date, with a myriad of proven computational and experimental capabilities. To this end, we have revisited an earlier CHS concept that employs a cryogenic capsule consisting of a DT layer encapsulated by a plastic (CH) ablator. The amorphous nature of CH allows for higher fuel compression by maintaining a relatively cold dense fuel plasma and permits higher fusion yields. In addition, the higher ablation efficiency of CH (over current high-density carbon ablators) gives additional margin for a fixed driver energy. We show that a design using a CH target fulfills the requirements for a break-even prototype power plant ($\eta G \sim 1$) while delivering 50 MW of electric power[3,4]. Since IFE energy generation proceeds from a series of ~100 ps duration output energy pulses, the assumption of a realistic $G \sim 10$ would require repetition rates approaching 10 Hz, for a driver energy of ~5 MJ. In this work, we will describe the original design and our efforts to use a machine learning approach for further optimization of the target and driver laser pulse. Additionally, the developed approach will also permit us to study the consequences on performance margin and gain in the presence of realistic variability in the target, driver and fielding conditions.

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* Work performed under the auspices of U.S. Department of Energy by LLNL under Contract DE-AC52-07NA27344 and supported by LDRD-21-ERD.041

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Experimental design for planar experiments to characterize shock properties of wetted foams*

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Polar direct drive (PDD) wetted foam (WF) implosions have recently been proposed as a promising opportunity to pursue increasingly efficient inertial confinement fusion implosions for scientific experiments as well as the pursuit of inertial fusion energy. These implosions involve large targets filled with cryogenic liquid DT which wicks into a foam layer. The liquid DT serves as both the ablator and the fuel. PDD WF implosions are thought to offer improvements over current indirect drive layered DT implosions due to improved laser coupling as well as relaxed symmetry and convergence requirements for ignition.[1]

The experimental campaign that is the focus of this work seeks to use a planar geometry to investigate laser ablation and shock propagation through D_2-wetted foams. Planar experiments are planned and scheduled at OMEGA with the objectives of measuring ablation/shock propagation speeds and observing shock front evolution in these heterogeneous targets, which are to be driven at ignition capsule intensities of ~2.5e14 W/cm^2. This work details the objectives and experimental design for the imminent experimental campaign, including target fabrication capabilities which enable these experiments.

*This work was supported by the Laboratory Directed Research and Development Program of Los Alamos National Laboratory under project number 20230034DR. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy (Contract No. 89233218CNA000001).

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Modeling of a Proposed Mitigation Mechanism for the Double Shell Ablator Joint*

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The double shell[1] is an alternative inertial confinement fusion concept that relies upon volumetric ignition of the deuterium-tritium (DT) fuel region, as opposed to hot spot ignition as in single-shell designs. An indirectly driven aluminum ablator compresses an interstitial foam cushion that supports the central high-*Z* tungsten inner shell (pusher). The foam mediates the transfer of kinetic energy from the aluminum outer shell to the inner shell during the collision, and the pusher then compresses and heats the DT fuel quasi-adiabatically. The high-*Z* pusher limits the radiative losses from the fuel, potentially allowing ignition at lower fuel temperatures.

A major challenge for the double shell concept comes from the fabrication process, which requires nesting the inner shell inside of the outer shell. The current approach[2] uses two hemi-spheres of aluminum that are mated along the equator to form the outer shell. The morphology of the ablator joint is predicted to significantly impact the performance of the capsule,[3] though a potential mitigation mechanism has been identified: a thin (~100's of nm) layer of gold coated on the exposed surfaces of the ablator joint gap is predicted to significantly improve yield.

We use the Eulerian radiation-hydrodynamics code xRAGE,[4] which includes the necessary treatments for modeling inertial confinement fusion and high-energy-density physics experiments,[5] to expand upon a previous simulation study. We find that, depending on the width of the ablator gap, different thicknesses of gold are required to mitigate its deleterious effects on capsule performance. Results are compared for two different pulse shapes, a reverse-ramp pulse that has been used previously and a novel two-shock pulse that is being explored currently.

* This work was supported by the US Department of Energy through the Los Alamos National Laboratory, operated by Triad National Security, LLC, for the National Nuclear Security Administration (Contract No. 89233218CNA000001). [LA-UR-24-24473]

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Simulation of polar direct drive wetted-foam capsule physics

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We investigate the unique physics of using hydrogen as the main ablation material to achieve high nuclear yields from a liquid DT-wetted layer capsule directly driven by the National Ignition Facility's (NIF's) current laser capabilities[1]. The capsule is composed of a thin plastic shell used to enclose a thick low-density annular 3D-printed matrix layer that contains the liquid DT fuel. Simulations predict high laser absorption fractions consistent with previous polar direct drive (PDD) MJ-class NIF experiments where >95% capsule absorption of the laser drive energy was achieved using a 5 mm diameter plastic capsule[2] with a surface intensity of 2.5×10^{14} W/cm^2. Moreover, superior double-digit hydro-efficiency is predicted and shown to be higher than any other ablator material having equal shell mass. The results of simulations using the HYDRA and xRAGE radiation-hydrodynamics codes will be shown to elucidate the laser drive characteristics of these materials. Fabrication efforts using 3D printing techniques are currently underway to construct these hybrid capsules for future NIF experiments. Since the fuel layer consists of a heterogeneous combination of a 3D-printed plastic lattice and liquid hydrogen fuel, dedicated planar cryogenic laser ablation experiments will be performed soon to assess the effects of heterogeneous ablation and propagation on the hydrodynamic evolution of these materials. An overview of these multi-Laboratory efforts will be shown.

*This work was supported by the Laboratory Directed Research and Development Program of Los Alamos National Laboratory under project number 20230034DR. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy (Contract No. 89233218CNA000001).

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Hydrodynamic versus Kinetic Mixing in ICF *

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Mixing between fuel and capsule is a well know source of performance degradation in ICF (Inertial Confinement Fusion). The mix includes hydrodynamic mixing and kinetics approximated in plasma transport. The convergence to minimum volume drives instabilities (RT, RM and KH) which can cascade to a broad multimode spectrum and ultimately the materials become mixed at the atomic level by kinetic transport processes. Predicting this atomic mix component of the hydrodynamics is critical to understanding capsule performance[1] and reaction rates especially in separated reactant experiments[2]. We examine mixing in radiation-hydrodynamic simulations[3] (xRAGE) which includes detailed options to treat the kinetic mixing in plasma fluid transport approximations for multi-component thermal species[4]. The kinetics modify the species mass, momentum and energy equations. The species drift velocities relative to the single fluid velocity of the hydrodynamic framework is the deterministic mechanism that generates atomically mixed components of the thermal (near Maxwellian) species. Simulation results are examined in several example cases to illustrate the important mixing physics near ICF conditions, comparing results with and without the kinetic effects represented in the plasma transport[4,5,6].

While a DNS ('direct numerical simulation' including radiation-hydrodynamics and plasma transport) is a preferable approach to model the thermal species mixing, this may be impractical in applications where the resolution requirements to represent the gradient scale lengths for the plasma transport are severe (ICF typically requires sub-micron resolutions). We discuss options to use a turbulent model to represent small scale (sub-grid) hydrodynamics. The conversion to atomically mixed components is still represented by the plasma transport across a sub-grid interfacial area which is increased by sub-grid hydrodynamics represented in the turbulence model. Additional model enhancements are required for application to hohlraum physics and in low density colliding plasma jets, wherein each species retains its own density, velocity and energy. Tracking each species as a separate fluid requires extensive modification of the existing steady state drift flux plasma transport model within the existing code framework of a multi-material single velocity hydrodynamic framework.

*This work conducted under the auspices of the ASC program, NNSA, Department of Energy, USA.

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Mode coupling and evolution in Rayleigh-Taylor instabilities and ICF applications*

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Rayleigh-Taylor (RT) instabilities are important fluid instabilities that arise in ICF capsule implosions, among other contexts. Multi-mode coupling is observed in experiments and plays a substantial role in material mix from RT instabilities. In this work, we study the evolution of highly multimodal perturbations (power law distribution) that approximate those found at manufactured material interfaces. We use simulations of over 2000 different perturbations in the LANL code xRAGE to identify distinct phases in the processes of bubble growth and bubble merger which can be visualized in a 2D phase portrait with clear regimes of mode growth and decay. Our results show that the dynamic evolution of the instability strongly depends on the mode of the perturbations and mode interactions. Merger process accelerates bubble growth. A non-Markovian region and a transition of the instability from: 1) initial exponential growth to 2) linear growth to 3) quadratic growth and finally the 4) asymptotic behavior, are clearly captured in the phase space. We have developed a quantitative model of bubble growth that reproduces the dynamic behavior of ensembles of perturbations. Implications for ICF capsules design against instabilities are discussed.

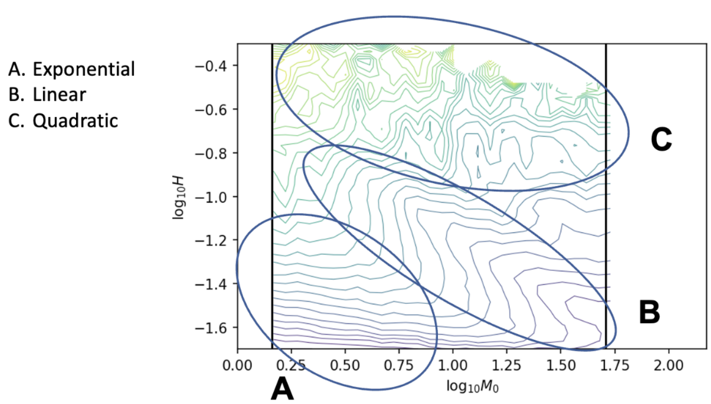

Figure 1: Stages of RT growth on phase portrait.

* This work was supported by the LANL ICF program and conducted under the auspices of the U.S Department of Energy by the Los Alamos National Laboratory under Contract No.89233218CNA000001.

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Simulations for Fast Ignition Studies*

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The historic breakeven laser fusion milestone reached at the NIF in December 2022, and subsequent shots that produced more fusion energy out than laser energy into the target, indicates that laser fusion could be a viable a route to fusion energy. While the current method (indirect drive) is currently being considered as an engine for an IFE plant, it is prudent to explore other options that may be more efficient/economical. Several alternative methods of achieving high gains have been proposed. One promising method of achieving high gain is to consider the possibility of separating the compression and ignition stages in the method. In particular, using short pulse lasers to create an intense burst of electrons to ignite an isochorically compressed DT target known as Fast Ignition[1] is one approach. Another approach, based on protons (or ions in general) produced using the TNSA method of energetic proton production, has received considerably less attention. We present select results from a combined theoretical/simulation and experimental program that is revisiting the physics underpinning both of these methods of laser-based fusion in light of recent developments in the field. Specifically, PIC simulations of proton generation[2] and hybrid simulations of resistive magnetic field generation will be discussed.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and the LLNL LDRD with tracking number 24-SI-003, and was supported by the Livermore Computing (LC) Grand Challenge Program.

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Friday, June 14, 2024

7:00am-8:30am **Breakfast in the Huntley Dining Room**

Oral Sessions 9 & 10 in the Talus Room of the Summit Hotel

Time	**Session 9: Diagnostics**	**Chair: Kevin Meaney**
8:30am	(**Invited**) *Quantitative measurements of MeV photon spectra using a filter stack spectrometer*	Wong, Tim, *LANL*
9:00	Nuclear imaging and shape characteristics of ignition shots at the National Ignition Facility	Durocher, Mora, *LANL*
9:20	*Progress in high-resolution x-ray spectroscopic measurements of radiation flow and compressed matter*	Kozlowski, Pawel, *LANL*
9:40	*X-Ray Conversion Efficiencies for Diffraction Experiments on Z*	Geissel, Matthias, *SNL*
10:00	*Diagnosing hot-spot symmetry via secondary DT-neutron spectroscopy at the NIF*	Adrian, Patrick, *LANL*
10:20	**Coffee Break**	
Time	**Session 10: Physics modeling and experiments**	**Chair: Josh Sauppe**
10:40am	(**Invited**) *Progress on understanding the drive deficit in indirect-drive NIF experiments*	Chen, Hui, *LLNL*
11:10	*Photochemically-Induced Acousto-Optic Fluid Simulations*	Oudin, Albertine, *LLNL*
11:30	*Experimental demonstration of ozone grating created by interfering ultraviolet lasers*	Ou,Ke, *Stanford*
11:50	*Simulating Radiation Flow through Lattices*	Recamier, Claire, *LANL*
12:10	*The Thinned Hohlraum Optimization for Radflow Experiments (THOR) Campaign on the National Ignition Facility*	Lester, Ryan, *LANL*
12:30	**Conference adjourns**	

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Quantitative measurements of MeV photon spectra using a filter stack spectrometer*

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The measurement of MeV photon spectra is a notorious challenge as photons in the MeV range (~1 to 10 MeV) are extremely penetrative and attenuate similarly in high-Z material. The filter stack spectrometer (FSS) is an attractive diagnostic for measuring MeV photon spectra as they are simple to field, compact, and insensitive to electromagnetic pulses. An FSS consists of alternating layers of filter materials and detectors, so that photons of different energies will attenuate and produce secondaries differently, and in turn, deposit energy on detectors differently. Although simple to field, extracting a spectrum from the FSS measurements is a major challenge. The FSS response is ill conditioned, so that there are many potential spectral solutions for a given FSS measurement. Typically, strong physics assumptions have been used to help break the degeneracy of the inversion; however, this leads to biases in extracted spectra.

In this talk, we present a new inversion method[1] based on perturbative minimization[2,3] that can extract the large-scale, primary features of MeV photon spectra without needing an *a priori* specification of a spectral shape or arbitrary termination of the algorithm. We benchmark the method against synthetically generated spectra prior to applying the method to experimental measurements of laser-driven x-ray sources and Bremsstrahlung sources generated by electron-target interactions. We will also describe future work aimed at overcoming existing limitations of our FSS measurements, including sensitivity to random error, reliance on single-shot detectors (image plates), and unfolding algorithms ill-suited for high-repetition rate applications.

* This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. This work was supported in part by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under Project No. 20220018DR. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). LA-UR-24-24213

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Nuclear imaging and shape characteristics of ignition shots at the National Ignition Facility

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The Nuclear Imaging System (NIS) has been capturing neutron images of Inertial Confinement Fusion (ICF) driven implosions for over a decade at the National Ignition Facility (NIF). This imaging system has evolved from one Line of Sight (LoS) to three nearly orthogonal LoS. This has allowed for the study of three-dimensional shape characteristics of ignition shots. Limited view tomography algorithms help visualize the burning hotspot in 3D, including the density distribution of the cold fuel surrounding the burning plasma. Recently, two of three LoS have been equipped to capture gamma-ray images, thus creating the opportunity to characterize the remaining ablator in 3D and assess fusion efficiency. This now comprehensive diagnostic suite has provided critical insight on mechanisms that have limited implosion performance; and with its neutron, X-ray and gamma-ray image reconstruction capabilities, NIS opens a window into shape characteristics of ignition shots and how symmetry affects ICF implosion performance.

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Progress in high-resolution x-ray spectroscopic measurements of radiation flow and compressed matter*

P. M. Kozlowski, A. T. Elshafiey, H. M. Johns, A. J. Neukirch, Dž. Čamdžič, T. Archuleta, C. Wilde, J. Jorgenson, B. Farhi, D. W. Schmidt, C. J. Fontes, C. Fryer, T. Byvank and T. Urbatsch
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X-ray spectroscopy has proven to be an invaluable diagnostic for measurements of temperature and charge state distribution in high energy density (HED) plasmas. Most hard x-ray spectrometers available at HED facilities have resolving powers of 1000 or less, and those that achieve high-resolution tend to be time-integrated. However, increasing resolution to resolving power > 1000 with a time-gated setup can enable detailed measurements of multiple emission/absorption lines that would otherwise be obscured due to mutual overlapping of lines. High-resolution can likewise reveal individual line shifts and splits, which provide insights into processes such as ionization potential depression, which currently lacks a general model. We present upgrades to our LANL x-ray spectrometer located at the Omega-60 Laser Facility, that have achieved time-gated near-eV resolution measurements of x-ray fluorescence spectra from warm dense Fe experiments on the XRFe experimental platform. This level of detail allows for resolution of K-alpha line shifts originating from the various Fe charge states. Building on this instrument's flexibility, we have extended the photon energy range to simultaneously measure Sc 1s-3p and V 1s-2p and V 1s-3p transitions with a resolving power of ~1300 in our XFOL platform experiments, which enables precise temperature measurements of both inclusions and background material as radiation flows through this stochastic medium.

*LA-UR-24-24376. Research presented in this presentation was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20220596ECR. This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001).

52nd Annual Anomalous Absorption Conference
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June 9th–14th, 2024

X-Ray Conversion Efficiencies for Diffraction Experiments on Z*

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We will present our latest data on absolute X-ray yields for mid-Z K-shell emission produced with the Z-Beamlet laser and compare them to Z-Petawatt efficiencies. We found that Z-Beamlet is a good X-ray driver up to 10 keV (Ge He_{α}), though the efficiency is very sensitive to pulse energy/intensity at this limit as shown in Fig. 1. For 15 keV (Zr K_{α}) and above, Z-Petawatt outperforms Z-Beamlet.
We will compare the impact of target geometry, surface structure, and observation angle for X-ray generation with Z-Petawatt before and after the recent improvements to the laser system.

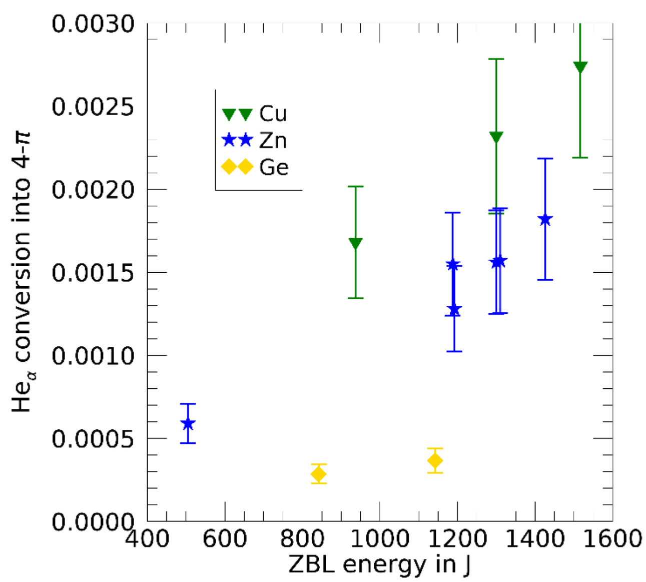

Fig. 1: X-ray Conversion efficiencies with Z-Beamlet for mid-Z elements

* *Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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.*

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Diagnosing hot-spot symmetry via secondary DT-neutron spectroscopy at the NIF*

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The directional energy spectrum of neutrons generated from in-flight fusion reactions of 1-MeV Tritons contains information about the hot spot symmetry. The National Ignition Facility (NIF) fields Symmetry Capsule (Symcap) implosions which have historically measured the symmetry of the radiation drive by measuring the hot spot shape via x-ray self-emission. This work demonstrates complimentary information is contained in the directional secondary DT-n spectrum. A Monte Carlo Model for the calculation of the direction secondary DT-n spectrum is used to interpret the results. A comparison of the x-ray and secondary DT-n data with the Monte Carlo model indicates 56% of the variance between the two data sets can be explained by a P2 asymmetry. More advanced simulations were used to suggest that unaccounted-for variance by the model is due to P1 and P4 asymmetries present in the hot spot. Overall, secondary DT-n spectroscopy is shown to contain important information that supplements the current diagnostic capability of the NIF. This technique may also be vitally important when shape measurements are needed and x-ray imaging is not possible, such as with Double-Shell implosion pursed at LANL.

*This work was supported in part by DOE/NNSA CoE under Contract No. DE-NA0003868 and the LLNL under Contract No. B640112; P. J. Adrian was supported by NNSA SSGF under Contract No. DE-NA0003960.

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Progress on understanding the drive deficit in indirect-drive NIF experiments

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The predicted implosion performance of deuterium-tritium fuel capsules in indirect-drive inertial confinement fusion experiments rely on precision calculations of the x-ray drive inside a laser-driven cavity "hohlraum". This in turn requires accurate simulations of the conversion of laser power into a spectrally dependent x-ray source and the subsequent x-ray absorption losses in the hohlraum wall. A set of experiments have revealed that the inaccuracy in the emission calculation for the gold "M-band" is likely responsible for much, if not all, of the long-standing "drive-deficit" problem in ignition scale hohlraum simulations. These experiments were performed on pairs of ViewFactor targets (see Figure 1) with the gas fill and laser pulse shapes used in on-going ignition experiments on NIF. The common hohlraum model with MHD and a ~20% reduction to the "M-band" opacity can bring the simulations into agreement with two independent measurements: the absolute radiation flux (both total and "M-band") and spectroscopic measurements of K-shell dopants placed in the wall. Such a model is applicable to high-energy density experiments that use high-Z hohlraums as drivers.

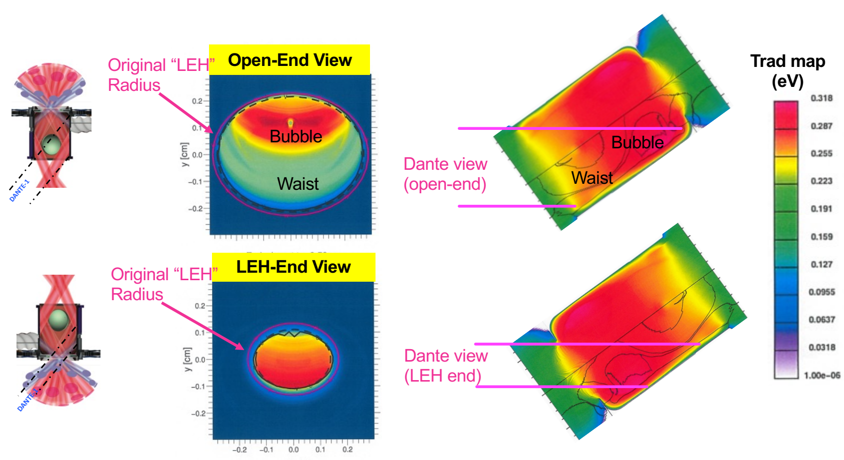

Figure 1. A pair of viewfactor targets provide different view of hohlraum internals.

This work was performed under the auspices of the U.S. Department of Energy by LLNS, LLC, under Contract No. DE-AC52- 07NA27344.

Photochemically-Induced Acousto-Optic Fluid Simulations*

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The damage threshold of solid optics is a main limiting factor for high-power laser facilities. Plasma photonics has been identified as a promising candidate to replace solid-state optical elements, but also suffer from some limitations, among which the short recombination time and the undesired nonlinear plasma phenomena.

A proof-of-principle experiment [1] has demonstrated that neutral gas optics can sustain large intensities (>1kJ/cm^2) while remaining more stable than plasmas. These gas optics are created by the density modulation from an acoustic/entropy wave, whose refractive index modulation turns the gas into a grating—or other diffractive elements. The wave is launched by the absorption of a modulated UV beam by ozone molecules introduced in the gas: the resulting ozone dissociation and subsequent chemical reactions rapidly heat the gas and initiate the wave[2]. The hydrodynamic response of the gas has been investigated with a 1D hydrodynamic code resolving Euler equations. A 3D Fresnel diffraction code is then used to calculate the diffraction efficiency. We will discuss the onset of nonlinear effects, both from the depletion of ozone and nonlinear wave excitation.

* This work was 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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[1] Y. Michine and H. Yoneda, Commun. Phys. 3, 24 (2020).

[2] P.Michel et al., Submitted to PRX (2024).

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Experimental demonstration of ozone grating created by interfering ultraviolet lasers

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Interfering laser beams can induce density modulations in gases [1] and plasmas [2], creating volume diffraction gratings. These transient optics are debris-resistant and feature much higher damage thresholds than traditional solid-state optics, providing a promising method towards efficiently manipulating high-energy and high-power laser beams. Specifically, interfering ultraviolet lasers can thermally induce density modulations in an ozone-oxygen mixture by periodically heating the gas in space. These gas optics can exist in the timescale of nanoseconds and are suitable for operating in extreme environments like those found near the final target in inertial confinement fusion (ICF) experiments.

In this work, we created an ozone grating experimentally using the 4th harmonic of an Nd:YAG laser as the pump. We demonstrated the efficient diffraction of a 1064 nm infrared beam by a gas grating and characterized several key properties of the system, such as its lifetime and the impact of ozone concentrations and probe incident angles on the diffraction efficiency. The experimental results will contribute to the development and validation of the theoretical model [3]. Special techniques such as gas-based spatial filtering were also developed and tested in order to develop more efficient gas gratings.

This work was partially supported by NNSA Grant DE-NA0004130, NSF Grant PHY-2308641, and the Lawrence Livermore National Laboratory LDRD program (23-FS-004).

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[3] P. Michel, L. Lancia *et al.*, "*Photochemically-induced acousto-optics in gases*," arXiv 2402.05219 (2024).

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Simulating Radiation Flow through Lattices*

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Recent experimental advances, such as the development of LANL's COAX platform for high energy density experiments, enable the study of radiation flow through exotic targets in unprecedented detail.[1] Heterogeneous media targets such as lattices, consisting of an optically thick strut material in an optically thin background foam, give rise to complex effects in how radiation couples to hydrodynamics. Experimental radiography captures density variations from the shock wave produced when the radiation goes subsonic, while absorption spectroscopy captures the spatial profile of the supersonic radiation. These diagnostic images from indirectly driven lattice experiments are used to constrain simulations run using LANL's radiation-hydrodynamics code, xRage/Cassio.[2]

The computational cost of simulating experimental lattices to highest degrees of fidelity are prohibitive. Extreme differences in length scales between regions rapidly drive up the number of cells needed to properly resolve features to unrealistic limits. Thus, we aim to develop and assess a selection of reduced-order and approximate models, ranging from a laterally infinite 3D domain to a fully homogenized 2D lattice model. For each simulated model, we examine metrics such as position of the radiation front, energy spectra, and angular profiles of radiation at specific locations and times, in an effort to characterize radiation flow through that simulation. A comparison of each simulation's metrics then informs how the geometry of a model influences the propagation of radiation.

*This work was performed by the Los Alamos National Laboratory, operated by Triad National Security, LLC for the National Nuclear Security Administration (NSSA) of the U.S. Department of Energy (DOE) under Contract No. 89233218CNA000001.

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[2] M. Gittings et al., "The RAGE radiation-hydrodynamics code," Comput. Sci. & Discov. 1:015005 (2008).

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The Thinned Hohlraum Optimization for Radflow Experiments (THOR) Campaign on the National Ignition Facility

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and
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The achievement of ignition and gain on the National Ignition Facility (NIF)[1] provides the opportunity to develop novel experiments that utilize the energy produced by the capsule implosion. High yield capsule implosions on the NIF are fielded inside of a cylindrical hohlraum, which is used to convert laser energy to X-rays that drive the implosion. In high yield implosions, X-ray fluxes from hohlraum re-heating from igniting capsules has been observed that exceed the fluxes generated from laser heating[2]. This enables the possibility of utilizing this hohlraum re-heating or even the X-ray output directly from the capsule to drive radiation flow experiments or opacity measurements relevant to astrophysical phenomena at conditions that are otherwise impossible to achieve in the laboratory. The THOR campaign on NIF aims to develop this capability.

The primary challenge is to design windows for the hohlraum that are thin enough to allow the radiation to burn through and expose an external package to capsule-generated radiation, yet thick enough to avoid producing a long-wavelength drive asymmetry observed by the capsule implosion that could prevent ignition. We have planned a series of experiments to optimize the window thickness and quantify imposed shape asymmetries on surrogate implosions. These data will be used to optimize a high-yield layered implosion attempt with THOR windows. We will discuss the design of the campaign, planned experiments, as well as simulations of the expected results.

This work was performed by the Los Alamos National Laboratory, operated by Triad National Security, LLC for the National Nuclear Security Administration (NSSA) of the U.S. Department of Energy (DOE) under Contract No. 89233218CNA000001.

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