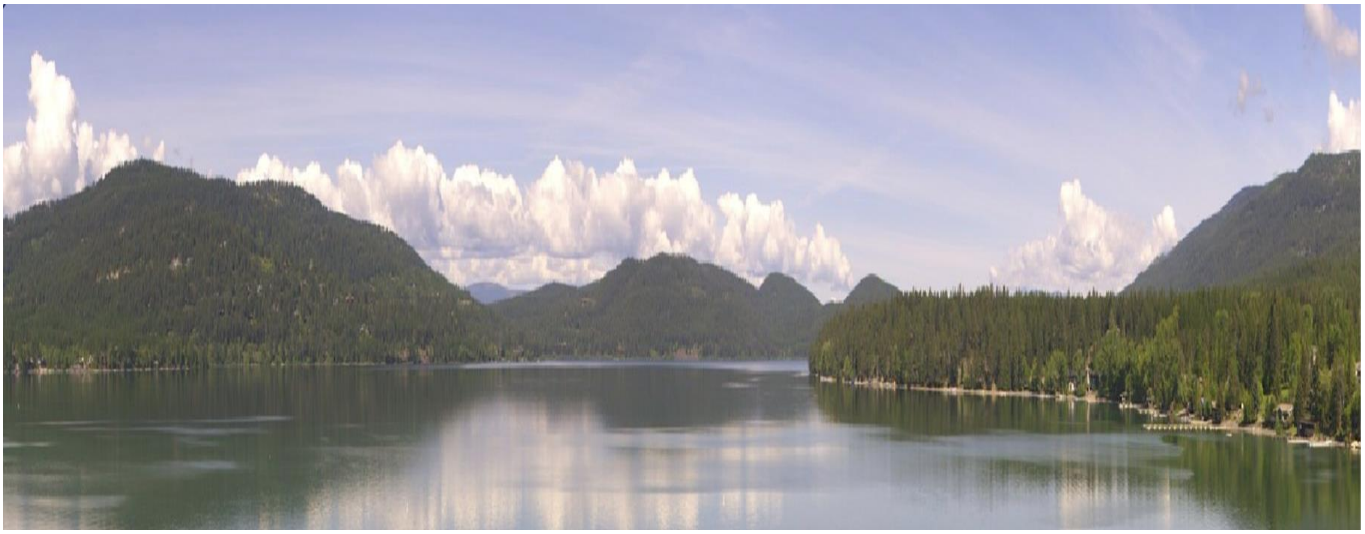
54th Anomalous Absorption Conference

May 11-15, 2026



Whitefish, Montana

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BLUE LASER FUSION

Physics of Plasmas

54th Anomalous Absorption Conference Agenda

Sunday, May 10, 2026

6:00-9:00 PM	Welcome Reception and Badge Pick-Up	Lakeside Pavilion

54th Anomalous Absorption Conference Agenda

Monday, May 11, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
8:15	**Introduction & Welcome**	**Jason Myatt, U. Alberta**
	Session 1: ICF: Shocks, Foams & Implosions	**Chair: Brian Haines**
8:30-9:00	Invited: Slowly rotating polarization state suppresses cross beam energy transfer in homogeneous expanding fusion plasmas	Gaurav Raj, Blue Laser Fusion
9:00-9:20	3D Simulations of Density Perturbations Seeded by the Structure of Dry and Wetted Foams	Adrien Pineau, LLE
9:20-9:40	Simulations of Shocks in Wetted Foams Irradiated by Intense Lasers Using the FLASH Code and Wetted Foam Target Stability	Andrey Solodov, LLE
9:40-10:00	Generation of Hot Electrons from Two Plasmon Decay and Monte Carlo transport in a 3D ALE-AMR hydrodynamics code for direct-drive ICF	Romain Liotard, LLE
10:00-10:20	Modeling direct-drive implosions with high-Z fuel dopants with the xRAGE code	Irina Sagert, LANL
10:20-10:40	Coffee Break	
	Session II: CBET I	**Chair: John Moody**
10:40-11:10	Invited: On the influence of optical smoothing techniques on cross-beam energy transfer	Yann Lalaire, CEA, DAM, DIF, F-91297 Arpajon, France
11:10-11:30	Comparison of laser absorption predictions from CBET models with experimental measurements	Dana Edgell, LLE
11:30-11:50	Numerical study of the impact of laser features on propagation within a plasma in the Inertial Confinement Fusion regime	Paula Cárdenas Ayala, French Alternative Energies and Atomic Energy Commission
11:50-12:10	Laser polarization effects on crossed-beam energy transfer in inertial confinement fusion	Pierre Michel, LLNL
12:10-1:10	Lunch in the Stumptown & Viking Rooms	
1:10-7:00	Open	
	Evening Plenary	**Chair: Wojciech Rozmus**
7:00-8:00	Creating Astrophysical Conditions at High Energy Density Facilities	Carolyn Kuranz, U. Michigan
8:00-10:00	**Poster Session I**	

54th Anomalous Absorption Conference Agenda

Monday, May 11, 2026 – Poster Session I, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Alejandro Campos, LLNL	Comparison of HED codes for ICF capsule simulations
P-2	Debolina Chakraborty, Stanford University	Resonantly Excited Structured Plasma Waves
P-3	Albert Countryman, UCLA	Kinetic Simulations of the Role of Pulse Shape and Density Scale Length on the Development of SRS under IFE Ignition Scale Plasma Conditions
P-4	Filipe Cruz, IST	Broadband laser mitigation of laser-plasma instabilities: a comparison of PIC simulations and Generalized Photon Kinetics
P-5	Christopher Grayson, LLNL	Beam Smoothing Effects on Laser–Plasma Instabilities: OMEGA 2D SSD for ICF-Relevant Plasmas
P-6	Andrew Longman, LLNL	Speckles with a Twist: Towards angular momentum smoothing in laser-plasma interactions
P-7	Bertrand Martinez, CEA DAM	Experimental characterization of metallic x-ray sources at the Omega laser facility
P-8	Jonathan Peebles, LLE	Utilizing the Electromagnetic Pulse from a High-Intensity Laser to Mitigate Laser Imprint
P-9	Benjamin Reichelt, LANL	Quantifying Low and Mid-Z Mix of an OMEGA Experiment Utilizing Nuclear and X-Ray Diagnostics
P-10	Wojciech Rozmus, University of Alberta	Laser–Plasma Coupling of Randomized Beams in Transverse Flow: Drag, Ion Heating, and Shock Formation
P-11	Camille Samulski, LANL	Exploring Capsule Design Space for Polar Direct Drive Inertial Fusion Energy Platforms
P-12	Atsushi Sunahara, Blue Laser Fusion	Irradiation Uniformity in a Direct-Drive Fusion Reactor Enabled by CBC-OEC Lasers
P-13	John Moody, LLNL	Comparison of Kinetic theory and PIC modeling of Magnetized laser-plasma interactions

54th Anomalous Absorption Conference Agenda

Tuesday, May 12, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session III: Laser Plasma Interactions	**Chair: Pierre Michel**
8:30-9:00	Invited: Absolute stimulated Raman scattering at densities below quarter critical	Russell Follett, LLE
9:00-9:20	Ray-tracing for diagnostic comparison at the Laser Mégajoule Facility	Cael Warner, U. Alberta
9:20-9:40	Experiment Design for Hot Electron Mitigation on the FLUX Platform	Janukan Sivajeyan, U. Alberta
9:40-10:00	Hello, World! pyF3D	Mikhail Belyaev, LLNL
10:00-10:20	Spectral phase optimization of broad band lasers enhances absolute instability thresholds beyond the coherence time limit	Archis Joglekar, Ergodic
10:20-10:40	Coffee Break	
	Session IV: ICF (Hohlraums, Rad Drive)	**Chair: Nicholas Ruof**
10:40-11:10	Invited: Contributions of Au Bubble Behavior to Hohlraum Bang Time Discrepancy	Brian Haines, LANL
11:10-11:30	When Marshak Waves Pass By: The Interface Temperature	Mordecai Rosen, LLNL
11:30-11:50	Initial results of the XFOL platform: studying radiation flow in a stochastic medium	Pawel Kozlowski, LANL
11:50-12:10	THOR: Developing a Next-Generation Platform for Radflow and Opacity Measurements	Ryan Lester, LANL
12:10-12:30	Maximization of Laser Coupling with Cryogenic Targets	Matthias Geissel, SNL
12:30-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-7:00	Open	
	Evening Plenary	**Chair: Jason Myatt**
7:00-8:00	Strategy to Achieve Robust Burn at the National Ignition Facility	Laurent Divol, LLNL
8:00-10:00	**Poster Session II**	

54th Anomalous Absorption Conference Agenda

Tuesday, May 12, 2026 – Poster Session II, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Skylar Dannhoff, MIT	Suppression of hohlraum wall expansion by pre-imposed axial magnetic fields on OMEGA
P-2	Blagoje Djordjevic, LLNL	How Symmetry Considerations Scale up to NextGen Drive Energies
P-3	Irem Nesli Erez, University of Colorado	Experimental Test of Magnetized LPI Theory Using Optical Thomson Scattering and Cross-Polarized CBET
P-4	Matthew Gjevre, University of Alberta	XUV Diagnostic System for Measuring the Focusing of Protons Produced by High Intensity Laser Pulses
P-5	Griffin Glenn, Sandia National Laboratories	Development of multi-frame 6 keV x-ray backlighting for the Z Machine using hybrid CMOS detectors
P-6	Elaine Koh, Stanford University/SLAC	Diffraction and Dispersion from Blazed Plasma Reflection Gratings
P-7	Ian Min-Roberts, University of Alberta	Laser Filamentation Seeded by Speckles and Particle Noise
P-8	Harsha Rajesh, Stanford University	Gas Power Meter and Beam Dump for High-Energy Lasers
P-9	Jill Schell, University of Michigan	Michigan Target Research and Fabrication (MiTRF)
P-10	Eleanor Tubman, University of California, Berkeley	Plasma expansion into background He-gas fills
P-11	Gina Vasey, LANL	Multigroup Radiation Diffusion with HOLO for Modeling PDD-EP
P-12	Erik Vold, LANL	Laser Driven Hydrodynamic Instabilities, Plasma Diffusion and Atomic Mixing in Inertial Confinement Fusion (ICF) Reactions

54th Anomalous Absorption Conference Agenda

Wednesday, May 13, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session V: ICF (Burn, Ignition NIF, Basic ICF, IFE)	**Chair: Andrey Solodov**
8:30-9:00	Invited: Towards Measuring Hotspot Temperature as a Proxy for Ignition Robustness	Benjamin Bachmann, LLNL
9:00-9:20	Important concepts commonly confused in fusion analysis	Baolian Cheng, LANL
9:20-9:40	Large-scale high-yield implosions for inertial fusion energy (IFE): enhanced performance and distinct physics characteristics	Darwin Ho, LLNL
9:40-10:00	Modeling Capsule Implosions in Indirect Drive THOR Experiments	Kevin Ma, LANL
10:00-10:20	Residual kinetic energy reduction in NIF inertial confinement fusion implosions	Nicholas Ruof, LLNL
10:20-10:40	Coffee Break	
	Session VI: CBET II	**Chair: Yann Lalaire**
10:40-11:10	Invited: New cross-beam energy transfer measurement platform at the National Ignition Facility	Nuno Lemos, LLNL
11:10-11:30	Validating cross-beam energy transfer models using indirect-drive ICF experiments at NIF	William Riedel, LLNL
11:30-11:50	Accuracy of the Ray-Tracing Modeling of Cross Beam Energy Transfer in Inertial Confinement Fusion Hohlraums	Albertine Oudin, LLNL
11:50-12:10	Cross-Beam Energy Transfer with Spectral Smoothing: influence of resonant frequency pairs on the energy transfer	Godefroy Meynard, French Alternative Energies and Atomic Energy Commission
12:10-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-2:30	Business Meeting in the Ramsey Room	
2:30-6:30	Open	
6:30-7:00	Reception, Lakeside Pavilion	
7:00-8:30	**Banquet in the Lakeside Pavilion**	
8:30-10:00	Fireside S’mores	

54th Anomalous Absorption Conference Agenda

Thursday, May 14, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session VII: Short Pulses, Compression	**Chair: Antonino Di Piazza**
8:30-9:00	Invited: Electron Dynamics in Realistic Short-Pulse, High-Intensity Laser Focal Fields	Caleb Guthrie, U. Alberta
9:00-9:20	Ionization-Seeded Current Filamentation in Collisionless Plasma Sheaths	Audrey Farrell, UCLA
9:20-9:40	Ultra-High-Intensity Regimes of Laser Self-Focusing	Caleb Redshaw, Stanford
9:40-10:00	High-Power Characterization of Ionization Diffraction Gratings	Victor Perez-Ramirez, Stanford University
10:00-10:20	Autoresonant Creation and Control of Plasma Structures	Jonathan Wurtele, UC Berkeley
10:20-10:40	Coffee Break	
	Session VIII: Optical Diagnostics: Thomson Scattering, CBET	**Chair: Jason Myatt**
10:40-11:10	Invited: Characterizing Plasma Conditions in ICF Hohlraums using 3 Optical Thomson Scattering	Steven Ross, LLNL
11:10-11:30	Thomson Scattering with Gain	David Turnbull, LLE
11:30-11:50	Measurements of plasma conditions with a high bandwidth ultraviolet laser using cross-beam energy transfer	Avi Milder, LLE
11:50-12:10	Geometric Optics Model of Thomson Scattering Enhanced by Parametric Coupling	Daniel Carleton, U, Alberta
12:10-12:30	Enhanced Ion-acoustic Wave Fluctuations Driven by Speckled Heater Beams	Kyle McMillen, LLE
12:30-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-7:00	Open	
	Evening Plenary	**Chair: Robert Fedosejevs**
7:00-8:00	Light-matter interaction in the strong-field QED regime	Antonino Di Piazza, LLE
8:00-10:00	**Poster Session III**	

54th Anomalous Absorption Conference Agenda

Thursday, May 14, 2026 – Poster Session III, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Sida Cao, Stanford University/SLAC	A Flying Focus with Arbitrary Directionality
P-2	Daniel Carleton, University of Alberta	Application of ray-tracing Thomson scattering theory to experimental data
P-3	Sarah Hansen, LANL	Validation of Scaling Capabilities of LANL’s xRage for Polar Direct Drive Implosions
P-4	Shaun Kerr, LLNL	First demonstration of a cone & wire backlighter for robust, high energy, small source size x-ray radiography using NIF-ARC
P-5	Sallee Klein, University of Michigan	High-energy-density Targets Fabricated by The University of Michigan
P-6	Jason Myatt, University of Alberta	Memories of Reuben Epstein
P-7	Vijay Patel, UCLA	Generalized multi-dimensional conservation laws for stimulated Raman and Brillouin scattering in a density gradient
P-8	Yuan Shi, University of Colorado	Particle-in-cell simulations of laser crossbeam energy transfer via magnetized ion-acoustic wave
P-9	William Taitano, LANL	Conditional Formulation for the Vlasov-Ampere Equations: A Novel Multiscale Structure Preserving Kinetic Plasma Formulation to Bridge Continuum and Kinetic Scales
P-10	Phil Travis, Ergodic	Optimizing designs and including multiscale physics in an implosion code via differentiable simulation
P-11	Frank Tsung, UCLA	Investigation of LPI near the quarter critical surface under the influence of temporal bandwidth
P-12	Justin Jeet, LLNL	Investigation of the D-T γ-to-neutron and D- 3 He γ-to-proton branching ratios at ICF facilities

54th Anomalous Absorption Conference Agenda

Friday, May 15, 2026

8:15	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session IX: High Energy Density	**Chair: Griffin Glenn**
9:00-9:30	Invited: Gas Optics for Tunable Beam Splitting, Harmonic Separation, and Spectral and Coherent Beam Combining	Ke Ou, Stanford University
9:30-9:50	Mean Force Kinetic Theory of Warm Dense Matter	Lucas Babati, U. Michigan
9:50-10:10	Coffee Break	
	Session X: ICF (R-T Instability, Radiation, Nuclear Diagnostics)	**Chair: Benjamin Bachmann**
10:10-10:30	Invited: Evidence of THOR Window Gap Closure in Experiment and Simulation	Damyn Chipman, LANL
10:30-10:50	Severity of the Deceleration Rayleigh-Taylor Instability in Inertial Confinement Fusion Targets	Jan Velechovsky, LANL
10:50-11:10	Hotspot mix diagnostics in Inertial Confinement Fusion experiments with the Nuclear Imaging System	Mora Durocher, LANL
11:10-11:20	Poster Awards and Conference Adjourns – See you next year!	
11:20	Grab and Go Lunch in the Stumptown & Viking Rooms	

Monday
May 11, 2026

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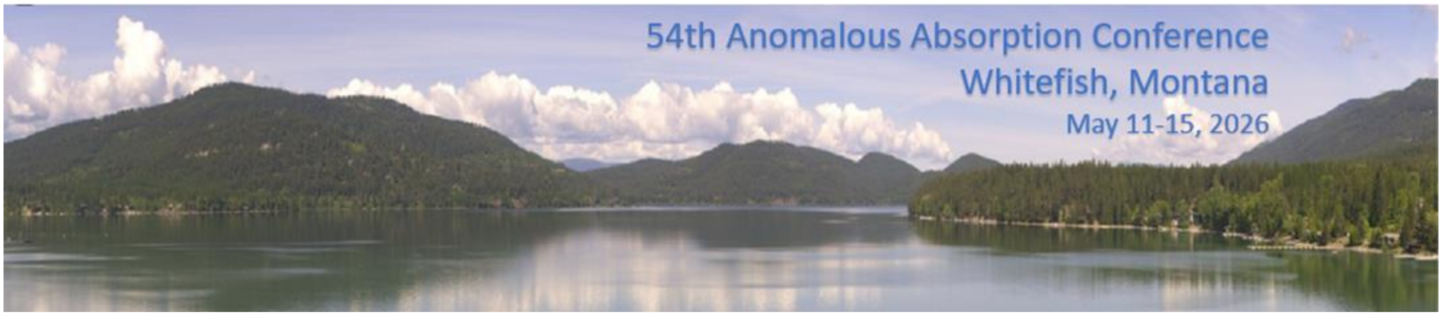
	Evening Plenary	**Chair: Wojciech Rozmus**
7:00-8:00	Creating Astrophysical Conditions at High Energy Density Facilities	Carolyn Kuranz, U. Michigan
8:00-10:00	**Poster Session I**	



Slowly rotating polarization state suppresses cross beam energy transfer in inhomogeneous expanding fusion plasmas

G. Raj,[1] A. Sunahara,[1] T. Cohen,[1] S. Gandrothula,[1] P. M. Pattison,[1] P. Rudy,[1] S. Nakamura,[1]
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Blue laser fusion (BLF) is developing a high-gain direct-drive inertial confinement fusion (ICF) power plant concept in which more than five hundred laser beams deliver multi-megajoule energy to a fusion target [1]. The system relies on coherent beam combining (CBC) together with optical enhancement cavities (OEC) to generate the required laser energy. During target irradiation, the coupling of laser energy into the plasma can be significantly influenced by laser-plasma instabilities (LPIs). These instabilities can perturb the spatial distribution of deposited energy and degrade the symmetry of the implosion. Among them, cross-beam energy transfer (CBET) is particularly important because it redistributes energy between intersecting laser beams through plasma mediated interactions, diverting energy away from the intended deposition region and potentially preventing ignition.

In this study, we introduce a method to suppress CBET by employing two circularly polarized laser beams with opposite helicity and a small frequency detuning that intersect within an expanding inhomogeneous plasma. Their superposition produces a slowly rotating polarization (SRP) state in the region where the beams overlap. Conventional mitigation strategies typically rely on broadband laser bandwidths. For example, for a laser wavelength of $\lambda_0 = 351$nm, a bandwidth of ≈ 8 THz, $\Delta\omega/\omega_0 \approx 1\%$ (where $\Delta\omega/2\pi$ and $\omega_0 = 2\pi c/\lambda_0$ are the laser bandwidth and angular frequency, respectively) would be required to eliminate CBET, which exceeds the capabilities of current ICF class laser systems. The approach proposed here avoids the need for large bandwidth by exploiting polarization dynamics generated by frequency detuned counter-rotating beams.

The interaction is examined using two-dimensional simulations with the laser plasma simulation environment (LPSE) [2]. Results demonstrate that the rotating polarization state can strongly reduce CBET across low and high intensity laser regimes and for side scattering and back scattering configurations. The simulations further reveal that the polarization evolution and rotation frequency within the overlap region are key parameters controlling the degree of suppression. This scheme provides a promising pathway toward minimizing CBET and achieving highly uniform laser irradiation of ICF targets, thereby improving energy coupling and enabling efficient implosion in future high gain direct-drive fusion reactors.

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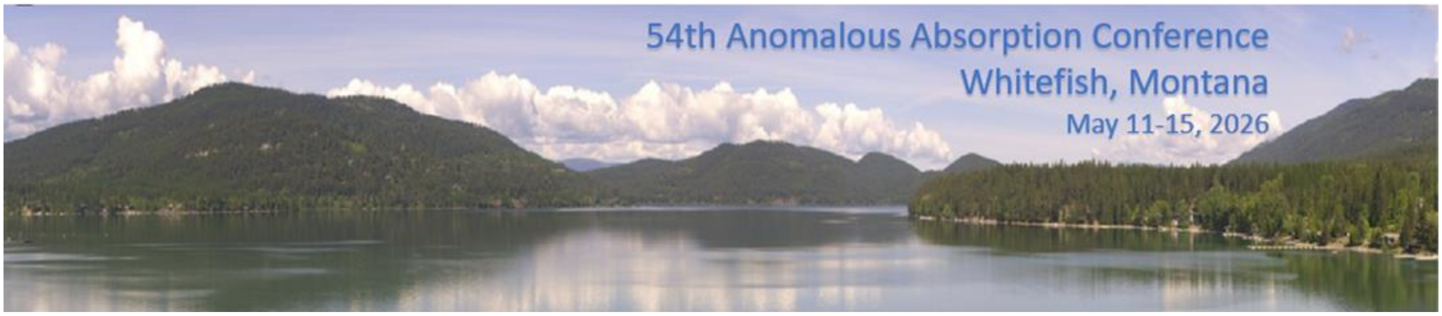
[1] A. Sunahara, G. Raj, T. Cohen, P. M. Pattison, P. Rudy, Y. Ohara, S. Iizuka, H. Ohta, and S. Nakamura, Opt. Express 33, 47104 (2025).

[2] J. F. Myatt, J. G. Shaw, R. K. Follett, D. H. Edgell, D. H. Froula, J. P. Palastro, and V. N. Goncharov, Journal of Computational Physics 399, 108916 (2019).



3D Simulations of Density Perturbations Seeded by the Structure of Dry and Wetted Foams*

A. Pineau,[1] A. Colaïtis,[1] T. J. B. Collins,[1] J. Peebles,[1] A. Solodov,[1] I. V. Igumenshchev,[1]
S. M. Fess,[1] L. Ceurvorst,[1] D. H. Froula,[1] and V. N. Goncharov[1]
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In laser direct-drive inertial confinement fusion (ICF), foams are a promising material expected to lead to high target performances while being relatively easy and inexpensive to produce. These foams are plastic matrices which may be dry (empty pores) or wet (pores containing deuterium-tritium) depending on the target design. Given the advances in additive manufacturing, the plastic matrix can be 3D printed allowing for a large variety of structures. Along with experiments, foam characterization requires multi-dimensional multiscale simulations due to the possible structure anisotropy and the difference between the structure sizescale and the foam layer thickness. Most of previous simulations were performed by assuming the foam as a homogeneous material with a density equal to the foam average density. We use here Excession[1,2], a 3D AMR-ALE radiative-hydrodynamic code, to directly mesh the foam structure and evaluate the resulting density perturbations on the hydrodynamics evolution.

We present a series of simulations modeling the propagation of a laser-driven shock in a target consisting of a plastic foil coated with an overcritical dry foam. Significant perturbations are observed with typical size approximately equal to the foam pore size. Shock perturbation amplitudes are found to be smaller when using a periodic logpile structure compared to a stochastic Voronoi structure for the considered foam thickness, which is a consequence of laser shinethrough and laser shadowing. On the contrary, areal density perturbations are found to have a smaller amplitude when using a Voronoi structure compared to a logpile structure, which results from foam homogenization. By comparing with similar simulations considering a wetted foam, we find that the density modulations near the ablation front are much larger in that case because of slower strut expansion and foam homogenization due to liquid DT. Finally, the role of radiation transport and the initial solid-to-plasma transition is investigated and we show that the resulting preheating strongly affects the amplitude of the density perturbations. This work opens the way to integrated simulations modeling the implosion of targets including foams and accurately evaluate the performance of such targets.

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* This work is supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award No. DE-SC0024863: IFE-STAR and AWD-00007026: INFUSE.

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[1] A. Colaitis, S. Guisset, J. Breil, *"A cell-centered AMR-ALE framework for 3D multi-material hydrodynamics. Part I: Lagrangian and indirect Euler AMR algorithms"*, J. Comp. Phys **552**, 114701 (2026)
[2] A. Colaitis, S. Guisset, J. Breil, *"A cell-centered AMR-ALE framework for 3D multi-material hydrodynamics. Part II: linesweep ALE rezoning for nonconformal block-structured AMR meshes"*, J. Comp. Phys **552**, 114702 (2026)

Simulations of Shocks in Wetted Foams Irradiated by Intense Lasers Using the FLASH Code and Wetted Foam Target Stability*

A. A. Solodov, T. J. B. Collins, A. Shvydky, R. C. Shah, I. V. Igumenshchev, A. Pineau, W. Trickey, D. Cao,
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Plastic foams saturated with liquid DT (wetted foams) have been proposed for use in many inertial confinement fusion and energy (ICF, IFE) target designs primarily for obviating layering challenges but also for advantages in stability and absorption. We present two-dimensional and three-dimensional simulations of laser interaction with planar wetted foam targets using the FLASH code, a highly versatile, parallel, adaptive mesh refinement, finite-volume Eulerian radiation-magnetohydrodynamics code with extended physics capabilities. These simulations address the impact of foam microstructure on the propagation of the laser-generated shock, post-shock plasma turbulence, homogenization, and subsequent acceleration. Systematic studies are being conducted as functions of foam density, pore size, and simulation dimensionality. Simulations demonstrate expansion of the plastic material into the surrounding DT ahead of the shock by the radiative preheat from the plasma corona, shock speed similar to that in a fully-homogenized plasma, difference in the turbulence regimes in two and three dimensions, and hydrodynamic instability of the accelerated wetted foam targets. We are particularly examining the impact of the foam structure on seeding of hydrodynamic instabilities in the ICF and IFE contexts.

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* 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 DE-NA0004144.

Generation of Hot Electrons from Two Plasmon Decay and Monte Carlo transport in a 3D ALE-AMR hydrodynamics code for direct-drive ICF

R. Liotard[1], A. Colaïtis[1]

[1]*Laboratory of Laser Energetics, University of Rochester, Rochester, NY*

Inertial Confinement Fusion (ICF) is a method of achieving nuclear fusion reactions by compressing a small mass of combustible material to high densities with the desired thermodynamic properties. In the direct-drive approach, high-power laser beams implode a spherical target consisting of DT fuel surrounded by a solid ablator. High-intensity laser beams interacting with the ablator plasma can drive Laser-Plasma Instabilities (LPI) such as Two-Plasmon Decay (TPD). These instabilities can generate suprathermal hot electrons, typically with energies E > 30-50 keV. These hot electrons can propagate deeply into the target and deposit their energy in the cold fuel, which can increase the fuel adiabat and significantly degrade implosion performance. Hot electron generation by LPIs has long been an open topic in the ICF community. Yet, transport models are not currently integrated into 3D direct-drive codes. Accounting for these electrons is crucial for understanding preheating effects in ongoing experiments and for reliably predicting the performance of future ignition designs.

This work focuses on the implementation of a coupled hot electron generation and propagation model within a 3D ALE-AMR radiation-hydrodynamics code. The generation mechanism is based on an absolute TPD model, which calculates the absolute intensity threshold for this instability at quarter-critical density ($n_e = n_c/4$) and the subsequent conversion rate of laser intensity into hot electrons. The model takes into account laser depletion and multibeam effects. The hot electron transport is handled by a 3D Monte Carlo module adapted to non-homogeneous plasmas. This approach allows for an accurate description of the electrons' scattering (including large-angle collisions), stopping power, and non-local energy deposition in the complex 3D geometry of an imploding target, while maintaining a reasonable computation time. This presentation focuses on the modeling aspects and will show preliminary results for OMEGA implosions.

This work is supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award No. DE-SC0024863: IFE-STAR and AWD-00007026: INFUSE.

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[1] A. Tentori et al. , Matter Radiat. Extremes **7**, 065902 (2022).
[2] E. Rovere et al. , Phys. Plasmas **30**, 042104 (2023)
[3] R. K. Follett et al. , Phys. Plasmas **24**, 102134 (2017).
[4] A. Colaïtis et al. , Journal of Computational Physics **552**, 114701 and 114702 (2026).

Modeling direct-drive implosions with high-Z fuel dopants with the xRAGE code*

I. Sagert[1], P.G. Maginot[1], C.-S. Wong[1], B. D. Keenan[1], E.G. Diaz[1], Z.J. Medin[1], K.A. Syed[1], C.J. Fontes[1], K.H. Farajnejadi[1], A.J. Andrews[1], R.S. Lester[1], J.R. Haack[1], S.H. Batha[1], K.A. Eriksen[1]
sagert@lanl.gov
[1]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Between 2006 and 2009, several experimental campaigns at the Omega Laser Facility studied the effect of high-Z dopants in D2 fuel of direct-drive implosions. Results from over 70 shots provided a record of implosion performance for different amounts of krypton, argon, and xenon in the gas fill. Numerical approaches have been struggling to reproduce the experimental data sets which include neutron yields, burn widths, and ion temperatures.

Here, we revisit the historic data with the multi-physics code xRAGE that is being developed at the Los Alamos National Laboratory. Using available and re-analyzed experimental data, we determine how well measurements can be matched with new simulations, testing the impact of different physics approaches to heat conductivity, nonlocal thermal equilibrium (nLTE), and plasma transport. We discuss numerical thermonuclear burn metrics such as neutron yields, bang times, and burn widths, but also examine X-ray emission from the implosion in the form of X-ray spectral and self-emission images.

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* Los Alamos National Laboratory is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract No. 89233218CNA000001. Release number LA-UR-25-27464.

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[1] G. A. Kyrala et al., High Energy Density Physics 3 (2007)

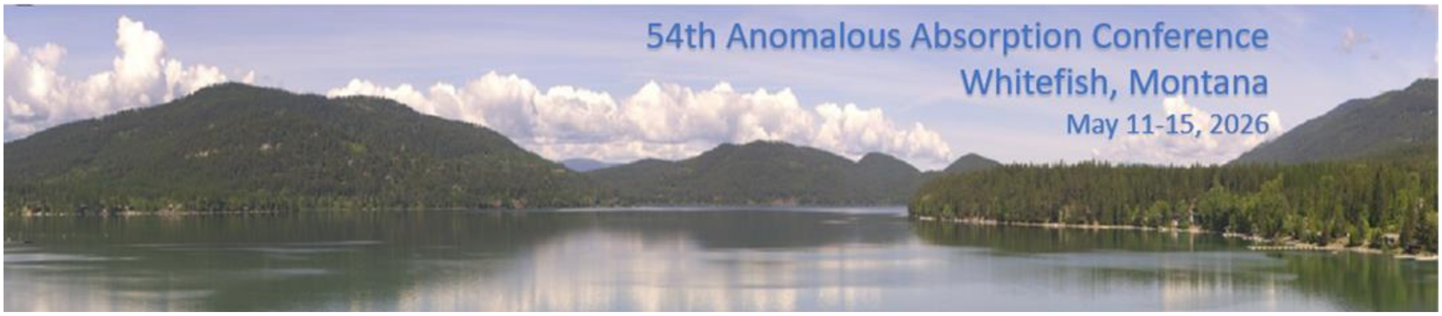
[2] D. C. Wilson et al., J. Phys: Conf. Series 112 (2008)

[3] W. J. Garbett, et al., J. Phys.: Conf. Series 112 (2008)

[4] E. S. Dodd, Phys. Plasmas 18 (2012)

[5] M. Gittings et al. Comput. Sci. Disc. 1.1, 015005 (2008)

[6] B. M. Haines et al. Phys. Plasmas 29, 083901 (2022)



On the influence of optical smoothing techniques on cross-beam energy transfer

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Optical smoothing of laser beams is widely used to better control laser propagation in inertial confinement fusion experiments[1], typically combining smoothing by spectral dispersion (SSD) with phase plates. Phase plates provide spatial smoothing by breaking the laser beam into a broad beam composed of small speckle structures[2], producing spatial incoherence. SSD, on the other hand, induces a periodic displacement[3] of these speckles through phase modulation and spectral dispersion. These techniques are employed in many high-energy laser facilities, including the National Ignition Facility and the Laser Mégajoule. It has been shown that Cross Beam Energy Transfer (CBET) can be significantly reduced when the realistic speckle structure of the beams is taken into account[4], potentially affecting the symmetrical compression of the fuel capsule in inertial fusion experiments[5].

We present a CBET model incorporating a realistic description of SSD, validated using PIC code and hydrodynamic paraxial code. This model shows that the power exchanged between beams results from a competition between spatial smoothing effects—either due to wavelength detuning between beams or plasma motion orthogonal to the direction of acoustic waves—and spectral dispersion effects. By simplifying this analytical model in the weak acoustic damping limit, we derive simple criteria for the influence of optical smoothing on CBET. This simplification also allows us to determine a CBET resonance width dependent on optical smoothing, forming the basis of a reduced CBET model for radiative hydrodynamics codes.

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*This work has been done under the auspices of CEA-DAM and the simulations were performed using HPC resources at TGCC/CCRT and CEA-DAM/TERA

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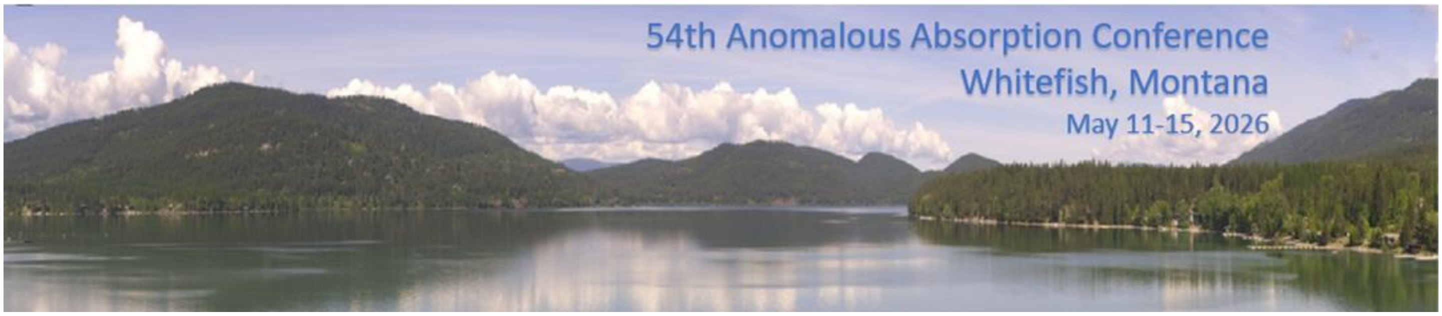
[1] H. Abu-Shawareb et al., "*Lawson Criterion for Ignition Exceeded in an Inertial Fusion Experiment,*" Phys. Rev. Lett. **132**, 065102 (2024).

[2] J. Garnier et al., "*Statistical analysis of the sizes and velocities of laser hot spots of smoothed beams*," Phys. Plasmas **8**, 4914 (2001).

[3] S. Skupsky et al., "*Improved laser beam uniformity using the angular dispersion of frequency-modulated light,*" J. Appl. Phys. **66**, 3456 (1989).

[4] A. Oudin et al., "*Theory and simulations of cross-beam energy transfer between speckled laser beams,*" Phys. Plasmas **32**, 042706 (2025).

[5] A. L. Kritcher et al., "*Design of the first fusion experiment to achieve target energy gain G>1,*" Phys. Rev. E **109**, 025304 (2024).



Comparison of laser absorption predictions from CBET models with experimental measurements

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The primary method of diagnosing the absorption of laser light in a direct-drive implosion is the measurement of the unabsorbed light scattered from the implosion. Time and spectrally-varying scattered light spectra measurements were the key to identifying cross-beam energy transfer (CBET) as the primary source of absorption degradation on OMEGA which has been critical to implosion performance improvements on OMEGA. Standard direct drive implosion modeling for OMEGA incorporates a CBET model into a 1-D hydrodynamics code.

However, CBET is inherently a 3-D problem due to differences between each beam, particularly the beam smoothing orientations on OMEGA. A 3-D CBET postprocessing code has shown that CBET induces large nonuniformities into the laser absorption and the distribution of scattered light.[1] The mode 1 orientation of the 3-D CBET modeled absorption corresponds to the direction of a persistent systematic mode 1 observed in OMEGA direct drive implosions.

The 3-D CBET postprocessor code is now been applied to cryogenic target implosions on OMEGA, including recent updating in the physics models for the Coulomb logarithm and ion screening. The 3-D predictions are compared to the 1-D hydrodynamics code and actual scattered light measurements. The predicted absorption distribution is compared to the mode-2 measured on the implosions to investigate if its source may be CBET related.

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[1] D. Edgell, A. Lees, R. Shah, A. Shvydky and D. Turnbull, “*Low-mode nonuniformity in direct-drive ICF implosions due to laser smoothing techniques employed on OMEGA,*” Phys. Plasmas **32**, 102701 (2025.


54th Anomalous Absorption Conference
Whitefish, Montana
May 11-15, 2026

Numerical study of the impact of laser features on propagation within a plasma in the Inertial Confinement Fusion regime

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In Inertial Confinement Fusion (ICF), as laser beams propagate through the plasma, various laser-plasma instabilities may occur that complicate the path to achieving fusion. Forward Stimulated Brillouin Scattering (FSBS) or the Filamentation Instability (FI) have in particular been identified as responsible for beam spray when the laser intensity exceeds a certain threshold [1,2]. Optical smoothing techniques, which consist in breaking both the spatial and temporal coherences of the laser pulse, have been used for several decades on large-scale laser facilities to mitigate laser-plasma instabilities. This work investigates the impact of the laser beam shape and dimensions on the development of propagation instabilities (FSBS and FI) both at best focus and at distances of a few millimeters from the focal region. The influence of the ion acoustic damping rate will also be discussed.

We have analyzed the impact of the near-field beam shape (Gaussian, disk, square, or rectangular) and of the far-field profile (Gaussian or hyper-Gaussian) on the beam spray threshold. The onset of beam spray is then interpreted using the criteria proposed in references [1] (FFOM) and [2,3] (GFOM). Our simulations show that the Quad LMJ configuration exhibits a significantly higher beam spray threshold than rectangular or square geometries, a behavior attributed to the larger numerical aperture associated with this configuration. We also investigate anamorphic rectangular geometries and observe that beam spray is reduced along the direction in which the speckle length is larger, both for rectangular and Quad [4]. Overall, the results indicate that both near-field and far-field beam shapes influence the beam breakup threshold and therefore contribute to the development of propagation instabilities. However, the observed trends suggest that the dominant parameter remains the total beam aperture. Finally, the effect of the position relative to beam focus is also examined by studying beam spray of the beam at a distance of 2 mm before and after the focal point. It is found that the beam at -2 mm (before) or +2 mm (after) from focus shows similar beam spray. Furthermore, even though the threshold (mean) intensity is larger for the beam at focus than it is for the beam out of focus, the threshold total power carried beam is smaller at focus than it is for the beam out of focus.

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1 D. H. Froula, L. Divol, N. B. Meezan, S. Dixit, P. Neumayer, J. D. Moody, B. B. Pollock, J. S. Ross, L. Suter, S. H. Glenzer; Laser beam propagation through inertial confinement fusion hohlraum plasmas. Phys. Plasmas 1 May 2007; 14 (5): 055705.
2Grech, M., Riazuelo, G., Pesme, D., Weber, S., \& Tikhonchuk, V. T. (2009). Coherent Forward Stimulated-Brillouin Scattering of a Spatially Incoherent Laser Beam a Plasma and Its Effect on Beam Spray. Physical review letters, 102(15), 155001.
3 Turnbull, D., Katz, J., Hinkel, D. E., Michel, P., Chapman, T., Divol, L., ... & Froula, D. H. (2022). Beam spray thresholds in ICF-relevant plasmas. Physical Review Letters, 129(2), 025001.
4 Moreau, J. G., Blanchot, N., Rousseaux, C., Baton, S. D., Penninckx, D., Fusaro, A., ... & Neauport, J. (2025). Stimulated Brillouin scattering dependence on polarization state, speckle shape, and polarization smoothing implementation. Physics of Plasmas, 32(3).

Laser polarization effects on crossed-beam energy transfer in inertial confinement fusion*

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Crossed-beam energy transfer (CBET) is a consequential process in inertial confinement fusion (ICF) experiments that depends on the polarization state of the interacting lasers and can, in turn, alter their polarization. We have derived analytical expressions for two-beam CBET with linearly and circularly polarized light, and will present simulations of CBET that include polarization effects for ICF conditions relevant to experiments on the National Ignition Facility (NIF). The results show that CBET mixes the polarization of the beams as they propagate through the target and leads to azimuthal power imbalances between beams within a given cone (i.e., at the same polar angle in the target chamber). These imbalances in CBET are shown to correlate with the imbalances in measured backscatter between beams of a same quadruplet in NIF experiments. We also show based on simulations that using circularly polarized instead of linearly polarized light is expected to produce similar overall levels of CBET within a cone of beams, but tends to reduce the azimuthal variations. This is expected to slightly improve irradiation symmetry and reduce the risk of backscatter from stimulated Brillouin scattering. Circular polarization may therefore be beneficial for the next generation of laser fusion drivers.

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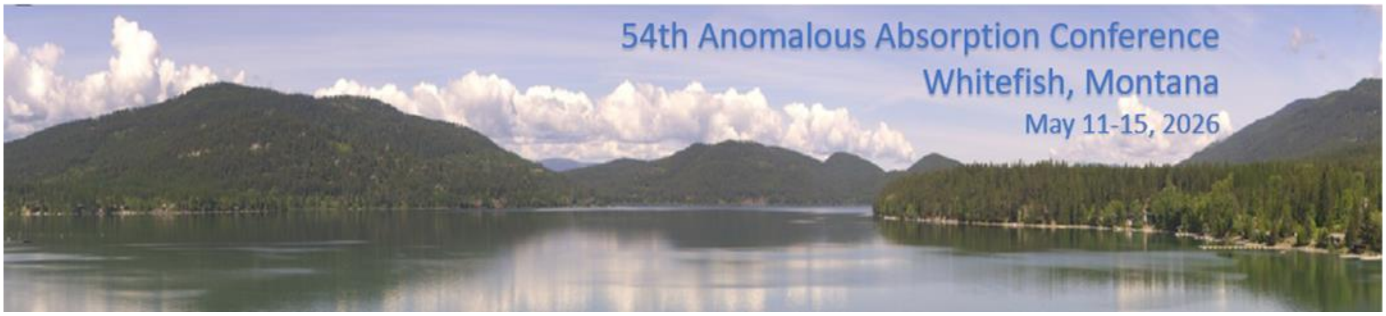
*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.



Creating Astrophysical Conditions at High Energy Density Facilities

Carolyn Kuranz

High Energy Density (HED) science is the study of matter in the extreme, where pressures are above 1 million atmospheres (10^6 atm ≡ 1 Mbar ≡ 0.1 TPa) and temperatures range from about 10,000 to over 1,000,000 K (a few eV to keVs). Such conditions can be created in inertial fusion experiments and naturally found throughout the Universe, for example, in accretion disks, planetary interiors, magnetospheres, supernova remnants, and astrophysical jets. Observations and simulations are key to understanding these complex phenomena. Astronomical observations certainly provide a wealth of information, but distance to these complex systems and the integrated nature of the measurements can limit our understanding. Astrophysical models and simulations can be computationally prohibitive due to the large range of spatial and temporal scales and the overall complexity of physical processes present. HED laboratory astrophysics experiments can complement both observational techniques and simulation results. HED facilities (e.g., NIF, Omega, Z-machine) can create systems on short timescales (picoseconds to nanoseconds) and small spatial scales (microns to millimeters) that allow us to investigate astrophysical objects and processes by creating similar conditions in controlled environments. Achieving a meaningful experimental analogy requires carefully considering factors such as the governing equations, appropriate spatial and temporal scaling, and global dynamics. I will present a framework for scaling astrophysical systems to laboratory conditions, carefully considering governing equations, spatial and temporal scaling, and global dynamics. Several HED laboratory astrophysics experiments will be highlighted to demonstrate how key physical processes can be isolated and studied in controlled settings.

54th Anomalous Absorption Conference Agenda

Monday, May 11, 2026 – Poster Session I, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Alejandro Campos, LLNL	Comparison of HED codes for ICF capsule simulations
P-2	Debolina Chakraborty, Stanford University	Resonantly Excited Structured Plasma Waves
P-3	Albert Countryman, UCLA	Kinetic Simulations of the Role of Pulse Shape and Density Scale Length on the Development of SRS under IFE Ignition Scale Plasma Conditions
P-4	Filipe Cruz, IST	Broadband laser mitigation of laser-plasma instabilities: a comparison of PIC simulations and Generalized Photon Kinetics
P-5	Christopher Grayson, LLNL	Beam Smoothing Effects on Laser–Plasma Instabilities: OMEGA 2D SSD for ICF-Relevant Plasmas
P-6	Andrew Longman, LLNL	Speckles with a Twist: Towards angular momentum smoothing in laser-plasma interactions
P-7	Bertrand Martinez, CEA DAM	Experimental characterization of metallic x-ray sources at the Omega laser facility
P-8	Jonathan Peebles, LLE	Utilizing the Electromagnetic Pulse from a High-Intensity Laser to Mitigate Laser Imprint
P-9	Benjamin Reichelt, LANL	Quantifying Low and Mid-Z Mix of an OMEGA Experiment Utilizing Nuclear and X-Ray Diagnostics
P-10	Wojciech Rozmus, University of Alberta	Laser–Plasma Coupling of Randomized Beams in Transverse Flow: Drag, Ion Heating, and Shock Formation
P-11	Camille Samulski, LANL	Exploring Capsule Design Space for Polar Direct Drive Inertial Fusion Energy Platforms
P-12	Atsushi Sunahara, Blue Laser Fusion	Irradiation Uniformity in a Direct-Drive Fusion Reactor Enabled by CBC-OEC Lasers
P-13	John Moody, LLNL	Comparison of Kinetic theory and PIC modeling of Magnetized laser-plasma interactions

Comparison of HED codes for ICF capsule simulations

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The variability in numerical discretizations and physics models across multi-physics HED codes can lead to different results for the same simulated experiments. This study quantifies the spread across rad-hydro codes that cover a broad spectrum of discretization strategies, modeling approaches, and development stages, such as the LLNL codes Hydra, Ares, and Marbl. Comparisons are performed for the NIF capsule design N210808, which contained a 3-layer diamond ablator driven by a 3-shock pulse and was the first to achieve ignition by most metrics [1]. The simulations exercise multiple physics packages, including multi-material hydro, photon radiation diffusion/transport, thermal conduction, material models, thermonuclear burn, etc. The sensitivity to 0D physics models, such as those for electron thermal conductivity, electron-ion coupling, and EOS scaling, is quantified. Similarly, the variability caused by different numerical techniques such as ALE, artificial viscosity, and quiet start is reported. Key output metrics compared include reaction rates, mass-averaged temperatures, capsule compression, and peak fuel velocity, among others. Special emphasis is placed on the Marbl code [2], which is a relatively recent multi-physics solver for HED applications currently under development at LLNL, and which leverages modern state-of-the-art computational methods [3].

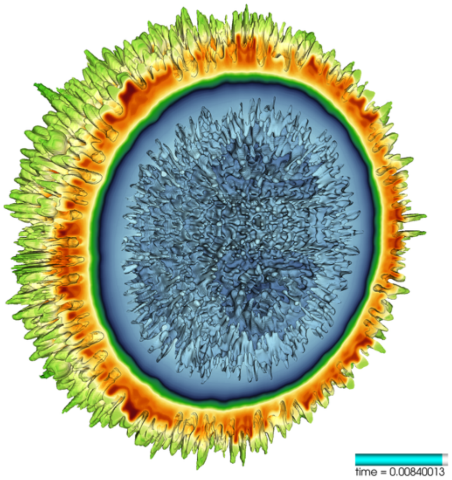

Figure: density contours obtained with the Marbl code of the DT ice and HDC inner ablator for the n210808 capsule, slightly before stagnation/burn.

*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-2016747

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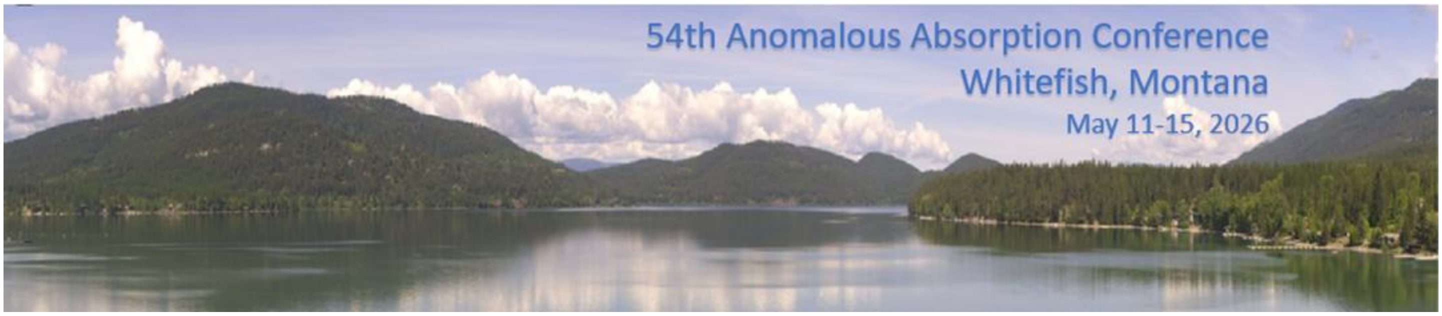
[1] H. Abu-Shawareb et al., “Lawson Criterion for Ignition Exceeded in an Inertial Fusion Experiment,” Phys. Rev. Lett. **Vol 129**, 075001 (2022).

[2] R. W. Anderson et al., “*The Multiphysics on Advanced Platforms Project: L1 Milestone Report,*” COJ-2020-0239, (2020).

[3] R. W. Anderson et al., “*High-order multi-material ALE hydrodynamics,*” SIAM J. Sci. Comput. **Vol 40**, No 1, page B32--B58 (2018).



Resonantly Excited Structured Plasma Waves

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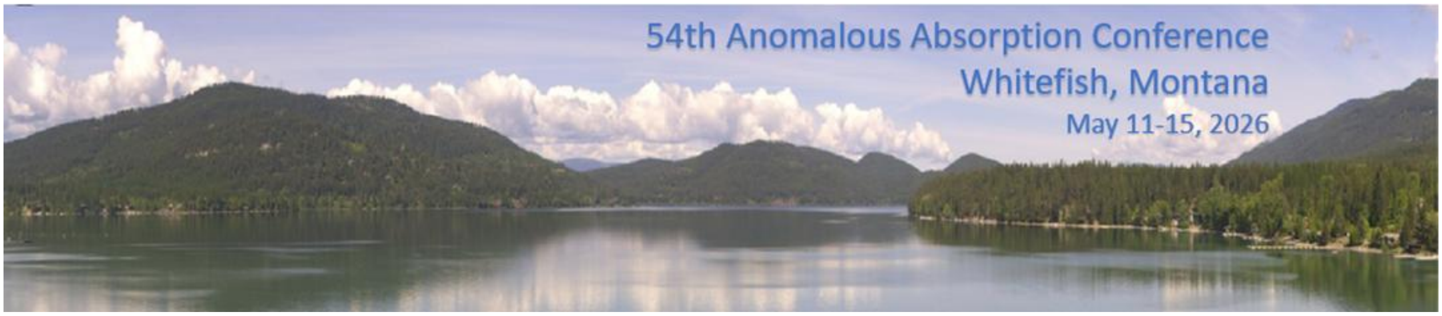
Spatiotemporal control of plasmas could enable a wide range of applications but remains challenging due to the rapid evolution and nonlinear processes inherent to plasmas. Structured laser-plasma interactions offer a promising route to such control, enabling transient plasma optics and targets for high-intensity applications. Among these interactions, resonant absorption allows for efficient coupling of an electromagnetic wave to plasma oscillations. Here we investigate resonant absorption as a mechanism to imprint the spatiotemporal structure of a laser pulse onto plasma oscillations. Particle-in-cell simulations of an arbitrarily shaped laser pulse interacting with a graded-density plasma demonstrate resonant excitation of an electron plasma wave that retains features of the incident pulse. These results reveal a pathway for dynamic and efficient shaping of plasmas with tailored spatiotemporal structure.

This work was supported by National Science Foundation grant PHY-2541940.



Kinetic Simulations of the Role of Pulse Shape and Density Scale Length on the Development of SRS under IFE Ignition Scale Plasma Conditions

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Laser-plasma instabilities (LPI) significantly impact the performance and viability of direct-drive inertial fusion energy (IFE) schemes by causing energy losses, asymmetric implosions, and fuel preheat from hot electrons. Understanding the development and interplay of key LPI processes—such as stimulated Raman scattering (SRS), two-plasmon decay, and cross-beam energy transfer—in inhomogeneous plasma density and temperature profiles relevant to IFE, and under varied laser drivers (differing in intensity, pulse shape, and bandwidth), is essential for developing effective strategies to control and mitigate their detrimental effects.

We have conducted a series of 1D kinetic particle-in-cell simulations using Osiris [1,2] to explore the development of SRS in plasma regimes relevant to ignition scale direct-drive IFE experiments. These simulations explore a parameter space spanning a wide range of density profile scale lengths, laser pulse intensities, durations and bandwidths, to determine the conditions under which SRS (at densities near and far below quarter critical) manifests in these plasmas. The parameters varied within these simulations are motivated by previous studies which use bandwidth to control LPI. Work by Wen et al. has used particle-in-cell simulations to demonstrate that increasing frequency bandwidth can effectively reduce convective SRS gain in the kinetic regime [3]. Additionally, recent work by Joglekar has demonstrated a method for using AI/ML to optimize temporal bandwidth in laser pulses to control LPI near the quarter-critical layer [4]. Our 1D kinetic simulations can verify the degree to which specific pulse shapes (such as those mentioned above) mitigate the growth of LPI holistically, with particular focus on the growth of forward SRS and convective backward SRS at lower plasma densities. We examine the spectral content of transmitted and reflected light and quantify the generation of heat flux past the quarter-critical surface. This work aims to contribute to establishing guidelines for predicting the efficacy of future ignition scale direct drive IFE experiments involving longer plasma density scale lengths and novel pulse shapes.

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*This work is supported by IFE-COLoR, LLE subcontract 00001031.

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[1] R. A. Fonseca et al., “OSIRIS: A three-dimensional, fully relativistic particle in cell code for modeling plasma based accelerators,” Lecture Notes in Computer Science, Vol. 2331, pp. 342–351 (2002)

[2] R. A. Fonseca et al., “Exploiting multi-scale parallelism for large scale numerical modelling of laser wakefield accelerators,” Plasma Phys. Controlled Fusion 55, 124011 (2013)

[3] H. Wen et al., “Suppressing the enhancement of stimulated Raman scattering in inhomogeneous plasmas by tuning the modulation frequency of a broadband laser,” Phys. Plasmas **28**, 042109 (2021).

[4] A. Joglekar, personal communication
(2025).

Broadband laser mitigation of laser-plasma instabilities: a comparison of PIC simulations and Generalized Photon Kinetics

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Laser-plasma instabilities (LPIs) play a critical role in inertial confinement fusion (ICF). Processes such as Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), or Two-Plasmon Decay (TPD) can redirect laser energy and generate hot electrons that preheat the fuel, degrading compression and ignition performance. Suppressing these instabilities is essential for achieving fusion-relevant conditions. Among the different mitigation strategies suggested, the use of broadband lasers has emerged as a promising approach[1-3]. However, the bandwidth dependence on these instabilities remains incompletely quantified.

In this work, we investigate the role of bandwidth and spectral structure in the development of LPIs under ICF-relevant conditions. We compare particle-in-cell (PIC) simulations performed with OSIRIS[4], extended to describe lasers with arbitrary bandwidths and spectral features, with the theoretical predictions of Generalized Photon Kinetics (GPK), focusing on the bandwidth dependence of the linear growth rates of SRS[5] and SBS backscatter[6]. Using GPK, we further examine how different laser spectra configurations influence instability development in multidimensional geometries. These results allow the study of effective strategies for employing broadband lasers to mitigate LPIs in inertial confinement fusion.

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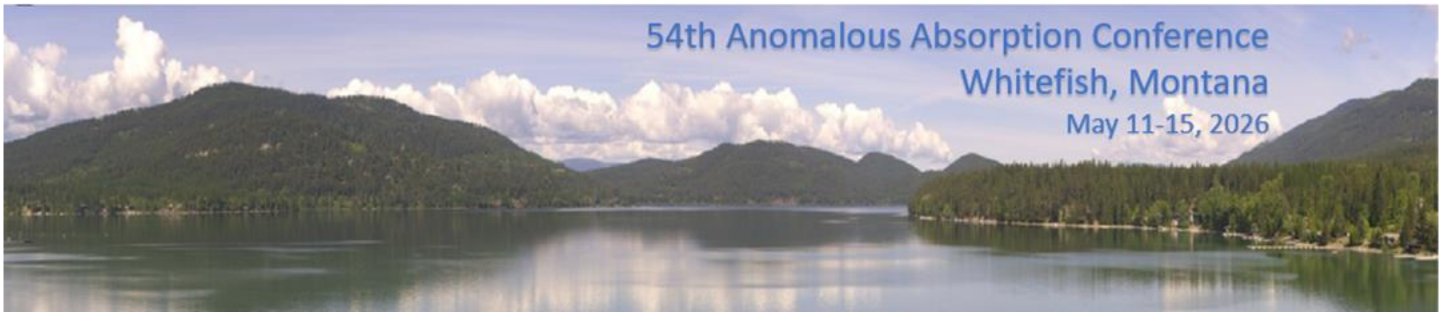
[1] J. J. Thomson and Jack I. Karush, Physics of Fluids **17**, 1608–1613 (1974)
[2] R. K. Follett, J. G. Shaw, J. F. Myatt, *et al.*, Physics of Plasmas **26**, 062111 (2019)
[3] A. Lei, N. Kang, Y. Zhao, *et al.*, Physical Review Letters **132**, 035102 (2024)
[4] R. A. Fonseca, L. O. Silva, F. S. Tsung, *et al.*, Lecture Notes in Computer Science **2331**, 342–351 (2002)
[5] J. E. Santos, L. O. Silva, and R. Bingham, Phys. Rev. Lett. **98**, 235001 (2007)
[6] B. Brandão, J. E. Santos, R. M. G. M. Trines, *et al.*, Plasma Phys. Control. Fusion **63**, 094003 (2021)



Beam Smoothing Effects on Laser–Plasma Instabilities: OMEGA 2D SSD for ICF-Relevant Plasmas*

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We investigate forward scattering and beam spray in ICF-relevant plasmas using pF3D simulations and scattering theory, with direct comparisons to beam-smoothing experiments at OMEGA employing 2D smoothing by spectral dispersion (SSD) and random phase plates (RPP) [1]. We validate simulations by comparing to experimentally measured beam spray, quantified by the increase in effective f-number or the corresponding broadening of the near-field beam radius. To disentangle the forward-scattering processes that contribute to beam spray and increase the effective f-number, we analyze the simulated structure function of plasma fluctuations in frequency and wave-vector across the SSD-imposed laser bandwidth. We use these spectral signatures to identify the roles of intra-beam energy transfer (IBET) [2], filamentation, and FSBS [3] in the development of small-angle scatter and transmitted-beam broadening. This approach links experimentally accessible beam-spray observables to the underlying forward-scatter physics. We discuss implications for the effectiveness of spatial and temporal smoothing via variations in RPP speckle statistics and SSD parameters in mitigating forward-scatter instabilities and controlling beam spray in ignition-relevant regimes in preparation for high-bandwidth experiments like FLUX.

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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.

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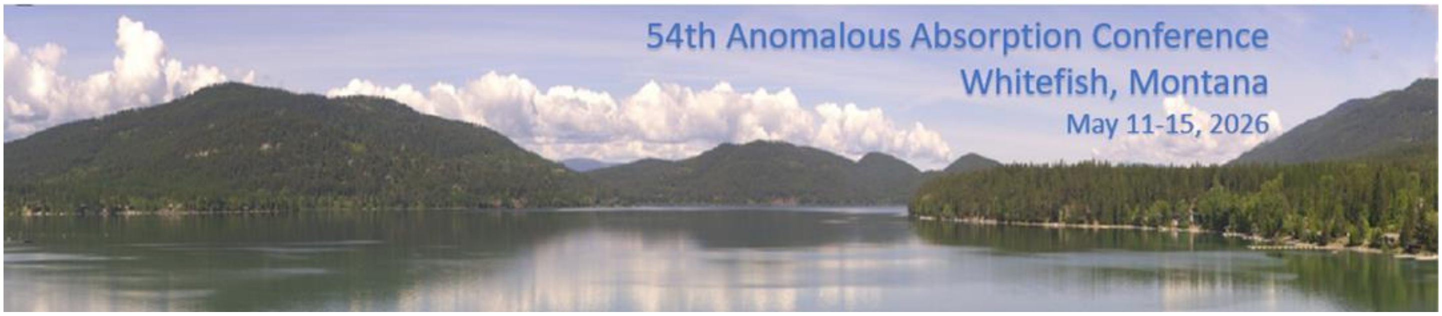
[1] D. Turnbull, J. Katz, D. E. Hinkel, *et al*., "Beam Spray Thresholds in ICF-Relevant Plasmas," *Physical Review Letters* **129**, 025001 (2022).
[2] J. D. Ludwig, P. M. Michel, T. Chapman, and M. Belyaev, "Dynamic Control of the Spatial Frequency Content of an Intense Laser via Intra-Beam Energy Transfer," *Physics of Plasmas* **31**, 022101 (2024).
[3] C. Ruyer, P. Loiseau, D. Turnbull, and V. Tikhonchuk, "Statistical Model of the Stimulated Forward Brillouin Scattering Driven by a Randomized Laser Beam in Plasma," *Physical Review E* **111**, 025207 (2025).



Speckles with a Twist: Towards angular momentum smoothing in laser-plasma interactions

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Beam smoothing techniques such as continuous phase plates, polarization smoothing, and smoothing by spectral dispersion have formed the backbone of laser–plasma instability (LPI) mitigation in inertial confinement fusion (ICF) schemes for decades. However, as drive energies continue to increase, so too does the risk of damaging backscatter. This raises the question: can additional mitigation strategies be developed?

One proposed alternative is to utilize angular momentum smoothing between crossing beams. Analogous to the use of frequency detuning between beams, it is possible to detune the net angular momentum between adjacent beams. This detuning can be shown to reduce overall backscatter at the single-speckle level [1,2], but has not yet been demonstrated in multi-speckle beams.

In this work, we explore this novel approach to beam smoothing through several avenues. We demonstrate the implementation and characterization of spiral phase optics in high-energy laser systems such as the Janus laser facility. In addition, we demonstrate the first relativistic-intensity spatiotemporal light springs generated with an ultrafast laser [3]. We further investigate the conservation of orbital angular momentum in speckled beams and explore possible mechanisms for inducing plasma rotation. Finally, we discuss how introducing an orbital angular momentum bandwidth between crossing laser beams may reduce backscatter growth rates.

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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 No. DE-AC52-07NA27344. This work was supported in part by the Laboratory Directed Research and Development (LDRD) program under Projects No. 24-ERD-031 and 25-LW-113; by the National Science Foundation under Grants No. DMR-1548924 and PHY-1753165; by the U.S. Department of Energy under Grant No. DE-SC0023504; and by the Natural Sciences and Engineering Research Council of Canada under Grant No. RGPIN-2019-05013

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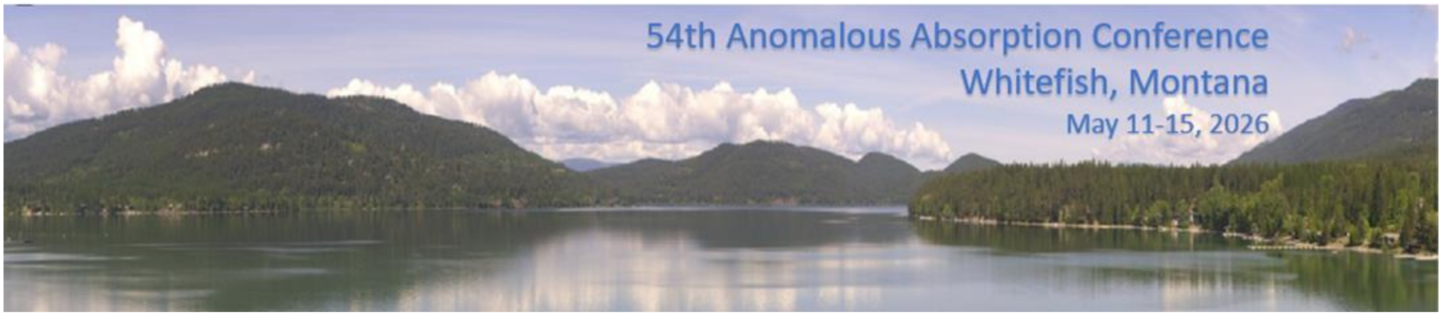
1 J. T. Mendonca et al, *Stimulated Raman and Brillouin backscattering of collimated beams carrying orbital angular momentum*, Phys. Rev. Lett. 102, 185005 (2009).

[2] Y. Guo, et al, *Suppression of stimulated Raman scattering by angularly incoherent light, towards a system of incoherence in all dimensions of time, space, and angle*. Matter and Radiata. at Extrem. 8, 035902 (2023).

[3] A. Longman et al., "*Spatiotemporal shaping of broadband helical light pulses at relativistic intensities,*" Under review, Nature Photonics (2025).



Experimental characterization of metallic x-ray sources at the Omega laser facility

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The development of kilojoule-class X-ray sources has significant applications in high-energy-density science, enabling radiography and absorption spectroscopy to characterize material properties. Radiation-hydrodynamic codes are the primary tool to characterize such sources. However, detailed and direct computation of plasma ionization and opacities is beyond the reach of modern supercomputers, particularly for non-local thermodynamic equilibrium (NLTE) plasmas. To address this, several simplified NLTE models[1-3] were implemented in the code Troll[4] developed at CEA. While these models offer computationally manageable run-times, they rely on strong hypotheses that require experimental validation.

In this work, we compare simulations including different opacity models to experimental results obtained at the OMEGA laser facility. The experiment aimed to assess the performance of x-ray sources driven from metallic foils made of zirconium (Zr), molybdenum (Mo), palladium (Pd) and spheres coated with silver (Ag), irradiated under a range of laser conditions. Radiant power and total emitted energy were measured over several spectral bands using the broadband spectrometers DMX and mini-DMX. In addition, the emissive hot plasma regions were diagnosed with Thomson scattering. The full set of experimental measurements was compared with predictions from two-dimensional radiation-hydrodynamic simulations performed using the code TROLL, showing overall good agreement.

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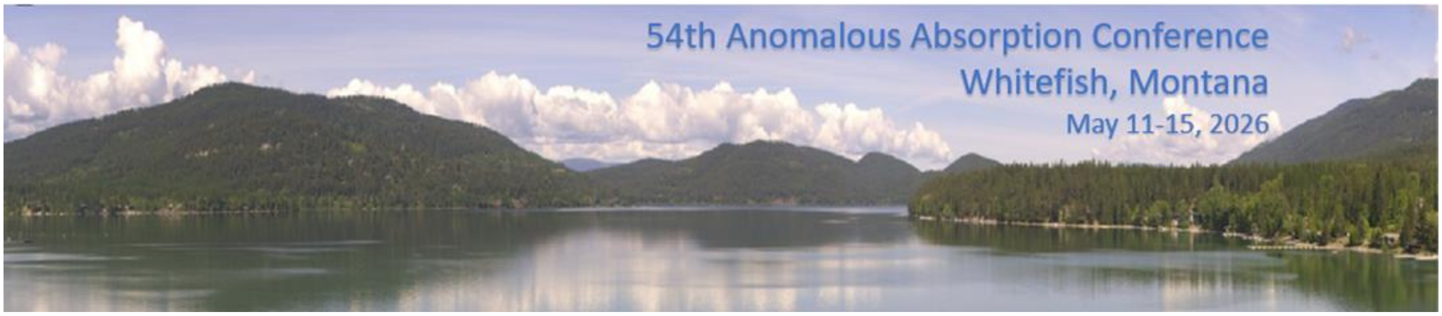
[1] M. Busquet, Phys. Fluids B 5, 4191-2026 (1993)
[2] C. Bowen and P. Kaiser J. Quant. Spec. Rad. Transf. 81, 85-96 (2003)
[3] F. Gilleron and R. Piron, High. Energy. Dens. Phys. 17, 219 (2015)
[4] E. Lefebvre et al., Nucl. Fusion 59, 032010 (2018)


54th Anomalous Absorption Conference
Whitefish, Montana
May 11-15, 2026

Utilizing the Electromagnetic Pulse from a High-Intensity Laser to Mitigate Laser Imprint

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Nonuniformities in laser direct drive inertial confinement fusion due to laser speckle and beam-to-beam intensity variations can seed hydrodynamic instabilities, such as Richtmyer–Meshkov (R-M) and Rayleigh–Taylor (R-T). Techniques to mitigate laser imprint often utilize a low-density plasma surrounding the target to expand the conduction zone, increasing thermal smoothing. To establish this plasma, complex targets with engineering challenges have been proposed using foams[1], multi-shell targets[2], or pre-expanded high-Z layers[3].

We propose and demonstrate a simpler approach: utilizing the electromagnetic pulse from a short-pulse high-intensity laser incident on the target's supporting structure to establish a low-density plasma over many nanoseconds prior to the implosion. We have used this platform, called "Zap", in several planar campaigns on EP and two joint shot days with spherical implosions on OMEGA. With planar radiography we demonstrate the ability to mitigate laser imprint, while providing insight into the mechanism by which the plasma is expanded. Joint shot days explored implosions with and without SSD beam smoothing, and with and without the short-pulse Zap. An increase in yield with Zap and SSD off was observed that exceeded SSD alone, indicating that the imprint was mitigated in these implosions. Finally, the path forward with further warm and cryogenic implosions will be presented.

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* 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 DE-NA0004144.

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[1] S. X. Hu, *et al.*, Phys. Plasmas 25, 082710 (2018)
[2] L. Ceurvorst, *et al.*, Phys. Rev. E 101, 063207 (2020)
[3] M. Karasik, *et al.*, Phys. Rev. Lett. 114, 085001 (2015)

Quantifying Low and Mid-Z Mix of an OMEGA Experiment Utilizing Nuclear and X-Ray Diagnostics

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Characterizing mix between the shell and hot spot has been the subject of many studies in Inertial Confinement Fusion (ICF). Shell mix can degrade yield through increased bremsstrahlung emission, lead to increased hot spot mass, or even be intentionally sought out to measure certain nuclear reactions. A common experimental setup to diagnose mix is to embed certain tracer species in the shell that can be measured with some diagnostic. In this work, we detail the design and analysis of a separated reactant experiment that simultaneously measures the mixture of low and mid-Z materials with the help of nuclear and x-ray diagnostics, respectively.

These experiments involve 200 nm thick alternating inner layers of CD + 2% Ti and CH + 2% Ge with a 3He fill, and an outer CH ablator 7 um thick. D3Hep emission serves as a mix signature for the low Z D species, while Multi-Monochromatic Imager data allows reconstruction of Ti and Ge number density profiles and electron temperature profiles via a novel reconstruction technique. Initial analysis suggests little no mix into the hot spot of mid-Z dopants regardless of location in the shell, in line with both kinetic and hydrodynamic/fluid diffusion modeling. Kinetic simulations and hydrodynamic simulations diverge more noticeably for the deuterium specie, with enhanced deuterium mix predicted by simulations.

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*This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, under Award Number DE-SC0024306; the experiment was conducted at the Omega Laser Facility with the beam time through the National Laser Users' Facility (NLUF). B. L. Reichelt was supported to do this work in part by the NNSA SSGF under Contract DE-NA0003960 until 2025. From 2025-present, this work was conducted 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.

Laser–Plasma Coupling of Randomized Beams in Transverse Flow: Drag, Ion Heating, and Shock Formation

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High-energy laser interaction with flowing plasmas can drive a range of collective responses, including beam bending and, via momentum conservation, a reduction of the plasma flow velocity [1]. When an initially supersonic flow is decelerated to subsonic speeds, the speckled structure of the laser intensity can promote shock formation within the plasma [2,3].

Motivated by experimental results from Omega, we investigate the physical processes governing shock formation and laser–plasma coupling in the presence of transverse plasma flow. In fluid descriptions, the deceleration associated with laser beam bending is captured through an effective drag coefficient [1,2]. This drag originates from ion scattering off localized electrostatic fields generated by ponderomotive forces and pressure gradients associated with laser speckles. Owing to the stochastic nature of this interaction, the directed kinetic energy of the flow is converted into ion thermal energy.

This presentation focuses on particle-in-cell (PIC) simulations of a random phase plate (RPP) laser beam interacting with a transverse plasma flow in the vicinity of the sonic layer. Ion heating due to scattering from speckle-induced fluctuations is identified and distinguished from heating associated with shocks and ion-acoustic waves driven by forward stimulated Brillouin scattering (FSBS) and filamentation instability. The simulation results are compared with theoretical models, and the parameter regimes relevant to shock formation, particle heating, and beam scattering are assessed.

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[1] H.A. Rose, Phys. Plasmas **3**, 1709 (1996).
[2] J. D. Ludwig, S. Hüller, H. A. Rose, C.Bruulsema, W.Farmer, P.Michel, A.Milder, G.F.Swadling, W.Rozmus, Phys. Plasmas **31** (3), 032103 (2024).
[3] A.L. Milder, C. Bruulsema, S. Hüller, C. Walsh, W. Rozmus, L. Yin, J. D. Ludwig, W. Farmer, B.J. Albright, H.A. Rose, G.F. Swadling, Phys. Rev. Res. **7,** 013163 (2025).

Exploring Capsule Design Space for Polar Direct Drive Inertial Fusion Energy Platforms*

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The successful demonstration of energy gain in inertial confinement fusion (ICF) supports the feasibility of laser fusion in laboratory settings and as a viable energy source. The next step towards energy scalability lies in developing cost-effective systems to requiring advanced target designs compatible with production scalability, efficient laser operations, and energy conversion systems. A polar direct drive (PDD) spherical target fielded on a facility with sufficient power for maximal energy production is one pathway for future planned high rep-rate experimental platforms. Using the Los Alamos National Laboratory's (LANL) common model framework (CMF) with the radiation hydrodynamic code xRAGE, we can ground our design exploration of PDD targets in validated physics modeling choices benchmarked against experimental data. Using Bayesian Optimization tools shaped, time dependent energy profiles and target design studies are performed in 1D. Theses 1D studies are used to as the basis for 2D complex simulations intended to explore the potential design space for high-gain capsules fielded at a 10MJ laser facility. This work presents the progress of the 1D high-gain capsule studies and the transition to 2D high fidelity modeling for the highest gain target designs. This document has been provided release under the identifier LA-UR-00-00000.

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Irradiation Uniformity in a Direct-Drive Fusion Reactor Enabled by CBC-OEC Lasers

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R. Fukuda,[1] S. Iizuka,[1] Y. Ohara,[1] H. Ohta,[1] A. Arefiev,[2] F. Beg,[2] S. K. Tsubakimoto,[3] and S. Nakamura[1]
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Recent advances in optical enhancement cavity (OEC)-based laser technology are enabling efficient generation of high-energy, high-repetition-rate laser pulses for direct-drive inertial confinement fusion. Building on these developments, we present a conceptual direct-drive inertial fusion energy (IFE) reactor featuring highly uniform irradiation and mitigation of laser-plasma instabilities (LPIs)[1].

In the proposed architecture, coherently combined fiber-laser pulses are injected into high-finesse optical cavities to generate fusion-relevant pulse energies without relying on conventional large-aperture glass amplifiers. A key advantage of this approach is its scalability to an extraordinarily large number of beams. Our reactor concept employs on the order of 500 to 5,000 laser beams to deliver multi-megajoule laser energy to the target at repetition rates of 4-10 Hz.

For direct-drive laser fusion, irradiation uniformity is one of the most critical requirements for stable and efficient implosion. Because CBC-OEC technology can support a far larger number of beams than conventional laser fusion drivers, it offers much greater flexibility in beam arrangement, pointing, and power distribution. We evaluate representative multi-beam direct-drive configurations and discuss how the very large number of beams improves target illumination. Our estimates indicate that this approach can realize extremely low irradiation nonuniformity and highly uniform target drive.

In addition to this geometric advantage, multi-color operation using slightly shifted central wavelengths can provide an effective relative bandwidth of about 1.9%, and the superposition of circularly polarized beams with different wavelengths can produce slowly rotating polarization on the target. These features are expected to mitigate LPIs, including cross-beam energy transfer (CBET).

These results highlight the potential of CBC-OEC technology as a scalable driver for highly uniform, reactor-relevant direct-drive fusion.

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[1] A. Sunahara *et al.*, “Laser-based Inertial Fusion Energy System Enabled by Optical Enhancement Cavities and a Direct-Drive Configuration Reactor,” *Optics Express* 33 47104-47120 (2025).

Preferred presentation format: Poster

Comparison of Kinetic theory and PIC modeling of magnetized laser-plasma interactions

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Experimental high energy density (HED) laboratory research typically involves using high-powered lasers propagating through plasmas with externally applied and/or self-generated magnetic fields. Interactions between the lasers and plasma can arise leading to effects such as stimulated Brillouin and Raman scattering, cross-beam energy transfer, filamentation and other interactions. The magnetic field can cause Faraday rotation of the lasers and introduce magnetized normal plasma modes to the interactions. New effects arise such as laser scattering in the direction of the pump laser's electric field polarization and stimulated scattering from ion and electron Bernstein modes. We have developed a semi-analytic kinetic model of laser scattering in a magnetized plasma [1] and compare the results with PIC simulations [2]. We discuss similarities and differences in the results and discuss ideas that can test the two models experimentally.

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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 by the LLNL-LDRD program under Project Number 23-ERD-025.

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[1] J. D. Moody, Y. Shi, "Vlasov theory of magnetized cross-beam energy transfer in a high energy density plasma", submitted to Physics of Plasmas (2026).

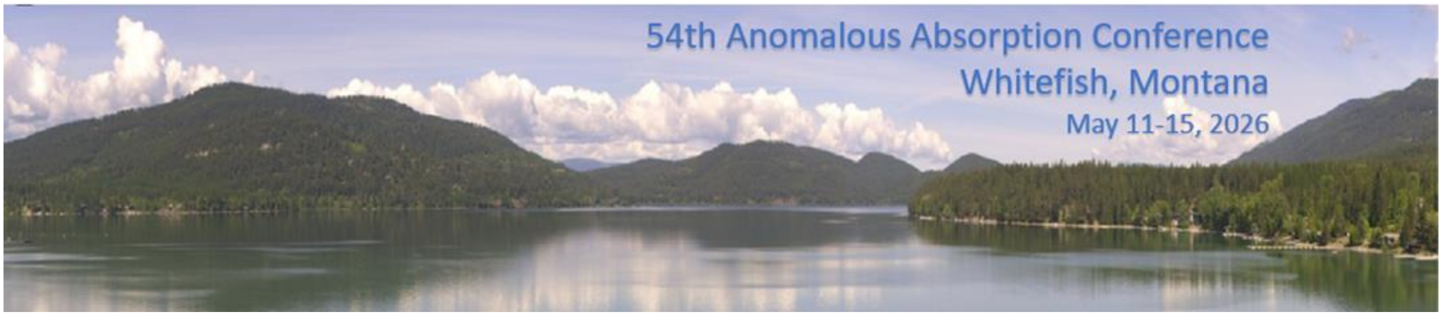
[2] Y. Shi, J. D. Moody, "Particle-in-cell simulations of laser crossbeam energy transfer via magnetized ion-acoustic wave," Physics, accepted (2026).

Tuesday
May 12, 2026

54th Anomalous Absorption Conference Agenda

Tuesday, May 12, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session III: Laser Plasma Interactions	**Chair: Pierre Michel**
8:30-9:00	Invited: Absolute stimulated Raman scattering at densities below quarter critical	Russell Follett, LLE
9:00-9:20	Ray-tracing for diagnostic comparison at the Laser Mégajoule Facility	Cael Warner, U. Alberta
9:20-9:40	Experiment Design for Hot Electron Mitigation on the FLUX Platform	Janukan Sivajeyan, U. Alberta
9:40-10:00	Hello, World! pyF3D	Mikhail Belyaev, LLNL
10:00-10:20	Spectral phase optimization of broad band lasers enhances absolute instability thresholds beyond the coherence time limit	Archis Joglekar, Ergodic
10:20-10:40	Coffee Break	
	Session IV: ICF (Hohlraums, Rad Drive)	**Chair: Nicholas Ruof**
10:40-11:10	Invited: Contributions of Au Bubble Behavior to Hohlraum Bang Time Discrepancy	Brian Haines, LANL
11:10-11:30	When Marshak Waves Pass By: The Interface Temperature	Mordecai Rosen, LLNL
11:30-11:50	Initial results of the XFOL platform: studying radiation flow in a stochastic medium	Pawel Kozlowski, LANL
11:50-12:10	THOR: Developing a Next-Generation Platform for Radflow and Opacity Measurements	Ryan Lester, LANL
12:10-12:30	Maximization of Laser Coupling with Cryogenic Targets	Matthias Geissel, SNL
12:30-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-7:00	Open	
	Evening Plenary	**Chair: Jason Myatt**
7:00-8:00	Strategy to Achieve Robust Burn at the National Ignition Facility	Laurent Divol, LLNL
8:00-10:00	**Poster Session II**	



Absolute stimulated Raman scattering at densities below quarter critical

R. K. Follett, J. P. Palastro, D. H. Froula, and D. Turnbull

Laboratory for Laser Energetics, University of Rochester

Substantial stimulated Raman backscatter (SRS) is regularly observed in experiments under conditions where calculated convective gains are small. These observations are often attributed to the filamentation instability causing local intensity enhancement and/or driving density perturbations that allow for absolute instability to occur. The conditions where absolute SRS can occur at densities below quarter critical are evaluated using LPSE and fully kinetic simulations in the context of recent OMEGA experiments. Absolute sidescatter and filamentation induced absolute backscatter are predicted to occur at similar laser intensities. These two instabilities can be difficult to distinguish experimentally because Langmuir decay induced turbulence leads to significant scattering from modes that are only convectively unstable with modest gain.

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* This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0004144 and the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award Number DE-SC0024863: IFE-STAR

Ray-tracing for diagnostic comparison at the Laser Mégajoule Facility

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The Laser Mégajoule Facility (LMJ)[1] is a MJ-class inertial confinement fusion (ICF) system using linearly polarized 351-nm wavelength lasers. Directly-driven planar targets in the LMJ, relevant to direct drive ICF, are prone to a Stimulated Raman Scattering (SRS) laser-plasma instability (LPI) which lowers nuclear fusion efficiency[2]. At the LMJ, SRS mechanisms have been investigated using unique diagnostics. Seven of the shots performed at the LMJ between 2024 and 2025 use 5 inner quads and 5 outer quads, each with a 1TW ~9 ns temporal pulse length for all 10 quads, or 2 TW ~4.5 ns temporal pulse width for staggered outers and inners, with a particular temporal envelope and asymmetry yielding distinct SRS mechanisms.

This presentation reviews efforts to ray-trace SRS in these experiments, and draw comparisons with near-backscatter imaging (NBI)[3] and full-aperture back-scatter station (FABS) diagnostics to deduce the mechanisms and sources of SRS. Two-dimensional (2D) DRACO hydrodynamics[4] are revolved into a three-dimensional (3D) profile assuming cylindrical symmetry, and pump lasers and SRS are traced using a novel 3D Eikonal Large Plasma Simulation Environment (ELPSE) numerical code to compare with the LMJ diagnostics.

Comparisons between the experimental measurement and ray-tracing simulation of the seven LMJ shots suggest that a major contributing cause of SRS is tangential side-scatter, with energy measured with the NBI on the order of 2.5 to 10 kJ or 0.25% to 1% the total input energy, which may not be adequately represented by the FABS. Spatiotemporally resolved measurements on the NBI over a wide angular spread, and their combination with ray-tracing, may enhance our understanding of SRS mechanisms and their predominant causes. Identifying the major causes of SRS will help to assess appropriate mitigation strategies such as polarization smoothing.

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*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.

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1. Denis, V., Néauport, J., Blanchot, N. & Lacombe, C. LMJ 2023 facility status. in *High Power Lasers for Fusion Research VII* vol. 12401 1240102 (SPIE, 2023).
2. Rosenbluth, M. N. Parametric Instabilities in Inhomogeneous Media. *Phys. Rev. Lett.* **29**, 565–567 (1972).
3. Trauchessec, V. *et al.* Time-resolved near backscatter imaging system on Laser MegaJoule. *Rev. Sci. Instrum.* **93**, 103519 (2022).
4. Radha, P. B. *et al.* Two-dimensional simulations of plastic-shell, direct-drive implosions on OMEGA. *Phys. Plasmas* **12**, 032702 (2005).

Experiment Design for Hot Electron Mitigation on the FLUX Platform

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Suprathermal electrons, arising from amplified electron plasma waves, pose a preheat risk in inertial confinement fusion. Two Plasmon Decay (TPD) is a laser plasma instability (LPI) where electron plasma waves are parametrically amplified near the quarter critical surface. Above a threshold intensity, the instability enters an absolute regime where EPWs are amplified exponentially in the absence of saturating mechanisms. Broadband probe beams have been shown to mitigate instabilities in the absolute regime and have a higher TPD intensity threshold.[1]

An upcoming planar CH target experiment on the FLUX (Fourth Generation Laser for Ultra Broadband Experiments) platform will compare the hot electron generation from broadband and narrowband laser beam pulses. DRACO radiation-hydrodynamics code simulations were used to determine the ideal beam configuration and plasma parameters for LPI simulations. FLUX pulses are modeled in the Laser Plasma Simulation Environment (LPSE) to investigate the effect of speckled broadband beams on absolute TPD intensity thresholds and hot electron generation. Based on the simulations, beam configurations and intensities are chosen to demonstrate the mitigation of hot electron generation of broadband beams.

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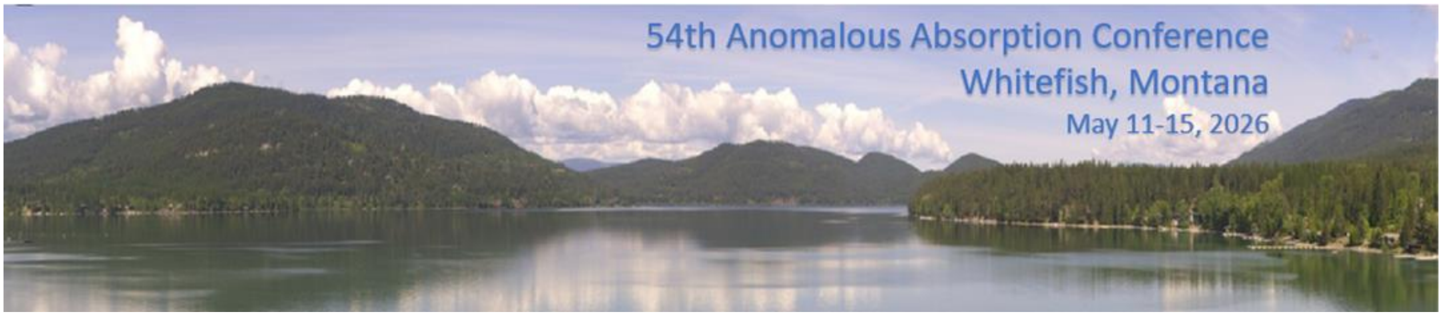
*This work was made possible by the resources provided by the Digital Research Alliance of Canada under the allocation RAC-2025-5336. This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0004144 and the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award Number DE-SC0024863: IFE-STAR

[1] R. K. Follett, J. G. Shaw, J. F. Myatt, H. Wen, D. H. Froula, J. P. Palastro; “Thresholds of absolute two-plasmon-decay and stimulated Raman scattering instabilities driven by multiple broadband lasers.” *Phys. Plasmas* 1 March 2021; 28 (3): 032103



Hello, World! pyF3D

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We present pyF3D, which is the evolution of the code pF3D developed at Lawrence Livermore National Laboratory (LLNL). pyF3D is a massively parallel code designed for simulating laser plasma instabilities (LPI) over a wide range of plasma conditions encountered in ICF experiments, including within hohlraums. We give an overview of the code and describe the class of problems it can be used to model. Additionally, we present new simulation results using pyF3D, which show that intra-beam energy transfer (IBET) induced by smoothing by spectral dispersion (SSD) can enhance beam spray.

A major new feature of pyF3D compared to previous versions of pF3D is the use of the Python programming language for tasks such as code steering, laser beam generation, error handling, user input processing, and implementation of user-defined functions. Other modifications include greater modularity, flexibility, input deck verification, and data output in HDF5 format. A suite of Python tools for analyzing simulation results is also available to users. As in previous versions of pF3D, a large algorithmic component of pyF3D is written in C and parallelized under MPI. Such a combination of features provides a streamlined user experience without sacrificing performance.

pyF3D includes a suite of test problems that runs under the Automated Testing System (ATS) framework and verifies a variety of physics features and packages. These include paraxial and nonparaxial laser beam propagation models, ponderomotive force, hydrodynamic evolution and Landau damping of ion acoustic waves, inverse bremsstrahlung absorption, local and nonlocal electron heat conduction models, filamentation, cross-beam energy transfer (CBET), stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), SSD, and polarization smoothing (PS), among others.

To demonstrate pyF3D on an LPI problem of interest, we simulate beam spray in the presence of SSD using the code. For plasma parameters relevant to ICF, we show that IBET induced by SSD can result in a time-dependent modulation of the beam f# at the SSD frequency. This effect leads to beam spray below the classical threshold for filamentation given by the filamentation figure of merit (FFOM).

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Spectral phase optimization of broadband lasers enhances absolute instability thresholds beyond the coherence time limit

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Broadband lasers suppress parametric instabilities in direct-drive inertial confinement fusion, with the coherence time providing a universal scaling of absolute instability thresholds for random spectral phases [Follett *et al.*, Phys. Plasmas **26**, 062111 (2019)]. We show that the spectral phase is an additional degree of freedom that can raise thresholds significantly beyond this baseline. Using an automatic-differentiation-enabled LPSE solver to perform gradient-based optimization over spectral phases, we find that transform-limited (TL) pulses—which concentrate energy into periodic bursts separated by quiescent intervals—raise the absolute TPD threshold to 4–8× the monochromatic value at both OMEGA-scale (2 keV, 200 μm) and ignition-scale (4 keV, 600 μm) conditions, exceeding the Follett random-phase result by a factor of 1.5–2× at the same bandwidth. Furthermore, a small quadratic spectral phase (chirp) applied as a perturbation to TL raises the threshold further still, while the pulse remains bursty with peak intensities only ~10–20% below the TL value. The sign of the optimal chirp depends on plasma conditions, and large chirp degrades the threshold as the burst structure dissolves.

The dominant suppression mechanism for TL pulses is duty-cycling: the parametric drive is interrupted between bursts, allowing daughter waves to damp or advect out of the resonance region before sustained growth can occur. The additional benefit of small chirp, however, cannot be explained by a purely temporal model and appears to involve the spatial structure of the absolute mode and its interaction with the frequency sweep. High-resolution spatiotemporal diagnostics aimed at resolving this mechanism will be presented. These results demonstrate that deterministic spectral phase structure is a significant and previously unexplored design parameter for controlling parametric instabilities in next-generation broadband ICF laser systems.

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Contributions of Au Bubble Behavior to Hohlraum Bang Time Discrepancy

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Hohlraums are high-Z cylinders used to convert laser energy into a uniform X-ray drive for capsule implosions on the National Ignition Facility (NIF). Integrated radiation-hydrodynamics simulations of capsule implosions inside hohlraums routinely exhibit bang times, which are highly sensitive to energy coupling to the capsule, that are 400-700ps later than experiment[1]. This suggests that simulations over-predict energy coupling to the capsule (referred to as a "drive defecit"), and this observation is consistent across extant codes with sufficient physics to model hohlraums. Recent work[1] performed as part of the Build-a-Hohlraum (BAH) campaign provides evidence that the drive deficit is primarily caused by inaccuracies in the modeling of non-LTE Au emission from the hohlraum wall, primarily for M-band photons, which have energies >2 KeV. We report on simulations of the BAH campaign[1] performed using the xRAGE radiation-hydrodynamics code[2]. Our xRAGE simulations show somewhat reduced discrepancies with bang time relative to previously reported simulations[1] despite exhibiting similar discrepancies in the level of M-band emission relative to the total. In our simulations, agreement with experimentally measured X-ray fluxes improves as a hohlraum window and associated hardware are added as well as when a gas fill and capsule are added. We attribute this improved agreement to the tamping effect these features have on the gold bubble growth in the hohlraum. Discrepancies are maximized when the hohlraum bubble collides on axis before the end of the laser pulse, a situation that is believed to be poorly modeled using hydrodynamics due to the relatively high temperature and low density of the bubble. We have begun running simulations using a plasma transport model[3] to evaluate how well this ameliorates the problem. This model has previously been used to exhibit improved agreement with neutron imaging from DT-filled hohlraum experiments performed on NIF[4].

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*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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[1] G.F. Swadling et al., "*Resolving discrepancies in bang-time predictions for indirect-drive ICF experiments on the NIF: Insights from the Build-A-Hohlraum campaign,*" Phys. Plasmas **32**, 052707 (2025).
[2] B.M. Haines et al., "*The development of a high-resolution Eulerian radiation-hydrodynamics simulation capability for laser-driven Hohlraums,*" Phys. Plasmas **29**, 083901 (2022).
[3] Vold et al., *"Plasma transport in an Eulerian AMR code,"* Phys. Plasmas **24**, 042702 (2017).
[4] D.P. Higginson et al., *"Direct Evidence of Multispecies Hydrodynamics in Ignition-Scale Hohlraums,"* Phys. Rev. Lett. **134**, 165101 (2025).

When Marshak Waves Pass By: The Interface Temperature

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There is current interest in designing and experimentally testing a thin "window" in the gold wall of a laser heated hohlraum that has produced an igniting capsule. This window can ultimately shine on an external physics package to extend the field of High Energy Density (HED), taking advantage of the enhanced temperature of the hohlraum following ignition. The window must still have some amount of gold to ensure good drive symmetry for the implosion of the ignition capsule. This thin gold must be backed by a lower Z material for structural integrity. Simulations of such a two-medium structure show the usual non-linear, x-radiation-driven, conduction-heating Marshak Wave (MW) propagating from inside the hohlraum outward through the thin gold. They also show the MW propagating further outward through the low Z backing. The radiation-hydrodynamic simulations show a particular transition temperature at the boundary of the two media. We present here an analytic theory for this value, as a function of the choice of low Z material, which matches the simulations well.

I prefer an oral presentation

LLNL-ABS-2016670

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Initial results of the XFOL platform: studying radiation flow in a stochastic medium*

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B. Farhi[1], C. Wong[1], D. Ross[1], I. Usov[1], C. Wilde[1], D. W. Schmidt[1], H. M. Johns[1], T. Urbatsch[1]

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Abstract

Understanding and modeling radiation traveling in a stochastic medium has been a problem of interest spanning multiple fields, including: astrophysics[1], atmospheric physics[2], and high energy density plasma physics[3]. Most radiation-hydrodynamics codes are built around a single transport equation with homogenized opacities, and these underlying assumptions may no longer be valid when simulating radiation flow in a stochastic medium. One crude workaround is to Monte Carlo average over an ensemble of simulations, but this is often computationally intractable. Another approach is to use the well-known Levermore-Pomraning closure (or one of its many extensions), but this approximation also has its limitations[4]. Furthermore, there is a paucity of experimental data for testing these approximations, likely due to the target fabrication challenges inherent in building a stochastic medium target.

In this talk, we will present initial results from the XFOL platform, fielded on Omega-60. XFOL is a successor to the COAX platform[5], and similarly utilizes a combination of point-projection backlighter radiography and X-ray absorption spectroscopy to characterize radiation flow. In the case of XFOL, the target consists of a Sc-laden silica aerogel foam as the background material, within which are contained V-coated microballoon inclusions. We simultaneously measure Sc and V absorption spectra to track the ionization balance and equilibration between these two components of our binary stochastic medium, which forms a unique data set for validation of radiation-hydrodynamics simulations.

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[1] A. Belleni-Morante G. Saccomandi. "Time-dependent photon transport in three dimensional interstellar cloud with stochastic clumps" *Astrophys. Space Sci.*, **234(1)**, 85-105 (1995)

[2] F. Malvagi, et al "Stochastic Radiative Transfer in Partially Cloudy Atmosphere" *J. Atmos. Sci.*, **50(14)**, 2146-2158 (1993)

[3] P. Keiter, et al "Radiation transport in inhomogeneous media" *Phys. Plasmas*, **15(5)**, 056901-7 (2008)

[4] C. Levermore, et al "Linear Transport Theory in a Random Medium" *J. Math. Phys.*, **27**, 2526-2536 (1986)

[5] H. Johns, et al "A temperature profile diagnostic for radiation waves on OMEGA-60" *High Energy Density Phys.*, **39**, 100939 (2021)

THOR: Developing a Next-Generation Platform for Radflow and Opacity Measurements*

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and

O. Landen (2), S. Prisbrey (2), E. Dewald (2), M. Martin (2), M. Foord (2), R. Heeter (2), N. Hash (2), K. Kasman (2), A. Kritcher (2), J. Kroll (2), K. Olsen (2), S. Paqueo (2), M. Rosen (2), N. Roskopf (2), C. Young (2), S. Vonhof (2)

and

W. Garbett (3), P. Graham (3), L. Hobbs (3), J. Morton (3)

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(3) Atomic Weapons Establishment (UK)

The achievement of ignition and gain on the National Ignition Facility (NIF) provides the opportunity to develop novel experiments that leverage the energy produced by the capsule implosion [1]. 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 have been observed to exceed the fluxes generated from the initial laser drive [2]. This opens the possibility of utilizing this X-ray output to drive radiation flow experiments and opacity measurements relevant to astrophysical conditions that are otherwise unattainable in the laboratory. The THOR (Thinned-Hohlraum Optimization for Radflow experiments) campaign on NIF seeks to develop this capability.

A series of experiments were designed to validate these models, systematically scanning window materials, thicknesses, and laser configurations to minimize perturbations while maximizing radiation throughput. These efforts culminated in the successful execution of a DT-layered implosion using THOR windows at ignition scale, achieving a yield of 2.40 ± 0.09 MJ, gain of 1.17, without measurable degradation to implosion symmetry. This shot represents the first demonstration of ignition in a hohlraum modified to allow radiation from ignition to flow out of the hohlraum, validating the THOR design and enabling future high-energy-density experiments driven by post-ignition x-ray output. This presentation will discuss the modeling strategy, asymmetry mitigation, and experimental results that establish THOR as a next-generation platform for radiation flow and opacity science.

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* 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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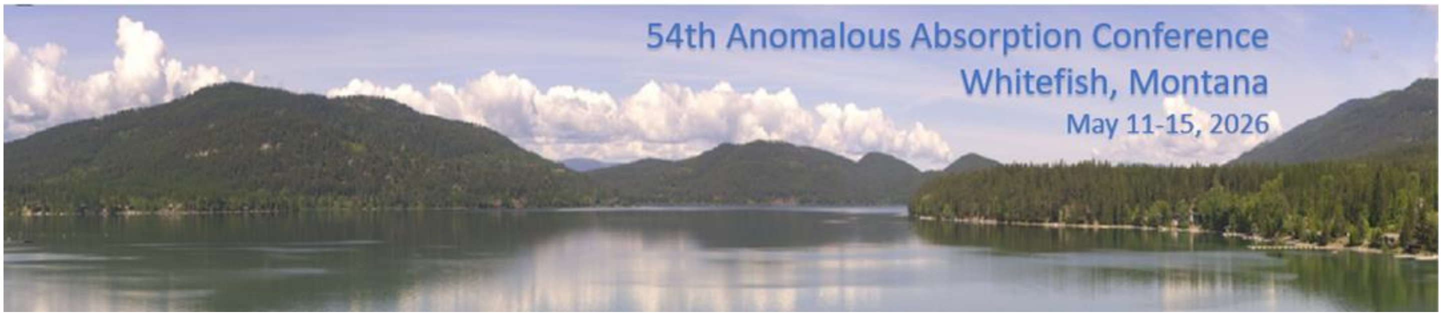
[1] Abu-Shawareb et al., Phys. Rev. Lett. 132, 065102, 2024.

[2] M. S. Rubery et al., Phys. Rev. Lett. 132, 065104, 2024.



Maximization of Laser Coupling with Cryogenic Targets*

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A major obstacle for depositing laser energy to targets in Magnetized Liner Inertial Fusion (MagLIF) is the need to contain the gas with a laser-entrance-hole window (LEH). With densities of 1.0-1.4 mg/cc at room temperature, previous experiments used a polyimide film of 1.56 µm thickness and 2.2 mm diameter which consumed about 1 kJ of laser energy at the maximum plausible beam spot size of 1.1 mm.

Though we already had successfully suppressed Stimulated Brillouin Backscatter as reported previously, we found that significant Stimulated Raman Backscatter was still present which could be eliminated by further increasing the focus size. This change required a reduction of the LEH thickness.

We will discuss the implementation of cryogenic cooling to enable the use of thinner and wider LEH windows along with a larger beam spots size. As a result, we dramatically reduced losses while keeping the laser propagation depth within a useful range for MagLIF, and we comfortably exceeded the previously unobtainable laser deposition of 2 kJ.

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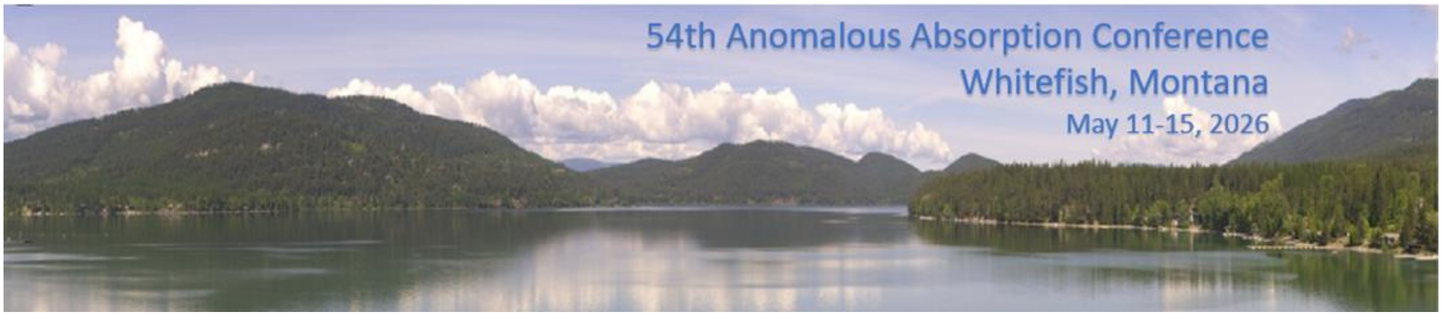
*SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.



Strategy to Achieve Robust Burn at the National Ignition Facility

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The National Ignition Facility (NIF) has reached the upper end of the ignition cliff using high quality 1 mm scale HDC capsules and precision laser delivery above 1.9 MJ, culminating in yields up to 8.6 MJ with ion temperatures near 18 keV. While repeatability at high yield has improved, performance remains sensitive to small fielding and drive perturbations. A central objective is to transition from cliff-limited ignition to a saturated burn regime where burnup fraction depends primarily on fuel areal density, with simulations indicating reproducible yields once Ti≥30keV and increasing robustness for Ti≥35keV. We summarize the experimental and modeling basis for these objectives, including neutron time of flight spectroscopy and down scattered ratio measurements that track ρR and burn dynamics. Approaching the plateau is expected to produce higher DSR, shorter burn duration, and more compact neutron images as burn occurs before rapid expansion. Ongoing NIF campaigns aim to increase kinetic energy coupling and compression through improved symmetry control and pulse shaping, increase hohlraum efficiency via reduced wall area designs, and improve ablator efficiency by revisiting lower Z CH and B4C options. Near term plans test these advances individually and in combination to approach Ti≈25keV and yields of 12 to 15 MJ on current 2.2 MJ capability. Achieving fully robust burn with margin for invasive applications likely requires the 2.6 MJ Enhanced Yield Capability upgrade.

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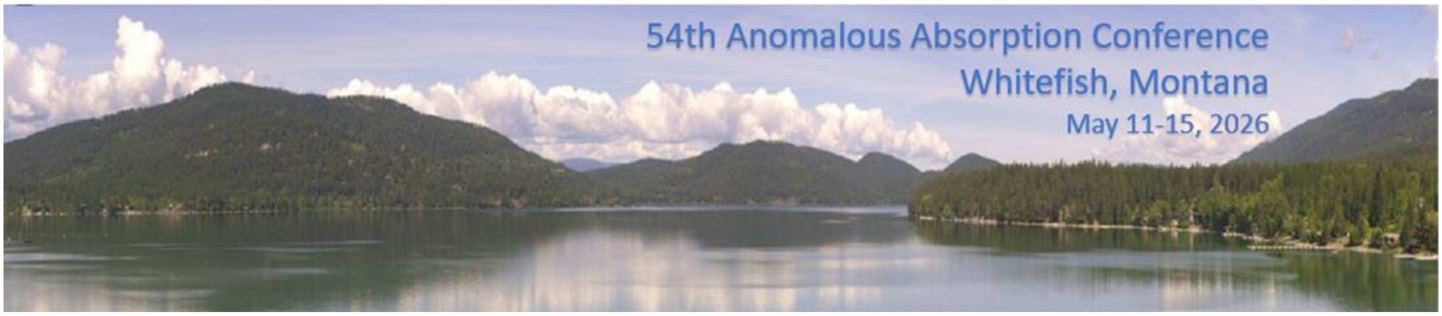
*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

54th Anomalous Absorption Conference Agenda

Tuesday, May 12, 2026 – Poster Session II, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Skylar Dannhoff, MIT	Suppression of hohlraum wall expansion by pre-imposed axial magnetic fields on OMEGA
P-2	Blagoje Djordjevic, LLNL	How Symmetry Considerations Scale up to NextGen Drive Energies
P-3	Irem Nesli Erez, University of Colorado	Experimental Test of Magnetized LPI Theory Using Optical Thomson Scattering and Cross-Polarized CBET
P-4	Matthew Gjevre, University of Alberta	XUV Diagnostic System for Measuring the Focusing of Protons Produced by High Intensity Laser Pulses
P-5	Griffin Glenn, Sandia National Laboratories	Development of multi-frame 6 keV x-ray backlighting for the Z Machine using hybrid CMOS detectors
P-6	Elaine Koh, Stanford University/SLAC	Diffraction and Dispersion from Blazed Plasma Reflection Gratings
P-7	Ian Min-Roberts, University of Alberta	Laser Filamentation Seeded by Speckles and Particle Noise
P-8	Harsha Rajesh, Stanford University	Gas Power Meter and Beam Dump for High-Energy Lasers
P-9	Jill Schell, University of Michigan	Michigan Target Research and Fabrication (MiTRF)
P-10	Eleanor Tubman, University of California, Berkeley	Plasma expansion into background He-gas fills
P-11	Gina Vasey, LANL	Multigroup Radiation Diffusion with HOLO for Modeling PDD-EP
P-12	Erik Vold, LANL	Laser Driven Hydrodynamic Instabilities, Plasma Diffusion and Atomic Mixing in Inertial Confinement Fusion (ICF) Reactions



Suppression of hohlraum wall expansion by pre-imposed axial magnetic fields on OMEGA*

S. G. Dannhoff,[1] C. A. Walsh,[2] G. D. Sutcliffe,[2] V. Valenzuela Villaseca,[2]
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Magnetized inertial confinement fusion (ICF) experiments are typically designed to explore the benefits of a pre-imposed magnetic field on the capsule's nuclear performance [1,2]. Less explored is the possibility that a pre-imposed magnetic field might also improve indirect-drive conditions by modifying the dynamics of the inward-expanding hohlraum wall motion. Though proposed in previous works and studied in planar foil geometries, experimental studies on the impact of a pre-imposed magnetic field aligned with the axis of a cylindrical hohlraum have not yet been reported [3]. Experiments at the University of Rochester's Laboratory for Laser Energetics OMEGA laser facility have been performed to study the impact of pre-imposed axial magnetic fields (B_0 ~25 T) on the plasma wall blowoff in vacuum Au rings. Self-emission x-ray framing camera images indicate that the buildup of magnetic pressure seeded by the pre-imposed field can slow the convergence of adjacent beam spot bubbles and reduce supersonic jet formation. D^3He proton radiographs display modifications in the magnetic field topology and strength due to the pre-imposed field and suggest that it may slow the inward radial expansion of coronal wall plasma. Synthetic diagnostic images from 3D HYDRA magnetohydrodynamic simulations are being performed to aid in the interpretation of these observations. These results advance our physics understanding of the impact of both self-generated and imposed magnetic fields on hohlraum wall blowoff and provide insight into an under-explored approach to improving hohlraum drive symmetry in ICF experiments.

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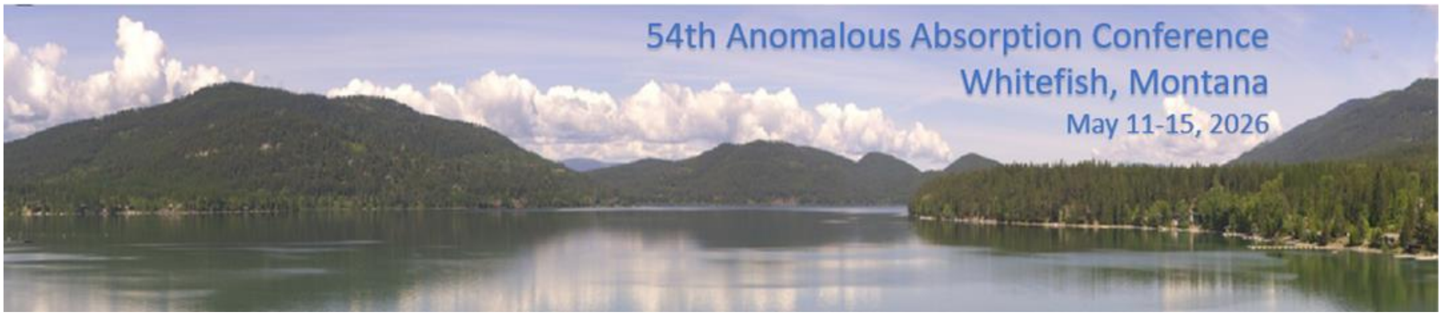
[1] J. D. Moody, B. B. Pollock, H. Sio, et al. "*The magnetized indirect drive project on the National Ignition Facility,*" Journal of Fusion Energy **41**, 7 (2022).

[2] D. J. Strozzi, H. Sio, G. B. Zimmerman, et al. *"Design and modeling of indirectly driven magnetized implosions on the NIF,"* Physics of Plasmas **31**, 092703 (2024).

[3] H.-B. Tang, G.-Y. Hu, Y.-H. Liang, et al. *"Confinement of laser plasma expansion with strong external magnetic field,"* Plasma Physics and Controlled Fusion **60**, 055005 (2018) .



How Symmetry Considerations Scale up to NextGen Drive Energies

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Symmetry remains an outstanding issue in the field of ICF as we are generally unable to predict it for NIF experiments without significant walk-up effort and tuning. This will remain important as we scale up drive energies in the context of Next Generation facility designs, where it is planned to increase the drive energy from 2 MJ up to 10 MJ, correspondingly increasing yields from 10 MJ up to potentially 300+ MJ. While radiation hydrodynamics codes are unable to accurately predict symmetry conditions they are able to predict features such as the general drive temperatures, shock timings, and absorption. In this study we examine how such features vary as we increase scale, where we consider symmetry metrics such as the time-dependent x-ray drive, shock propagation, and Legendre decomposition of the compressed capsule. We consider hydro-scaling as well as a temperature-conserving 2.6x energy scaling that compensates for wall losses due to Marshak wave propagation.[1,2] While this is only representative of current experiments and modeling capabilities, here we present how the physics of symmetry plays out in our codes today.

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* This work was conducted under the auspices of the U.S. Department of Energy by LLNL under contract DE-AC52-07NA27344.

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[1] J. Hammer and M. D. Rosen, "*A consistent approach to solving the radiation diffusion equation*," Phys. Plasmas **10**, 1829 (2003)
[2] K. Baker, O. Jones, C. Weber, *et al*., "*Hydroscaling indirect-drive implosions on the National Ignition Facility*," Phys. Plasmas **29**, 062705 (202)

Experimental Test of Magnetized LPI Theory Using Optical Thomson Scattering and Cross-Polarized CBET*

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Laser–plasma interaction (LPI) physics plays an important role in high-energy-density plasmas, yet key theoretical predictions remain largely untested experimentally when the plasma is magnetized. We present a focused experimental campaign designed to test fundamental predictions of magnetized LPI theory using optical Thomson scattering (OTS) diagnostics. In this experiment, a laser-driven coil produces ~150 T field and we probe a foil plasma using a second-harmonic (527 nm) Thomson scattering beam. The OTS diagnostic measures both the ion-acoustic wave (IAW) and electron plasma wave (EPW) branches of the scattered spectrum. Theory predicts that when the magnetic field is oriented perpendicular to the plasma wave vector ($B \perp k$), the EPW spectrum exhibits electron cyclotron oscillations, whereas no oscillatory structure is expected when $B \parallel k$. Synthetic spectra indicate that these oscillations should be observable in the measured EPW signal with signal-to-noise greater than two, after accounting for the angular collection of the diagnostic. We will present our experimental findings from an OMEGA shot day in April. Additionally, as a ride-along experiment, we investigate cross-beam energy transfer (CBET) in the same magnetized plasma. Theory[1] and particle-in-cell simulations[2] suggest that CBET between orthogonally polarized laser beams becomes allowed due to magnetization. We will present our April shot day results and our plan for another OMEGA shot day in July. Successful observation of the predicted effects has the potential to provide a direct experimental test of magnetized LPI theory and establish a technique for diagnosing local magnetic fields in high-energy-density plasmas.

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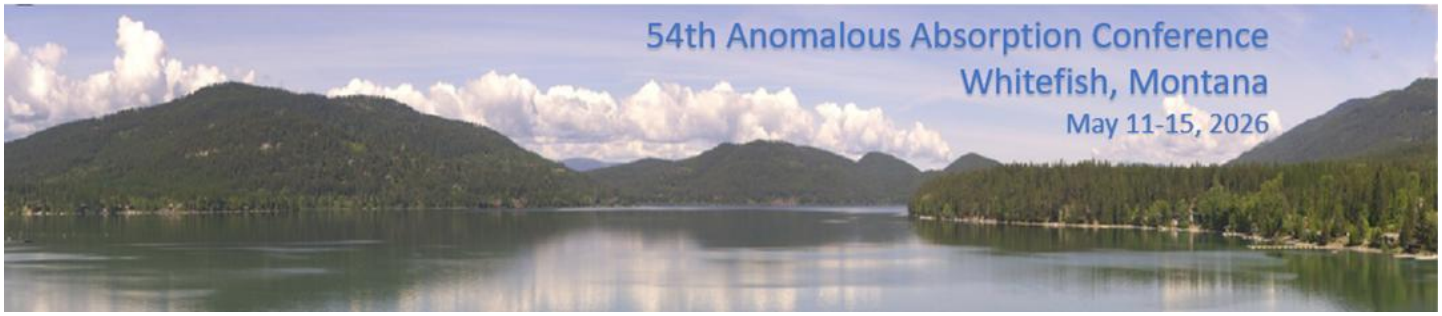
[1] J. D. Moody and Y. Shi , “Vlasov theory of magnetized cross-beam energy transfer in a high energy density plasma ” Under review at Physics of Plasmas (2026).

[2] Y. Shi and J. D. Moody, “Particle-in-Cell Simulations of Laser Crossbeam Energy Transfer via Magnetized Ion-Acoustic Wave,” *Physics* **8**, 25 (2026).



XUV Diagnostic System for Measuring the Focusing of Protons Produced by High Intensity Laser Pulses

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Proton fast ignition schemes for inertial confinement fusion make use of laser driven high-energy proton beams produced through the well-known TNSA mechanism. [1,2] In order to achieve the required proton flux for fusion the generated protons must be focused by using a hemispherically shaped thin foil target. [2,3]. The hemispherical target will cause the generated protons to focus on the center of the hemisphere, creating a high proton flux at this point.

To measure proton flux from these hemispheres, as well as investigate spatial distribution, a secondary flat thin foil target can be placed in the proton path, close to proton focus. Proton flux is sufficient to cause heating of the secondary target up to several eV. [3] This causes the target to enter a warm dense matter state during which it will emit heat through Planckian blackbody emission. By imaging this emission over a narrow band of XUV emission the spatial distribution of temperature across the target can be extracted.

A proton focusing experiment, of the form described above, was performed at the ZEUS laser facility at the University of Michigan. XUV emission centered at 93eV was imaged off of the rear side of the secondary target using a spherical multilayer mirror designed for photons of this energy. The time integrated photon flux at this energy was imaged onto an Andor XUV camera allowing for temperature profiles to be measured. Hydrodynamic simulations of the interaction are being carried out for comparison with the data. The XUV imaging diagnostic, simulations, and analysis techniques are discussed along with initial heating images.

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1 – M. Roth, et. al. “Fast Ignition by Intense Laser-Accelerated Proton Beams”, Phys. Rev. Lett. Vol. 86, 436, (2001)

2 – T. Bartal, et. al. “Focusing of short-pulse high-intensity laser-accelerated proton beams”, Nat. Phys. Vol. 8, pp. 139-142, (2012)

3 - P.K. Patel, et al. "Isochoric heating of solid-density matter with an ultrafast proton beam." Phys. Rev. Lett. Vol. 91, No. 12, (2003)

4 – R. Snavely et. al. “Laser generated proton beam focusing and high temperature isochoric heating of solid matter”, PoP. 14, 092703, (2007)

Development of multi-frame 6 keV x-ray backlighting for the Z Machine using hybrid CMOS detectors*

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Spherical crystal x-ray imagers are key diagnostic instruments for experiments throughout high energy density physics. On the Z Machine at Sandia National Laboratories, x-ray backlighting with spherical crystal imaging is routinely used to obtain high-resolution radiographs in studies of the magneto-Rayleigh-Taylor instability or the electrothermal instability, both of which must be understood and controlled as part of the Magnetized Liner Inertial Fusion (MagLIF) concept. The present capability[1] provides one frame along each of two lines of sight, with the x-ray signal captured by time-integrating imaging plates. Acquiring multiple temporally gated frames along each line of sight would offer a variety of exciting advances, including detailed tracking of plasma features within a single shot and improved signal-to-noise levels by temporally gating out self-emission from the Z implosion.

Here we describe an x-ray backlighter and spherical crystal imager that integrates advanced hybrid CMOS detectors developed at Sandia National Laboratories[2] to enable multiple time-gated frames along each line of sight. The new imager, which continues to use the 6.151 keV Mn He_α line, accommodates the Icarus sensor while maintaining comparable spatial resolution (~15 μm) and signal levels to those obtained using the previous imaging plate-based system. We additionally present radiation hydrodynamic simulations and experiments exploring the acquisition of up to three frames along a single line of sight with a variety of inter-pulse delays, illustrating the capability to vary timing configurations according to experimental requirements. These results promise to significantly extend the diagnostic capabilities of the Z Machine and facilitate detailed studies of instabilities relevant to MagLIF.

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*SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

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[1] G. R. Bennett, I. C. Smith, et al., "*2-20 ns interframe time 2-frame 6.151 keV x-ray imaging on the recently upgraded Z Accelerator: A progress report,*" Review of Scientific Instruments **79**, 10E914 (2008)

[2] J. L. Porter, Q. Looker, L. Claus, "*Hybrid CMOS detectors for high-speed X-ray imaging,*" Review of Scientific Instruments **94**, 061101 (2023)

Diffraction and Dispersion from Blazed Plasma Reflection Gratings

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As laser systems achieve increasingly higher powers, damage thresholds of solid optics present a critical bottleneck for reaching higher intensities for short-pulse laser applications, such as X-ray generation and laser wakefield acceleration. At current high-power laser facilities, the solid gratings used for pulse compression in chirped-pulse-amplification (CPA) lasers must be approximately one meter in width to withstand the power from the incident beam. Plasma gratings offer a promising alternative to solid gratings due to their significantly higher damage thresholds, and furthermore, are inherently tunable by simply modifying the pump lasers.

We performed numerical analysis using a two-dimensional particle-in-cell (PIC) code to simulate the formation and performance of an overdense plasma with the sawtooth profile characteristic of blazed gratings in conventional solid optics, examining grating surfaces relevant to ultrafast laser compression. A parametric study was conducted to evaluate angular dispersion, diffraction efficiency, and damage thresholds as key performance metrics. These computational results suggest the viability of blazed plasma reflection gratings for ultra-high-power chirped-pulse-amplification lasers.

This work was supported by NSF Grant PHY-2541940.

Laser Filamentation Seeded by Speckles and Particle Noise

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Abstract

Laser filamentation is a nonlinear instability that leads to transverse beam breakup during laser propagation in plasma. Its growth depends on stochastic perturbations that seed the instability. In laser–plasma experiments such perturbations may originate from speckle structures produced by phase plates or from intrinsic particle noise in the plasma.

In this work we model filamentation of a Gaussian probe beam seeded by speckles and particle noise using a time dependent nonlinear paraxial equation. The probe configuration is chosen to represent Thomson-scattering probe beams used in hohlraum experiments and in dedicated OMEGA experiments [1]. Speckle fields are generated either with a standard disk like random phase plate or with an annular spectral distribution representing the cone-like intensity structure produced by phase plates in NIF-scale laser systems. The resulting intensity modulation drives kinetic plasma-density perturbations through the ponderomotive force. Particle noise is modeled using a rigorous kinetic description of plasma fluctuations arising from particle discreteness.

Simulations compare the development of filamentary structures seeded by speckles and by kinetic particle noise, including analysis in Fourier space and comparison with linear instability theory. The results provide a framework for interpreting probe-beam filamentation in hohlraum geometries and are applicable to dedicated OMEGA experiments such as [1].

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[1] K. R. McMillen et al., "Enhanced Ion-acoustic Wave Fluctuations Driven by Speckled Heater Beams," APS Division of Plasma Physics Meeting, Abstract ZI02.6 (2025).

Gas Power Meter and Beam Dump for High-Energy Lasers

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Gaseous optics exhibit substantially higher laser-induced damage thresholds than their solid counterparts, enabling high-intensity operation without permanent degradation[1,2]. In this work, we present a design for a gas-based beam dump and power meter based on saturated absorption that can measure the average power of a pulse train or the per-pulse energy of a laser with a known repetition rate. We have experimentally demonstrated an ozone-based device. Ozone strongly absorbs ultraviolet light in the Hartley band (approximately 200–320 nm), including the 266 nm wavelength used in our experiment. We develop and confirm a model for ozone absorption that predicts the length required for complete energy deposition and the resulting gas temperature rise. By calibrating the gas temperature rise against incident pulse energy, we demonstrate accurate, per-pulse energy measurements at the millijoule scale with an all-gas absorber. Finally, we analyze scaling pathways toward operation at kilojoule and megajoule energies and discuss extension of the concept to other laser wavelengths through appropriate gas selection. These results establish gas-phase optics as a viable platform for high-damage-threshold beam dumping and energy measurement, enabling the use and accurate characterization of high fluence beams.

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* This work was supported by NNSA Grant DE-NA0004130, the U.S. Department of Energy, Advanced Research Projects Agency-Energy (ARPA-E) under Award Number DE-AR0002056, by the Laboratory Research and Development Program at LLNL under Project Tracking Code No. 24-ERD-001, and Xcimer Energy. This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory (LLNL), under Contract No. DE-AC52-07NA27344.

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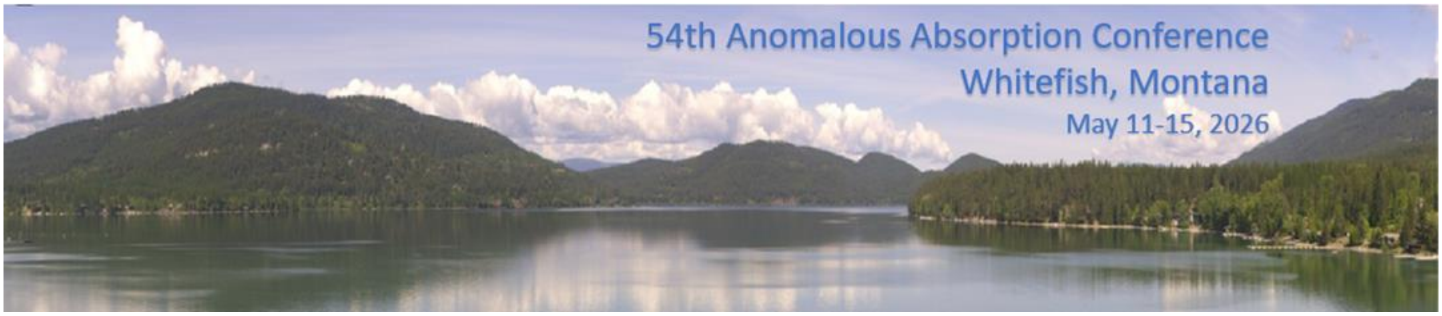
[1] Michine, Y., Yoneda, H., "*Ultra high damage threshold optics for high power lasers*," Commun Phys **3**, 24 (2020).
[2] P. Michel, et. al, "*Photochemically induced acousto-optics in gases*," Phys Rev. App. **22**, 024014 (2024).



Michigan Target Research and Fabrication (MiTRF)

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Michigan Target Research and Fabrication (MiTRF), located at the University of Michigan, has the distinct capability of fabricating targets for a variety of high-energy-density (HED) physics experiments. We have been assembling targets for the Omega Laser Facility, the Jupiter Laser Facility, Z, and several other facilities for over a decade. We have a thoughtful and comprehensive approach to the target fabrication process that serves researchers from National Laboratories, Universities, and Private Industry. We provide comprehensive CAD modeling support, fabrication and assembly, characterization and metrology of individual components and finished targets, hand delivery to the facility, and on-site experimental support. We work closely with Dana Design machine shop which provides high-precision machined target components and fixturing for target assembly and deployment.

MiTRF has been a member of LaserNetUS since 2023, which allows us the opportunity to contribute to the broader HED community by providing targets for many experimental configurations fielded at LaserNetUS facilities. MiTRF now also offers our target fabrication services for sale via purchase order, without the need for a contract. Our services include laser-cutting components, precision multi-step complex assemblies, target design and CAD, metrology, and more.

Our laser-cutting capabilities include cutting foils ranging from 2-500μm thick in materials such as aluminum, copper, gold, tungsten, tantalum, polyimide, PEEK, vanadium, iron, and more. We also laser-cut wires with diameter 50-200μm in materials such as tantalum, tungsten, copper, tin, and aluminum. We can also cut pinholes or tiny features with tight tolerances (5μm) within a part.

As HED experiments push toward higher precision and more complex geometries, the need for tight tolerances and specialized fabrication expertise becomes critical. Through a combination of specialized laser-cutting capabilities, multi-step assembly expertise, and a simplified purchasing method, MiTRF serves as a vital bridge between experimental design and execution. Our participation in LaserNetUS reflects a commitment to broad scientific support, providing the HED community with the high-precision components and technical reliability necessary for successful experiments.

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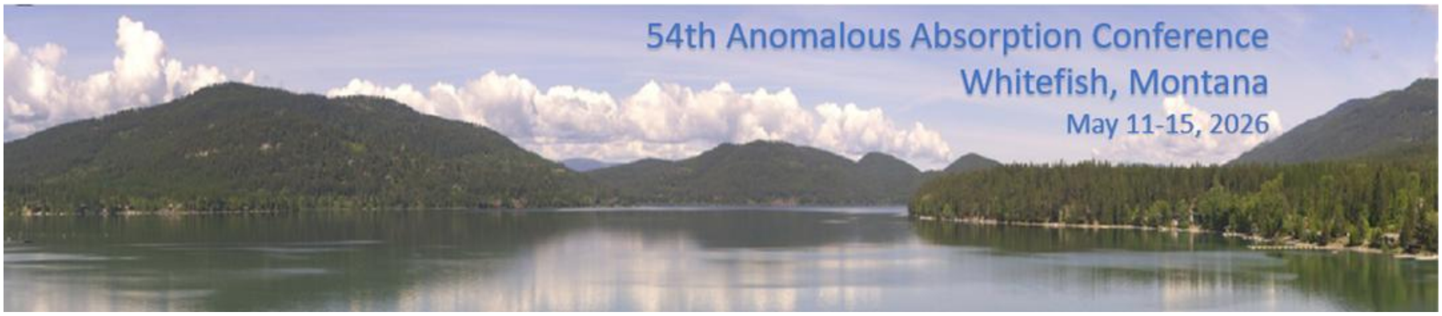
*This work is funded by the DOE LaserNetUS Initiative under grant DE-SC0024546 and NNSA grant DE-NA0004146.



Plasma expansion into background He-gas fills

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Understanding plasma conditions within hohlraums is critical to ensuring we have accurate modelling of laser plasma instabilities and achieve symmetric implosions. Regions such as the laser entrance hole and gas-plasma interfaces are key locations where processes such as cross-beam energy transfer take place[1,2]. These processes are dependent on well-defined plasma conditions to ensure that predictive models can accurately capture the relevant dynamics.

We have conducted experimental campaigns at the OMEGA EP Laser Facility to investigate simplified geometries, exploring the propagation of a plasma bubble into a helium gas and the resulting plasma conditions. This configuration provides hohlraum-relevant background gas conditions through which a copper plasma bubble expands. The evolution of the bubble is monitored using dual-axis orthogonal proton radiography, optical probing, and x-ray imaging to characterise the plasma conditions during expansion.

Results from optical probing indicate some disagreement between the expansion rates predicted by simulations and those observed experimentally, as well as the emergence of smaller-scale filamentary structures. These observations suggest the presence of strong magnetic and electric field instabilities within the plasma bubble that may be influencing the expansion dynamics. We also observe the formation of several interfaces during the expansion, including those associated with the copper plasma, mixing regions, and possible reverse shock structures.

Simulations using GORGON [3], HYDRA [4] and K2 [5,6] are explored across a range of tuning parameters to determine how best to reproduce the experimental observations and to understand the implications for hohlraum modelling in inertial confinement fusion.

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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.

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[1] P. Michel et al., Phys. Rev. Lett. 102, 025004 (2009)
[2] J. D. Moody et al., Nat. Phys. 8, 334-349 (2012)
[3] J. P. Chittenden et al., Plasma Phys. Control. Fusion 46, B457 (2004)
[4] M. M. Marinak et al., Phys. Plasmas 8, 2275 (2001)
[5] A. R. Bell and M. Sherlock, PPCF 66, 035014 (2024)
[6] M. Sherlock et al., Phys. Plasmas 24, 082706 (2017)


54th Anomalous Absorption Conference
Whitefish, Montana
May 11-15, 2026

Multigroup Radiation Diffusion with HOLO for Modeling PDD-EP*

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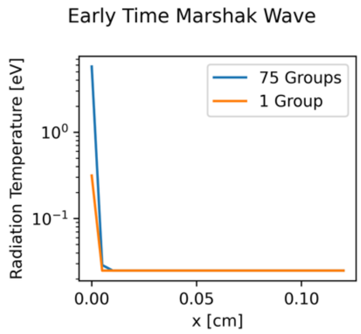

Figure 1: Marshak wave problem with multigroup opacities and boundary temperature source of 15 eV. The multigroup implementation shows significantly more heating.

The polar-direct-drive exploding pusher (PDD-EP) setup at the National Ignition Facility is a useful platform for neutron sources, opacity experiments, radiochemistry, and laboratory astrophysics [1-3]. Previous work has demonstrated that an accurate modeling of such a system is challenging and necessitates a code containing multiple complex physical effects [3,4]. Radiation hydrodynamics simulations result in persistent discrepancies in observable metrics like yield, burn width, and neutron spectrum inferred temperatures when compared to experiments. Estimating the plasma Knudsen number from these rad-hydro results suggests kinetic effects may be important, and preliminary calculations using these codes suggest a multigroup radiation implementation is also necessary. By incorporating kinetic effects and gray radiation diffusion physics, the iFP Vlasov-Fokker-Planck code has shown improved agreements with PDD-EP experiments, driven by effects like kinetically enhanced species stratification and viscous heating induced convergence reduction [4]. This work focuses on implementing a high-order low-order (HOLO) solver for multigroup radiation diffusion in iFP. The HOLO multigroup implementation removes the assumption of a Planckian energy distribution, allows hard x-rays to penetrate further, and corrects the LO gray system by introducing energy weighted cross sections.

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* 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.

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[1] M. Hohenberger et. al., "*Polar direct-drive experiments on the National Ignition Facility,*" Physics of Plasmas **22**, 056308 (2015)

[2] C. Yeamans et. al., "*High yield polar direct drive fusion neutron sources at the National Ignition Facility,*" Nuclear Fusion **61**, 046031 (2021)

[3] J. Marozas et. al., "*Polar-direct-drive simulations and experiments,*" Physics of Plasmas **13**, 056311 (2006)

[4] W. Taitano et al., "*A coupled Vlasov-Rosenbluth-Fokker-Planck and radiation modeling of a NIF polar direct drive exploding pusher capsule,*" APS-DPP (2024)

Laser Driven Hydrodynamic Instabilities, Plasma Diffusion and Atomic Mixing in Inertial Confinement Fusion (ICF) Reactions

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Abstract

Laser driven heating in Inertial Confinement Fusion (ICF) drives the compression of fuel and capsule while simultaneously generating hydrodynamic instabilities and plasma diffusive mixing. Hydrodynamic mixing (mass averaged flow as predicted in computational simulations with a single fluid velocity) at material interfaces does not change the atomic mixture compositions and so influences the reaction rates only through the mass averaged fluid velocity, density, and temperature. Kinetic effects are represented in transport theory as plasma species diffusion and produce mixing at the atomic level. This modifies the reaction rates of the isotopic species atomically mixing near material boundaries.

Progress is reported on models to represent species reactivities determined by the plasma diffusively driven atomic mix during laser heating in ICF. This presentation will describe on-going work to represent reaction rates more accurately in computational cells which include a boundary between two (or more) materials. One model, SINGE, uses a plasma driven atomic mix volume fraction (material averaged or by reactive isotope) to modify the reaction rates for isotopes in each of the materials within a computational cell, and also computes reaction rates between all isotopes in the atomically mixed volume fraction in each computational cell. This will reduce the reactivity within each material at a boundary and will allow an additional contribution to reactivity between materials which atomically mix by plasma diffusion across the material interface. Examples will be shown, including the evolving atomically mixed volume fractions in test problems.

Wednesday
May 13, 2026

54th Anomalous Absorption Conference Agenda

Wednesday, May 13, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session V: ICF (Burn, Ignition NIF, Basic ICF, IFE)	**Chair: Andrey Solodov**
8:30-9:00	Invited: Towards Measuring Hotspot Temperature as a Proxy for Ignition Robustness	Benjamin Bachmann, LLNL
9:00-9:20	Important concepts commonly confused in fusion analysis	Baolian Cheng, LANL
9:20-9:40	Large-scale high-yield implosions for inertial fusion energy (IFE): enhanced performance and distinct physics characteristics	Darwin Ho, LLNL
9:40-10:00	Modeling Capsule Implosions in Indirect Drive THOR Experiments	Kevin Ma, LANL
10:00-10:20	Residual kinetic energy reduction in NIF inertial confinement fusion implosions	Nicholas Ruof, LLNL
10:20-10:40	Coffee Break	
	Session VI: CBET II	**Chair: Yann Lalaire**
10:40-11:10	Invited: New cross-beam energy transfer measurement platform at the National Ignition Facility	Nuno Lemos, LLNL
11:10-11:30	Validating cross-beam energy transfer models using indirect-drive ICF experiments at NIF	William Riedel, LLNL
11:30-11:50	Accuracy of the Ray-Tracing Modeling of Cross Beam Energy Transfer in Inertial Confinement Fusion Hohlraums	Albertine Oudin, LLNL
11:50-12:10	Cross-Beam Energy Transfer with Spectral Smoothing: influence of resonant frequency pairs on the energy transfer	Godefroy Meynard, French Alternative Energies and Atomic Energy Commission
12:10-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-2:30	Business Meeting in the Ramsey Room	
2:30-6:30	Open	
6:30-7:00	Reception, Lakeside Pavilion	
7:00-8:30	**Banquet in the Lakeside Pavilion**	
8:30-10:00	Fireside S’mores	


54th Anomalous Absorption Conference
Whitefish, Montana
May 11-15, 2026

Towards Measuring Hotspot Temperature as a Proxy for Ignition Robustness

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Robust ignition requires reproducible, saturated yields despite variations in symmetry, adiabat and mix. A key stagnation observable for gauging ignition robustness at a given areal density is the DT hotspot temperature, but as experiments climb the ignition cliff, standard inference becomes increasingly biased in opposite directions: Neutron time-of-flight based Tion inferences systematically overestimate the true thermal temperature as rising explosion velocities broaden the neutron spectrum. Te derived from the spatially integrated x-ray continuum spectrum underestimates the DT temperature as cooler and brighter ablator emission surrounding the hotspot becomes more dominant. Here we discuss a path to improved DT hotspot thermal temperature measurements, by combining 3D-spatially resolved x-ray based temperature measurements[1,2] that separate hotspot from ablator emission with neutron-based analyses that aim to account for bulk-flow broadening. Cross comparing these approaches provides a practical pathway to temperature measurements in the ignition regime and a sharper diagnostic lever for assessing ignition robustness.

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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.

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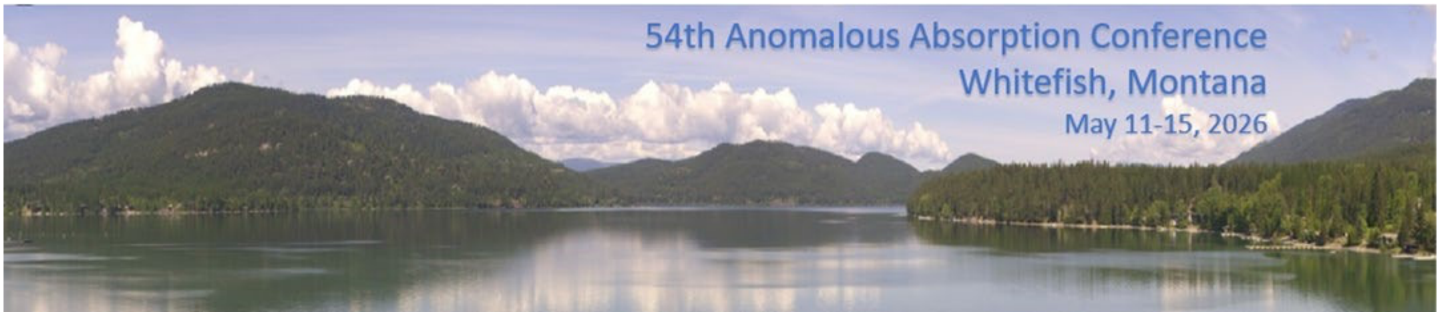
[1] K. W. Wong and B. Bachmann, “*Three-dimensional electron temperature measurement of inertial confinement fusion hotspots using x-ray emission tomography,*” Rev. Sci. Instrum. **93**, 073501 (2022).
[2] B. Bachmann *et al.*, “*Direct Experimental Proof of the Principal Role of Reduced High-Mode Hydrodynamic Mix in Recent Ignition Success on NIF,*” Phys. Rev. Lett. **135**, 065101 (2025).



Important concepts commonly confused in fusion analysis

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Abstract

Since the first demonstration of thermonuclear (TN) ignition at the National Ignition Facility (NIF), the pursuit of scalable fusion energy has accelerated across both government and private sectors. Achieving practical fusion energy requires not only technological advances, but also a rigorous and unambiguous understanding of the physics conditions necessary for a self-sustained thermonuclear burn.

Although nearly two decades of experiments at NIF and OMEGA have significantly advanced fusion science, key ambiguities remain in the interpretation of thermonuclear data. Several critical concepts are frequently conflated, including ignition criteria; required fuel areal density versus total areal density; burn width versus confinement time; disassembly time versus assembly time; burn efficiency versus burn parameter and temperature; thermonuclear burn versus self-sustained burn; and nuclear reaction history versus extrema.

These distinctions are fundamental, not semantic. Inconsistent definitions directly affect performance assessment, target optimization, and projections for fusion energy scalability. A physically consistent framework is essential to guide future experimental design and interpretation.

In this presentation, we examine the fundamental differences among these concepts, clarify common misconceptions through illustrative examples, and discuss their implications for target design and the pathway toward robust, self-sustained fusion burn. (LA-UR-26-21557)

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*This work conducted under the auspices of the U.S. Department of Energy by the Los Alamos National Laboratory under contract number 89233218CNA000001.

Large-scale high-yield implosions for inertial fusion energy (IFE): enhanced performance and distinct physics characteristics*

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Following the achievement of multi-megajoule yield implosions at the National Ignition Facility (NIF), the next objective is to attain an even higher yield. As the sizes of the capsules and their projected yields increase, several performance improvements occur: (a) The peak radiation drive temperature decreases with larger capsule sizes. (b) The burn fraction becomes less susceptible to perturbations when the hotspot temperature exceeds ~30 keV. (c) The dopant layer, located in the inner region of the ablator, is essential for maintaining a neutral Atwood number at peak velocity. The thickness ratio of this layer to that of the ablator decreases as the size of the capsule increases. This reduction results in reduced remaining ablator mass fraction, and enhanced rocket efficiency. (d) For a given level of surface roughness, the percentage of yield reduction caused by Rayleigh-Taylor instability decreases despite an increase in growth factor at the ablation front. Gain curves and gain scaling, along with the neutron and x-ray spectra, relevant to first-wall designs for IFE reactors, will be presented. In all implosions conducted at NIF, the burn wave is a subsonic deflagration. However, as the capsule size increases and the burn becomes more robust, the burn front transitions from subsonic to supersonic. This supersonic burn front is driven by the alpha-particle absorption flux, distinct from the supersonic nuclear detonation that occurs in a Type Ia supernova. A supersonic burn wave allows the maximum burn rate to be achieved before the fuel-layer undergoes significant expansion. We will provide a scaling formula that characterizes this transition. The supersonic burn wave triggers an explosion in the fuel layer, compressing the core of the hotspot to extreme density and temperature. As a result, the electrons become mildly thermal-relativistic. We will present relativistic corrections to the thermodynamics and transport processes in large-scale implosions.

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* Work performed under the auspices of the U.S. DOE by LLNL under contract DEAC52-07NA27344 and supported by SCW1835

Modeling Capsule Implosions in Indirect Drive THOR Experiments

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Following the achievement of ignition and gain on the National Ignition Facility (NIF), it was observed that high-yield capsule implosions exhibited significant hohlraum re-heating that produces X-ray fluxes stronger than the initial radiation drive[1]. Subsequently, the Thinned Hohlraum Optimization for Radflow (THOR) experimental campaign was developed with the intention of utilizing this enhanced X-ray emission for opacity measurement and radiation flow experiments. Fundamentally, the THOR campaign seeks to modify high-yield capsule hohlraum designs with the inclusion of thinner high-Z “windows” at the waist which burn-through duration of the laser drive, becoming sufficiently optically thin for the re-heat generated X-rays to escape. But the performance of high-yield capsule implosions is sensitive to asymmetries in the x-ray drive. So, a significant design challenge lies in the prescription of windows thin enough to enable radiation outflow, but thick enough not to significantly perturb the x-ray drive. Recently, a high-yield igniting capsule implosion was fielded from a hohlraum with THOR windows, producing 7.89 x 10^{17} neutrons (2.4 MJ of energy) from 2.05 MJ of laser energy, for a net gain of ~1.2.

This work will present simulation modeling of capsule implosions from THOR experiments using the radiation-hydrodynamics code xRAGE[2,3]. We will compare the performance and experimental measurables from the igniting THOR shot to its unperturbed equivalent[4], towards characterizing the impact of the THOR windows on capsule performance. In addition, we will present pre-shot modeling of upcoming THOR experiments, which utilize thinner windows to facilitate faster window burn-through time and greater emitted x-ray fluxes.

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*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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[1] Rubery et al., Phys. Rev. Lett. 132, 065104, 2024.
[2] M. Gittings et al., “The RAGE radiation-hydrodynamics code,” Comput. Sci. Discov. 1, 015005 (2008).
[3] B. M. Haines et al., “High resolution modeling of indirectly driven high-convergence layered inertial confinement fusion capsule implosions,” Physics of Plasmas 24, 052701 (2017)
[4]A. L. Kritcher et al., “Design of the first fusion experiment ot achieve target energy gain G > 1,” Physical Review E 109, 025204 (2024)

Residual kinetic energy reduction in NIF inertial confinement fusion implosions*

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In 2.05 MJ and 2.2 MJ Hybrid-E DT layered ignition implosions at the National Ignition Facility (NIF), fluence compensated down scattered neutron images (FCDSNI) show significantly higher fuel areal density on the capsule poles than the capsule equator at stagnation time. The asymmetry in the fuel areal density indicates a reduction in confinement of the hot-spot due to low mode asymmetry swings during the implosion that also leaves residual kinetic energy (RKE) in the shell that's not converted to hot-spot internal energy[1, 2, 3]. These combined effects are predicted to degrade neutron yield by ~2×. A series of 2D in-flight capsule radiography experiments (2DConA) and DT layered experiments (drive energy is truncated from 2.05 MJ to 1.9 MJ due to current NIF limitations), with design changes relative to Hybrid-E, have been done to test the impact of reducing P_2 symmetry swings on the fuel areal density asymmetry. The design changes are a 250 µm re-point of the 50° outer beams along the hohlraum axis (requiring a +400 µm longer hohlraum for beam clearance through the laser entrance holes) and a pole hot x-ray drive at early times giving a 10% P_2 / P_0 drive asymmetry onto the capsule. These two changes add more flux on the capsule poles earlier in time and are predicted to re-distribute the fuel areal density more uniformly at stagnation and reduce the in-flight to hot-spot P_2 asymmetry swing on the capsule.

Each 2DConA tested one design change at a time (N241125: 50° re-point, N241230: 50° re-point + pole hot early time drive, N250713: N241230 repeat with re-tuned two color inner-to-outer beams laser $\Delta\lambda$) and demonstrated a 5× reduction in the in-flight to hot-spot P_2 swing with a round hot-spot at stagnation compared to the equivalent Hybrid-E 2DConA N240304. As a result of these changes, the DT layered experiments showed for the first time higher fuel areal density on the capsule equator than on the capsule poles in the FCDSNI, in contrast to higher fuel density on the poles ("polar ice caps") observed in Hybrid-E and other ICF implosions. Furthermore, a full drive 2.05 MJ DT layered experiment is scheduled in July, using these design changes, to compare the performance to the N250222 and N250406 2.05 MJ Hybrid-E implosions that currently hold the fusion energy yield record on the NIF. This experiment will validate whether RKE design changes that reduce the P_2 swings also improve the DT fuel compression and increase the fusion energy yield.

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*This work performed under the auspices of U.S. Department of Energy by LLNL under Contract DE-AC52-07NA27344

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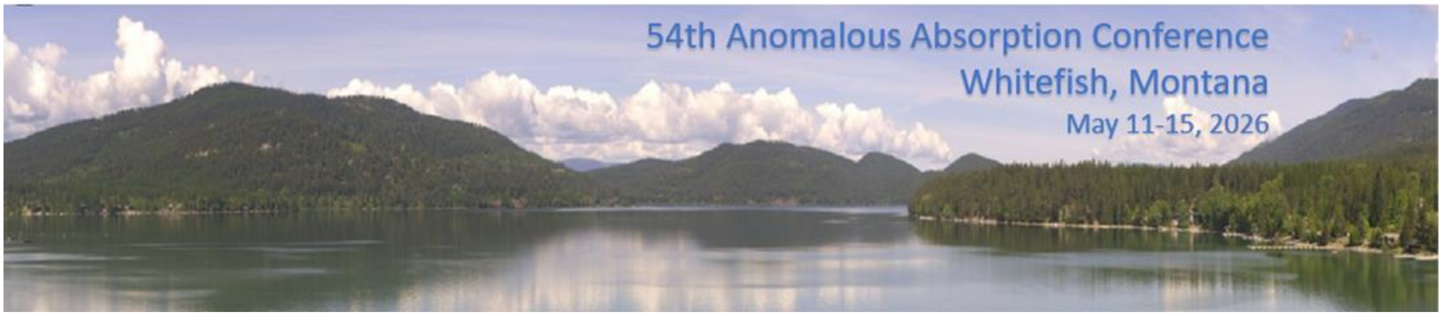
[1] A. L. Kritcher et al., *Phys. Plasmas* **21**, 402708 (2014)
[2] O. A. Hurricane et al., *Phys. Plasmas* **27**, 062704 (2020)
[3] O. A. Hurricane et al., *Phys. Plasmas* **29**, 012703 (2022)



New cross-beam energy transfer measurement platform at the National Ignition Facility

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Cross beam energy transfer (CBET) is a primary lever for controlling implosion symmetry in all ignition designs at the National Ignition Facility (NIF). Its importance is expected to grow as laser driver energies extend beyond today's multi-megajoule regime toward next generation facilities operating near 10 MJ. In indirect drive inertial confinement fusion (ICF) experiments at NIF, CBET redistributes laser power among the 192 beams through ion wave mediated coupling in the hohlraum plasma, shaping the spatial and temporal x-ray drive symmetry on the capsule.

Although CBET has been essential to achieving ignition, it is effectively a poorly constrained tuning knob in current integrated models, where empirical clamps are often used to match experiments. Current radiation hydrodynamics simulations do not reliably predict low mode shape and symmetry, and CBET modeling routinely relies on an empirical plasma wave amplitude limiter. This limiter must be re tuned for each target design, laser pulse, and wavelength detuning configuration, leaving ambiguity about whether it compensates for missing CBET physics or for other errors in hohlraum or capsule modeling. The resulting uncertainty increases the number of tuning shots and reduces confidence in extrapolations to higher energy facilities.

We report a new suite of NIF experiments (2025 to 2026) designed to directly measure CBET in a hohlraum-like environment. We developed a novel experimental platform that, for the first time, quantifies the time resolved transfer of power from outer to inner beam cones as a function of wavelength detuning $\Delta\lambda$ and hohlraum gas fill density. High fidelity, time gated x ray images of the inner cone individual 32 beams provide unprecedented maps of post CBET beam power and intensity across an entire NIF hemisphere.

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* *This work was performed under the auspices of U.S. DOE by Lawrence Livermore National Laboratory (LLNL) under Contract DE-AC52-07NA27344*

Validating cross-beam energy transfer models using indirect-drive ICF experiments at NIF

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Cross-beam energy transfer (CBET), a three-wave instability whereby energy is transferred between overlapping laser beams in the presence of a background plasma, is a critical tool to control implosion symmetry in indirect-drive experiments at the National Ignition Facility (NIF). Standard practice in post-shot modeling of implosion symmetry currently utilizes ad hoc limiters on the CBET-driven ion acoustic wave amplitudes to reproduce observed symmetry. As part of a larger effort to improve predictive capability in hohlraum modeling, we have developed a new experimental platform to directly quantify total CBET between inner beams and outer beams as a function of time. In this configuration, the bottom half of NIF drives a quartraum (a truncated hohlraum with no capsule). The outer beams strike the interior of the quartraum, while the inner beams exit through the top and hit a titanium plate. The resulting ~5 keV K-shell x-ray emission from the titanium plate is used to infer the laser intensity of each individual inner beam. Here we present simulated predictions of CBET as a function of wavelength detuning (Δλ) at nominal background gas fill density and separately as a function of fill density for a nominal Δλ. Results are compared against multiple independent experimental diagnostics to quantify the interaction.

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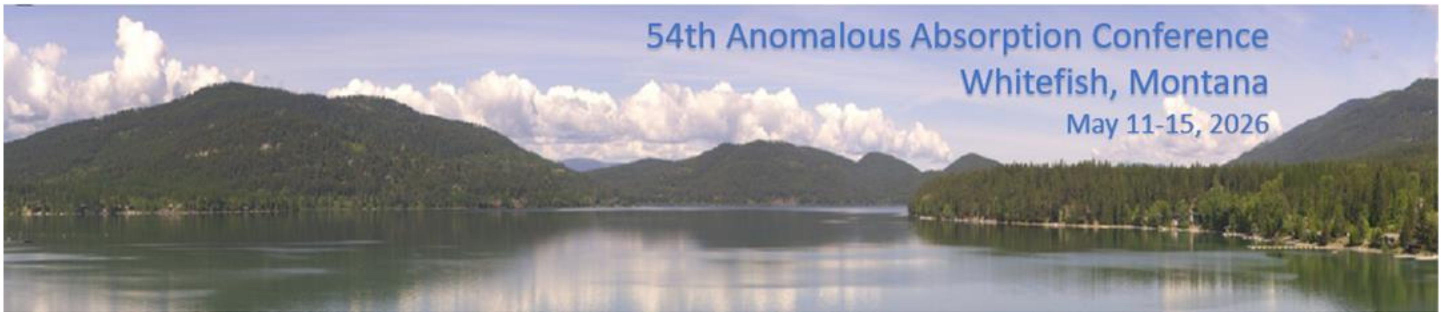
* *This work was performed under the auspices of U.S. DOE by Lawrence Livermore National Laboratory (LLNL) under Contract DE-AC52-07NA27344. IM release number LLNL-ABS-2017121*



Accuracy of the Ray-Tracing Modeling of Cross Beam Energy Transfer in Inertial Confinement Fusion Hohlraums*

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Cross Beam Energy Transfer (CBET) is a three-wave coupling process involving two laser beams and an ion-acoustic wave. In Inertial Confinement Fusion (ICF) hohlraums, many laser beams intersect, and CBET occurs at each crossing. Because of the large hohlraums size, simulations are typically performed at the hydrodynamic scale, which motivates the use of reduced CBET models.

A recent analytical study[1] showed that ray-tracing models can accurately capture the average transferred power, provided the beam angular spread is considered. This angular spread, set by the beam f-number, is however not always included in inline CBET models. The f-number effect leads to a substantial broadening of the resonance shape for two crossing beams in a homogeneous, weakly Landau-damped plasma. However, in realistic hohlraums, where many beams cross in an inhomogeneous plasma, the impact of the f-number effect is expected to be less significant.

Here, we examine the influence of the f-number on CBET in ICF hohlraums using a full-scale model[2] that computes CBET from hydrodynamic simulation maps. We also evaluate the range of validity of the strongly damped approximation in weakly Landau-damped plasmas, such as gold. All these conclusions are verified against fluid simulations performed with pF3D.

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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.

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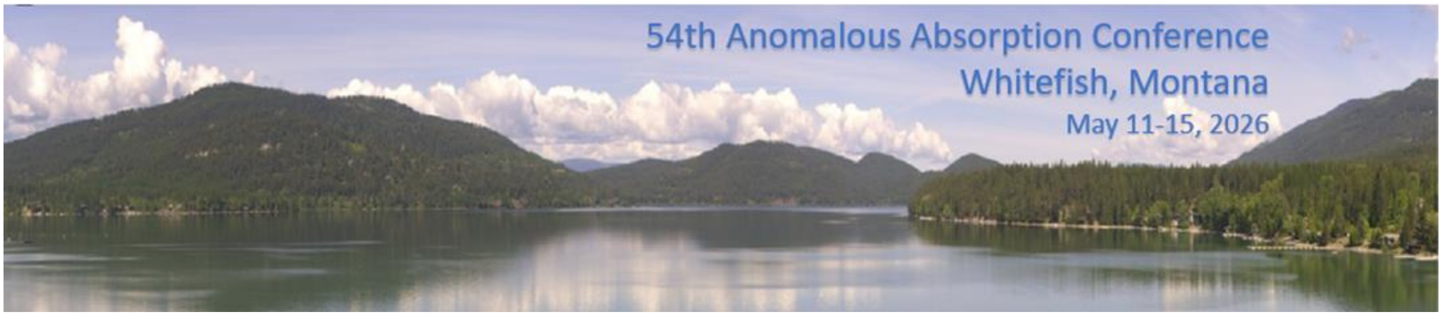
[1] A. Oudin et al. Phys. of Plasmas (2025).
[2] P. Michel et al. Phys. of Plasmas (2009).



Cross-Beam Energy Transfer with Spectral Smoothing : influence of resonant frequency pairs on the energy transfer

G. Meynard[1,2,3,], S. Hüller[1], G. Riazuelo[2,3] and D. Penninckx[2,3]
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Oral presentation : Cross-beam energy transfer (CBET) is a critical laser-plasma instability in inertial confinement fusion, where crossing laser beams exchange energy through ion-acoustic waves. When beams are smoothed using random phase plates (RPP) or smoothing by spectral dispersion (SSD), the local resonance conditions are distributed in both wavevector and frequency space. We present a comprehensive study with full paraxial wave simulations using the Harmony code[1].

Our key finding is that spectral and angular smoothing geometrically and spectrally broaden the resonance window. While this geometric decoherence reduces the peak energy transfer at the exact acoustic resonance compared to standard plane-wave models, it allows energy transfer to persist even when the global beat detuning is far from resonance via resonant frequency and wavevector pairs introduced by the SSD and RPP.

We show a comprehensive parameter sweep of Harmony simulations across a broad parameter space relevant to NIF and LMJ experiments (modulation depth M $\in [0, 15]$, damping $\nu_s \in [0.025, 0.2]$, detuning $\Omega_b = \Delta\omega - \mathbf{k}_s.\boldsymbol{v}_p \in [0, 2]\omega_s$ with $\Omega_b = \omega_s$being the resonance). Finally, we confirm our numerical results by demonstrating excellent agreement with recently developed analytical composite gain models.

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* This work has been done under the auspices of CEA-DAM, and the simulations were performed using HPC resources at TGCC/CCRT.

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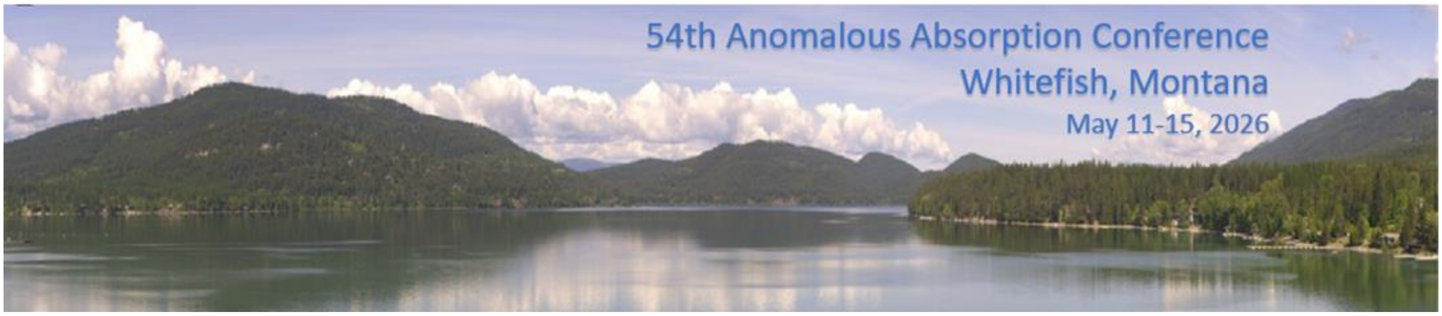
[1] Hüller S, Masson-Laborde PE, Pesme D, Casanova M, Detering F, Maximov A. 2006 Harmonic decomposition to describe the nonlinear evolution of stimulated Brillouin scattering. Phys. Plasmas, 13, 022703. (doi:10.1063/1.2168403)

Thursday
May 14, 2026

54th Anomalous Absorption Conference Agenda

Thursday, May 14, 2026

7:45	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session VII: Short Pulses, Compression	**Chair: Antonino Di Piazza**
8:30-9:00	Invited: Electron Dynamics in Realistic Short-Pulse, High-Intensity Laser Focal Fields	Caleb Guthrie, U. Alberta
9:00-9:20	Ionization-Seeded Current Filamentation in Collisionless Plasma Sheaths	Audrey Farrell, UCLA
9:20-9:40	Ultra-High-Intensity Regimes of Laser Self-Focusing	Caleb Redshaw, Stanford
9:40-10:00	High-Power Characterization of Ionization Diffraction Gratings	Victor Perez-Ramirez, Stanford University
10:00-10:20	Autoresonant Creation and Control of Plasma Structures	Jonathan Wurtele, UC Berkeley
10:20-10:40	Coffee Break	
	Session VIII: Optical Diagnostics: Thomson Scattering, CBET	**Chair: Jason Myatt**
10:40-11:10	Invited: Characterizing Plasma Conditions in ICF Hohlraums using 3 Optical Thomson Scattering	Steven Ross, LLNL
11:10-11:30	Thomson Scattering with Gain	David Turnbull, LLE
11:30-11:50	Measurements of plasma conditions with a high bandwidth ultraviolet laser using cross-beam energy transfer	Avi Milder, LLE
11:50-12:10	Geometric Optics Model of Thomson Scattering Enhanced by Parametric Coupling	Daniel Carleton, U, Alberta
12:10-12:30	Enhanced Ion-acoustic Wave Fluctuations Driven by Speckled Heater Beams	Kyle McMillen, LLE
12:30-1:30	Lunch in the Stumptown & Viking Rooms	
1:30-7:00	Open	
	Evening Plenary	**Chair: Robert Fedosejevs**
7:00-8:00	Light-matter interaction in the strong-field QED regime	Antonino Di Piazza, LLE
8:00-10:00	**Poster Session III**	



Electron Dynamics in Realistic Short-Pulse, High-Intensity Laser Focal Fields

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In the analysis of high-power laser-plasma interactions, a Gaussian intensity profile is often assumed. Furthermore, the paraxial approximation is commonly used to simplify calculations of the focal spot and only scalar fields are considered.[1] However, most high-power laser systems employ flat-top intensity profiles, and many utilize low f# focusing parabolas to produce high interaction intensities. Under these conditions, the fields are no longer Gaussian in form, and the assumptions underlying the paraxial approximation break down. In these cases, a more rigorous vectorial solution is required.[2]

This limitation becomes particularly apparent when calculating single electron dynamics within the focal volume. Ponderomotive acceleration of electrons is proportional to the gradient of the field intensity profile.[3] Under ideal Gaussian conditions, this corresponds to a single central peak from which electrons scatter. In realistic fields, however, diffraction produces regions of zero intensity associated with Airy rings and Lommel zeros, resulting in multiple intensity peaks. In very high-intensity systems, these secondary peaks can themselves ponderomotively accelerate electrons to relativistic energies, thereby complicating the electron dynamics within the field.[4]

In this work, we demonstrate a more complete computational analysis of the focal region, comparing different techniques to compute the vectoral fields. We then show how the distribution of electrons accelerated in the focal volume differs when using accurate models of the field compared to a simple Gaussian model.

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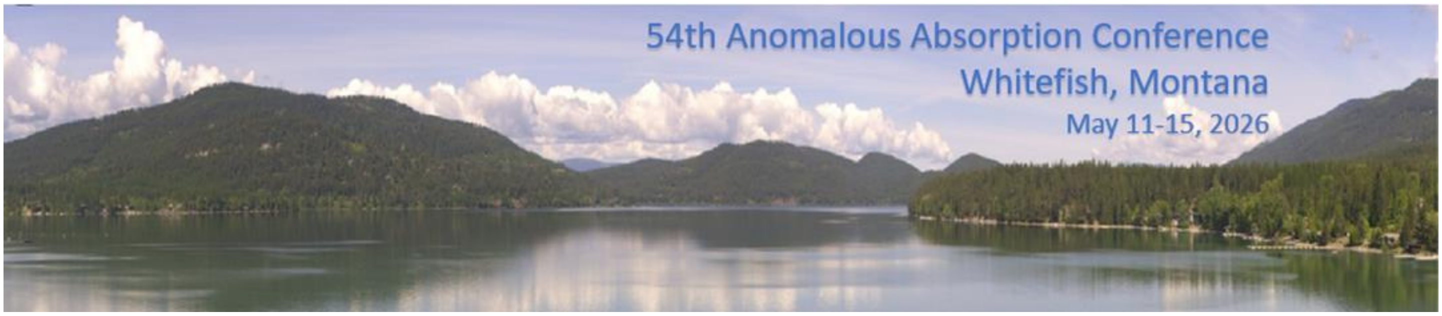
[1] W. L. Erikson and S. Singh, "*Polarization properties of Maxwell-Gaussian laser beams,*" Phys. Rev. E **49**, no. 6, 5778–5786 (1994).

[2] J. Peatross, M. Berrondo, D. Smith, and M. Ware, "*Vector fields in a tight laser focus: comparison of models,*" Opt. Express **25**, no. 13, 13990 (2017).

[3] F. V. Hartemann *et al.*, "*Nonlinear ponderomotive scattering of relativistic electrons by an intense laser field at focus,*" Phys. Rev. E **51**, no. 5, 4833-4843 (1995).

[4] A. Longman *et al.*, "*Toward direct spatial and intensity characterization of ultra-high-intensity laser pulses using ponderomotive scattering of free electrons,*" Physics of Plasmas **30**, no. 8, 082110 (2023).



Ionization-Seeded Current Filamentation in Collisionless Plasma Sheaths*

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We report a novel seeding mechanism for current filamentation instability in a less studied regime of overdense yet predominantly collisionless laser-plasma interactions. This mechanism was identified using a gas jet target experimental platform at Brookhaven National Laboratory's Accelerator Test Facility, where a relativistic intensity 2 ps (FWHM) long-wavelength infrared pump laser interacts with a gas jet plasma that is overdense to the pump yet transparent to a near infrared probe laser, enabling simultaneous measurements of high spatial resolution self-generated magnetic fields via Faraday rotation polarimetry and density filaments via interferometry. Supporting simulations show that the observed filaments form as a result of the highly nonlinear dependence of the ionization rate on the local sheath electric field produced by the cloud of hot electrons accelerated by the pump laser, which is then reinforced by the local surplus of ions in the ionization front as newly ionized electrons move upstream to form the return current. This locally enhanced ionization gives rise to 20-μm-scale filaments of plasma that generate local azimuthal magnetic fields reaching MG strengths and can last for over one hundred picoseconds. The onset of filamentation at the ionization front can be seen by a significant decrease in the expansion velocity of the plasma, an effect we observe in both simulation and experiment for the first time.

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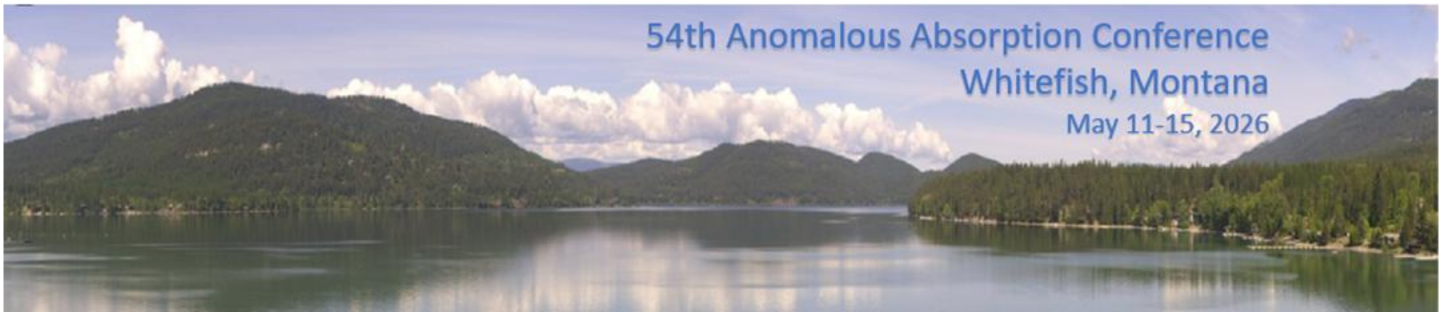
* This material is based upon work supported by the U.S. Department of Energy under Grant No. DE-SC0010064, as well as the University of California, Los Angeles and Lawrence Livermore National Laboratory under Grant No. B670378.



Ultra-High-Intensity Regimes of Laser Self-Focusing

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Self-focusing in plasmas, a nonlinear optical effect that causes a laser pulse to collapse into one or more tightly focused filaments, is a problem of both fundamental and practical interest. A self-focusing laser can be guided over propagation distances much longer than would otherwise be possible, which is important, for instance, in achieving high electron energies through bubble-regime laser wakefield acceleration[1]. Self-focusing due to the relativistic nonlinearity is well-understood in the weakly relativistic limit, where it occurs above a critical power that depends only on the plasma density and the laser frequency[2]. However, self-focusing beyond that limit is more complex.

We investigate short-pulse laser self-focusing and collapse over a range of intensities and densities, from below the critical power through the radiation reaction regime. Using analytic theory and particle-in-cell simulations, we find that self-focusing behavior changes significantly at high intensities. In the ultrarelativistic limit, the relativistic quiver nonlinearity fails to induce a sufficient change in phase velocity to overcome diffraction, and self-focusing is thus suppressed. The required intensity can be surprisingly low for tenuous plasmas (on the order of 10^{19} W/cm^2 for a near-infrared laser propagating through a plasma at 0.2% of the critical density). Self-focusing can also be suppressed by electron ejection from the pulse, for which we estimate a threshold intensity by balancing the relativistic ponderomotive force against the resulting charge separation. We find that both the relativistic quiver and ponderomotive ejection thresholds reduce to the same scaling dependencies on the pulse width and a similarity parameter N/a_0. Finally, we examine the impact of radiation reaction and electron-positron pair production on self-focusing at extreme intensities.

This work was supported by National Science Foundation grants PHY-2308641 and PHY-2541940.

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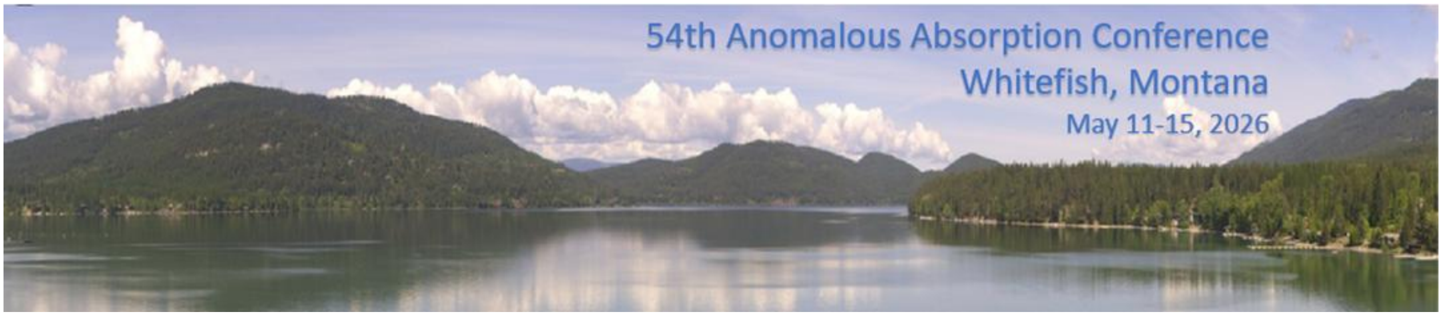
[1] S. P. D. Mangles et al., "*Self-injection threshold in self-guided laser wakefield accelerators,*" Phys. Rev. ST Accel. Beams **15**, 011302 (2012).
[2] G.-Z. Sun et al., "*Self-focusing of short intense pulses in plasmas,*" Phys. Fluids **30**, 526-532 (1987).



High-Power Characterization of Ionization Diffraction Gratings*

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Progress towards next-generation high-power lasers has been limited by the damage threshold of solid-state optics. The requirement for large and expensive components prevents the development of compact, cost-effective systems operating at peak powers from hundreds of petawatts to exawatts. Plasma optics offer a promising solution because their damage thresholds are orders of magnitude higher than those of solid-state materials. In particular, ionization diffraction gratings could enable chirped-pulsed amplification architectures with much higher peak-power outputs by replacing the final solid-state compression grating in a laser compressor[1].

Ionization gratings are formed by crossing two intense laser beams in a neutral gas. The resultant interference pattern ionizes the gas only within the constructive interference, creating a periodic refractive index modulation that functions as a diffraction grating. Prior experiments conducted at the millijoule scale[2,3] have shown single-shot efficiencies up to 60%[3] and average diffraction efficiencies up to 35%. However, for higher-power lasers, it is important to demonstrate that ionization gratings can diffract pulses with hundreds-of-millijoules to joule-scale energies. Here, we show that pulses with approximately 100 mJ of energy can be diffracted with an average efficiency above 40% while maintaining excellent beam quality and focusability.

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[1] M.R. Edwards and P. Michel, “Plasma Transmission Gratings for Compression of High-Intensity Laser Pulses,” *Physical Review Applied*, **18**, 2 (2022).
[2] M.R. Edwards et al., “Greater than Five-Order-of-Magnitude Postcompression Temporal Contrast Improvement with an Ionization Grating”, *Physical Review Letters*, **133**, 155101 (2024).
[3] M. R. Edwards et al, “Control of intense light with avalanche-ionization plasma gratings,” *Optica*, **10**, 1587 (2023).

Autoresonant Creation and Control of Plasma Structures*

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Fully kinetic particle-in-cell (PIC) simulations using the **SMILEI**[1] code are employed to investigate autoresonant[2] plasma beat-wave excitation in plasmas with linearly and quadratically varying density profiles. We first demonstrate that spatial variation of the background plasma density can induce phase locking between two laser drivers with fixed frequencies. This autoresonant phase locking enables control of the plasma-wave amplitude: the saturation amplitude can exceed the classical Rosenbluth–Liu limit[3] and, for certain laser intensities, approach the nonrelativistic wave-breaking threshold.

For a quadratic density profile and appropriate parameters, two pairs of counter-propagating lasers can excite a nonlinear structure that persists after the driving lasers exit the system. These PIC results are consistent with previous fluid studies[4] in which a plasma-wave "time crystal" is excited by two pairs of counter-propagating chirped lasers in a homogeneous plasma. A heuristic theory based on autoresonant synchronization with the local plasma frequency is found to agree well with the simulation results. The simulations also extend earlier work[5] on autoresonance in Raman backscatter and on large-amplitude beat-wave excitation in inhomogeneous plasmas.

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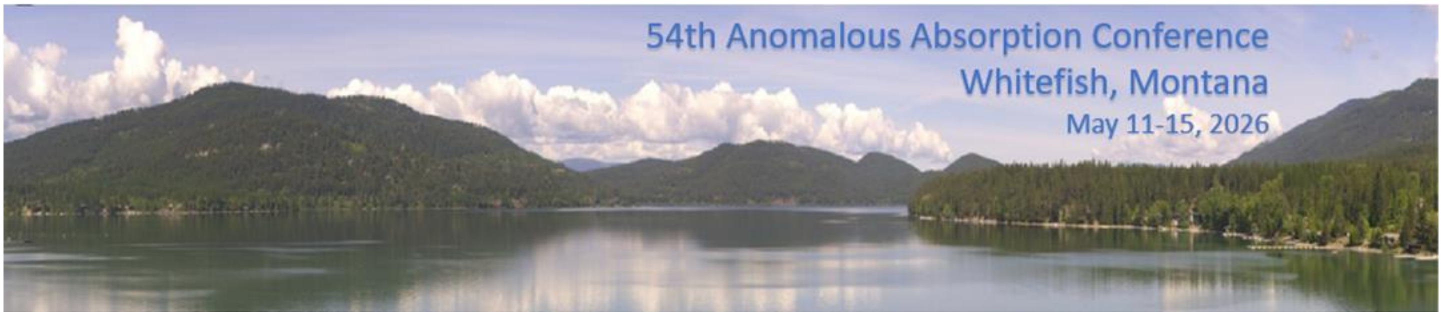
*Work of C.R. and J.S.W. partially supported by the Berkeley-France Fund. The project received computational support from the National Academic Infrastructure for Supercomputing in Sweden and partial support from the Swedish Research Council.

References:
[1] J. Derouillat, et al., Comput. Phys. Commun. **222**, 351 (2018).
[2] J. Fajans and L. Friedland, Am. J. Phys. **69**, 1096 (2001).
[3] M. N. Rosenbluth and C. S. Liu, Phys. Rev. Lett. **29**, 701 (1972).
[4] V. Munirov, et al., Phys. Rev. **E 106**, 055201 (2022); Phys. Rev. Research 4, 023150 (2022).
[5] T. Chapman et al., Phys. Rev. Lett. **108**, 145003 (2012); O. Yaakobi, et al., Phys. Plasmas **15**, 032105 (2008); M. Luo, et al., Phys. Plasmas **29**, 072709 (2022).



Characterizing Plasma Conditions in ICF Hohlraums using 3ω Optical Thomson Scattering*

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Understanding plasma conditions in National Ignition Facility (NIF) indirect-drive inertial confinement fusion (ICF) hohlraums is essential for predicting laser energy coupling and the time-dependent conditions that govern capsule drive. This talk presents the first measurements of plasma dynamics in the laser entrance hole region of a NIF ICF hohlraum using the NIF Optical Thomson Scattering diagnostic using a 3ω (351nm) probe laser.

Thomson scattering measurements in a driven ICF hohlraum at 3ω are challenging because the probe shares the same wavelength as the drive beams, producing substantial background. In these experiments, background is mitigated through careful selection of the scattering geometry, enabling measurements of plasma dynamics up to approximately 50% of peak drive power.

We report the observed evolution of the hohlraum fill plasma. Interpreting these data, we infer the arrival times of the shock launched into the fill by the explosion of the laser entrance hole (LEH) membrane, and the rarefaction that follows as the LEH plasma accelerates out through the open LEH. These measurements are compared with predictions from state-of-the-art hohlraum radiation-hydrodynamics modeling, and areas of disagreement between data and simulations are discussed.

These Thomson scattering data provide new experimental constraints for hohlraum models. Such constraints are essential for developing a truly predictive hohlraum simulation capability, which is critical for assessing new hohlraum designs for NIF and future, larger-scale facilities.

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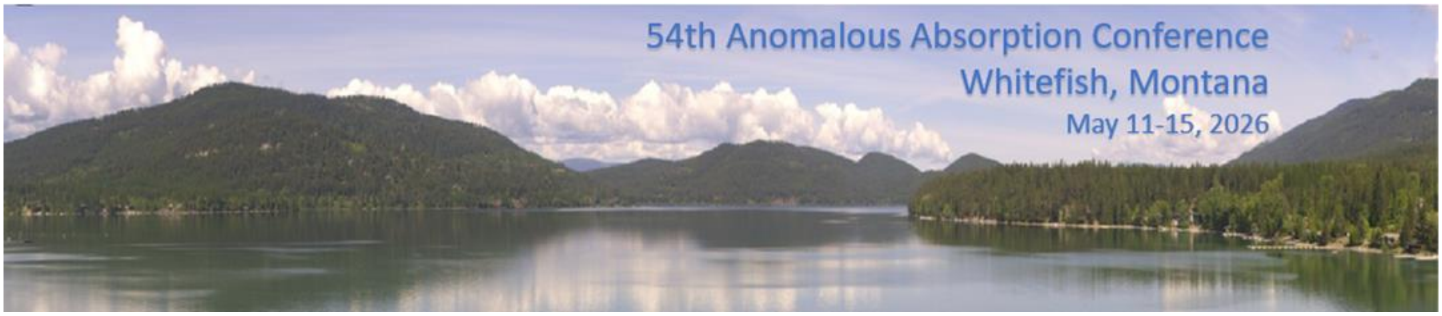
*This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344



Thomson Scattering with Gain*

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Thomson-scattering signals can be significantly modified by convective gains associated with the stimulated Raman scattering and stimulated Brillouin scattering instabilities as the scattered light traverses the probe beam. Gain results in amplification and narrowing of the red-shifted (i.e., Stokes) scattered light, whereas blue-shifted (anti-Stokes) features are depleted and broadened, making the relative prominence of these features a key signature of gain. In experiments conducted at the University of Rochester's Omega Laser Facility, small convective gains < 1 were found to significantly modify measured Thomson-scattering signals, resulting in substantial errors in the inferred plasma conditions (up to ~20%) if the gains were not included in the analysis.[1] Neglecting to account for instability growth has been a ubiquitous source of error in previous Thomson-scattering measurements.

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* 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 DE-NA0004144, and the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, under Award Number DE-SC0024863.

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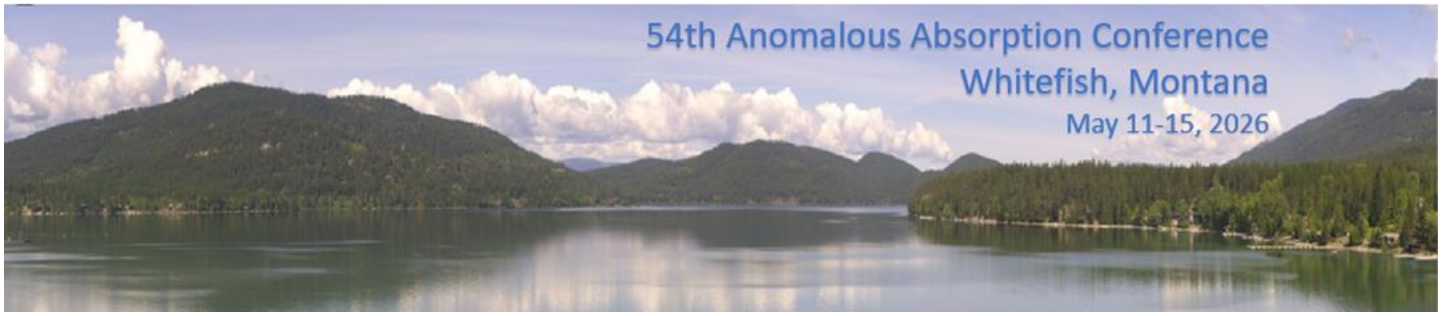
[1] D. Turnbull *et al*., "*Thomson Scattering with Gain*," submitted to Phys. Rev. Lett. (2026).



Measurements of plasma conditions with a high bandwidth ultraviolet laser using cross-beam energy transfer*

A. L. Milder[1], D. Turnbull[1], J. Katz[1], R. Shah[1], R. Dean[1], R. Follett[1], C. Dorrer[1], E. Hill[1], A. Colaitis[1], N. R. Shaffer[1], W. Rozmus[2] and D. H. Froula[1]
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The Fourth-generation Laser for Ultrabroadband eXperiments (FLUX) brings a new capability to the Laboratory for Laser Energetics. FLUX delivers a spectrally incoherent beam with 5 nm of bandwidth centered around 351 nm to the target chamber of the Omega Laser Facility. The first experimental use of FLUX, was to demonstrate a plasma diagnostic that can measure spatially localized plasma conditions utilizing the CBET interaction. The ion-acoustic resonances transfer energy between the FLUX beam and a narrow band OMEGA beam (i.e., cross-beam energy transfer (CBET) moves energy between the two beams). The locations and width of the resonant peaks in the output spectrum provide a measure of the electron and ion temperature, respectively, and the magnitude of transfer was used to determine the plasma density. This technique was compared with simultaneous Thomson scattering measurements showing good agreement in measured plasma conditions and the effect of CBET model on the extracted conditions.

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* This work is supported by the Department of Energy under contract numbers: DE-NA-0004144 and DE-SC0024863

Geometric Optics Model of Thomson Scattering Enhanced by Parametric Coupling*

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Laser-produced plasmas at fusion-relevant scales generate intense Bremsstrahlung emission, which constitutes a significant background for Thomson scattering (TS) diagnostic measurements. This background can be mitigated by increasing the intensity of the TS probe beam, thereby improving the signal-to-noise ratio of the scattered spectra. However, sufficiently high probe intensities may induce parametric coupling between the probe beam and plasma density fluctuations, resulting in finite gain for scattering instabilities such as stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS).

We present a ray tracing based theoretical framework for the description of incoherent TS augmented by the finite gain of scattering instabilities and incorporate this framework into a practical tool for the interpretation of experimental spectra. The scattered radiation is described through the eikonal approximation, including convective gain arising from probe driven scattering instabilities for arbitrary scattering angles. We consider the weak-gain regime for absolutely stable plasmas, in which parametric coupling enhances the red-shifted side and suppresses the blue-shifted side of the TS spectrum. Furthermore, accurate sampling of plasma inhomogeneity within the scattering volume provides a rigorous means of treating inhomogeneous plasmas in TS experiments.

In this work, we present a two-dimensional version of the ray-tracing code and clearly outline its potential extension to realistic geometries, such as those obtained from large-scale hydrodynamic simulations or independent experimental measurements. Thomson scattering spectra illustrating our ray tracing method using plasma conditions based on radiation-hydrodynamic simulations are shown in the Poster session.

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* This work was supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award No. DE-SC0024863: IFE-STAR and the U.S. DOE, National Nuclear Security Administration, under Award No. DE-NA0004144: University of Rochester "National Inertial Confinement Fusion Program."

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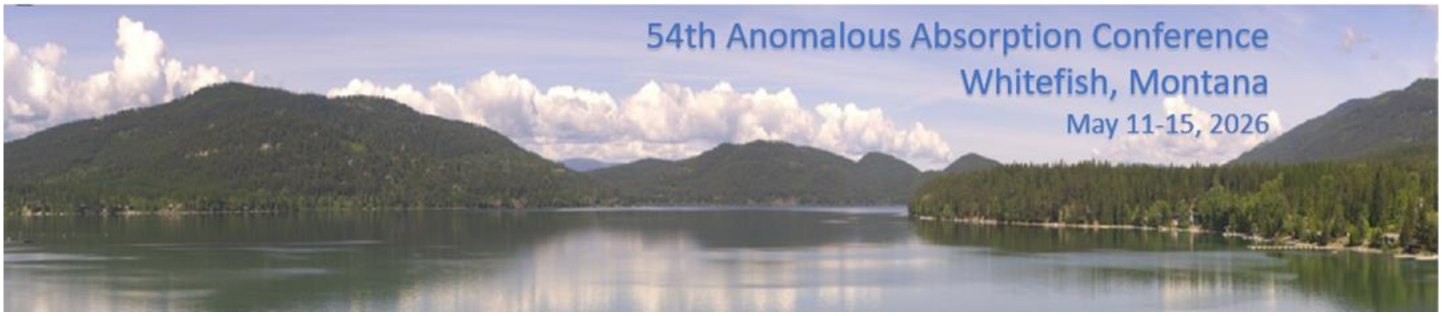
[1] D. E. Carleton, J. F. Myatt, W. Rozmus, C. Bruulsema, A. Milder, J.P. Palastro, and D. H. Froula, "Geometric optics model of Thomson scattering enhanced by parametric coupling," submitted to *Phys. Plasmas* (2026).



Enhanced Ion-acoustic Wave Fluctuations Driven by Speckled Heater Beams

K.R. McMillen, R.K. Follett, A.L. Milder, J. Katz, H.G. Rinderknecht, D.H. Froula, J.P. Palastro, D.J. Haberberger, and J.L. Shaw

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Laser facilities investigating indirect and direct-drive fusion techniques including the National Ignition Facility, Laser Mégajoule, and the OMEGA 60 system at the Laboratory for Laser Energetics, employ distributed phase plates (DPPs) to improve on-target laser uniformity and to mitigate hydrodynamic and laser-plasma instabilities (LPI). DPPs provide nearfield phase aberrations on the beams that produce characteristic speckled intensity distributions on target. Here, we provide evidence that gas-jet plasmas heated by these speckled beams with no smoothing by spectral dispersion (SSD) are subject to increased ion-acoustic wave (IAW) fluctuations that can enhance LPI. Experiments performed on the OMEGA 60 laser system couple a 2-ns 2ω Thomson scattering probe into a gas-jet plasma ionized and heated by 0.5-ns 3ω heater beams utilizing SG5-850 DPPs and no SSD. Resulting time-resolved Thomson scattering measurements show enhanced power scattered by ion-acoustic wave (IAW) fluctuations while the speckled heater beams are on. However, once the heater beams have turned off, the IAW-scattered power returns to thermal levels.

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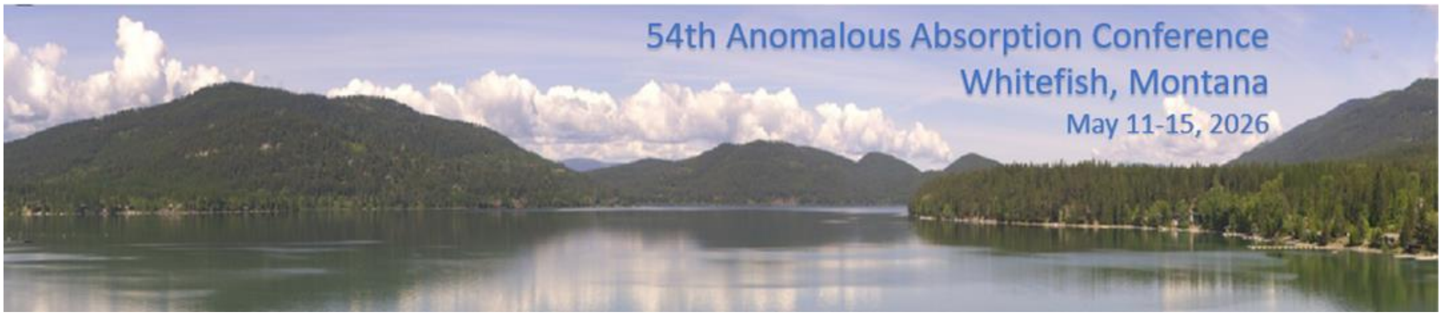
*This material is based upon the work supported by the Department of Energy [National Nuclear Security Administration] University of Rochester “National Inertial Confinement Fusion Program” under Award No. DE-NA0004144 and the Department of Energy, Office of Science, Office of Fusion Energy, under Award Numbers DE-SC0021057 and DE-SC0024863.



Light-matter interaction in the strong-field QED regime

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Quantum electrodynamics (QED) is a well-established physical theory and its predictions have been confirmed experimentally in various regimes and with extremely high accuracy. However, there are still areas of QED that deserve theoretical and experimental investigation, especially when physical processes occur in the presence of intense background electromagnetic fields, i.e., of the order of the so-called "critical" field of QED or *Schwinger field*, a regime known as *strong-field QED* regime [1-3].

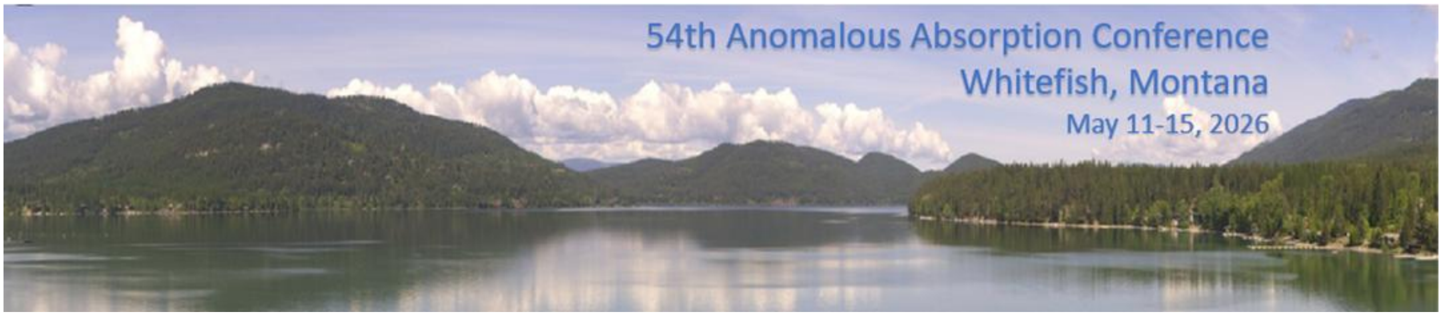
After a broad introduction on the electromagnetic interaction, I focus on some representative examples of currently open problems in the case of strong-field QED in intense laser fields [1-3]. First, I will discuss how quantum effects modify the radiation by ultrarelativistic electrons, a process which has a classical counterpart. Then, I will move to two phenomena, which are purely quantum mechanical: vacuum polarization and pair production. These phenomena have changed our perception of the quantum vacuum as they occur due to the fact that quantum mechanically electromagnetic fields do also interact in vacuum. Related to this, I will mention some recent theoretical proposals to measure these quantum effects by employing intense structured light. Finally, if time allows, I will conclude with a short introduction on the so-called *Ritus-Narozhny conjecture*, which states that in the presence of ultra-high laser fields the effective "strength" of the electromagnetic interaction approaches that of the strong interaction, which underpins nuclear phenomena.

A. Di Piazza, C. Mueller, K. Z. Hatsagortsyan, and C. H. Keitel, Rev. Mod. Phys. **84**, 1177 (2012).
[2] A. Gonoskov, T. G. Blackburn, M. Marklund, and S. S. Bulanov, Rev. Mod. Phys. **94**, 045001 (2022).
[3] A. Fedotov, A. Ilderton, F. Karbstein, B. King, D. Seipt, H. Taya, and G. Torgrimsson, Phys. Rep. **1010**, 1 (2023).

Thursday, May 14, 2026 – Poster Session III, Stumptown and Viking Rooms

8:00-10:00 PM

P-1	Sida Cao, Stanford University/SLAC	A Flying Focus with Arbitrary Directionality
P-2	Daniel Carleton, University of Alberta	Application of ray-tracing Thomson scattering theory to experimental data
P-3	Sarah Hansen, LANL	Validation of Scaling Capabilities of LANL's xRage for Polar Direct Drive Implosions
P-4	Shaun Kerr, LLNL	First demonstration of a cone & wire backlighter for robust, high energy, small source size x-ray radiography using NIF-ARC
P-5	Sallee Klein, University of Michigan	High-energy-density Targets Fabricated by The University of Michigan
P-6	Jason Myatt, University of Alberta	Memories of Reuben Epstein
P-7	Vijay Patel, UCLA	Generalized multi-dimensional conservation laws for stimulated Raman and Brillouin scattering in a density gradient
P-8	Yuan Shi, University of Colorado	Particle-in-cell simulations of laser crossbeam energy transfer via magnetized ion-acoustic wave
P-9	William Taitano, LANL	Conditional Formulation for the Vlasov-Ampere Equations: A Novel Multiscale Structure Preserving Kinetic Plasma Formulation to Bridge Continuum and Kinetic Scales
P-10	Phil Travis, Ergodic	Optimizing designs and including multiscale physics in an implosion code via differentiable simulation
P-11	Frank Tsung, UCLA	Investigation of LPI near the quarter critical surface under the influence of temporal bandwidth
P-12	Justin Jeet, LLNL	Investigation of the D-T γ-to-neutron and D- 3 He γ-to-proton branching ratios at ICF facilities



A Flying Focus with Arbitrary Directionality

S. Cao[1], D. Singh[1], L. Mack[2], J. P. Palastro[2], and M. R. Edwards[1]
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Laser pulses with controlled focal-point trajectories have shown considerable promise for tailoring laser-plasma interactions, yet prior realizations have largely restricted focal motion to the axis of pulse propagation. This work presents a new flying-focus scheme that lifts that constraint, enabling the focal point to move both along and across the propagation direction independently by combining a chirped laser pulse with a diffractive lens and diffraction grating[1]. The direction and speed of the focal spot motion can be systematically adjusted by varying the lens focal length, grating period, and chirp. To validate the concept, simulations are presented for a holographic implementation appropriate for high-power operation, where two off-axis pump beams with distinct focal lengths imprint the phase equivalent of a chromatic lens-grating pair onto a gas or plasma target, while the same functionality is accessible through conventional solid-state or adaptive optical elements for moderate-power systems. This extended control over focal point dynamics broadens the design space for a range of laser-based applications, including laser wakefield acceleration of ions[2], nonlinear Thomson scattering, and terahertz emission from surface plasmons.

This work was partially supported by NSF Grant PHY-2308641 and NNSA Grant DE-NA0004130. The work of J.P.P. and L.M. was supported by the Department of Energy Office of Science under Award Numbers DE-SC0021057 and DE-SC0025497/SUB0000841 and the Department of Energy National Nuclear Security Administration under Award Number DE-NA0004144.

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[1] S. Cao, D. Singh, L. S. Mack, J. P. Palastro, and M. R Edwards, "*A flying focus with arbitrary directionality*," arXiv preprint arXiv:2510.14195 (2025)

[2] Z. Gong, S. Cao, J. P Palastro, and M. R Edwards, "*Laser wakefield acceleration of ions with a transverse flying focus*," Phys. Rev. Lett. **133**, 265002 (2024)

Application of ray-tracing Thomson scattering theory to experimental data

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A ray-tracing framework[1] has been developed to model Thomson scattering (TS) from electron density fluctuations arising from particle discreteness. This approach combines ray dynamics of both the probe laser and scattered radiation with TS theory, including parametric coupling associated with side-scattered stimulated Raman and Brillouin scattering (SRS and SBS). In Ref. [1], the eikonal approximation is used to describe the convective gain of scattering instabilities driven by the TS probe and particle noise in inhomogeneous plasmas. In the limit of a homogeneous plasma and negligible parametric coupling, the model reduces to the standard TS cross section and scattered intensity. For inhomogeneous plasmas, the ray-tracing formulation provides a rigorous framework for computing TS spectra while accounting for density gradients and spatial variations of plasma parameters.

In this presentation, we apply the new TS theory to the interpretation of experimental data. We revisit beryllium sphere plasma experiments designed to investigate radiation-hydrodynamic modeling in a simple geometry.[2] In particular, we demonstrate the impact of parametric coupling on the asymmetry of the ion-acoustic resonance in the TS spectrum. The revised interpretation is compared with radiation-hydrodynamic and Vlasov–Fokker–Planck simulations, providing improved insight into thermal transport. Finally, we demonstrate the effectiveness of the ray-tracing approach in analyzing recent bow-shock experiments,[3] enabling measurements of shock velocity and associated jump conditions.

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* This work was supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Award No. DE-SC0024863: IFE-STAR and the U.S. DOE, National Nuclear Security Administration, under Award No. DE-NA0004144: University of Rochester "National Inertial Confinement Fusion Program."

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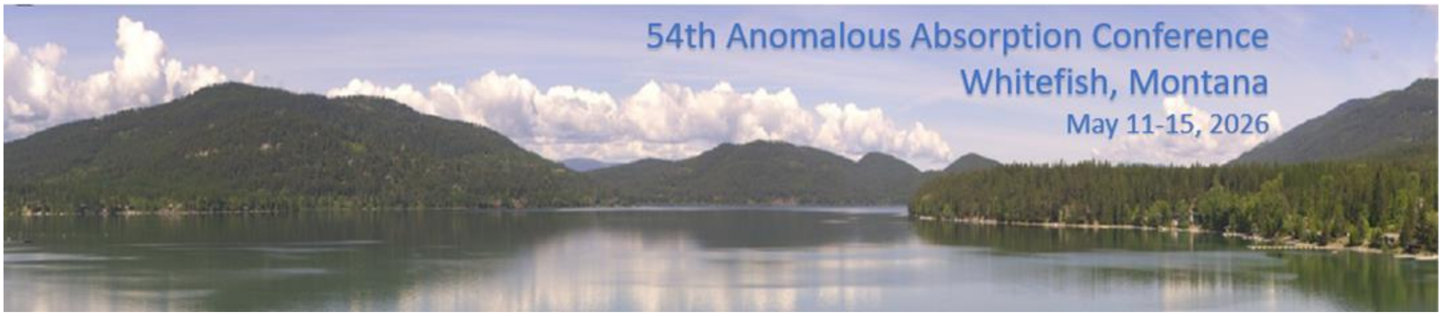
[1] D. E. Carleton, et al., submitted to Phys. Plasmas (2026)
[2] W. A. Farmer, et al. Phys. Plasmas 27 (2020)
[3] A.L. Milder, et al., Phys. Review Research 7, 013163 (2025)



Validation of Scaling Capabilities of LANL's xRage for Polar Direct Drive Implosions

S. E. Hansen,[1] J. L. Kline,[1] C. C. Samulski,[1] P. B. Radha,[1] E. S. Dodd,[1] M. J. Schmitt,[1] and G. E. Kemp[2]
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Direct drive target designs provide the greatest opportunity for symmetric, directionally independent targets that are favorable for future inertial fusion energy (IFE) systems. These symmetric target designs, combined with the polar direct drive (PDD) approach, reduce plant complexity, making a more robust power plant design. For this reason, Los Alamos National Laboratory is using the radiation hydrodynamics code xRage to design IFE targets for the polar direct drive configuration. The most promising IFE target designs are too large to be fielded on current laser facilities, requiring the ability to scale the designs in size. Using xRage, we are modeling PDD capsule implosions at Omega and National Ignition Facility (NIF) scales to ground our modeling choices with data and build a basis to make the same increase in scale from NIF up to our IFE capsule designs. This work presents results from modeling a common suite of experiments used to build credibility into our IFE target designs, as well as gaps in capabilities. This document has been provided release under the identifier LA-UR-00-00000.

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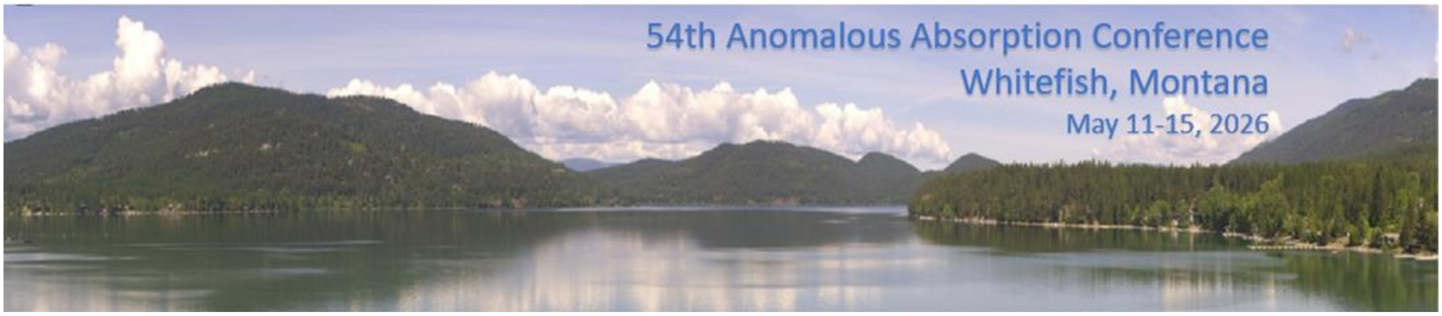
*This work is supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, FWP No. 0024882: IFE-STAR. This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy. (Contract No. 89233218CNA000001)



First demonstration of a cone & wire backlighter for robust, high energy, small source size x-ray radiography using NIF-ARC

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High energy density (HED) radiography requires x-ray backlighters that are high energy and bright, with small effective source size and robustness to shot-to-shot variations. Many wire and flag backlighters are sensitive to laser prepulse and pointing, degrading repeatability and radiographic performance. We report the first test of a novel backlighter concept to reach < 20 μm source size, > 200 keV average photon energy, and sufficient brightness to image NIF implosions. The design uses a compound parabolic concentrator (CPC) cone coupled to a gold wire bremsstrahlung converter and is driven by the NIF Advanced Radiographic Capability (ARC) laser. It aims to mitigate prepulse via a closed cone tip that shields the converter from direct laser illumination, reduce pointing sensitivity through a large acceptance aperture, and improve coupling to MeV electrons and photons using long scalelength plasma formation in the cone.

The experiment used four ARC beamlets (2.4 kJ total, 10 ps, co-timed) into a CH-only CPC cone with a 0.5 mm long, 20 μm diameter Au wire at the tip, pointed toward the radiography axis 56° from the laser axis. Tungsten sphere radiography objects (600 μm diameter) and tantalum step wedges (1, 2, 3, and 10 mm) were used to characterize the source strength, spectrum and radiograph performance along the axis. Excellent radiographic data was obtained, with a high energy (>100 keV) spectrum measured. Forward fitting of the tungsten sphere radiographs yielded an effective source size smaller than the converter diameter, with FWHM ~12 μm. The source properties will be presented and the suitability for different platform radiography assessed. Future optimization of both wire and electron source will be discussed.

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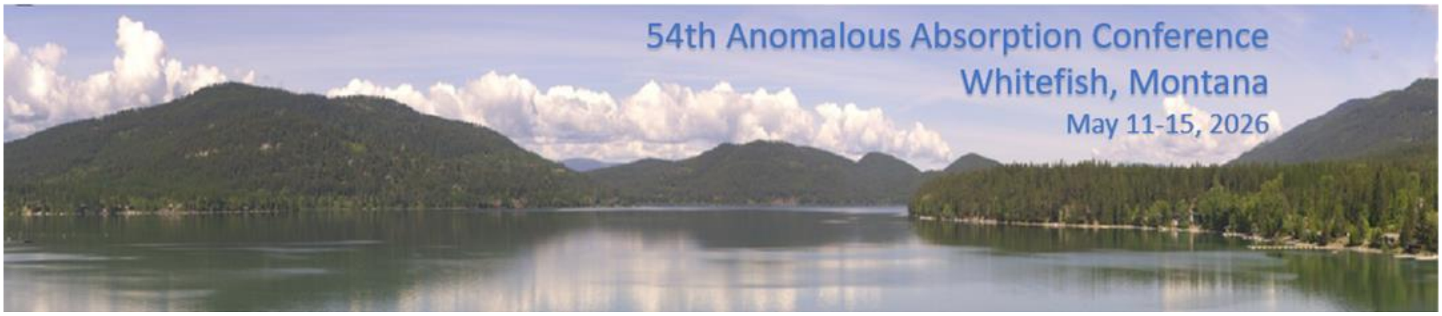
* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-2016847.



High-energy-density Targets Fabricated by The University of Michigan

S. R. Klein,[1] J. P. Schell,[1] S. Zuhrić,[1] D. Gillespie,[2] and C. C. Kuranz[1]
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Michigan Target Research and Fabrication (MiTRF) laboratory at the University of Michigan has the distinctive capability of fabricating targets for a wide variety of high-energy-density physics experiments. We have been assembling targets for experiments fielded at OMEGA, JLF and Z facilities, and many others for nearly two decades. The MiTRF team of staff and students take a thoughtful approach to the fabrication process serving the broader HED community, such as those at National Laboratories, Universities, LaserNetUS and LLE PIs.

Our builds include CAD models and drawings taken from VisRads or simple sketches, characterization of individual components and metrology photos of finished targets. All photos are given to the PI, along with component characterization and/or metrology measurements in a comprehensive and well-organized spreadsheet. The targets are hand delivered to the facility with shotday support provided if appropriate.

MiTRF has several in-house capabilities, such as laser-cutting components and high fidelity digital microscope photos with up to 2500x magnification. We also have many trusted partners to procure components not made in our lab. We work very closely with Dana Design machine shop. Dana Design provides tightly-toleranced machined target components, as well as jigs for precise assembly and experimental fixturing.

MiTRF became an official LaserNetUS node in 2023, allowing us the opportunity to significantly contribute to the HED community by providing funding for targets with many experimental configurations fielded at a wider variety of institutions. To continue serving the HED community we have worked with the University of Michigan to enable us to operate like a business. We can now accept customers from anywhere without the use of contracts. Through these expanded opportunities we endeavor to provide the highest quality targets meeting PIs' specifications.

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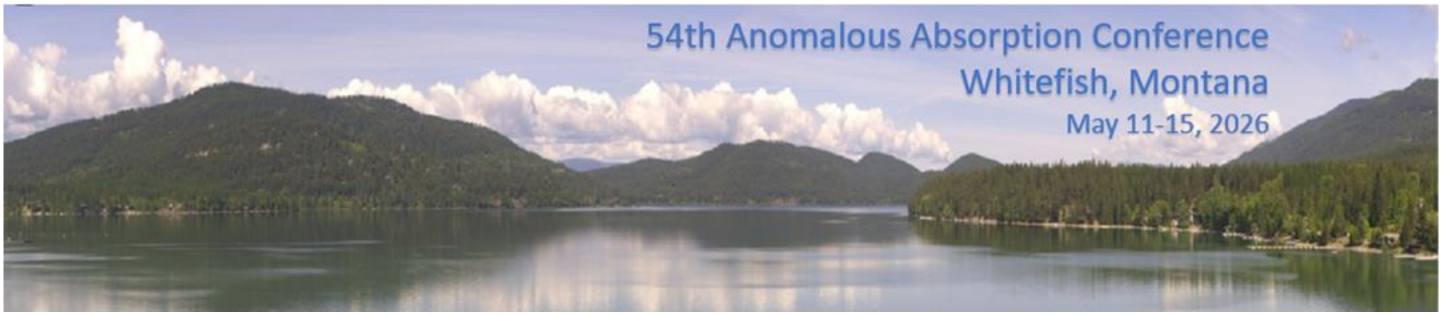
* This work is funded by the Department of Energy LaserNetUS under grant number DE-SC0024546 and the U.S. Department of Energy NNSA Center of Excellence under cooperative agreement number DE-NA0004146.



Generalized multi-dimensional conservation laws for stimulated Raman and Brillouin scattering in a density gradient

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Generalized local and multi-dimensional conservation laws of action, energy, momentum, and angular momentum are derived for stimulated Raman (SRS) and Brillouin backscattering (SBS) in a density gradient within the paraxial ray approximation. A Lagrangian density is found that reproduces the well-known envelope equations for SRS and SBS in density gradients in the absence of damping. Using Noether's theorem, the symmetries of the Lagrangian density are used to obtain local conservation laws for quantities that can easily be identified as the action, energy, and momentum. These multi-dimensional conservation laws reduce to the one-dimensional Manley-Rowe relation and frequency and wavenumber matching conditions. Additional symmetries of the action lead to conversation laws for new quantities that are identified as contributions to the energy and momentum of the wave from frequency and wavenumber shifts, and to the orbital angular momentum. Augmentation of the conservation laws in the presence of damping and extensions of the Lagrangian to include higher order corrections to the paraxial ray equation and nonlinear frequency shifts are also provided.

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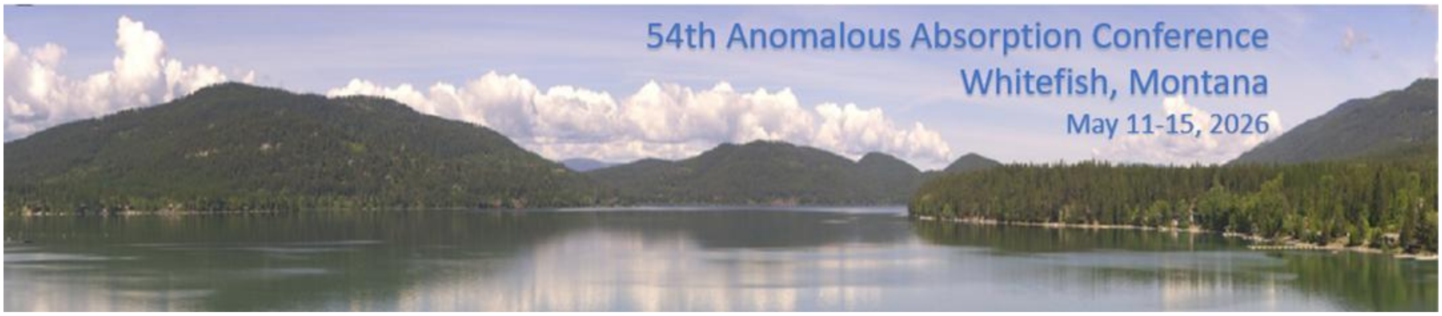
*Work supported by DOE, LLE, and LLNL.



Particle-in-cell simulations of laser crossbeam energy transfer via magnetized ion-acoustic wave

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Large magnetic fields, either imposed externally or produced spontaneously, are often present in laser-driven high-energy-density systems. In addition to changing plasma conditions, magnetic fields also directly modify laser-plasma interactions (LPI) by changing participating waves and their nonlonear interactions. In this paper[1], we use two-dimensional particle-in-cell (PIC) simulations to investigate how magnetic fields directly affect crossbeam energy transfer (CBET) from a pump to a seed laser beam, when the transfer is mediated by the ion-acoustic wave (IAW) quasimode. Our simulations are performed in the parameter space where CBET is the dominant process, and in a linear regime where pump depletion, distribution function evolution, and secondary instabilities are insignificant. We use a Fourier filter to separate out the seed signal, and project the seed fields to two electromagnetic eigenmodes, which become nondegenerate in magnetized plasmas. By comparing the seed energy before CBET occurs and after CBET reaches quasi-steady state, we extract CBET energy gains of both eigenmodes for lasers that are initially linearly polarized. Our simulations reveal that starting from a few MG fields, the two eigenmodes have different gains, and magnetization alters how the gains depend on laser detuning. The overall gain decreases with magnetization when the laser polarizations are initially parallel, while a nonzero gain becomes allowed when the laser polarizations are initially orthogonal. These findings qualitatively agree with theoretical expectations[2].

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* This work is 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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[1] Y. Shi, J. D. Moody, "*Particle-in-cell simulations of laser crossbeam energy transfer via magnetized ion-acoustic wave,*" Physics, accepted (2026).
[2] J. D. Moody, Y. Shi, "Vlasov theory of magnetized cross-beam energy transfer in a high energy density plasma", submitted to Physics of Plasmas (2026).

Conditional Formulation for the Vlasov-Ampere Equations: A Novel Multiscale Structure Preserving Kinetic Plasma Formulation to Bridge Continuum and Kinetic Scales

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Kinetic plasma models such as the Vlasov–Fokker–Planck equations are inherently multiscale in both space and time. There is growing interest in applying these equations to high-energy-density systems, including inertial confinement fusion and pulsed power devices to better capture the transport during hot conditions [1,2]. Among the many challenges in their numerical treatment, the simultaneous enforcement of multiple physical constraints—such as conservation laws, quasi-neutral asymptotics, positivity of the distribution function, and involution properties—has remained elusive.

We present a novel yet self-consistent reformulation of the Vlasov equation based on the conditional distribution function framework [3]. This approach applies a sequence of coordinate and variable transformations to decouple the evolution of conserved moments from the modified kinetic equation and transfer them to an associated system of moment equations. As a result, constraint enforcement is segregated from the high-dimensional kinetic equation into lower-dimensional moment equations, where such structures are more naturally expressed—for example, conservation laws are inherently embedded in the mass, momentum, and energy equations.

We further develop a compatible discretization strategy tailored to this formulation and demonstrate, for the first time, the simultaneous preservation of these constraints in canonical electrostatic test problems, including the multiscale ion acoustic shock problem. Finally, we show how this framework could be extended to tackle long-standing limitations of classical kinetic plasma models in supporting non-ideal-gas equation of state by isolating local dynamics within the moment system through appropriate equation-of-state and transport closures in the strongly coupled regime.

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*This work conducted 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.

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[1] J.J. van de Wetering et al., *"Particle-in-cell simulations of burning ICF capsule implosions,"* arXiv:2506.02273v1

[2] O.M. Mannion et al., *"Evidence of non-Maxwellian ion velocity distributions in spherical shock-driven implosions,"* Phys. Rev. E, **108** (3), 035201 (2023).

[2] W.T. Taitano et al., *"A conditional formulation of the Vlasov-Ampere equations: a conservative, positivity, asymptotic, and Gauss law preserving scheme,"* J. Plasma Phys., in press (2026).

Optimizing designs and including multiscale physics in an implosion code via differentiable simulation

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Paragraph 1

Laser-based fusion can be framed as a high-dimensional design optimization problem over capsule and laser parameters. The recent development of autodifferentiation (“autodiff”) packages allows gradient propagation through an entire simulation, enabling gradient-based, high-dimensional optimization that would otherwise be intractable using conventional methods. We are developing LagrADEPT (Lagrangian Automatic Differentiation Enabled Plasma Transport): a fully differentiable single-fluid Lagrangian 1D radiation-hydrodynamics code written in Python and JAX. We demonstrate this optimization capability by tuning the laser pulse shape with O(100) parameters for direct-drive implosions using simplified energy deposition and transport models. This differentiable framework also enables in-situ calibration or training of free parameters and surrogates in the simulator using experimental observables or data from higher-fidelity solvers.

Paragraph 2

Current efforts to extend LagrADEPT prioritize kinetic effects and laser-plasma interactions (LPI). Self-consistent nonlocal transport will be modeled by an embedded kinetic electron thermal transport module via a Vlasov Fokker-Planck code with a spherical harmonic decomposition of the electron distribution function. A model for hot electron generation, LPI preheat, and inverse Bremsstrahlung absorption are currently being integrated into the hydrodynamic solver. Results of optimizing yield with respect to laser parameters will be presented.

Investigation of LPI near the quarter critical surface under the influence of temporal bandwidth

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Previous works by Follett *et al*[1,2] have shown that the threshold of absolute instabilities near the quarter critical surface can be raised through a small amount of laser bandwidth. More recently, Joglekar and co-workers[3] have shown, using a differentiable version of LPSE, that an optimal spectrum exists which can maximize the LPI threshold for a fixed amount of averaged laser power and bandwidth[3]. Using 1D and 2D OSIRIS simulations, we have shown that the dominant instability for current IFE-COLoR designs is the high-frequency hybrid instability (HFHI) where the backward daughter wave can have a mixed ES/EM polarization, and its threshold can be modified via temporal bandwidth, similar to either bSRS and TPD as demonstrated previously. We will also demonstrates the effects of the ML-derived optimal pulse on the HFHI instability in 2D and discuss the plans to develop an optimization workflow using Bayesian optimization and Python coupled with 1D and 2D OSIRIS simulations which can be used to maximize the bSRS and HFHI thresholds for a fixed averaged laser power and bandwidth under conditions which are being considered by the IFE-COLoR fusion hub.

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1 R. K. Follett, J. G. Shaw, J. F. Myatt, H. Wen, D. H. Froula, and J. P. Palastro, *Phys. Plas.,* **28**, 032103 (2021).

2 R. K. Follett, J. G. Shaw, J. F. Myatt, C. Dorrer, D. H. Froula, and J. P. Palastro, *Phys. Plas.,* **26**, 062111 (2019).

3. A. S. Joglekar, R. K. Follett, D. H. Froula, and J. P. Palastro, "Optimal bandwidth spectra for minimizing Two Plasmon Decay", 2025 Anomalous Absorption Conference, Sedona, AZ, USA (2025).

Investigation of the D-T γ-to-neutron and D-^{3}He γ-to-proton branching ratios at ICF facilities

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The deuterium-tritium (D-T) γ-to-neutron branching ratio ($^{3}\mathrm{H}(\mathrm{d},\gamma)^{5}\mathrm{He}/^{3}\mathrm{H}(d,n)^{4}\mathrm{He}$) has been previously measured in several different experimental platforms including beam-target based, inertial confinement fusion (ICF), and magnetic confinement fusion (MCF) plasmas. A unique feature accessible to ICF plasma-based measurements, in contrast to accelerators and magnetic confinement, is the ability to probe lower center of mass energies. ICF based measurements also enable temporal separation of the γ signal from neutron induced backgrounds which can be problematic in other platforms. γ detectors at ICF facilities typically utilize the Cherenkov mechanism to attain fast detector response times, a requisite for the inherently short duration of ICF implosions. Recent measurements of the branching ratio exploit the better known ^{12}C neutron inelastic scattering cross section ($^{12}\mathrm{C}(\mathrm{n},\mathrm{n}'\gamma)^{12}\mathrm{C}$), in puck-based experiments, to absolutely calibrate the γ detectors. [1-2] A recent MCF based experiment utilizes scintillator-based detectors, with γ energy resolution, to determine both the shape of the gamma spectrum resulting from D-T fusion as well as the branching ratio. [3-4] There however remains discrepancies in the obtained results across the different experiments. In this work, recent experiments to measure the D-T γ-to-neutron and D-^{3}He γ-to-proton branching ratios, performed at ICF facilities, will be discussed along with preliminary results.

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LLNL-ABS- 2017030

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[1] J. Jeet et al., *Inertial-confinement fusion-plasma-based cross-calibration of the deuterium-tritium γ-to-neutron branching ratio*, Phys. Rev. C **104**, 054611 (2021).

[2] Z. L. Mohamed et al., *γ-to-neutron branching ratio for deuterium-tritium fusion determined using high-energy-density plasmas and a fused silica Cherenkov detector*, Phys. Rev. C **107**, 014606 (2023).

[3] M. Rebai et al., *First direct measurement of the spectrum emitted by the* $^{3}\mathrm{H}(^{2}\mathrm{H},\gamma)^{5}\mathrm{He}$ *reaction and assessment of the relative yield* $\gamma 1$ *to* $\gamma 0$, Phys. Rev. C **110**, 014625 (2024).

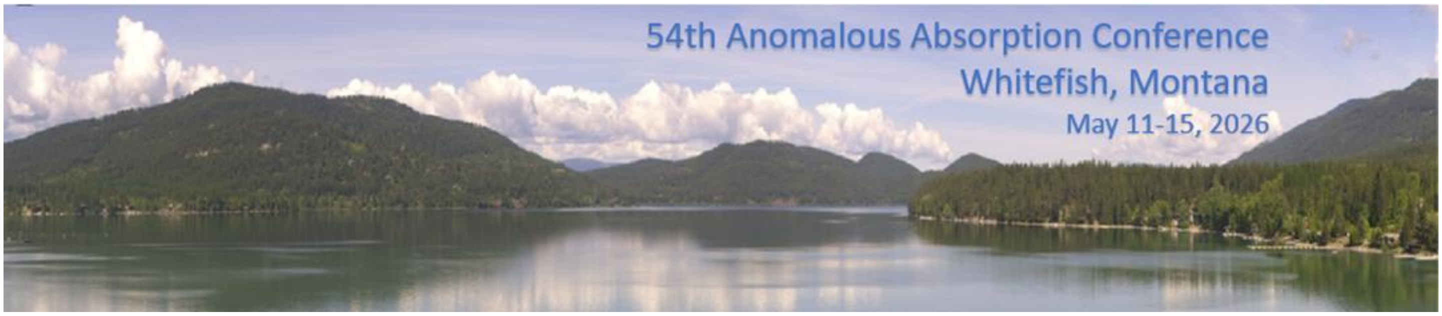
[4] A. Molin et al., *Measurement of the Gamma-Ray-to-Neutron Branching Ratio for the Deuterium-Tritium Reaction in Magnetic Confinement Fusion Plasmas*, Phys. Rev. Lett. **133**, 055102 (2024).

Friday
May 15, 2026

54th Anomalous Absorption Conference Agenda

Friday, May 15, 2026

8:15	Grab and Go Breakfast in the Ramsey Pre-Function Area	
	Session IX: High Energy Density	**Chair: Griffin Glenn**
9:00-9:30	Invited: Gas Optics for Tunable Beam Splitting, Harmonic Separation, and Spectral and Coherent Beam Combining	Ke Ou, Stanford University
9:30-9:50	Mean Force Kinetic Theory of Warm Dense Matter	Lucas Babati, U. Michigan
9:50-10:10	Coffee Break	
	Session X: ICF (R-T Instability, Radiation, Nuclear Diagnostics)	**Chair: Benjamin Bachmann**
10:10-10:30	Invited: Evidence of THOR Window Gap Closure in Experiment and Simulation	Damyn Chipman, LANL
10:30-10:50	Severity of the Deceleration Rayleigh-Taylor Instability in Inertial Confinement Fusion Targets	Jan Velechovsky, LANL
10:50-11:10	Hotspot mix diagnostics in Inertial Confinement Fusion experiments with the Nuclear Imaging System	Mora Durocher, LANL
11:10-11:20	Poster Awards and Conference Adjourns – See you next year!	
11:20	Grab and Go Lunch in the Stumptown & Viking Rooms	



Gas Optics for Tunable Beam Splitting, Harmonic Separation, and Spectral and Coherent Beam Combining

K. Ou,[1] S. Cao,[1] H. Rajesh,[1] D. Singh,[1] V. M. Perez-Ramirez,[1] D. Chakraborty,[1] C. Redshaw,[1] E. Koh,[1] P. Dedeler,[1]
M. M. Wang,[2] A. Oudin,[3] E. Kur,[3] J. M. Mikhailova,[2] L. Lancia,[4] C. Riconda,[5] P. Michel,[3] and M. R. Edwards[1]
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Gas optics have emerged as a compelling platform for manipulating high-energy lasers due to their ultra-high damage threshold and inherent debris resistance. The formation process relies on imprinting the interference pattern of a pair of deep-ultraviolet lasers into an O_3-O_2-CO_2 mixture via spatially modulated energy deposition. As a result, a substantial gas density modulation that matches the imprinted pattern can be induced, allowing the structured gas to function as an efficient diffractive optic. We have experimentally demonstrated gas diffraction gratings with near-unity efficiency and comprehensively studied their optical quality and characteristics under various conditions[1]. This approach has further been applied to realize an efficient diffractive lens capable of collimating lasers at extremely high intensity[2]. Here, we will present the latest advances in gas optics, including demonstrations of capabilities that extend well beyond simple beam steering. Specifically, we will show that gas gratings can be configured for tunable beam splitting, spectral beam splitting and combining, and coherent beam combining. Since these optics can sustain laser fluence above 1 kJ/cm^2, our results suggest that gas gratings could enable experimental geometries that would be impossible otherwise.

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[1] K. Ou, H. Rajesh et al., "Near-Unity-Efficiency Gas Gratings for Ultraviolet, Visible, and Infrared High-Power Lasers," arXiv:2601.09963 (2026).
[2] D. Singh, K. Ou et al., "Holographic Gaseous Lenses for High-Power Lasers," arXiv:2510.02659 (2025).

Mean Force Kinetic Theory of Warm Dense Matter

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Hydrodynamic descriptions of plasmas for inertial confinement fusion applications are reliant on transport coefficients for a wide span of material regimes. These coefficients can be particularly difficult to model in the warm dense matter regime, where strong coupling and degeneracy become important. Most often, in this regime, plasma kinetic theories with uncontrolled approximations or tables of expensive density functional theory calculations, which do not contain electron-electron interactions, are used to bridge the gap between typical plasmas and condensed matter. A model, based on plasma kinetic theory, is presented to fill this gap. It uses the Boltzmann-Uehling-Uhlenbeck kinetic equation along with full quantum scattering to model the degeneracy of the system and the potential of mean force to correctly model equilibrium correlations. A Chapman-Enskog expansion can be performed on this kinetic equation to give expressions for transport coefficients in terms of "bracket integrals". The bracket integrals are solved numerically but can be done so more efficiently than a density functional theory simulation. With this framework, electronic transport coefficients are calculated for Hydrogen at various densities and temperatures, as well as in solid density Aluminum. The model performs well in the warm dense matter regime agreeing with DFTMD and experimental data, where it exists. It also matches the correct plasma limit agreeing with typical kinetic theories. This is easily seen with the Lorenz number (the ratio between thermal and electrical conductivities), where the model matches the Wiedemann-Franz law in the degenerate regime, and the Spitzer limit in the plasma regime. In the plasma regime, DFTMD incorrectly limits to a Lorentz plasma, a theoretical plasma with no electron-electron interactions. That being said, this model is still a gas based kinetic theory and is not expected to work to the condensed matter regime.

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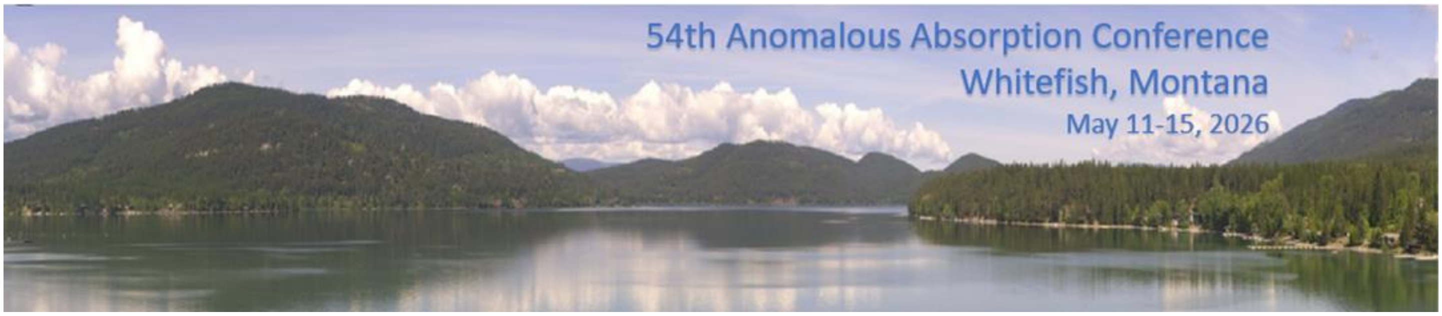
54th Anomalous Absorption Conference
Whitefish, Montana
May 11-15, 2026

Evidence of THOR Window Gap Closure in Experiment and Simulation[*]

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With the advent of ignition at the National Ignition Facility (NIF), strong hohlraum reheating has been observed – stronger than the x-ray flux generated to drive the implosion[1]. The Thinned Hohlraum Optimization for Radflow (THOR) campaign aims to establish a platform for using the products of ignition for radiation and opacity measurements on the NIF. This is done by engineering windows into the hohlraum wall that burn through at the appropriate time to release the fusion-generated radiation. The balance is to do so without breaking the delicate symmetry required to achieve ignition[2].

NIF shot N251012 was a 2D convergent ablator (2DConA) experiment which included two THOR windows. The THOR windows were 2.5 µm thick gold inserts backed by a 35 µm thick Epon layer to cover a 2-mm diameter manufactured hole in the hohlraum. A small gap of approximately 30 µm between the window and the hohlraum wall was designed to avoid bending the window. During assembly, we observed variability in the window gap size. Regardless, we predicted that the gap would close due to ablation of the gold. Experimental data gathered from the shot shows evidence of the gap closure, and simulations support this analysis. DANTE radiation flux data show radiation coming from the THOR window, including initial "leakage," a drop in signal due to the window closure, and the reemission from the capsule through the THOR window. Simulation scans of the size and geometry of the window gap bracket the size of the gap and show the same features observed in the experimental data. Understanding the dynamics of the THOR windows is crucial to establishing a platform for studying and using the products of ignition to drive radiation flow experiments on the NIF.

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[1] M. S. Rubery, et al., "Hohlraum Reheating from Burning NIF Implosions," Phys. Rev. Lett. 132, 065104, 2024.
[2] R. S. Lester, et al., "THOR: Developing a Next-Generation Platform for Radflow and Opacity Measurements," invited talk presented at 67th Annual Meeting of the APS Division of Plasma Physics, Long Beach, CA, Nov. 2025.

Severity of the Deceleration Rayleigh-Taylor Instability in Inertial Confinement Fusion Targets*

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Abstract

Interfacial material mixing is a well-studied yield-degradations mechanism in Inertial Confinement Fusion (ICF). The theory for Rayleigh-Taylor Instability (RTI) is often being applied to study the mixing during rapid deceleration of a ”heavy” Carbon shell supported by a ”light” D-T gas inside an ICF target[1,2,3,]. We discuss the constraints of the theory when applied to such conditions. In particular, we show that the contribution of deceleration RTI to material mixing is limited for current ICF targets.

Results

The size of material mixing regions is measured by transverse mixing width. For incompressible RTI, the width increases indefinitely as the instability reached self-similar growth. This is not true for compressible fluids. For the iso-thermal case, the initial density profile is piecewise exponential with a discontinuity at the material interface. As materials mix, the density eventually becomes monotone and there is no more driving force for the instability[4]. For the iso-choric case, the temperature profile is linear with the horizontal gradient proportional to capsule deceleration. The size of the heavy fluid reservoir is thus limited by the height at which temperature drops to zero. Both cases yield maximum mixing width at the order of 10 microns for the current best performing targets when analyzed using the theory of RTI. Given the total width of the DT ice layer around 70 microns, this mixing width would be negligible for the observed fusion gain.

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*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. LA-UR-26-21892.

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[1] R. Betti, et al. *"Hot-spot dynamics and deceleration-phase Rayleigh–Taylor instability of imploding inertial confinement fusion capsules."* Physics of Plasmas **8**.12 (2001): 5257-5267.

[2] L. Yin, et al. *"Plasma kinetic effects on interfacial mix and burn rates in multispatial dimensions."* Physics of Plasmas **26**.6 (2019).

[3] K. Cherng, S. Lele, and D. Livescu. *"Heat transfer and transport property contrast effects on the compressible Rayleigh-Taylor instability."* Physical Review Fluids **9.4** (2024): 043904.

[4] D. Aslangil, and M. Wong. *"Investigation of strong isothermal stratification effects on multi-mode compressible Rayleigh–Taylor instability."* Physics of Fluids **35**.8 (2023).

Hotspot mix diagnostics in Inertial Confinement Fusion experiments with the Nuclear Imaging System

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The Nuclear Imaging System (NIS) is a diagnostic tool that has been providing three-dimensional (3D) visualization of burn volumes for Inertial Confinement Fusion (ICF) driven implosions. NIS records both primary and down-scattered neutron images to reconstruct the distribution of the dense cold fuel surrounding the hotspot and study the conditions of ICF implosions at stagnation. Fluence-Compensated Down-Scattered Neutron Imaging (FCDSNI) is a technique that provides information about the cold fuel distribution by correcting for the spatial convolution of down-scattered images with the primary neutron fluence. By adapting a similar methodology and using 3D neutron fluence, a 3D density distribution can be inferred. This offers a new diagnostic perspective on cold fuel structure and asymmetry. Furthermore, ion temperature imaging techniques are being developed to produce spatially resolved ion temperature distributions. A one-dimensional proof-of-concept has been successfully demonstrated at the OMEGA laser facility, and a quasi-two-dimensional proof-of-concept is being designed for demonstration. Both these diagnostic tools can provide critical insight to assess hotspot mix, implosion performance and fundamental plasma properties in ICF experiments.

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