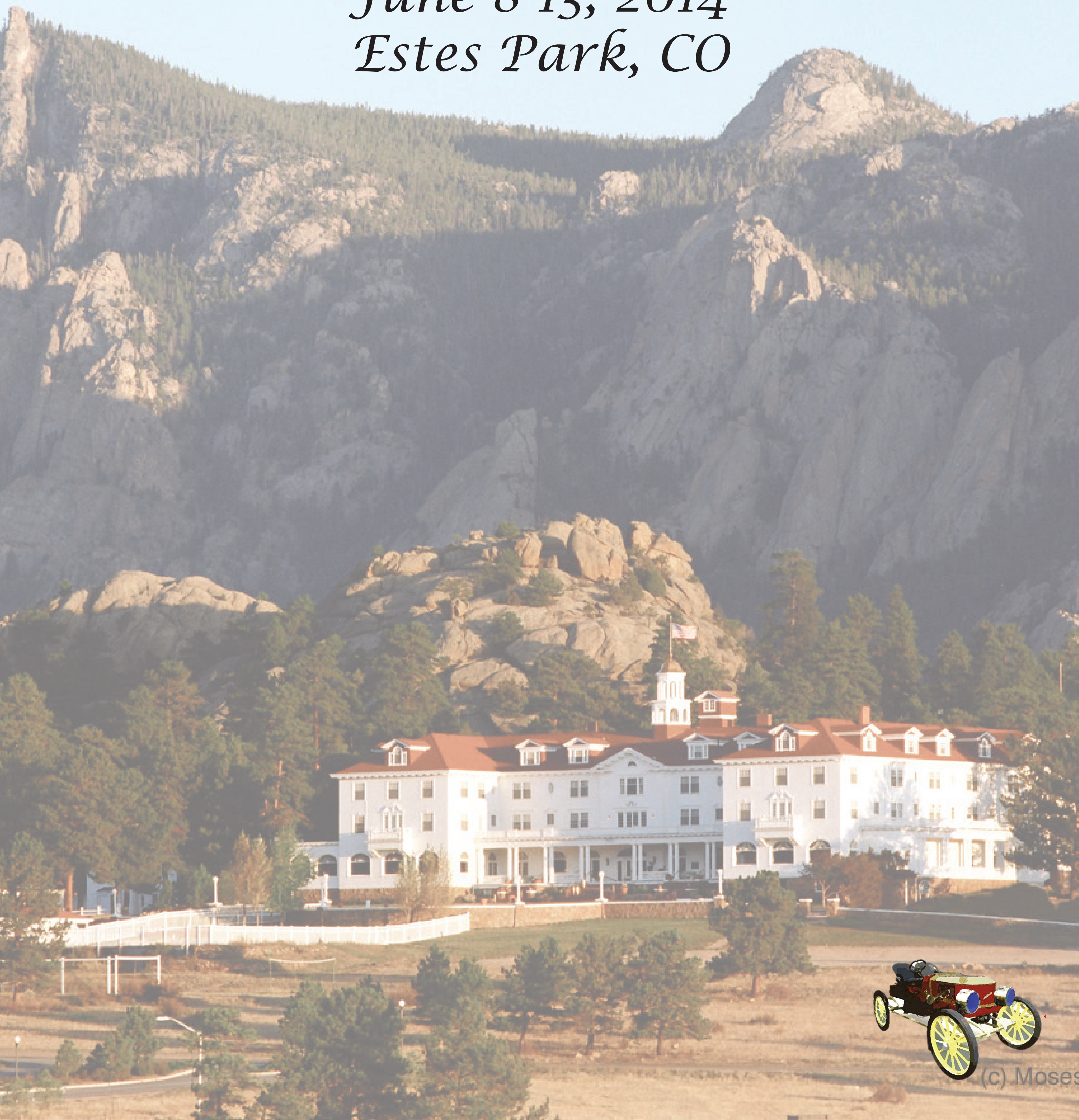
44th Annual
Anomalous Absorption Conference
Book of Abstracts

June 8-13, 2014
Estes Park, CO



44th Annual Anomalous Absorption Conference
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Control of Stimulated Raman Scattering in the Strongly Nonlinear and Kinetic Regime Using Spike Trains of Uneven Duration and Delay: STUD Pulses*

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Laser-plasma instabilities (LPI) pose a risk to the realization of laser-driven inertial confinement fusion (ICF) ignition. ICF ignition currently uses continuous, ns-time-scale, high-intensity laser beams. Because of LPI, this is far less effective than a novel technique[1] employing deterministic on-off modulation in time, and scrambling the laser speckle patterns in space. This technique, called the Spike Trains of Uneven Duration and Delay (STUD pulse) program, has been invented and demonstrated from moderate to high gain, where the repeated accumulation of growth locally in any portion of the plasma is halted by spreading the instability process throughout the plasma.[1,2] This presentation will focus on the application of STUD pulses to Stimulated Raman Scattering (SRS) where kinetic nonlinearity dominates the evolution of driven electron plasma waves (EPW) and where multi-laser-speckle, cooperative behavior proceeds through the exchange of hot electrons and SRS scattered light.[3] Kinetic simulations indicate that order-of-magnitude reduction in SRS reflectivity is possible even in this highly nonlinear and kinetic regime. The key is to keep local accumulation of repeated growth under check, occurring in less than a full hot spot per spike and allowing scrambling and healing of the growth process so that significant secondary, nonlinear processes can not occur, disallowing the self-organized state.[4]

* 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 LANS, LLC under contract DE-AC52-06NA25396. BA acknowledges the support of DOE OFES HEDP and SBIR grants.

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[1] B. Afeyan and S. Hüller, "Optimal Control of Laser- Plasma Instabilities using Spike Trains of Uneven Duration and Delay (STUD Pulses)," *Phys. Rev. Lett.* (submitted); also arXiv:1304.3960.
[2] B. Afeyan and S. Hüller, *Europ. Phys. J. Web of Conferences* **59**, 05009 (2013); also arXiv:1210.4462; S. Hüller and B. Afeyan, *Europ. Phys. J. Web of Conferences* **59**, 05010 (2013); also arXiv:1210.4480.
[3] L. Yin, B. J. Albright, H. A. Rose, K. J. Bowers, B. Bergen and R. K. Kirkwood, *Phys. Rev. Lett.* 108, 245004 (2012).
[4] B. J. Albright, L. Yin, and B. Afeyan, "Control of Stimulated Raman Scattering in the Strongly Nonlinear and Kinetic Regime Using Spike Trains of Uneven Duration and Delay: STUD Pulses," *Phys. Rev. Lett.* (submitted); also arXiv:1304:4814

44th Annual Anomalous Absorption Conference
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Interface-Free Ignition Double-Shell Designs for High Margin to Inner Shell Mix*

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Double-shell targets are distinguished from conventional hot-spot single-shell targets by a volume ignition mode that is of interest to ignition science due to characteristically low threshold ignition temperatures (~4 keV), high thermonuclear burn fractions, vacuum hohlraum fielding [1] and robust margin to hohlraum flux asymmetry [2]. The well-known challenges with double shells include target fabrication complexity, relatively low energy gain with respect to inertial fusion energy applications, and sensitivity to problematic mix between the DT fuel and high-*Z* inner shell. Double-shell fabrication was successfully demonstrated on the Omega laser facility [3], and the available use of cryogenic filling capabilities on the NIF relaxes the requirements of inner-shell material strength for room temperature fielding. The previously reported yields of NIF-scale double shell designs are on the order of several MJ, making them an attractive candidate for ignition studies. The widely acknowledged most serious challenge with double-shell ignition is the ability to suitably control fuel-pusher mix. To address this physical requirement, an interface-free inner-shell design is described that provides high margin to mix by arranging for a vanishing Atwood number at all "interfaces". This design makes use of the latest developments in 3D nano-lithographic printing of graded density foams. Quite broadly, this strategy for controlling mix with additive manufacturing techniques has application beyond ignition double shells and potentially could be applied to single-shell targets.

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[1] P. Amendt *et al*., Phys. Plasmas **9**, 2221 (2002); P. Amendt *et al*., Phys. Plasmas **14**, 056312 (2007).
[2] M.N. Chizhkov *et al*., Laser Part. Beams **23**, 261 (2005).
[3] P. Amendt *et al*., Phys. Rev. Lett. **94**, 065004 (2005); H.F. Robey *et al*., Phys. Rev. Lett. **103**, 145003 (2009).

*Work performed under the auspices of U.S. Department of Energy by LLNS-LLC under Contract DE-AC52-07NA27344 and supported by LDRD-14-ERD-031

[Oral]

44th Annual Anomalous Absorption Conference
Estes Park, CO

Exploding Pusher Implosion Dynamics in the Fluid to Kinetic Regime*

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The shock-flash episode of an ignition single-shell target on the NIF represents the incipient phase of the evolution of the hot spot. Near this time the mean free paths of the shocked ions prior to shock flash can transiently exceed the radius of the shock, thereby delocalizing the shock front and violating the fluid approximation that underlies mainline radiation-hydrodynamic simulation techniques. Although the shock flash phase lasts only several hundred picoseconds (at most) compared with the ~1 ns hot-spot formation time, errors in our modeling may impact the subsequent implosion dynamics. A recently obtained comprehensive database on the Omega laser facility that spans the fluid to kinetic regime of an exploding pusher implosion by varying the (D^3He) fuel density is the first step in assessing the kinetic features of an ignition target. A modeling study of this database is presented that suggests a transition from a centrally peaked burning plasma profile in the fluid limit to a shell-like topology as the kinetic regime is approached in the limit of low fuel density. Such a shell solution suggests that the burning fuel is contiguous with the mid-Z (SiO_2) exploding pusher ablator and is potentially sensitive to classical ion diffusion effects. On the other hand, the kinetic regime implies long mean free paths and an effective homogenization of the burning fuel within the SiO_2 ablator. Proton penumbral core imaging on the Omega laser provides time-integrated radial burn profiles that can further constrain candidate kinetic modeling.

[1] M. Rosenberg *et al*., Phys. Rev. Lett. (to appear).

* Work performed under the auspices of U.S. Department of Energy by LLNS-LLC under Contract DE-AC52-07NA27344 and supported by LDRD-11-ERD-075.

[Oral: prefer to follow Rosenberg's invited presentation]

A velocity survey for shock-ignition at the National Ignition Facility

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Shock ignition (SI)[1] has been proposed as a low-energy, high-gain alternative path to ignition at the National Ignition Facility (NIF). In SI, a high-intensity (several times 10^{15} TW/cm^2) laser spike pulse added at the end of the main compression pulse launches a strong shock into the precompressed capsule, raising the hot-spot pressure and temperature. Because of this spike pulse, SI targets can achieve ignition temperatures at lower shell velocities than standard hot-spot implosions. As with hot-spot inertial confinement fusion, optimizing ignition margin in SI implosions requires finding an implosion velocity that balances 1-D target performance with multidimensional stability characteristics. Polar-drive SI designs for the NIF at 700 kJ will be reviewed and compared for stability and margin in 1-D and 2-D simulations at implosion velocities varying from 2.6 to 3.0×10^7 cm/s. Stability studies will include both polar-drive beam geometry and beam repointing as well as laser imprinted nonuniformities from laser speckle.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] R. Betti *et al.*, "*Shock ignition of thermonuclear fuel with high areal density*," Phys. Rev. Lett. **98**, 155001 (2007).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Efficient simulation of 2+2-D multi-species plasma waves using an Eulerian Vlasov code*

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In this poster we discuss multi-species aspects of the Eulerian-based kinetic code LOKI that evolves the Vlasov-Poisson system in 2+2-dimensional phase space (Banks et al., Phys. Plasmas 18, 052102 (2011)). In order to control the inherent cost associated with phase-space simulation, our approach uses a minimally diffuse, fourth-order-accurate discretization (Banks and Hittinger, IEEE T. Plasma Sci. 39, 2198--2207). The scheme is discretely conservative and controls unphysical oscillations. Details of the numerical approach will be presented, and the implementation on modern highly concurrent parallel computers will be discussed. We will present results of 2D simulations of propagating ion acoustic waves (IAWs) created using an external driving potential. The evolution of the plasma wave field and associated self-consistent distribution of trapped electrons and ions is studied after the external drive is turned off. Over a range of plasma parameters the wave is found to be unstable to both longitudinal and transverse perturbations (Winjum et al., Phys. Rev. Lett. 111, 105002 (2013), Chapman et al., Phys. Plasmas 21, 042107, (2014)). For further discussion of instabilities see poster by R. Berger.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and funded by the Laboratory Research and Development Program at LLNL under project tracking code 12-ERD-061

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Observation of early shell-dopant mix in OMEGA direct-drive implosions and comparisons with radiation-hydrodynamic simulations*

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Understanding the evolution of mix during the implosion and its effect on the thermonuclear (TN) burn is crucial for High Energy Density Physics in support of Stockpile Stewardship, one of the main missions of the Los Alamos National Laboratory (LANL). LANL is currently in the process of developing the next generation mix and burn platform to investigate the physics of TN burn, the morphology of mix during the implosion, and how the interplay between the two affects the nuclear performance. The design of the experiment will utilize current state-of-the-art complex codes and it is important to understand the accuracy with which they can reproduce the experimental data.

A comprehensive mix and burn study was recently performed on the Omega laser facility at Laboratory for Laser Energetics. CH plastic shell capsules were doped with mid-Z material (Ti) to attain the spectroscopic signature of mix during a directly driven implosion. Temporally, spatially, and spectrally resolved x-ray image data were interpreted with the aid of radiation-hydrodynamic simulations and provided information about the mix morphology. The comparison between the simulated and experimental data revealed that simulations with a turbulent mix model replicate many of the observed spectroscopic features, such as the initial time of the emission, the centrally peaked narrow band multiple monochromatic imager data, and the general Ti line structure. However, the codes were not able to reproduce the early migration of Ti into the core. This suggests that phenomena in addition to the turbulent mix, such as instabilities seeded by the capsule surface roughness and/or laser illumination non-uniformities, could be responsible for transporting Ti into the core at approximately the same time as the shock hits the center of the capsule. Detailed comparisons between OMEGA experimental data and synthetic spectroscopic diagnostics results from radiation-hydrodynamics calculations will be shown.

*This work was conducted under the auspices of the U.S. Department of Energy by Los Alamos National Security, LLC under Contract No. DE-AC52-06NA25396

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Preliminary Design for Hybrid Shock Ignition*

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Hybrid Shock-Ignition (HSI) is an alternate fusion energy concept that combines indirect drive and shock ignition schemes in order to access new regimes in National Ignition Facility (NIF) hohlraum physics. Building off of a tetrahedral hohlraum design[1] for experiments at the OMEGA laser facility, we have preliminary designs for spherical hohlraums with symmetrically arranged laser entrance holes for indirect-drive beams for the initial compression of the capsule and holes for direct-drive beams to drive a strong ignitor shock to further compress and ignite the fuel. The baseline hohlraum has an inner radius of 1400µm, while the capsule has an outer radius of 275µm, a Ge-doped CH shell of 55µm, and DD fuel. A LANL Eulerian hydrodynamic code is being used to find optimal laser drive, hohlraum, and capsule specifications, via criteria such as implosion symmetry, implosion time, and neutron yield. At first, drive will be modeled using a radiation source to mimic the hohlraum drive, and later, ignitor beams will be added. Designs are being proposed for experiments to develop the HSI platform on the sub-ignition scale OMEGA laser facility in FY15, with a future goal of designing and fielding HSI experiments on the ignition-scale National Ignition Facility (NIF).

*This work was conducted under the auspices of the U.S. Department of Energy by Los Alamos National Security, LLC under Contract No. DE-AC52-06NA25396, with funding from Laboratory Directed Research and Development Exploratory Research (LDRD-ER) proposal #20140180ER.

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[1] J. M. Wallace, T. J. Murphy, N. D. Delamater, K. A. Klare, J. A. Oertel, G. R. Magelssen, E. L. Lindman, A. A. Hauer, P. Gobby, J. D. Schnittman, R. S. Craxton, W. Seka, R. Kremens, D. Bradley, S. M. Pollaine, R. E. Turner, O. L. Landen, D. Drake, J. J. MacFarlane, "*Inertial Confinement Fusion with Tetrahedral Hohlraums at OMEGA*", Phys. Rev. Letters **82**, 19 (1999).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Stimulated Brillouin scattering: Modeling the effects of Cross Beam Power Transfer on Near-Field images, the frequency spectrum, and reflectivity for Gold and Gold-Boron plasmas†

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This presentation demonstrates that detailed modeling of the stimulated Brillouin scattering (SBS) of the outer cone of NIF beams requires consideration of the effects of cross beam power transfer (CBPT) on each of the four beams within a Quad. Recent experiments[1] have demonstrated that adding the light ion Boron to the Gold wall of the hohlraum reduces SBS. The amount of power reflected for pure gold walls and gold-boron walls varies from beam to beam within the quad. The frequency spectrum shows two features that are interpreted as backscatter from the gold plasma and from the hohlraum gas fill plasma. To quantitatively model the reflectivity, the asymmetric near-field images, and the reflectivity, the amount of power transferred to and from each of the four beams in the Quad must computed.[2] The unequal distribution of power on the beams increases the SBS growth rate and reduces the amount of polarization smoothing.[3]

For details of the measurements and CBPT, see presentations by J. Ralph, J. D. Moody, D. P. Turnbull, and P. Michel.

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

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[1] J. Ralph, this conference
[2] P. Michel, this conference
[3] D. Turnbull, this conference

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Modulational Instability of Plasma Waves in 1D+1V and 2D+2V Vlasov simulations†

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In this poster, we present results from Vlasov simulations of the growth of transverse and longitudinal modulations of electron plasma (EPW) and ion acoustic waves (IAW) as well as the self-consistent modification of the electron and ion distributions in the resulting turbulent nonlinear state.[1]

The Trapped Particle Instability (TPI)[2]was identified in 1D+1V Vlasov simulations as a saturation process for Stimulated Raman Scattering (SRS).[3] In 2D and 3D PIC simulations, transverse modulations of the EPW, also driven by trapped electrons, have also been associated with SRS saturation.[4] Theoretical work predicted the growth rate and wavenumber dependence of these transverse modulations.[5] Here we show qualitative agreement with the theory for the transverse modulations but excellent agreement with the theory for the longitudinal TPI.

We also present simulations of an IAW transverse modulation instability driven by trapped particles for a variety of ratios of T_e/T_i where $T_{e,i}$ are the electron, ion temperatures.

For discussion of simulation techniques, see poster by J. W. Banks.

†*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344 and funded by the Laboratory Research and Development Program at LLNL under project tracking code 12-ERD-061.*

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[1] Winjum et al, PRL 111,105002 (2013)
[2] Kruer, Dawson, Sudan, PRL 23,838 (1969)
[3] Brunner and Valeo, PRL 93, 145003 (2004)
[4] Yin, et al, PoP 15, 013109 (2008); Yin, et al, PRL 99, 265004 (2007)
[5] Dewar et al, PRL 28, 215 (1972); Rose and Yin, PoP 15,042311 (2005)

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Shocks waves in high power laser plasma interactions

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Some recent experiments on the interaction of high power lasers with plasmas have shown evidence of shock like structures with very high electric fields existing over very short distances. In inertial confinement fusion capsules the existence of fields of more than 10^{10} Vm^{-1} over distances of the order of 10-100 nm have been observed. In other experiments with intense lasers interacting with over dense plasmas high energy proton beams with small energy spread are observed. We propose a theory to describe laminar ion sound structures in a collisionless plasma. Reflection of a small fraction of the upstream ions converts the well- known ion acoustic soliton into a structure with a steep potential gradient upstream and with downstream oscillations. The strong electric field is also responsible for separation of the fuel in a DT mix which can alter the neutron yield. The theory provides an explanation for these laser plasmas experiments relevant to inertial fusion and to ion acceleration.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Measurements of gas/shell mix in implosions at the National Ignition Facility using the CD Symcap platform*

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Surrogate implosions play an important role at the National Ignition Facility (NIF) for isolating aspects of the complex physical processes associated with fully integrated ignition experiments. The newly developed CD Symcap platform[1] has been designed to study gas-shell mix in indirectly driven, pure T_2-gas filled CH-shell implosions equipped with 4 μm thick CD layers. This configuration provides a direct nuclear signature of mix as the DT yield (above a characterized D contamination background) is produced by D from the CD layer in the shell, mixing into the T-gas core. The CD layer can be placed at different locations within the CH shell to probe the depth and extent of mix. CD layers placed flush with the gas-shell interface and recessed to up to 8 μm have shown that most of the mix occurs at the inner-shell surface. However at 8 μm recessed, the DT yield remains above background suggesting that plastic from deeper in the shell, injected by ablation front instabilities, may also play an important role. Furthermore, time-gated x-ray images of the hotspot show large brightly-radiating objects traversing through the hotspot around bang-time, which are likely chunks of CH/CD plastic.[2] In addition, an implosion series at increased convergence has begun and the preliminary results will be discussed.

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

[1]Smalyuk et. al., Physical Review Letters **112**, 025002 (2014).
[2]M. A. Barrios et. al., Physics of Plasmas **20**, 072706 (2013).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

iFP: an optimal, fully conservative, fully implicit, 1D-2V Vlasov-Fokker-Planck solver*

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Plasma collisionality conditions during the implosion of an ICF capsule vary widely. Early in the implosion process, the plasma is cold and very collisional, and fluid models are appropriate to describe the relevant dynamics. Later in the implosion, however, the plasma becomes very hot, and the collisional mean free path becomes a large fraction of the system size. In this regime, kinetic phenomena become important, and a fully kinetic treatment is needed to assess their impact on compression and yield in ICF capsules.

The kinetic simulation of an ICF capsule implosion is, however, non-trivial. At the very minimum, one must solve the multispecies 1D-2V Vlasov-Fokker-Planck (VFP) equation for the fuel ions. The small separation between the Gamow reactivity velocity peak v_G and the fuel thermal velocities v_{th} ($v_G \sim \sqrt{3} v_{th}$), prevents the use of asymptotic approximations to the collision operator. Thus, one must consider its Landau/Rosenbluth form, which is an integro-differential system of difficult numerical treatment. Furthermore, depending on the regime, the VFP equation supports very disparate time scales (8 or 9 orders of magnitude) between collisional and dynamical time scales. This, in turn, motivates the use of implicit algorithms.

In this study, we present the first (to our knowledge) fully conservative (mass, momentum, and energy), fully nonlinearly implicit Vlasov-Rosenbluth-Fokker-Planck solver in 1D-2V. The approach achieves exact numerical conservation (in practice, to nonlinear tolerance) by nonlinearly enforcing the collision operator symmetries, and by enslaving numerical truncation errors.[1] The approach features an adaptive scheme in velocity space that optimally resolves the distribution function locally, thus substantially decreasing the velocity space resolution requirements regardless of temperature disparity and variations. Solver-wise, the code relies on demonstrated Jacobian-free Newton-Krylov strategies.[2] We will demonstrate the efficiency and accuracy properties of the scheme with several challenging 0D-2V and 1D-2V numerical examples.

*This work is funded by the Thermonuclear Burn Inititative at LANL, and conducted under the auspices of NNSA of the U.S. Department of Energy at Los Alamos National Laboratory, managed by LANS, LLC under contract DE-AC52-06NA25396.

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[1] W. Taitano et al, "*Charge-and-Energy Conserving Moment Based Accelerator for a Multi-Species Vlasov-Fokker-Planck-Ampère System, Part II: Collisional Aspects*," J. Comput. Phys., submitted (2014)
[2] L. Chacón et al, "*An implicit energy-conservative 2D Fokker-Planck algorithm: II- Jacobian-free Newton-Krylov solver*," J. Comput. Phys., **157**, 654-682 (2000)

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Saturation mechanisms of stimulated Brillouin scattering in Vlasov simulations†

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The decay of a single-frequency ion acoustic wave (IAW) to daughter IAW modes has been correlated previously with the saturation of stimulated Brillouin scatter (SBS) in experiments[1]. This decay, known as two-ion decay (TID), has been detected in dedicated Thomson scattering experiments[2]. Ongoing laboratory experiments studying the decay of electron acoustic waves, which are similar to IAWs, have demonstrated an analogous decay mechanism[3]. Across a broad range of plasma parameters, the TID rate was studied using highly resolved Vlasov simulations in Ref. 4, in which TID was shown to lead to soliton generation and rapid ion heating. Crucially, IAW energy was found to crash at the onset of decay-driven turbulence, providing a potentially effective SBS saturation mechanism not described by fluid theory[4].

We present here findings on the role of TID in the saturation of SBS using a Vlasov code, which solves the Vlasov-Poisson-Maxwell system of equations in one dimension. Particle-in-cell codes, used in previous studies of TID in SBS[5], may seed or obscure TID with unphysical noise; the Vlasov-Poisson-Maxwell solver employed here is quasi-noiseless and allows precise study of TID. The growth rate of TID for an SBS-driven IAW is compared to a system in which the IAW is excited by a prescribed driver.

†This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344 and funded by the Laboratory Research and Development Program at LLNL under project tracking code 12-ERD-061. IM: LLNL-ABS-653295.

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[1] H. C. Bandulet, C. Labaune, K. Lewis, and S. Depierreux, Phys. Rev. Lett. **93**, 035002 (2004).

[2] C. Niemann, S. H. Glenzer, J. Knight, L. Divol, E. A. Williams, G. Gregori, B. I. Cohen, C. Constantin, D. H. Froula, D. S. Montgomery, and R. P. Johnson, Phys. Rev. Lett. **93**, 045004 (2004).

[3] F. Anderegg, M. Affolter, and C. F. Driscoll, in *Bulletin of the 55th Annual Meeting of the APS Division of Plasma Physics* (2013), Vol. **58**, No. 16.

[4] T. Chapman, S. Brunner, J. W. Banks, R. L. Berger, B. I. Cohen, and E. A. Williams, Phys. Plasmas **21**, 042107 (2014).

[5] C. Riconda, A. Heron, D. Pesme, S. Hüller, V. T. Tikhonchuk, and F. Detering, Phys. Rev. Lett. **94**, 055003 (2005); B. I. Cohen, E. A. Williams, R. L. Berger, D. Pesme, and C. Riconda, Phys. Plasmas **16**, 032701 (2009); erratum, Phys. Plasmas 16, 089902 (2009).

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Thermonuclear ignition criterion in NIF *

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We have developed an analytical physics model for thermonuclear (TN) burn in inertial confinement fusion (ICF) capsules from fundamental physics principles. We have applied the model and derived a general thermonuclear ignition criterion in terms of the areal density and temperature of the hot fuel. The newly derived TN ignition threshold and its alternative forms include the minimum requirement of hot fuel pressure, mass, areal density, and burn fraction for given designs. We compared our criteria with existing theories, simulations, and the National Ignition Facility (NIF) experimental data. Our ignition threshold is more stringent than those in existing literature, and our results compare reasonably well with the NIF data. Differences between this model and other models are discussed.

* This work was performed under the auspices of the U.S. Department of Energy by the Los Alamos National Laboratory under Contract No. W-7405-ENG-36. Reference LA-UR-14-22886.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Relativistic Transparency Experiments at the Trident Laser*

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With near-diffraction-limited irradiance of 3 x 10^{20} W/cm^2 on target and prelase contrast better than 10^{-9}, we have accessed the regime of relativistic transparency (RT) at the Trident Laser. The goal was to assess electron debris emitted from the target rear surface with phase-contrast imaging (PCI) and current density measurements (hence, the total electron current). Companion diagnostics show whether the experiments are in the target-normal-sheath-acceleration mode or in the RT regime. The superb laser contrast allows us to shoot targets as thin as 50 nm. PCI at 527 nm is temporally resolved to 600 fs. It has shown the evolution of electron behavior over tens of ps, including thermal electrons accompanying the ion jet, accelerated to many tens of MeV earlier in time. Faraday-cup measurements indicate the transfer of many μC of charge during the laser drive. As a ride-along experiment using a gas Cherenkov detector (GCD), we have detected gamma rays of energy > 5 MeV. This radiation has a prompt component and a lesser source, driven by accelerated ions, that is time resolved by the GCD. The ion time of flight is compared to Thomson parabola data. Electron energy spectra are also collected.

*This work conducted under the auspices of the United States Department of Energy contract DE-AC-52-06NA25396

LA-UR-14-22370

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Modeling of Cross Beam Energy Transfer in Direct-Drive Implosions

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Laser-Plasma Interactions (LPIs) are a fundamental component of Inertial Confinement Fusion (ICF) and involve a large variety of temporal and spatial scales. Theoretical and numerical works, as well as recent experiments on NIF and OMEGA laser facilities have highlighted the importance of modeling LPI in large-scale codes. We present results of the modeling of several particular cases of Cross Beam Energy Transfer (CBET), studied with a new module using the Paraxial Complex Geometrical Optics method implemented in the radiative hydrocode CHIC [1]. ICF beams are modeled by bundles of thick Gaussian rays arranged so as to reproduce the average statistics of KPP-smoothed super-Gaussian beams. Two-dimensional planar simulations of direct-drive implosions are conducted in a framework similar to the beam configuration of the OMEGA facility, using the SG4 phase plates. The capsule symmetry and laser irradiation field during the implosion are defined by the geometry of the interacting beams and show significant deformations. CBET between beams at 20° and 40° greatly degrades the irradiation symmetry by smoothing out low Legendre modes while amplifying numerous higher frequency modes to values above 12%, ultimately leading to a thin capsule with large modulations (see Fig. 1). CBET produces hydrodynamic perturbations of small wavelength that may impact the efficiency of ICF schemes.

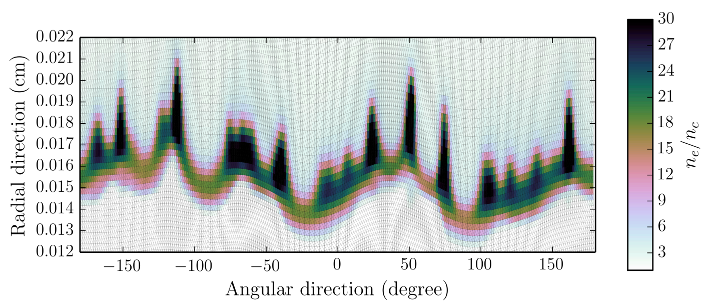

Fig 1. (Preliminary results) Close-up of the shell density field (normalized to the critical density) near the implosion end, represented in the r-θ plane. CBET is enabled between beams separated by 40°.

[1] A. Colaïtis, G. Duchateau, P. Nicolaï, and V. Tikhonchuk. Phys. Rev. E, 89:033101, Mar 2014.

*This work is partially supported by the EURATOM within ”Keep in Touch” activities and the project ANR-12-BS04-0006-04 from the French National Agency of Research.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Modeling of Laser-Plasma Interactions and Realistic ICF beams with Hydrocodes: the Thick Rays Approach

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Nonlinear laser-plasma interactions (LPI) are a fundamental component of the physics of Inertial Confinement Fusion (ICF). Taking LPI into account in large-scale radiative hydrocodes is challenging and relies on a correct description of the laser intensity field. The latter can be reconstructed from the inverse Bremsstrahlung absorption computed by Ray-Tracing (RT) codes, based on Geometrical Optics, but it implies the dominant role of the collisional absorption and requires large computing resources. We propose an alternative method based on optical thick rays described by a Gaussian shape. To that end, the Paraxial Complex Geometrical Optics (PCGO) is adapted for light waves in an inhomogeneous medium and modified to include the inverse Bremsstrahlung absorption and the ponderomotive force. Compared to the standard RT approach, the PCGO model leads to more accurate and smoother power deposition patterns and better diffraction modeling. In contrast, the intensity-reconstruction technique used in RT codes to model nonlinear LPI leads to artificial filamentation and fails to reproduce realistic ponderomotive self-focusing distances, intensity amplifications and density channel depletions, whereas PCGO succeeds (see Fig. 1). The overlap of Gaussian PCGO beamlets can be designed so as to produce intensity variations, or pseudo-speckles, that reproduce the beam envelope, contrast and high-intensity statistics of that predicted by the laser propagation code Mirò that resolves the nonlinear Schrödinger equation. The pseudo-speckle pattern imposed by PCGO produces modulations in the irradiation field and capsule shell that are of interest for studying the laser-plasma coupling at hydrodynamical scales and account for realistic laser irradiation from experimental conditions. The thick ray model is expected to be an improvement for modeling accurately nonlinear LPI in large scales hydrocodes.

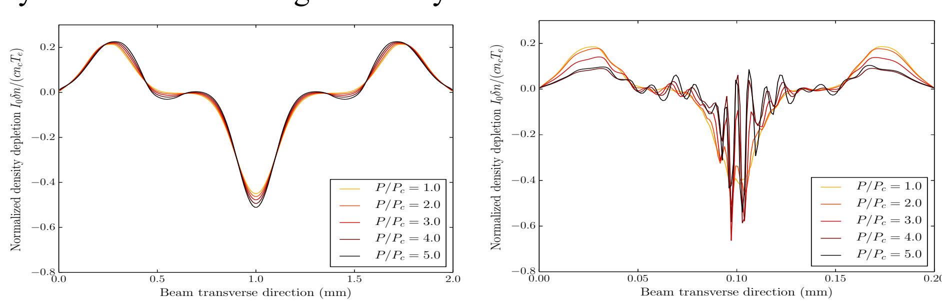

Fig 1. On-axis density depletion caused by the ponderomotive force of a Gaussian laser beam. (Left) PCGO is in good agreement with the theoretical solutions whereas the Ray-Tracing (right) produces noisy profiles, even with diffraction modeling.

*This work is partially supported by the EURATOM within "Keep in Touch" activities and the project ANR-12-BS04-0006-04 from the French National Agency of Research.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Al Line Absorption Spectroscopy of Colliding Shock Wave Experiment on the Trident Laser

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Results are presented from colliding shock wave experiments at the Trident laser facility at the Los Alamos National Laboratory. The experiment uses simultaneous irradiation on both sides of a plastic slab with an embedded thin Aluminum layer using the two drive beams of Trident with 120 J/beam and 0.53 μm laser wavelength. The idea is to have laser driven shock waves propagate through the plastic and collapse on the Al foil thus generating a hot and dense uniform Al plasma which can be analyzed with absorption spectroscopy. A thin layer of samarium on one side of the CH slab is directly irradiated by the laser and provides a self-backlighting source to probe the shocked Al layer at the center of the slab. Absorption features from K-shell transitions in F-, O-, N- and C-like Aluminum were observed in the spectral region of 1.45 – 1.6 keV. The experiment was modeled with the LASNEX hydrodynamics code using LTE opacity data for the compressed Aluminum. The resulting simulated absorption spectrum obtained from post processing the hydrodynamics calculation is compared with the spectroscopic observations from the Gated Imaging Spectrometer. Assuming the shocked Al region conditions are uniform and well modeled, these results can give an accurate measurement of the Al opacity for the experimental condition, as well as contribute to the development of absorption spectroscopy diagnostics for laser produced plasmas.

Work performed by Los Alamos National Laboratory under contract DE-AC52-06NA25396 for the National Nuclear Security Administration of the U.S. Department of Energy.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Diamonds in the rough: High-Density-Carbon capsule implosions on the NIF*

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June will mark the anniversary of the first High-Density-Carbon (HDC) experimental campaign on the National Ignition Facility (NIF) [1]. HDC is thought to be a “better” ablator (compared to CH), leading to better implosion performances and suggesting the possibility of reaching ignition on the NIF with a 3-shock implosion. Such a system can be driven by a laser pulse shorter than 10 ns, possibly in a near vacuum hohlraum (NVH)[2]. NVHs support essentially zero laser-plasma interaction: 98% absorption, negligible hot electrons production and no cross-beam energy transfer, but symmetry control remains a concern. The first DT layered HDC 2-shock implosion in a NVH with 1.2 MJ of laser drive led a primary neutron yield of 2e15, close to expectations. This talk will report on experimental progress for 2, 3 and 4-shock HDC implosions, our current level of understanding and the path forward for the next 12 months.

[1] J. S. Ross *et al.*, “High-Density Carbon Capsule Experiments on the NIF”, submitted to *Phys. Rev. Lett.*
[2] A. J. Mackinnon *et al.*, ”High-Density Carbon Ablator Experiments on the NIF”, accepted for publication in *Phys. Plasmas*.

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

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

A base-line model for ICF implosions in xRAGE*

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xRAGE[1] is a radiation-hydrodynamics code using a Godunov solver on an Eulerian mesh with an adaptive mesh refinement (AMR) algorithm, and a radiation diffusion algorithm. It has been used to study fluid flow in highly distorted systems, where arbitrary Langrian Eulerian (ALE) methods are not the method of choice, which can include ICF. A version of the code, called CASSIO, uses an implicit Monte Carlo (IMC) method for radiation transport. However, the physics packages available and relevant to ICF have changed over time, these include laser propagation, three-temperature plasma physics and non-LTE opacity calculations. As the code and physics packages undergo modification, or new physics becomes available (*e.g.* laser propagation), the new code must be tested. Thus, a suite of validation problems is being developed for testing under conditions relevant to ICF.

The direct-drive ICF capsules fielded for the High-Z project[2] will be used as the initial suite of validation problems. These capsules were designed to study the physics of how a quantity of mixed shell material impacts performance, and a dopant (Ar, Kr, or Xe) was added to the fuel during manufacture in a controlled manner. Data from the project was well documented, and can be used to validate both the laser driver and calculation of the plasma conditions during neutron production. This presentation will discuss the capsule experiments and the physics used in the modeling, as well as a brief overview of the software framework used to standardize the verification and validation process. Future work will also be discussed, including additional sources of validation data.

*This work conducted under the auspices the U. S. Department of Energy by the Los Alamos National Security, LLC under contract DE-AC52-06NA25396. LA-UR-14-22665

[1] M. Gittings, R. Weaver, M. Clover, et al., Comp. Sci. and Disc., 1 015005 (2008).
[2] E. S. Dodd, J. F. Benage, G. A. Kyrala, et al., Phys. Plasmas, 19 042703 (2012).

The effect of OMEGA cryogenic implosion improved-performance strategies on two-plasmon decay*

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The 3-D multibeam common-wave gain has proven to be a convenient scaling law to unify two-plasmon–decay (TPD) experiments with different laser-plasma geometries. The model uses 3-D ray-trace calculations of the laser intensity and *k* vectors at the plasma quarter-critical surface, including the reduction in intensity caused by cross-beam energy transfer (CBET).

One possible CBET mitigation strategy for OMEGA cryogenic implosions is to reduce the ratio R_b / R_t where R_b and R_t are the laser beam and target radii, respectively. This strategy is expected to increase TPD because of the higher intensities at the quarter-critical surface. Layers of mid-*Z* material embedded in the target shell have been proposed to mitigate TPD in cryogenic implosions.

The common-wave gain scaling is calculated for implosions with reduced R_b / R_t and mid-*Z* layer targets and compared to experimental data. The effect of the above mitigation strategies on TPD on future cryogenic implosions is estimated.

* This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Wakefield excitation using multiple incoherent laser pulses in a plasma channel*

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The wakefield generated in a plasma by incoherently combining a large number of low energy laser pulses is studied analytically and by means of fully-self-consistent particle-in-cell simulations. The structure of the wakefield has been characterized and its amplitude compared with the amplitude of the wake generated by a single (coherent) laser pulse. We show that, even though the wakefield within the volume occupied by the laser pulses is incohernet, behind this region the structure of the wakefield can be regular and suitable for accelerating electrons to high energy. Furthermore, the wake amplitude can be comparable or equal to the one obtained by using a single pulse with same energy. Since no phase control is required, we expect that the fundamental requirements to achieve incoherent combination are more relaxed compared to coherent combination, thereby enabling a technologically simpler path for design of high-average power, high-repetition rate laser-plasma accelerator applications.

*This work was supported by the Director, Office of Science, Office of High Energy Physics, of the U.S. DOE under Contract No. DE-AC02-05CH11231, and used the computational facilities (Hopper, Edison) at the National Energy Research Scientific Computing Center (NERSC).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Absorption Measurements of Stark-broadened Hydrogen Balmer Line Shapes and Strengths*

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We perform experiments[1] to measure multiple hydrogen Balmer lines in laboratory plasmas at white dwarf (WD) photospheric conditions ($T_e \sim 1$ eV, $n_e \sim 10^{17}$ cm^{-3}) to test the theoretical line profiles used in WD atmosphere models. X-rays from a z-pinch dynamic hohlraum generated at the Z Pulsed Power Facility at Sandia National Laboratories irradiate a gas cell to initiate formation of a large (120x20x10 mm) plasma. We observe our plasma in emission and in absorption simultaneously along relatively long (~120 mm) lines of sight perpendicular to the heating radiation. Using a large, radiation-driven plasma aides us to achieve homogeneity along our observed lines of sight, and with time-resolved spectroscopy we can measure lines at a range of electron densities that spans an order of magnitude. Observing our plasma in absorption not only provides the signal-to-noise to measure relative line *shapes*, it allows us to measure relative line *strengths* because the lines share the same lower level population. This can constrain the theoretical weighting factors used to describe the lowering of the ionization potential or occupation probability associated with these Balmer lines. We discuss the status of our relative line shape comparisons and the potential of testing theoretical weighting factors.

*Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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[1] R. E. Falcon et al., "*An Experimental Platform for Creating White Dwarf Photospheres in the Laboratory*", High Energy Density Physics **9**, 82-90 (2013).

Characterization of neutron energy spectra from a short-pulse laser driven neutron source generated by the TRIDENT laser

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We present a full characterization energy spectra of a short pulse laser-driven neutron source. The ultra-high contrast short-pulse laser at TRIDENT laser was focused onto a thin plastic primary target in order to accelerate ions to relativistic speeds and the neutrons were then produced by nuclear reactions of the ions deposited in a secondary Be or Cu targets that acted as neutron converters[1,2]. This experiment was a first demonstration of the Break Out Afterburner (BOA) acceleration mechanism that through making thin CH and deuterated plastic CD targets relativistically transparent accelerates more ions to higher speeds used to create a more energetic neutron source with significantly higher neutron yields than previous experiments[1,2]. Using this technique we observed neutron yields of 10^{10} neutrons/sr with maximum energies of 80 MeV when *f/3* off-axis parabolic mirror was used to focus the beam onto the primary target and up to 170 MeV with *f/1.5*. The neutron spectra were measured by five neutron time-of-flight (NTOF) detectors at various positions and distances from the source. Each detector consisted of a NE102 plastic scintillator connected to fast Hamamatsu R1250A Photo Multiplier Tube (PMT) and a digital 3 GHz and 1 GHz oscilloscopes. The NTOF detectors observed that emission of neutrons is a superposition of an isotropic component into 4π and a directional component. The isotropic neutron emission peaking at 3.5 MeV resulted from the $^{9}Be(d, n)$ and $^{9}Be(p, n)$ reactions in the converter material and was observed for both CH and CD primary targets. The forward directed jet-like contribution with peaks at 25 MeV for *f/3* and 70 MeV for *f/1.5* parabola, which was a product of break-up reaction of the forward moving deuterons accelerated from the primary target and was thus observed only in the case of deuterated targets. Energy dependance of the neutron spectra were also observed as a function of the separation of the primary and secondary targets. This work was performed under the auspices of the US Department of Energy by the Los Alamos National Laboratory under the Contract No. DE-AC52-06NA25396 and supported by the Rosen Scholar award, LDRD, HIC4FAIR and BMBF.

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1 M. Roth et al., Phys. Rev. Lett. 110, 044802 (2013).
2 D. Jung et al., Phys. Plasmas 20, 056706 (2013).
3 L. Yin, et al., Laser and Part. Beams. 24, 291 (2006).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Measuring the properties of warm dense matter with an ultra-bright seeded x-ray laser

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Recent x-ray scattering experiments performed at the MEC end-station of the LCLS, have demonstrated novel plasma measurements of the electron temperature, pressure, and density by simultaneous high-resolution angularly and spectrally resolved x-ray scattering from shock-compressed materials in the warm dense regime. Such measurements provide the structural properties relating the microscopic quantities in terms of thermodynamic properties using first-principles calculations[1].

In our study, two 527-nm, 3-ns, 4.5-J laser beams irradiate opposing ends of 50 μm thick Al, Mg, and diamond foils thereby launching two counterpropagating shock waves into the solid samples. Separately a 50 fs LCLS x-ray laser pulse, at a photon energy of $E_0 = 8$ keV, has been focused to a 5 - 10 μm spot and delayed after the shock has reached the coalescence point. Conditions before and during shock coalescence are probed with spectrally and wavenumber resolved x-ray scattering. These data provide a critical experimental test of our state-of-the art DFT-MD modeling capability and allow for detailed measurements of the material properties at pressures exceeding 5 Mbar.

* This work conducted under the auspices of Lawrence Livermore National Laboratory (LLNL) under Contract DE-AC52-07NA27344 and supported by Laboratory Directed Research and Development (LDRD) grant 11-ER-050. This work was performed at the Matter at Extreme Conditions (MEC) instrument of LCLS, supported by the DOE Office of Science, Fusion Energy Science under contract No. SF00515 and supported under FWP 100182 and DOE Office of Basic Energy Sciences, Materials Sciences and Engineering Division, contract DE-AC02-76SF00515.

[1] S. H. Glenzer and R. Redmer, Rev. Mod. Phys. **81**, 1625 (2009).

The Shear and ReShock Platform on NIF*

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Los Alamos has developed a High Energy Density (HED) shock tube platform driven by indirect drive at the National Ignition Facility (NIF) for studies of shock-driven turbulent mix in Inertial Confinement Fusion (ICF) capsules. A series of experiments has been performed at NIF to compare to data taken at the Omega laser facility that investigated turbulence-driven mix from two counter-propagating shocks, which generate a strongly sheared mix-layer. The induced Kelvin-Helmhotz instability quickly turns turbulent and the evolution of this tracer layer is measured using Big Area BackLighter (BABL) radiography. Comparison of this data with simulations from the code RAGE has been performed to improve our predictive capability for ICF experiments. RAGE implements the Besnard-Harlow-Rauenzahn (BHR) mix model, which is intended for turbulent transport in fluids with large density variations, and is currently being tested for applications in the ICF regime.

*Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396.

Ultraviolet Thomson scattering from two-plasmon–decay electron plasma waves driven by multiple laser beams*

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Thomson scattering is used to probe electron plasma waves (EPW's) driven by the common-wave two-plasmon–decay (TPD) instability near quarter-critical density. Between two and five laser beams ($\lambda_{3\omega}$ = 351 nm) illuminated planar CH targets with 300-μm-diam (FWHM) laser spots with overlapped intensities ~10^{15} W/cm^2. A 263-nm Thomson-scattering beam was used to probe densities ranging from 0.2 to 0.25 n_c, where n_c is the critical density for 351-nm light. The Thomson-scattered power and frequency spectrum from primary TPD-driven EPW's are consistent with the common-wave and linear growth rate theories of two-plasmon decay, respectively. Thomson-scattering spectra taken while probing various regions of k space show the presence of secondary decay modes of TPD-driven waves. Experimental results are compared to *ZAK3D* and particle-in-cell simulations.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Mitigation of cross-beam energy transfer in direct-drive plasmas*

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Cross-beam energy transfer (CBET) in OMEGA cryogenic direct-drive–ignition hydrodynamic-equivalent designs significantly reduces the ablation pressure.[1] To maintain an ignition-relevant velocity and areal density, this reduction in ablation pressure requires that the mass of the shell and the adiabat be reduced by 75% and 50%, respectively. Measurements indicate that hydro-equivalent implosions are hydrodynamically unstable. Reducing the diameter of the laser beams by 60% was shown to mitigate CBET but at the cost of increasing the drive nonuniformity.[2] Several methods for reducing the diameter of the laser beams while maintaining acceptable drive uniformity are being investigated for OMEGA: (1) directly reducing the laser spots over the entire laser pulse and (2) reducing the diameter of the laser spots after a sufficient conduction zone has been generated. This two-state zooming is predicted to maintain low-mode uniformity while mitigating CBET.[3]

Cryogenic experiments using mitigation schemes, reduced laser-spot sizes, imprint experiments relevant to sub-aperture zooming, and a full-aperture zooming technique will be discussed. Full-aperture zooming is expected to both minimize the ideal laser beam imprint and maintain the overlapped uniformity while recovering 100% of the ablation pressure lost to CBET. This results in a hydrodynamically equivalent design with an IFAR = 15 (α = 3.2). Current cryogenic implosions with this IFAR are predicted to recover >90% of the 1-D areal density and >30% of the 1-D yield.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] V. N. Goncharov *et al.*, "*Improving the hot-spot pressure and demonstrating ignition hydrodynamic equivalence in cryogenic DT implosions on OMEGA*," to be published in Physics of Plasmas.
[2] D. H. Froula *et al.*, "*Increasing hydrodynamic efficiency by reducing cross-beam energy transfer in direct-drive implosion experiments*," Phys. Rev. Lett. **108**, 125003 (2012).
[3] I. V. Igumenshchev *et al.*, "*Effects of local defect growth in direct-drive cryogenic implosions on OMEGA*," Phys. Plasmas **20**, 082703 (2013).

Transmission Studies for MagLIF Laser-Entrance-Holes*

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The concept of "Magnetized Liner Inertial Fusion" (MagLIF)[1], which is pursued by Sandia National Laboratories (SNL), requires the deposition of laser energy into a fuel-filled metal cylinder that is exposed to an external magnetic field. The complexity of the laser-plasma-interaction as well as the influence of non-uniformities in the laser beam profile make predictions about the light propagation through a heated, foil covered laser-entrance-hole (LEH) very difficult.

Laser energy losses in the LEH have an immediate influence on the performance of MagLIF experiments. In order to further understand this critical issue, a series of studies investigating the transmission of laser light delivered by the Z-Beamlet laser has been performed at the 'Pecos' target area in the Z-Backlighter facility of SNL. We studied the transmitted spatial beam profile (X-ray pinhole images of witness plates), temporal profile (photo-diode) and energy (full beam calorimeter) while varying focus position, laser pulse train, window thickness, and LEH aperture size. The initial findings already proved to be essential for the forward planning and optimization of MagLIF related experiments at SNL. Now, more comprehensive experiments with surrogate fuel (gas fill) and applied pulsed external B-fields are in preparation.

One outcome of the experimental efforts in the Pecos target area is the possibility of close proximity laser beam profile enhancement measures, which can be integrated into the MagLIF target design. The advantages and disadvantages of such measures have been investigated in a dedicated experimental campaign and will also be presented.

*Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

[1] S.A. Slutz et al.: Phys. Plasmas **17**, 056303 (2010) and PRL **108**, 025003 (2012).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

LANL Nuclear Diagnostics for NIF*

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LANL has led the development of several nuclear diagnostics currently being used or planned for the National Ignition Facility (NIF): Gamma Reaction History, Neutron Imaging and Prompt RadChem.

The primary objective of the Gamma Reaction History (GRH) diagnostic is to provide bang time and burn width information in order to constrain implosion simulation parameters such as shell velocity and confinement time. This is accomplished by measuring DT fusion gamma-rays with energy-thresholded Gas Cherenkov detectors that convert MeV gamma-rays into UV/visible photons for high-bandwidth optical detection. Burn-weighted CH ablator areal density is also inferred based on measurement of the ^{12}C(n,n') gammas emitted at 4.44 MeV from DT neutrons inelastically scattering off carbon nuclei as they pass through the plastic ablator. Future gamma ray diagnostic efforts are focused on improved sensitivity, temporal bandwidth, spectroscopy & imaging.

The Neutron Imaging System (NIS) is a pinhole camera consisting of a high-Z aperture array placed 32.5 cm from the imploding capsule and a capillary scintillator array, positioned 28 m away, viewed by two separate optical imaging systems coupled to CCD cameras. The CCDs are gated to see both the primary, unscattered neutrons, as well as neutrons down-scattered in the surrounding cold DT fuel, providing spatial imaging of the reactive hot spot as well as the cold dense fuel layer. Efforts are proceeding to generate co-registered neutron and x-ray images to determine if differences may provide insight into mix and asymmetry.

Prompt-radiochemistry diagnostics provide insight into the mix and stopping power within an ICF implosion at the NIF. Stopping power may be inferred by measuring the high-energy, reaction-in-flight (RIF) neutron spectrum using nuclear reactions such as ^{169}Tm(n,3n)^{167}Tm, which has a threshold of 15 MeV. Diagnosing mix through knock-on charged particle reactions at the fuel-ablator interface requires collection of activated capsule debris followed by prompt in-situ assay. Progress on these diagnostics is presented.

*This work conducted under USDOE contract DE-AC52-06NA25396.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

High-density carbon (HDC) ablators for NIF ignition capsules*

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HDC ablators show high performance based on simulations and recent experiments. HDC capsules have good 1-D performance because HDC has relatively high density (3.5 g/cc), which results in a thinner ablator that absorbs more radiation and consequently results in high implosion velocity. HDC ablators also have short pulses (10 ns or less), allowing the use of low gas-filled or near-vacuum hohlraums which provide high coupling efficiency. Recent HDC 2-shock conA experiment has achieved a peak velocity of 400 km/s with coupling efficiency close to 100%. A DT-layered shot had achieved neutron yield of 2×10^{15}. In this presentation, we show ignition designs using 2, 3 and 4 shocks. Their advantages and disadvantages will be discussed. Two-shock designs have the shortest pulse length but have the worst 1-D ignition margin because of the high adiabat. Four-shock designs have the highest 1-D ignition margin with the lowest fuel adiabat, but have higher RT ablation front growth. This disadvantage can be overcome by using a picket to generate the 1^{st} shock. The picket reduces the RT growth factor while the decaying 1^{st} shock lowers the adiabat further. The picket has the additional advantage of shortening the pulse length. A 3-shock design for achieving alpha heating using a high-gas-fill (1.6 mg/cc) hohlraum will be presented. To minimize cold-ablator pre-heat by M-band radiation, an inner ablator layer doped with 0.25 at.% W is preferred. The dopant improves the overall stability of the capsules. Detailed 2-D simulations using NLTE modeling for W radiation from the hot-spot shows that the capsule can tolerate close to 400 ng of W-doped ablator material in the hot spot. If W is replaced with Si, the entire ablator has to be uniformly doped with 3 at.% of Si. Surprisingly, the hot spot can tolerate about the same amount of ablator mass for the 3 at.% Si-doped HDC ablator as it can for W-doped ablator. This is because Si radiates less and consequently raises the hot spot temperature which in term increases the electron heat conduction. Comparison of simulations with experimental data for HDC implosion experiments will be presented.

*This work was performed under the auspices of the US DoE by LLNL under Contract DE-AC52-07NA27344

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Magnetized HDC ignition capsules for yield enhancement and implosion magnetohydrodynamics*

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Imposing a magnetic field on capsules can turn capsules that fail to ignite, because of low 1-D margin (e.g., relatively low implosion velocity ~ 365 km/s and relatively high fuel adiabat ~ 2.1), into igniting capsules that give yield in the MegaJoule range. The imposed magnetic field can be amplified by up to O(10^3) as it is being compressed by the imploding shell, e.g. if the initial field is 50T, then the field in the hot spot of the assembled configuration can reach > 10^4 T. (We are currently designing hardware that can provide a field in the 50T range inside NIF hohlraums.) With this highly compressed field strength, electron conduction perpendicular to the field is completely suppressed and the gyro radius of alpha particles becomes smaller than the hot spot size. Consequently, the heating of the hot spot becomes more efficient. Furthermore, the magnetic field reduces the RTI growth and therefore the hotspot cooling caused by mix is reduced. The imposed field can also prevent hot electrons in the holhraum from reaching the capsule.

We choose capsules with high-density carbon (HDC) ablators for this study. HDC capsules have good 1-D performance because HDC has relatively high density (3.5 g/cc), which results in a thinner ablator that absorbs more radiation and results in higher implosion velocity. HDC ablators also have short pulses (10 ns or less), allowing the use of low gas-filled or near-vacuum hohlraums which provide high coupling efficiency. A recent HDC 2-shock conA experiment achieved a peak velocity of 400 km/s with coupling efficiency near 100%, and a DT-layered shot produced neutron yield of 2×10^{15}.

We describe a 2-D simulation of a 3-shock HDC capsule, using a radiation pulse that is derived from keyhole data, that gives multi MJ yield in a 1-D simulation but fails to ignite in 2-D, when nominal surface roughness is included. However, once a 50T initial field is imposed, 2-D simulations give multi MJ yield. We will show detailed magnetohydrodynamic evolution of the implosion. Because the magnetosonic speed is different in the direction perpendicular to the field than in the parallel direction and because the magnetic field traps electrons more efficiently than ions, the Ti and Te evolve differently as the shock wave approaches the center. When the implosion is close to the assembled configuration, the field in the center approached 10^4 T. Then the magnetic field pressure is no longer negligible in comparison to the hydrodynamic pressure and the shell geometry starts to deviate from a spherical configuration.

HDC capsules with 2-shock pulses have low margin because of their high adiabat, and it is difficult to achieve ignition in realistic 2-D simulations. The improvement in performance for 2-shock magnetized capsules will be presented.

*This work was performed under the auspices of the US DoE by LLNL under Contract DE-AC52-07NA27344

Explaining ICF implosions with reduced ion-kinetic transport models*

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We use a *reduced ion-kinetic* (RIK) model in fluid-based simulations to explain a wide variety of ICF capsule implosions, when the ion mean free path is large. The RIK model represents several important kinetic processes/effects using a local gradient-diffusion approximation[1]: ion mass transport; ion momentum transport (i.e., viscosity); ion energy transport; and fusion reactivity reduction owing to modified ion distributions ("Knudsen II")[2]. The RIK model in 1D fluid simulations permits a good simultaneous explanation of time- and space-integrated observables (e.g., yields, burn temperature, bang time, and absorbed energy) in highly diverse OMEGA 60-beam direct-drive capsules, including, for example, MIT "pressure scan" glass-shell D^3He capsules[3] and MIT thin-deuterated-shell plastic ^3He capsules[4]. But the RIK model currently has some difficulty explaining observables (e.g., shell ρR, proton burn radius) related to the spatial distribution of material. Perhaps enhanced shell heating, from preheat, mass-diffusion heating (ion enthalpy transport), or non-local electron transport, will account for the discrepancies. The difficulty is not as big a problem for thin shells as for thicker shells. We expect that the success of the RIK model should motivate development of more accurate, self-consistent kinetic transport models.

*This work conducted under USDOE contract DE-AC52-06NA25396.

[1] G. Zimmerman, private communication (1978, 2000, 2014)
[2] K. Molvig et al., PRL **109**, 095001 (2012); B. J. Albright et al., Phys. Plasmas **20**, 122705 (2013)
[3] M. J. Rosenberg et al., PRL (accepted, 2014)
[4] H. G. Rinderknecht et al., PRL **112**, 135001 (2014)

Fast electron transport and spatial energy deposition in imploded fast ignition cone-in-shell targets*

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Understanding fast electron generation and transport is extremely important for the development of the fast ignition (FI) scheme of laser fusion. We report on the first experimental observation of the spatial energy coupling of cone-guided fast electrons into an imploded FI plasma core. Spatial energy deposition of the fast electrons was characterized via fast electron produced Kα fluorescence from a Cu tracer added to the CD shell of a cone-in-shell target at 1% atomic density. Two-dimensional images of the Cu Kα fluorescence (8.048 keV) were obtained using a spherically bent Bragg crystal imager. 54 of the 60 OMEGA beams (18 kJ) were used for fuel assembly, and the high intensity OMEGA-EP beam (10 ps, 0.5 - 1.5 kJ, $I_{peak} > 10^{19}$ W/cm^2), was focused onto the inner cone tip with various timing delays relative to the OMEGA beam, to produce fast electrons. The data show Cu Kα emission from a 300 μm region surrounding the cone tip, correlating well with the predicted core size at ~300 ps before the maximum compression from radiation-hydrodynamic simulations of the shell implosion. Total integrated Kα yield was seen to increase with OMEGA- EP by as much as 70%. The emission also emanates from as far back as 100 μm from the inner cone tip, indicative of an electron source position with a large standoff distance from the tip of the cone, consistent with the presence of an extended pre-plasma from the OMEGA-EP pre-pulse. Neutron yield enhancements were detected using a Neutron Time-of-Flight Detector (nTOF) with thermal neutrons increasing by a factor of 2. The hybrid-PIC code, ZUMA, was used to examine the sensitivity of the simulation results on fast electron source parameters. These new findings will help facilitate the optimization of fast electron energy coupling through advanced target and implosion designs.

*This work was performed under the auspices of U.S. DOE under contracts DE-FC02-04ER54789 (FSC), DE-FG02-05ER54834 (ACE) and DE-NA0000854 (NLUF). The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

LA-UR-14-22516

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Multi-view Study of Hydrodynamic Instability in OMEGA Direct-Drive Implosions via X-ray Spectrally Resolved Imaging

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Abstract. In a series of implosion experiments performed at the OMEGA laser facility, spherical plastic shells doped with a titanium tracer-layer in the shell and filled with deuterium gas were directly-driven with low-adiabat shaped laser pulses. The titanium x-ray emergent intensity distribution is recorded with a streaked spectrometer and three identical, gated multi-monochromatic x-ray imager (MMI) instruments fielded along quasi-orthogonal lines-of-sight (LOS). The data show K-shell line emission and absorption features dependent on the initial location of the titanium tracer. The absorption features are due to K-shell transitions in L-shell ions that are backlit by the continuum radiation emitted in the core. To interpret these observations, the MMI spectrally-resolved image data were processed to obtain narrow-band images[1] and spatially-resolved spectra[2] based on the titanium spectral features. Areal density maps independently extracted from each set of data and LOS were assembled to provide symmetry information of the implosion near peak compression. A Fourier analysis of these maps yields a three-dimensional picture of hydrodynamic instability near the fuel-shell interface, which has been associated with degradation of the performance of the implosion through disruption of the shell and mixing of cold shell material into the hot core. Shell performance is measured through the target breakup fraction[3] and mix width obtained from the Fourier analysis. We present results from shots driven with low-adiabat pulse shapes, supported by DOE/NLUF Grant DE-NA0000859, and LLNL; and new analysis of a shot done with polar direct-drive as part of the DIME campaign, supported by C10 and C14.

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[1] T. Nagayama, R. C. Mancini, R. Florido, R. Tommasini, J. Koch, J. Delettrez, S. P. Regan, V. Smalyuk, J. Applied Physics **109**, 093303 (2011)
[2] T. Nagayama, R. C. Mancini, R. Florido, R. Tommasini, J. Koch, J. Delettrez, S. P. Regan, V. Smalyuk, Phys. Plasmas **19**, 082705 (2012)
[3] V. A. Smalyuk, J. A. Delettrez, S. B. Dumanis, V. U. Glebov, V. N. Goncharov, J. P. Knaur, F. J. Marshall, D. D. Meyerhofer, P. B. et al, Phys. Plasmas **10**, 1861, (2003)

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Energetics and symmetry in near-vacuum and low gas fill hohlraums*

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Most ignition experiments carried out on the NIF to date have used hohlraums with helium gas fill at 1-1.6 mg/cc density in order to prevent excessive hohlraum wall motion and help to control drive symmetry. A unique feature of 2-shock HDC ignition designs is that they require a much shorter (~ 7 ns) laser pulse than the ~ 20 ns duration pulses that are typically used for 3-shock or 4-shock CH ablator designs, so there is less time for the wall to move. As a result, it is possible to reduce the hohlraum gas fill to near vacuum density (0.03 mg/cc) and still successfully implode a 2-shock HDC capsule. Experiments using "near vacuum" hohlraums have demonstrated low backscatter (< 2%) and effective drives that are much closer to high flux model[1] predictions than for typical gas-filled hohlraums.

However, although the drive symmetry in the initial near-vacuum hohlraums experiments has been tolerable, hohlraum simulations indicate that late in time the inner cone beams are absorbed far short of the hohlraum waist, with a subsequent loss of P2 control. Also the near-vacuum hohlraums may be susceptible to outer cone glint shining directly on the capsule. To alleviate these symmetry risks, we undertook a series of 2-shock HDC experiments in a larger 6.72 mm diameter hohlraum. We have tested two gas fills – 0.03 mg/cc (near-vacuum) and 0.6 mg/cc (low gas fill). The backscatter levels remain low for both gas fill densities. This result is discussed in terms of the calculated linear gains. The measured glint is reduced for 0.6 mg/cc fill. The drive symmetry and drive production relative to modeling are different for the two gas fills and these differences are discussed in detail.

*Prepared by LLNL under Contract DE-AC52-07NA27344.

[1] M. D. Rosen, H. A. Scott, D. A Hinkel, et al., High Energy Density Physics 7, 180 (2011)

Analysis of spatially-resolved spectra and Ti-tracer distribution in OMEGA implosions*

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We discuss the observation and analysis of implosion-core spectrally-resolved image data from titanium-doped, deuterium-filled OMEGA direct-drive implosions. The targets were deuterium filled, spherical plastic shells of varying thicknesses and gas pressures with a thin Ti-doped tracer layer at the fuel-shell interface. The spectral features from the titanium tracer are primarily observed at the collapse of the implosion and recorded with a streaked spectrometer and three identical gated, multi-monochromatic x-ray imager (MMI) instruments fielded along quasi orthogonal lines-of-sight. Both streaked and gated data show simultaneous emission and absorption features associated with titanium K-shell line transitions. The spectrally-resolved images recorded with MMI were processed to obtain narrow-band images[1] and spatially-resolved spectra characteristics of contour regions on the image[2]. An Abel inversion of the image's intensity profiles reveals the spatial distribution of the titanium tracer in the core and thus provides critical information on the symmetry and hydrodynamic stability of the implosion. A complementary analysis method of the spatially-resolved titanium x-ray lines provides information about the mixing of Ti into the core. A multi-layer spectroscopic model was developed and used for the analysis of space-resolved spectra to extract electron temperature and density of the plasma in the core. In addition, space-resolved spectra were also used to extract the size of the hot-spot in the implosion core. Results are presented for experiments performed with different shell thicknesses, filling pressures and laser pulse shapes.

*Work supported by DOE/NLUF Grant DE-NA00002267, LANL, and LLNL

[1]T. Nagayama, *et al*, J. App. Phys. 109, 093303 (2011).
[2]T. Nagayama, *et al*, Phys. Plasmas 19, 082705 (2012).

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Chaotic electron orbits for large amplitude plasma wave simulations in one and two dimensions*

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Kinetic simulations of large-amplitude electron plasma waves (EPW) in one and two dimensions (1-2D) using the SAPRISTI[1] and LOKI[2] Vlasov codes have shown the generation of both longitudinal and transverse sideband instabilities. In this work, the corresponding electron orbits are studied in order to elucidate the nonlinear evolution and final state of the distribution function. Generically, the orbits are chaotic where wave-particle resonances due to different mode components overlap, yet retain adiabatic invariants further away. The existence of chaotic regions can induce saturation by reducing both the free energy and the coherence of the motion that is required for the trapped particle instability.

For 1D domains that are much larger than a single wavelength, the initial linear instability induces phase mixing at nearly conserved adiabatic invariant. During nonlinear saturation, the modulational electric field allows electrons to wander between wave troughs and generates a chaotic zone along the separatrix of the primary phase-space island. Over long times, the distribution flattens, implying that the entire resonant zone is affected by chaos. As modulations become quiescent, particle trapping becomes robust again, but there is no longer free energy available to drive instability.

For moderate aspect ratio, periodic 2D domains develop quasi-stationary final states when restricted to a single wavelength in the longitudinal direction. The 2D structure can either be generated by transverse instability of a 1D initial state or can be created directly using a 2D driver. At unit aspect ratio, the orbits are approximately integrable and the 2D state approximates the sum of two 1D waves propagating in orthogonal directions. However, for other aspect ratios, the trajectories are not integrable and chaotic motion develops where the two primary resonances overlap. The distribution often develops an ergodic "ring" that approximately depends on wave-frame energy alone. The chaotic layer determines the filling of the ring and gaps in the ring appear to correspond to phase-space island structures. In 2D, the untrapped portion of the ergodic ring cannot couple to the electric potential, but acts as a kinetic reservoir for potential energy released during the formation of the 2D state.

*LLNL-ABS-653275 performed under the auspices of the US DOE by LLNL under Contract DE-AC52-07NA27344 and funded by LLNL LDRD 12-ERD-061.

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[1]S. Brunner and E. J. Valeo, Phys. Rev. Lett. **93**, 145003 (2004).
[2] J. W. Banks and J. A. F. Hittinger, IEEE Trans. Plasma Sci. **38**, 2198 (2010); J. W. Banks, R. L. Berger, S. Brunner, B. I. Cohen, and J. A. F. Hittinger, Phys. Plasma **18**, 052102 (2011).

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Kinetic Effects in Inertial Confinement Fusion*

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Sharp background gradients, inevitably introduced during ICF implosion, are likely responsible for the discrepancy between the predictions of the standard single-fluid rad-hydro codes and the experimental observations. On the one hand, these gradients drive the inter-ion-species transport, so the fuel composition no longer remains constant, unlike what the codes assume. On the other hand, once the background scale is comparable to the mean free path, a fluid description becomes invalid. This point takes on special significance in plasmas, where the particle's mean free path scales with the square of this particle's energy. The distribution function of energetic ions may therefore be far from Maxwellian, even if thermal ions are nearly equilibrated. Ironically, it is these energetic, or tail, ions that are supposed to fuse at the onset of ignition. A combination of studies is being conducted to clarify the role of such kinetic effects on ICF performance. We present our latest results on the multi-fluid modeling of inertially confined plasmas and implications of the tail ions for the implosion dynamics. Implementing these findings in a code promise to provide a tool capable of modeling a realistic ICF implosion and burn in a reasonable computational time while having all the essential kinetic effects retained.

*This work was partially supported by the Laboratory Directed Research and Development (LDRD) program of LANL.

[1] G. Kagan and X.Z. Tang, Phys. Plasmas **19**, 082709 (2012).
[2] G. Kagan and X.Z. Tang, Phys. Lett. A **378**, 1531 (2014).
[3] G. Kagan, S.D. Baalrud and J. Daligault, "*Transport Formalism for Weakly and Moderately Coupled Multi-component Plasmas*", Phys. Plasmas (in review).
[4] G. Kagan et al, "Energetic Ions in Inertial Confinement Fusion Implosion" (to be submitted).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Absorption of high-contrast, intense short laser pulses on solids*

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We study the interaction of a 10J / 100fs intense laser pulse with solid aluminum using 1D and 2D kinetic / collisional particle simulations. In particular we are interested in an accurate description of the early phase of the interaction where the target is still cold, assuming that no plasma formation has set in before the arrival of the pulse. While most of the laser pulse is reflected, penetration of light into the skin layer and collisional heating lead to fast heating of the skin layer, and an increasing absorption of light into several groups of energetic electrons. We discuss details of the resulting electron spectrum, and plasma conditions expected immediately behind the interaction region under realistic conditions.

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

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

COMPUTATIONAL STUDY OF LASER-ACCELERATED PROTON BEAM TRANSPORT IN SOLID DENSITY MATTERS *

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Laser-accelerated proton beams can be focused to high density ($>10^{19}$ particles/cm^3) and intense current (100s kA) with a spherically curved target. It is a major challenge to understand the physics of such intense laser-accelerated proton beams' transport in solid density matter self-consistently accounting for the matter's response to the intense beam and the beam's behavior in the matter. These proton beams can heat a thin solid foil rapidly to be a partially-ionized matter state, having solid densities and temperature of 1~100s eV. In this regime, proton transport and stopping differ from cold matter or an ideal fully ionized plasma [1-2].

To study this regime, we modeled proton beams in solid targets using LSP, hybrid fluid particle-in-cell (PIC) simulations with a new ion stopping power calculation module that we have implemented in the code. This module covers both warm and hot dense regimes taking into account electronic stopping power of bound electrons and free electrons for the total proton stopping power. In a simulation, the proton stopping power is dynamically updated with target temperature and electron density variation applying the equation of state (EOS) at each time step. The kinetic PIC function of LSP describes well the collective effects in beam and target such as self-generated electromagnetic fields and beam filamentation instabilities. We will present details of the systematic studies we have conducted, made possible with this module, including the dependences of proton beam transport on the beam densities, pulse durations, energy spectra, target materials and initial target temperatures.

*This work conducted under the auspices of U.S. Department of Energy contracts DE-AC52-07NA27344 and DE-NA0002034 (NLUF)

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[1] J. F. Ziegler et al., "*Stopping of energetic light ions in elemental matter*", J. Appl. Phys. 85, 1249 (1999).
[2] G. Faussurier et al., "*Equation of state, transport coefficients, and stopping power of dense plasma from the average atom model self-consistent approach for astrophysical and laboratory plasmas*", Phys. Plasmas 17, 052707 (2010).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

A New Theory of Mix in Omega Capsule Implosions*

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The primary physical mechanism thought to be responsible for pusher / ablator mix in ICF implosions is the evolution of hydrodynamic instabilities at material interfaces. Recent experimental data on both the National Ignition Facility (NIF) and Omega support the presence of mix earlier and deeper than what is predicted by hydrodynamic mix models. In this presentation, we put forth a new mix model that relies on the development of a charge-separation electrostatic double-layer at the fuel-pusher interface early in the implosion of an Omega plastic ablator capsule.[1] The model predicts a sizable pusher mix (several atom %) into the fuel. The expected magnitude of the double-layer field is consistent with recent radial electric field measurements in Omega plastic ablator implosions.[2]

Our new theory relies on two distinct physics mechanisms. First, and prior to shock breakout, the formation of a plasma double layer at the fuel-pusher interface due to fast preheat-driven ionization. The double-layer electric field accelerates pusher ions fairly deep (10-50 μm) into the fuel, resulting in significant mix. Second, after the localized double-layer mix has occurred, the inward-directed fuel velocity behind the converging shock transports these pusher ions inward via Coulomb friction. In our presentation, we first discuss the foundations of this new mix theory[1] within the context of an Omega plastic ablator implosion. Next, we discuss our own interpretation of the radial electric field measurements on Omega plastic ablator implosions.[2] We compare and contrast our own interpretation of this experimental data with the interpretation that has been put forward in Ref. 3. Finally, we discuss the hydrodynamic mechanism that is responsible for transporting the pusher material, already mixed via the double-layer deep into the fuel, on the shock convergence time scale.

*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 LANS, LLC under contract DE-AC52-06NA25396..

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[1] D.A. Knoll et al., "*Plasma Double-Layer Initiated Mix in ICF implosions*", Phys. Rev. Lett., (2014, in review).
[2] C.K. Li et al., "*Monoenergetic-Proton-Radiography Measurements of Implosion Dynamics in Direct-Drive Inertial-Confinement Fusion*", Phys. Rev. Lett. **100** (2008) 225001
[3] P.A. Amendt et al., *"Electric field and ionization-gradient effects on inertial confinement fusion implosions"*, Plasma Phys. and Control. Fusion, **51** (2009) 124048

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Achieving Symmetry with Polar Direct Drive*

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Direct Drive (DD) is a well developed and robust platform for ICF and HED experiments. It allows simple access for experimental diagnostics and provides high laser to capsule coupling energy and therefore high burn temperatures per drive. In fact, majority of implosion experiments on Omega are done in DD configuration. With NIF's current preference for lower energy shots to protect optics and increase turn-around time on one hand, and demand for higher implosion temperatures to study thermonuclear burn on the other, DD offers a viable alternative to indirect drive. However, applying extensive Omega DD knowledge to NIF requires understanding the differences between Polar direct drive (PDD) and Symmetric direct drive. In particular, achieving symmetric implosions in PDD is essential for attaining high temperatures and neutron yields, and efficiently utilizing the laser energy. Recent Defect Induced Mix Experiment (DIME) campaigns on NIF and Omega have demonstrated the ability to achieve and sustain symmetric implosions via cone power tuning in PDD configuration. The designs and post-shot analysis work were performed with rad-hydro code HYDRA. Specifically, DIME Omega campaign confirmed P_2 tunability that was in agreement with the code predictions using only flux-limited heat conduction model. Furthermore, experiments on NIF demonstrated that by reducing the energy in polar cones P_2 was sustained below 7% for the entire implosion. In addition, it is important to recognize the impact of laser-plasma interactions (LPI) on the implosion. It was found that when the laser intensity surpasses 10^{15}W/cm^2, flux-limited conduction model in HYDRA was insufficient to accurately predict the dynamics of the DIME implosions and non-local heat transfer as well as cross-beam energy model were required.

*Work performed by Los Alamos National Laboratory under contract DE-AC52-06NA25396 for the National Nuclear Security Administration of the U.S. Department of Energy.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Revisiting hot electron generation in ignition-scale hohlraums*

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Recent work[2] invoking hot electron preheat in NIC ignition experiments is motivating a fresh look at hot electron generation in ignition-scale hohlraums. Various mechanisms for high energy electron generation are considered, with particular attention to their time dependence and the potential role of the $2\omega_{pe}$ instability in the main laser pulse[3]. The energy at risk calculations[4] are updated to include the effects of cross beam energy transfer on the time-dependent energy and intensity of the inner beams as well as improvements in the calculated plasma conditions. The generation of hot electrons by the Raman-scattered light driving the $2\omega_{pe}$ instability and the effect of the Weibel instability on the propagation of the hot electrons are also briefly considered. Uncertainties in interpreting the energy in hot electrons from hard x-ray measurements and techniques to reduce hot electron generation are discussed.

*This work was performed under the auspices of the Lawrence Livermore National Security, LLC, (LLNS) under Contract DE-AC52-07NA27344.
1. LLNL Consultant

2. H. F. Robey, *et. al.*, Phys. Plasmas 21, 022703 (2014)
3. William L. Kruer, Nathan Meezan, S. P. Regan, *et. al*,, Journal of Physics Conference Series 244, 022020 (2010)
4. S. P. Regan, *et. al*,. Phys. Plasmas 17, 020703 (2010)

44th Anomalous Absorption Conference,
8 Jun 2014 , Estes park , Colorado, USA

Possible use of 1D X-ray spectral imaging to measure plasma spatial properties.

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ABSTRACT

Ionized atoms emit characteristic X-rays that are dependent on the local plasma conditions. The lines may be used to characterize electron and ion densities as well as electron temperature and local electromagnetic fields. Here we will show how 1D imaging of the spectra may be used to distinguish different spatial distributions of spectator ions. Radial spectral imaging would be used to infer the local plasma conditions. Absolute emission would give the spectator density distribution. We will discuss the possible applications to an example problem.

* This work is supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under contract DE-AC52-06NA25396.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Influence of chronometry on hydrodynamic stability: design of Direct-Drive experiments

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We present here the 2D design of future Direct-Drive (DD) experiments which will be carried out in July 2014 at the OMEGA facility. Hydrodynamic stability of capsule is a major concern for DD and Indirect-Drive (ID) implosions. Stability can be greatly affected by the chronometry of the drive. The objective of these experiments is to study the impact of chronometry on the stability of the target.
Target will be filled with 15 bars of DT or DD-Argon. Diameter will be about 900 microns. Plastic shell thickness, 25 microns, was chosen to increase the target stability. Target dimensions will be the same for all the shots. The first two pulses are a square pulse and a 2-step-pulse. These two pulses, after rarefaction wave creations and shock reflections, drive 3 shocks. A third pulse, a truncated 2-step-pulse, is proposed for a 2-shocks-only configuration. Hydrodynamic stability decreases with the number of steps: convergence ratio increases from Rc=14 to Rc=20 whereas adiabat decreases from 3.5 to 2. For some shots, a P4 asymmetry will be created by lowering energy of some laser beams. Core asymmetries will be measured by neutron imaging (DT) and x-ray emission imaging (DDAr). Predicted core asymmetries depend strongly on the pulse shape, due to phase inversion.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

A plasma-based laser amplifier via the SBS mechanism*

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Plasma-based laser amplification has been recently receiving much attention. Using a plasma as an amplifying medium opens new possibilities in manipulating laser light at high intensities since it overcomes solid state based technology that is limited by the damage threshold of optical components. In this frame, we have demonstrated a way to perform direct amplification of short, intense laser light pulses using plasmas. This amplifier is based on the interaction and energy exchange between a long moderate-intensity *pump* pulse providing the energy, and a short less energetic *seed* pulse that is amplified. This energy redirection is made possible due to the response of the ion waves in the plasma medium to the intense laser excitation. The *Brillouin Backscattering* mechanism in the regime of *strong coupling* exploits a forced, low frequency response of the plasma to fulfill the electromagnetic coupling.

After demonstrating the feasibility of such amplification scheme[1], we recently performed an experiment at the ELFIE facility (LULI), in order to improve and optimize the conditions of such an interaction in terms of energy exchange. A few J - few ps -10^{16} W.cm^{-2} *pump* pulse was made to interact with a few mJ - 400 fs - ~10^{14} W.cm^{-2} *seed* pulse in a preformed plasma, in a fully counter-propagating configuration. The electromagnetic coupling, through the excitation of an ion acoustic (Brillouin) structure, efficiently occurs overcoming competing mechanisms. Absolute amplification, of similar value compared to standard laser amplifier, of the seed pulse has been recorded for the first time in this scheme. Results will be reviewed and discussed.

*This work was conducted under the auspices of LASERLAB-EUROPE (grant agreement no. 284464, EC's Seventh FrameworkProgramme)

[1] L.Lancia *et al.,* Phys. Rev. Lett. **104**, 025001 (2010)

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Structure and Dynamics of Supersonic Plasma Jets, Jet Collisions, and their Spontaneous Fields*

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High-Mach-number plasma jets are fundamental astrophysical phenomena in the universe. Understanding the spatial structure and temporal evolution of jets, and the interactions between colliding jets, is important for frontier astrophysics and for the basic science of high-energy-density physics. Proton images of unprecedented clarity in recent experiments reveal the structures and dynamics of pairs of laser-generated, high-Mach-number plasma jets that collide at various angles[1]. The measurements are modeled with hydrodynamic simulations and analytical analysis. The jet streamlines indicate that the colliding plasma flows stagnate in the interaction region and subsequently spread sideways along the bisector plane due to the rarefaction expansion. For collisions of two noncollinear jets, the measured flow structure is reproduced by an analytical model that predicts a characteristic feature with a narrow structure pointing in one direction and a much thicker one pointing in the opposite direction. Spontaneous magnetic fields, largely azimuthal along the colliding jets and generated by collisional current drive in the interaction region as well as by the Biermann battery effect around the laser spots, are demonstrated to be "frozen in" the plasma flow and advected along the jet streamlines. These studies provide novel insight into the interactions and dynamics of colliding plasma jets.

* This work was supported in part by US DOE and LLE National Laser User's Facility (DE-FG52-07NA28 059 and DE-FG03-03SF22691), LLNL (B543881 and LDRD-08-ER-062), LLE (414090-G), and FSC at the U. of Rochester (412761-G).

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[1] C. K. Li et al., "Structure and Dynamics of Colliding Plasma Jets", Phys. Rev. Lett. **111**, 235003 (2013).

Oral presentation is preferred.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Two-plasmon decay instabilities in a plasma with ion density fluctuations*

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Previous study found that the two-plasmon decay (TPD) modes in the low density region were important to hot electron generation in direct-drive inertial confinement fusion[1]. These modes were linked to ion density fluctuations generated by the absolute TPD modes and formed the first stage for electron acceleration due to their low phase velocities. Here we investigate the excitation mechanism of these modes by studying linear growth of TPD instabilities in a plasma with ion density modulations under parameters relevant to OMEGA experiments using LTS[2] fluid simulations. It is found that when a sinusoidal static ion density modulation is added to the linear plasma density profile, the otherwise convective TPD modes become absolute with a growth rate depending on the modulation amplitude and wave number. The maximum absolute growth rate is ~70% of the corresponding homogeneous TPD growth rate, much higher than the convective growth rate without the ion density modulation. This may explain why in Particle-in-Cell simulations these modes were only found in the nonlinear stage when ion density fluctuations were present.

*This work was supported by NNSA under Corporate Agreement No. DE-FC52-08NA28302; by DOE under Grant No. DE-FC02-04ER54789; by NSF under Grant No. PHY-1314734; and by NSCF under Grant No. 11129503. The research used resources of the National Energy Research Scientific Computing Center.

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[1] R. Yan, C. Ren, J. Li, A. V. Maximov, W. B. Mori, Z.-M. Sheng and F. S. Tsung, "Generating energetic electrons through staged acceleration in the two-plasmon-decay instability in inertial confinement fusion", Phys. Rev. Lett **108**, 175002 (2012).

[2] R. Yan, A. V. Maximov and C. Ren, "The linear regime of the two-plasmon decay instablility in inhomogeneous plasmas", Phys. Plasmas **17**, 052701 (2010).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

X-ray imaging and spectroscopy of polar-drive implosions at OMEGA*

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In a series of polar-drive implosions performed at OMEGA several x-ray spectrometers were fielded to record the signal from Ar and Ti tracers added to the core and shell, respectively. The instruments included time-integrated (XRS) and streaked (SSCA) spectrometers as well as gated monochromatic imagers (MMI). Analysis of the Ar streaked data produced the time-history of density and temperature in the core. The gated images provided information about symmetry along both the polar axis and the equatorial plane lines-of-sight. In addition, a generalized Abel inversion of narrow-band images and detailed analysis of spatially resolved spectra extracted from spectrally resolved images recorded with the MMI produced spatial distributions of plasma conditions and mix (T. Nagayama et al, Phys. Plasmas **19**, 082705 (2012)). Comparisons were made with results from post-processed 3D simulations to provide further insight into the interpretation of the experimental results and to constrain the simulation physics model.

*This work is supported by LANL Contract 156715

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

SECHEL: a CBET post-processor for hydro codes Early results for rugby-shaped hohlraums

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Much attention has been given in the past years to the CBET phenomenon in ICF, either as a hindrance or as a tool to attain it[1,2]. We present in this communication the CBET post-processing code SECHEL (standing for *Simulateur des ÉCHanges d'Énergie Laser*) and the first results obtained on various high-temperature plasmas, either homogeneous or simulated by the CEA/DAM FCI2 laser-hydrodynamics code.

SECHEL derives from a non-saturated steady-state model[3,4,5] of the CBET in a plasma. It treats coherently the laser absorption and the energy transfers in a pre-calculated plasma where a number of beams propagate in a common average direction. As the beams can be accurately described, the dependency of the CBET on the polarization state and the intensity ratios can then be probed.

Every beam being discretized with many "beamlets", SECHEL also calculates the deformation of laser power fronts. It can hence become a useful tool for ICF hohlraum design, giving not only the inter-cones energy imbalance but also the inner-spot modification of the heating term on the gold cavity. Early results obtained on a rugby-shaped hohlraum are shown, some exhibiting a substantial change.

The code has been validated by comparison with analytical results in 2D and 3D configurations; the error increases with the intersection but stays within very acceptable levels (typ. much below 5%). The most part is a corrigible systematic bias due to beams' discretization.

As of today, a simple *ad hoc* maximum-level condition on the ionic perturbation is implemented. Near-future additions will include more refined saturation models (benefitting from 3D localization of the CBET), self-coherent retro-propagation of given SBBS waves, refraction of the beamlets and finally the inclusion in FCI2 to obtain a self-coherent laser-hydrodynamics simulation.

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[1] P. Michel L. Divol, E.A. Williams, S. Weber, C.A. Thomas, D.A. Callahan, S.W. Haan, J.D. Salmonson, S. Dixit, D.E. Hinkel, M.J. Edwards, B.J. MacGowan, J.D. Lindl, S.H. Glenzer and J. Suter, "*Tuning the implosion symmetry of ICF targets via controlled crossed-beam energy transfer*", PRL **102**, 025004 (2009).
[2] P. Michel L. Divol, E.A. Williams, C.A. Thomas, D.A. Callahan, S. Weber, S.W. Haan, J.D. Salmonson, N.B. Meezan, O.L. Landen, S. Dixit, D.E. Hinkel, M.J. Edwards, M.J. Edwards, B.J. MacGowan, J.D. Lindl, S.H. Glenzer and J. Suter, "*Energy transfer between laser beams crossing in ignition plasmas*", Phys. Plasmas **16**, 042702 (2009).
[3] C.J. McKinstrie, J.S. Li, R.E. Giacone and H.X. Vu, "*Two-dimensional analysis of the power transfer between crossed laser beams*", Phys. Plasmas **3**, 2686 (1996).
[4] C.J. McKinstrie, A.V. Kanaev, V.T. Tikhonchuk, R.E. Giacone and H.X. Vu, "*Three-dimensional analysis of the power transfer between crossed laser beams*", Phys. Plasmas **5**, 1144 (1998).
[5] V.V. Eliseev, W. Rozmus, V.T. Tikhonchuk and C.E. Capjack, "*Interaction of crossed laser beams with plasmas*", Phys. Plasmas **3**, 2215 (1996).

Cross-beam energy transfer mitigation strategy for NIF polar drive*

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The cross-beam energy transfer (CBET) effect causes two beams to exchange energy via stimulated Brillouin scattering,[1] which increases scattered light, alters time-resolved scattered-light spectrum, and redistributes absorbed light. Reduced absorption, implosion velocity and altered scattered-light spectra in symmetric direct-drive and polar-drive (PD) experiments on the OMEGA Laser System and the National Ignition Facility (NIF) are attributed to CBET. The CBET effect package (*Adaawam*) incorporated into the 2-D hydrodynamics code *DRACO*[2] is an integral part of the 3-D ray-trace package (*Mazinisin*). The CBET exchange occurs primarily over the equatorial region in PD, where successful mitigation strategies concentrate. Any CBET mitigation strategy (spatial, frequency, or temporal) can be combined. Manipulating spot shapes improves performance by reducing CBET interaction volume. Detuning the initial laser wavelength ($d\lambda_0$) shifts the CBET resonance and reduces the interaction volume, which improves performance provided the $d\lambda_0$ is large enough. Employing opposed $\pm d\lambda_0$ in each hemisphere offers the best CBET mitigation. The larger the detuning, the more significant the mitigation effect becomes and the longer the effect is sustained during the pulse; e.g., ±6-Å UV provides satisfactory mitigation for NIF-scale designs. The current NIF layout presents an implementation challenge for detuning mitigation because symmetric $d\lambda_0$ shifts and simple PD repointing prevent wavelength separation over the equator. Altering the NIF PD repointing strategy while maintaining symmetry yields an evaluation platform using $d\lambda_0 = \pm 3$-Å UV. Simulations (2-D *DRACO)* predict measurable results: shell trajectory and shape and scattered-light spectrum and distribution.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] C. J. Randall, J. R. Albritton, and J. J. Thomson, "*Theory and simulation of stimulated Brillouin scatter excited by nonabsorbed light in laser fusion systems*," Phys. Fluids **24**, 1474 (1981).
[2] P. B. Radha *et al.*, "*Multidimensional analysis of direct-drive, plastic-shell implosions on OMEGA*," Phys. Plasmas **12**, 056307 (2005).

Examining the evolution towards turbulence through spatio-temporal analysis of multi-dimensional structures formed by instability growth along a counter propagating shear layer*

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The LANL counter-propagating shear campaign is focused on examining instability growth and its transition to turbulence relevant to mix in ICF capsules. The counter-propagating shear experimental platform is designed to use anti-symmetric flows about a shear interface to examine isolated Kelvin-Helmholtz instability growth in the absence of a transverse pressure gradient across the interface.[1] This platform is being fielded on both the OMEGA laser facility and the NIF. The target design geometry allows us to benchmark the LANL RAGE hydrocode that includes the BHR turbulence model. The current work uses metal tracer layers (Al or Ti) to observe the growth of the mix region, i.e. providing a mix width. This width is then compared against simulations to evaluate the BHR model.[2] However, the metal tracer layer does not expand uniformly, but breaks up into multi-dimensional structures that are initially quasi-2D due to the target geometry. We are developing techniques to analyze the multi-D structure growth along the tracer layer surface[1] with a focus on characterizing the time dependent spectrum of structure sizes for appraising a transition to turbulence in the system. Capturing the motion of interfaces during the transition to turbulence may provide tighter constraints on initialization schemes for the BHR model. To this end, we are analyzing the images using a wavelet based analysis suited to diagnosing single-time radiographs of the tracer layer surface with observed non-repetitive structures, as well as identifying temporal trends in radiographs taken at different times across several different experimental shots. We will also present information on and initial data from the development of a streaked imaging platform to analyze the temporal evolution of the transition structures over a single experimental shot.

*This work conducted under the auspices of the U.S. Department of Energy by LANL under contract DE-AC52-06NA25396

[1] F. W. Doss et al., *"Instability, mixing, and transition to turbulence in a laser-driven counterflowing shear experiment"*, Phys. Plasmas **20**, 012707 (2013)
[2] F. W. Doss et al., *"The high-energy-density counterpropagating shear experiment and turbulent self-heating"*, Phys. Plasmas **20**, 122704 (2013)

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Polarization rotation from stimulated scattering of laser beams off plasma waves *

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Two electromagnetic waves crossing in a plasma can exchange energy as they scatter off the density modulation generated by their beat wave, as is the case for crossed-beam energy transfer (CBET) or short pulse plasma amplification. If the waves are not initially linearly polarized with their polarization directions perfectly aligned, then the 3-wave coupling can modify their polarization properties (polarization direction and ellipticity). We will present the theory of polarization rotation from laser beams scattering off plasma waves, and show its consequences for backscatter in experiments on the National Ignition Facility (NIF). Polarization effects in CBET on NIF can strongly modify the energy distribution between beams of a same quadruplet, and modify or even cancel the effects of polarization smoothing for backscatter mitigation[1].
We will show new calculations of CBET for NIF experiments that include the full polarization evolution of the 192 NIF laser beams. These calculations show an excellent agreement with measurements of stimulated Brillouin scattering (SBS) on the NIF, and provide an explanation for the systematic SBS variations observed between beams of a same quadruplet. SBS can thus be used as a probe of the laser beams' polarization modifications induced by CBET, both for the beams' amplification and for their state of polarization[2].

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

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[1] R. L. Berger, this conference
[2] D. P. Turnbull, this conference

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Highly-resolved 2D Simulations of Interface-Free Ignition Double-Shell Targets*

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Double-shell targets, consisting of a high-*Z* (typically gold) inner-shell concentrically supported by a low-density foam inside a low-*Z* ablator, are attracting attention as a complementary approach to the main-line single shell ignition design. The original design[1] was shown to be highly unstable to the growth of perturbations on the outer surface of the inner shell as the converging outer ablator pushes back on the outward expanding inner-shell from hohlraum L-shell preheat[2]. This mechanism proved to be highly damaging when low-order modes (l>200) were seeded at the outer surface of the inner shell, leading eventually to shell breakup at maximum convergence and ignition failure. This instability was computationally shown to be controlled by tamping of the inner shell by a low-*Z* material[2]. However, while the growth of these instabilities was substantially reduced and proven to keep the shell intact according to computations, the possibility of having such an inherently unstable system is undesirable. Therefore, a further improvement in the double-shell targets was proposed. A redesigned inner-shell consisting of a density graded mixture (pure gold inner surface continuously doped with copper until a pure Cu outer region is reached) followed by a material matching surrounding foam[3]. Simulations of these targets have shown a near 1D hydrodynamic performance. However, further interface instabilities are possible, in particular between the high-*Z* inner surface of the inner-shell and the fuel. To mitigate these instabilities, a new concept has been proposed that utilizes the latest developments in 3D nano-lithography, which potentially allows for the fabrication of an interface-free target[4]. To demonstrate the viability of this new design we have undertaken a series of 2D highly-resolved computer simulations using the code HYDRA. In this paper we will present the results of our simulations and possible future directions.

* Work performed under the auspices of U.S. Department of Energy by LLNL under Contract DE-AC52-07NA27344 and supported by LDRD-14-ERD-031

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[1] P. Amendt *et al*., Phys. Plasmas 9, 2221 (2002).
[1] J. L. Milovich *et al*., Phys Plasmas 11, 1552 (2004).
[3] J. L. Milovich *et al*., IFSA Proceedings, Monterey, 065004 (2005)
[4] P. Amendt *et al*., this conference.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Current status of the laser Megajoule facility and program overview

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The laser Megajoule (LMJ) facility developed by The French Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), is under completion at CEA/CESTA. The 176 beams of the facility will deliver a total energy of 1.4 MJ of 0.35 μm (3ω) light and a maximum power of 400 TW. All specifications have been tested on qualification sub-systems, and on the LIL prototype.
The laser bundle assemblies are now completed in the four laser bays, and the laser slabs of the power amplifier, the transport mirrors and the focusing systems are being installed. The first shots at 1.05 μm (1ω) have been performed, and the 8 initial beams, the target positioner, the diagnostics and the diagnostic manipulator are under test to carry out the first experiments by the end of 2014. Then the LMJ will increase its capacities with the completion of new beam lines and diagnostics.
The LMJ is designed to provide the experimental capabilities to study High Energy Density Physics (HEDP), and is a keystone of the French Simulation Program, which combines improvement of physics models, high performance numerical simulation, and experimental validation. Using a variety of pulse shapes, it will be possible to bring material to extreme conditions with temperature of 100's MK and pressures of 100's Gbar. One of the LMJ's goals is to obtain ignition and burn of DT via inertial confinement fusion with the indirect drive approach. Achieving ignition is the most constraining for the facility and requires a coordinated program associating the facility itself, as well as optimized ignition targets[1], plasma diagnostics, and simulation tools.
During the growth of LMJ's capacities, starting at the end 2014, CEA will perform focused experiments dedicated to fundamental physics (equation of state, opacity, transport), laser-plasma interaction, implosion hydrodynamics, and hydrodynamic instabilities in order to improve our predictive capability. This path forward will help us to secure our ignition point design.
A coupled PW beam (the PETAL project*, part of the CEA opening policy) will extend the LMJ's experimentations field on HEDP.
LMJ/PETAL will be open to the scientific community.

*The PETAL project is being performed under the auspices of the Conseil Régional d'Aquitaine, of the French Ministry of Research and of the European Union.

[1] S. Laffite and P. Loiseau, "*Design of an ignition target for the laser megajoule, mitigating parametric instabilities*", Physics of Plasmas **17**, 102704 (2010).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Non-linear Structure of the Diffusing Gas-Metal Interface in a Thermonuclear Plasma*

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The theoretical structure of the diffusion layer that develops from an initially sharp gas-metal interface is described. The layer dynamics under isothermal and isobaric conditions is considered so that only mass diffusion (mixing) processes can occur. Since electron and ion pressures are not separately constant, diffusion fluxes of the baro-diffusion type occur and actually dominate the flux over most of the layer. The layer develops a distinctive structure with asymmetric and highly non-linear features. On the gas side of the layer the diffusion coefficient goes nearly to zero, causing a sharp "front", or well defined boundary between mix layer and gas. This non-linear structure is similar to the Marshak thermal waves, but in the mixture variable. It keeps the mixing layer and clean gas regions separated. On the metal side of the interface, gas profiles decay into the metal in the manner of classical linear diffusion with some trace gas mixed into the metal at all distances. Similarity solutions for the non-linear waves are given and compared to the full time-dependent solutions. The similarity solution profiles compare well with simulations done using a full kinetic code (LSP) for the ions. A criterion for the diffusion layer to influence thermonuclear burn is given as a function of the global cavity ρR, temperature and the increase in interfacial area due to hydrodynamic stirring.

* This research was supported by the US DOE/NNSA, performed in part at LANL, operated by LANS LLC under contract number DE-AC52-06NA25396.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Laser-Plasma interactions: Their impact on NIF and other laser systems*

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Laser plasma interactions (LPI) often play a significant role in laser produced plasma experiments both through direct and indirect effects. For example, in NIF hohlraums, overall performance is reduced by the significant backscattered laser power, primarily via stimulated Raman scattering (SRS). The large level of SRS generates high-energy electrons which can preheat the fuel and limit the fuel convergence. Crossed-beam energy transfer (CBET) in the laser-entrance hole provides an LPI mechanism for redistributing laser power in a way which benefits implosion symmetry. In a different type of laser experiment, laser power absorption causes the high-energy electrons in the energy distribution to source a current which drives a controlled magnetic field. Small-signal LPI is at the heart of many plasma characterization techniques such as Thomson scattering, Faraday rotation, and interferometry. These measurements rely on the modification of the probe laser phase or frequency as the result of scattering or transmission of a probe beam.

This talk will be presented in several parts. First, we will update the status of LPI on NIF hohlraums showing the characteristics of backscatter light on several of the new ignition targets. This will include a review of recent changes to the backscatter instrument. Second, we will report on a new measurement capability of the NIF backscatter instrument which detects the polarization of backscattered light from NIF hohlraums. This detector provides a new method to determine which beams participate in CBET. In addition to the NIF results, polarization measurements of Faraday rotation have been used in recent laser-generated magnetic field experiments to diagnose the resulting B-field, estimated to be ~ 30 T for 1 kJ of laser energy. This is part of an effort to improve hohlraum performance using controlled magnetic fields. Finally, we will describe a new use of the NIF backscatter system for plasma characterization. In one experiment low amplitude SRS is used as a “Thomson-like” probe to determine plasma density. Thomson scattering has also allowed us to distinguish between different NLTE models in Omega Au sphere experiments designed to replicate NIF hohlraum wall conditions. We will report on plans for a NIF Thomson detector capable of diagnosing scattered light from a 351 nm or 263 nm probe beam.

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

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Lasnex Predictions for Z Opacity Experiments Using Tampers of Increased Mass (LA-UR-14-22444)

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2-D Lasnex [1] radiation hydrodynamics simulations have been performed for Fe/Mg opacity experiments carried out at Sandia National Laboratories' Z facility. The Z facility has a demonstrated capability for obtaining opacity measurements for iron in the 800-1800 eV x-ray range[2] by showing agreement with PRISMSPECT, MUTA, and OPAL opacity models within experimental error bars. A unique characteristic of the Z platform is that the dynamic hohlraum (DH) serves to both heat and backlight a thin sample of material. For experiments carried out in 2006 using thin and thick Fe/Mg targets the plasma at sample center was shown to be not significantly affected by gradients, NLTE conditions, or background subtraction. Because the Fe/Mg sample near 156 eV is much cooler than the back lighter (~314 eV) the self emission of the sample could also be neglected and was smaller than the experimental tolerances.

These experiments have been successfully repeated on the upgraded Z machine, ZR. More recently, efforts have focused on achieving opacity measurements for iron with increased electron density and temperature. Data for plasma conditions closely corresponding to the solar radiation/convection transition region are of great interest. Increased mass CH and Be tampers have recently been used to attempt to increase the sample electron density and temperature to 8×10^{22} e-/cm^3 and 193eV. The time-dependent sample conditions and hydrodynamics will be discussed for CH and Be tampers. It has been shown that shading of the CH by the iron sample has a strong effect on the resulting transmission. In contrast, the Be tamper evolves similarly whether the iron is present or not. Instantaneous and time integrated simulated transmission spectra for both tampers will be presented. Measurement of the spatially and temporally resolved x-ray spectrum is in progress for the new ZR, and could help constrain the simulations.

References

1 G. B. Zimmerman and W. L. Kruer, Comments Plas. Phys. **2** (2), 51 (1975).
2 J. E. Bailey, G. A. Rochau, C. A. Iglesias, J. Abdallah, J. J. MacFarlane, I. Golovkin, P. Wang, R. C. Mancini, P. W. Lake, T. C. Moore, M. Bump, O. Garcia, and S. Mazevet, Phys Rev Lett **99** (26) (2007).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

The Effect of Turbulent Kinetic Energy on Inferred Ion Temperature from Neutron Spectra*

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Measuring the width of the energy spectrum of fusion-produced neutrons from deuterium or deuterium-tritium plasmas is a commonly used method for determining the ion temperature in inertial confinement fusion implosions. In a plasma with a Maxwellian distribution of ion energies, the spread in neutron energy arises from the thermal spread in the center-of-mass velocities of reacting pairs of ions. Fluid velocities in ICF are of a similar magnitude as the center-of-mass velocities and can lead to further broadening of the neutron spectrum, leading to erroneous inference of ion temperature. Motion of the reacting plasma will affect DD and DT neutrons differently, leading to disagreement between ion temperatures inferred from the two reactions. This effect may be a contributor to observations over the past decades of ion temperatures higher than expected in simulations,[1] ion temperatures in disagreement with observed yields,[2] and different temperatures measured in the same implosion from DD and DT neutrons.[3] This difference in broadening of DD and DT neutrons also provides a measure of turbulent motion in a fusion plasma.

*This work was performed under the auspices of the U.S. DOE by LANL under contract DE-AC52-06NA25396.

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[1] O. L. Landen, C. J. Keane, B. A. Hammel, W. K. Levedahl, P. A. Amendt, J. D. Colvin, M. D. Cable, R. Cook, T. R. Dittrich, S. W. Haan, S. P. Hatchett, R. G. Hay, R. A. Lerche, R. McEachern, T. J. Murphy, M. B. Nelson, L. Suter, and R. J. Wallace, *Phys. Plasmas* **3**, 2094 (1996).

[2] J. R. Rygg, J. A. F. C. K. Li, F. H. S`eguin, R. D. Petrasso, J. A. Delettrez, V. Y. Glebov, V. N. Goncharov, D. D. Meyerhofer, S. P. Regan, T. C. Sangster, and C. Stoeckl, *Phys. Plasmas* **13**, 052702 (2006).

[3] H.-S. Park, O. A. Hurricane, D. A. Callahan, D. T. Casey, E. L. Dewald, T. R. Dittrich, T. D¨oppner, D. E. Hinkel, L. F. B. Hopkins, S. L. Pape, T. Ma, P. K. Patel, B. A. Remington, H. F. Robey, and J. D. Salmonson, *Phys. Rev. Lett.* **112**, 055001 (2014).

A numerical investigation of two-plasmon–decay localization in 60-beam spherical implosion experiments on OMEGA*

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The localization of the two-plasmon–decay (TPD) instability to specific angular regions of the quarter-critical surface in spherical implosion experiments on OMEGA has been demonstrated through the imaging of both half- and three-halves harmonic emission.[1] Localization is possible because TPD is a multibeam instability[2] and different locations on the quarter-critical surface are driven by beams whose angles and intensities vary according to polar angle and azimuth. The degree of localization has been quantified through a series of 3-D numerical calculations. These calculations were performed with a 3-D nonlinear Zakharov model of TPD[3] that has been extended to take into account the specific beam geometry of OMEGA. Based on these results, estimates for localized electron plasma temperature excursions are estimated and compared with those inferred from experiment.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] W. Seka *et al*. "*Localized time-resolved electron temperature measurements indicate nonuniformly driven two-plasmon–decay instability in directly driven implosions,*" submitted to Physical Review Letters.
[2] D. T. Michel *et al.*, "*Experimental validation of the two-plasmon-decay common-wave process*," Phys. Rev. Lett. **109**, 155007 (2012); C. Stoeckl *et al.*, "*Multibeam effects on fast-electron generation from two-plasmon-decay instability*," Phys. Rev. Lett. **90**, 235002 (2003).
[3] J. Zhang *et al.*, "*Multibeam two-plasmon decay from linear threshold to nonlinear saturations,*" submitted to Physical Review Letters; H. X. Vu *et al.*, "*Nonlinear development of the two-plasmon decay instability in three dimensions*," submitted to Physics of Plasmas.

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Integrated simulations of a NIF vacuum hohlraum platform for imploding CH capsules*

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The impact of asymmetries on ICF capsule performance can be studied in simplified, low-convergence CH capsule implosions[1]. For simplified implosions at the NIF scale, laser-driven vacuum hohlraums offer several potential advantages over gas-filled hohlraums. These include low backscatter with high x-ray conversion efficiency (~85-90%)[2] and reduced hot electron production compared to the more standard He gas-filled hohlraums. In addition, unlike the situation for NIF gas-filled hohlraums, it is hypothesized that integrated high-flux model simulations of NIF vacuum hohlraums will accurately predict both Dante measurements[3] of time-resolved hohlraum radiant intensity (or x-ray flux), and streaked backlit radiographs[4] of the capsule implosion without the need for *ad hoc* multipliers on the laser input power. Of course, important disadvantages of vacuum hohlraums are related to reduced symmetry control due to wall motion and the lack of cross-beam laser power transfer capability.

In this presentation, integrated simulations of the vacuum hohlraum with CH capsule are dissected in a time-resolved fashion to map out the flow of energy within this system – including x-ray energy escaping the hohlraum, x-ray energy retained in hohlraum walls and coronal plasma, and x-ray energy absorbed by the capsule. The integrated simulations are post-processed to provide predicted Dante x-ray flux measurements and synthetic streaked backlit images of the imploding capsule. Ultimately, the simulated data can be compared with experimental results to constrain the simulations and test the multiplier-free hypothesis for simulations of NIF vacuum hohlraums with capsules.

*This work was performed at LANL, operated by LANS, LLC for the U.S. DoE under Contract No. DE-AC52-06NA25396; and at LLNL, operated by LLNS, LLC for the U.S. DoE under Contract No. DE-AC52-07NA27344.

---

[1] V. A. Thomas and R. J. Kares, "*Drive asymmetry and the origin of turbulence in an ICF implosion,*" Phys. Rev. Lett. **109**, 075004 (2012).
[2] R. E. Olson et al., "*X-ray conversion efficiency in vacuum hohlraum experiments at the National Ignition Facility*", Phys. Plasmas **19**, 053301 (2012).
[3] J. L. Kline et al., "*The first measurements of soft x-ray flux from ignition scale hohlraums at the National Ignition Facility using Dante",* Rev. Sci. Instrum., **81**, 10E321 (2010).
[4] D. G. Hicks et al., "*Implosion dynamics measurements at the National Ignition Facility*", Phys. Plasmas **19**, 122702 (2012).

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Overview of collisionless shock experiments using intense lasers*

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Astrophysical collisionless shocks are ubiquitous, occurring in supernova remnants, gamma ray bursts, and protostellar jets. They occur when the ion-ion collision mean free path is much larger than the system size. High power laser experiments are ideal to study microphysics questions relevant to on shock formation; magnetic field generation; and particle acceleration[1]. Many experiments have been performed on the laser facilities where high velocity plasmas are created by using two high intensity laser pulses to irradiate two plastic disks faced each other[2]. The electric and magnetic fields in the counter-streaming plasmas were imaged with proton probes. Many reported electrostatic collisionless shock formation[3] and magnetic field amplification via plasma interactions from the laser driven laboratory experiments[4]. The recent proton probe experiments on Omega show filamentary structures of Weibel instabilities[5,6], that are from electromagnetic nature and the inferred the magnetization level could be as high as ~1%. These results imply significance of electromagnetic instabilities in the plasma interactions in the ICF and astrophysical conditions. This paper will review the recent experimental results from Omega, Gekko, LULI, Vulcan and the other laser facilities as well as the simulation results and the theoretical understanding of these observations. The planned NIF experiments will be presented where it will be possible to observe the fully formed shocks.
* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

---

[1] H. Takabe, *et al*., "*High-Mach Number collisionless shock and photo-ionized non-LTE plasma for laboratory astrophysics with intense lasers*", Plasma Phys. Control. Fusion, **50**, 124057 (2008).
[2] J. S. Ross *et al*., "*Collisionless Coupling of Ion and Electron Temperatures in Counterstreaming Plasma Flows*", Phys. Rev. Lett., **110**, 145005 (2013).
[3] Y. Kuramitsu, *et al*., "*Time Evolution of Collisionless Shock in Counterstreaming Laser-Produced Plasmas*", Phys. Rev. Lett., **106**, 175002 (2011).
[4] G. Gregori, *et al*., "*Generation of scaled protogalactic seed magnetic fields in laser-produced shock waves*", Nature, **481**, 480-484 (2012).
[5] W. Fox, *et al*., "*Filamentation Instability of Counterstreaming Laser-Driven Plasmas*", Phys. Rev. Lett., **111**, 225002 (2013).
[6] C. M. Huntington, *et al*., "*Observation of magnetic field generation via the Weibel instability in interpenetrating plasma flows*", in preparation (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Results, Progress, and Plans for Magnetized Liner Inertial Fusion (MagLIF) on Z*

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The magnetized liner inertial fusion (MagLIF) concept is a promising approach to achieving large fusion yields on the Z facility[1,2]. By utilizing pre-magnetized and pre-heated fusion fuel, the required implosion velocity, convergence, and stagnation pressure required to achieve fusion conditions is substantially reduced.

The first integrated MagLIF experiments have obtained DD neutron yields as high as 2e12 and plasma temperatures of 3-4keV [3]. These experiments incorporated both pre-magnetized and preheated fusion fuel and demonstrated dramatic improvement in fusion performance over previous experiments with identical targets that did not incorporate both of these design elements.

In this paper, we present results and plans for both integrated and focused MagLIF experiments that investigate a number of key physics issues including, liner instabilities (electrothermal, magneto-Rayleigh-Taylor, deceleration Rayleigh-Taylor, etc.), laser energy coupling to the fusion fuel, magnetic flux compression, and suppression of electron heat transport by the axial magnetic field.

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the National Nuclear Security Administration under contract DE-AC04-94AL85000. Support provided in part by the Laboratory Directed Research and Development Program at Sandia.

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[1] S. A. Slutz, M. C. Herrmann, R. A. Vesey, A. B. Sefkow, et. al., "Pulsed-power-driven cylindrical liner implosions of laser preheated fuel magnetized with an axial field", Phys. Plasmas 17, 056303 (2010).
[2] A. B. Sefkow, S. A. Slutz, J. M. Koning, M. M. Marinak, et. al., "Design of magnetized liner inertial fusion experiments using the Z facility", submitted to Phys. Plasmas (2014).
[3] M. R. Gomez, S. A. Slutz, A. B. Sefkow, D. B. Sinars, et. al., "Experimental demonstration of fusion-relevant conditions in magnetized liner inertial fusion", submitted to Phys. Rev. Lett. (2014).

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Demonstration of Stimulated Brillouin Scatter reduction using Borated Gold Hohlraums on the National Ignition Facility*

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New target platforms for indirect drive ignition on NIF are being introduced to improve capsule and hohlraum performance. A number of these targets are showing increased Stimulated Brillioun Backscattering (SBS) late in the laser pulse on the outer cone beams incident near the laser entrance hole. SBS results from the scattering of the laser pulse from the resonantly driven ion acoustic waves. This scattering leads to a reduction in laser power available for x-ray drive in an ignition hohlraum. In addition, SBS poses a damage risk to optics in the NIF beamlines. In these experiments, we have demonstrated a factor of 5 reduction in the SBS power from outer cone beams in a NIF hohlraum by doping the Au hohlraum wall with 40% Boron. The addition of a single lower Z species to a plasma composed of a single higher Z species has been shown to suppress the growth of ion acoustic waves and therefore SBS through increased damping on smaller scale facilities and in simulations. These experiments investigated SBS in room temperature (300 K) Neopentane-filled full ignition scale hohlraums. The experiments, comprised 2 shots, the firtst in a hohlraum with a 1.5 micron layer of 60/40 Gold/ Boron and the second, a control shot using a pure gold hohlraum. The 1 MJ, 370 TW laser pulse, used in both experiments, is a modified version of the 4-shock pulse used for low adiabat implosion experiments. The backscatter from the outer cone beams on NIF is measured using the FABS diagnostic which quantifies the temporally and spectrally resolved SBS power. Measurements show approximately a 5x reduction in SBS power in the portion of the spectrum originating in the wall plasma. An increase of about a factor of 2 was also observed in the SBS originating in the gas in the Gold Boron experiment. Detailed simulations of a NIF hohlraum show suppression of SBS by adding Boron. Experimental and simulation results will be presented.

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

X-ray spectroscopy of implosions at the National Ignition Facility*

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X-ray spectroscopy in the 6- to 16-keV photon energy range is used to diagnose the plasma conditions of ignition-scale targets at the National Ignition Facility (NIF). The stagnated implosion has a central hot-spot region surrounded by a cold and dense compressed shell. The DT hot spot has a T_e in the 2- to 4-keV range and an n_e of $\sim 10^{25}$ cm^{-3}, while the compressed shell is several times denser and cooler. The compressed shell is comprised of an outer layer of CH doped with trace amounts of Cu and Ge and an inner layer of DT fuel. Hydrodynamic instabilities mix material from the outer layers into the hot spot. The amount of hot-spot mix mass is determined from the absolute brightness of the Cu and Ge K-shell emission. The Cu and Ge dopants placed at different radial locations in the CH ablator show the ablation-front hydrodynamic instability is primarily responsible for hot-spot mix. Low neutron yields and hot-spot mix mass between 30 and 4000 ng are observed.[1] Most of the Ge-doped CH remains in the compressed shell and attenuates x rays from the hot spot. Electron screening, ionization, continuum lowering, and Stark broadening affect the absorption features. In the Fermi-degenerate compressed shell the inferred T_e is in the 100- to 400-eV range and the n_e is $\sim 5 \times 10^{25}$ cm^{-3}.
*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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[1] S. P. Regan *et al*., "*Hot-spot mix in ignition-scale inertial confinement fusion targets*," Phys. Rev. Lett. **111**, 045001 (2013).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

A quasilinear model for hot electron generation in two-plasmon decay instabilities in direct-drive inertial confinement fusion*

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Previous PIC simulations found that the two-plasmon decay (TPD) modes in direct-drive inertial confinement fusion generated hot electrons in a staged fashion[1]. Here we present a quasilinear model for hot electron generation under given plasma waves. The model is based on the Vlasov equation and describes how hot electron generation depends on background plasma temperatures and plasma wave amplitudes and the spatial variation of its phase velocity. The results will be compared with PIC simulations.

*This work was supported by NNSA under Corporate Agreement No. DE-FC52-08NA28302; by DOE under Grant No. DE-FC02-04ER54789; by NSF under Grant No. PHY-1314734; and by NSCF under Grant No. 11129503. The research used resources of the National Energy Research Scientific Computing Center.

[1] R. Yan, C. Ren, J. Li, A. V. Maximov, W. B. Mori, Z.-M. Sheng and F. S. Tsung, "Generating energetic electrons through staged acceleration in the two-plasmon-decay instability in inertial confinement fusion", Phys. Rev. Lett **108**, 175002 (2012).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Probing hohlraum plasma conditions by neutronics from fusion in the hohlraum volume*

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We explore the idea of obtaining information about the plasma conditions inside an ignition scale hohlraum, by introducing material into the hohlraum volume that can fuse. This could be a CD ablator on the outside of a (preferably dudded) capsule, whose hot ablated plasma fills part of the hohlraum volume. It could be DT, DD, or DHe3 as the fill gas of the hohlraum, replacing the usual He for cryo hohlraums, or C5D12 replacing the usual neo-pentane (C5H12) for warm hohlraums. Localizing the fusion interaction volume, such as by deuterating only the laser entrance hole window, or by strategic placement of deuterated foams, is also possible.

Deriving information regarding Te, is possible, but problematic, since fusion rates are sensitive to Ti, not Te. We discuss the issues of predicting absolute values of the volumetric fusion yield, since mix, and / or kinetic effects such as ion diffusion will affect the fusion rates.

We propose a possible experiment that could be of value, which would be to look for a *relative* change in fusion production with a change in “delta lambda”. The cross beam energy transfer (CBET) process is predicted[1] to heat up the ions, so fusion rates will vary with the amount of CBET that is occurring. This hohlraum fusion method could test that prediction.

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

[1] P. Michel, W. Rozmus, E. A. Williams, L. Divol, R. L. Berger, R. P. J. Town, S. H. Glenzer, and D. A. Callahan, “*Stochastic Ion Heating from Many Overlapping Laser Beams in Fusion Plasmas*”, Phys. Rev. Lett **109**, 195004 (2012).

Prefer: Oral presentation

LLNL-ABS-653123

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Exploring hydro to kinetic regimes in ICF*

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Clear evidence of the transition from hydrodynamic-like to strongly kinetic shock-driven implosions is, for the first time, revealed and quantitatively assessed. Implosions with a range of initial equimolar D^3He gas densities show that as the density is decreased, hydrodynamic simulations strongly diverge from and increasingly overpredict the observed nuclear yields, from a factor of ~2 at 3.1 mg/cm^3 to a factor of ~100 at 0.14 mg/cm^3 (see Figure). (The corresponding Knudsen number, the ratio of ion mean-free-path to minimum shell radius, varied from 0.3 to 9; similarly, the ratio of fusion burn duration to ion diffusion time, another figure of merit of kinetic effects, varied from 0.3 to 14.) As a first step to garner insight into this transition, a reduced ion kinetic (RIK) model was implemented within the framework of a 1D radiation-transport code. After empirical calibration, the RIK simulations reproduce the observed yield trends, largely as a result of ion diffusion and the depletion of the reacting tail ions. Future experimental work will investigate the possible impact of the (kinetic) shock-convergence phase on the subsequent (hydrodynamic) compression phase in ignition-relevant implosions on NIF. Two burn-history diagnostics are being developed to study these effects, as well as kinetic-related multiple-ion effects such as species separation.

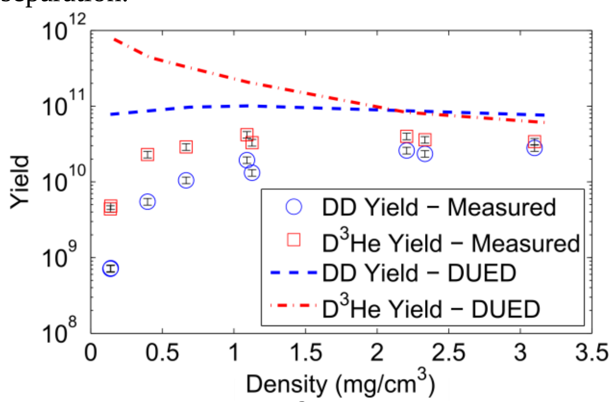

Fig. Measured DD and D^3He yields increasingly deviate from the predictions of the DUED hydrocode in the low-density (kinetic) limit.

*This work is supported in part by US DoE (Grant No. DE-NA0001857, DE-FC52-08NA28752), FSC (No. 5-24431), NLUF (No. DE-NA0002035), LLE (No. 415935-G), LLNL (No. B597367). S. A. is supported by Italian grants PRIN 2009FCC9MS and Sapienza 2012 C26A12CZH2.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Detailed characterization of interpenetrating plasma with Thomson Scattering*

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Thomson scattering has proven to be a valuable technique for spatially and temporally resolved measurements of plasma conditions in laser-generated plasmas. This technique has now become a routine diagnostic on the Omega Laser Facility, providing detailed plasma characterization for many experiments. One particular set of experiments studied the interaction of interpenetrating plasma flows at high Mach-number. Thomson Scattering from Ion-acoustic and Electron-plasma fluctuations provides time and space resolved electron temperature (Te), ion temperature (Ti), electron density (Ne), and plasma flow velocity (V_flow) in the interpenetrating region. The spectral measurements can be explained by almost perfectly interpenetrating plasmas (resulting in non-Maxwellian ion temperature distributions) and show evidence of resistive and strong kinetic heating mechanisms due to the opposing flows. A form factor for Thomson scattering was developed to allow the extraction of Te, Ti, Ne and V_flow in counter-streaming plasmas. Recent developments extend this analysis to interpenetration of different ionic species, which is compared with experimental data (C, Be). Extending this research to higher laser powers and energies on the National Ignition Facility (NIF) will be discussed.

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

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Beam-smoothing incidence for LPI experiments of a 3ω, 15 kJ, 6-ns laser pulse in gas-filled hohlraums at the LIL facility

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Propagation issues and laser parametric instabilities (LPI) have been investigated at the Ligne d'Intégration Laser facility (LIL, CEA-Cesta, France). Stimulated Raman (SRS) and Brillouin (SBS) scattering were driven by firing four laser beams (one quad) into millimeter size, gas-filled hohlraum targets. The aim of the experiment was to quantify the effect beam smoothing techniques both to LPI development and to beam transmission through large plasmas.

On the LIL facility, the beams are focused by means of 3ω gratings, and the quad delivers energy on target of 15 kJ at 3ω in a 6-ns shaped laser pulse. The targets consist of 1.5-mm or 4-mm long, open cylindrical hohlraums, filled with 1-atm neo-pentane (C_5H_{12}) gas. At maximum laser power, the mean electron density and electron temperature are calculated to be 9-10% n_c and 2.5 keV respectively. The beam is optically smoothed at least with a random phase plate and 2 GHz SSD modulator. The effect to LPIs in adding the 14 GHz modulator and/or crossed polarizations in checkerboard geometry on the quad is studied here.

After a brief presentation of the LIL facility and of the main diagnostics devoted to the experiment, we focus to LPI and transmitted light measurements (spectra, power and images) acquired along with the optical smoothing options. As previously observed from other kJ facilities (Nova and Omega facilities), the overall LPI reflectivities gradually decrease as the intensity contrast in the focal spot (integrated over dozens picoseconds) is lower. In 4-mm long plasmas and at intensities $I \sim 9x10^{14}$ W/cm^2, the total reflectivity (mostly SRS) is reduced from 30% (worst case) to 15% (best case). In the same time, the transmitted energy of the beam through the plasma increases. Interestingly, depending on the plasma length, the gain in transmission does not match the reflectivity drop. Propagation issues due to crossed beam polarizations seem to be significant and will be discussed with the help of 2D-hydrodynamic calculations.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Electron distribution functions and linear plasma response in hot ICF plasmas with a temperature gradient*

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We examine non-Maxwellian electron distribution functions that result from thermal transport in ignition scale targets and the linear plasma response in such non-equilibrium plasma states. In particular, we examine linear plasma wave damping, the gain coefficient for the growth of stimulated Raman scattering (SRS), and the Thomson scattering cross-section. Our results suggest the need for including kinetic effects in mainline ICF simulations of laser-plasma interaction.

In ignition-scale hot plasmas, temperature gradients and thermal transport occurring primarily via fast electrons modify the electron distribution function such that it differs substantially from thermal equilibrium (Maxwell-Boltzmann). This modification is significant in the velocity range resonant with Langmuir waves produced by SRS. We have examined this coupling between nonequilibrium distribution functions and the modified damping of Langmuir waves, and in general the levels of plasma fluctuations. Form factors and Thomson scattering cross-sections in such plasmas display unique characteristics of the background conditions. Higher order transport theory and Fokker-Planck simulations using the OSHUN code have been employed in the theoretical studies of these processes.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Understanding fuel magnetization and mix with nuclear reactions in magneto-inertial fusion*

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Magneto-inertial fusion (MIF) aims to relax the ignition requirements for inertial confinement fusion by magnetizing the fuel during implosion. This inhibits charged particle transport across field lines, insulating the fuel somewhat from its surroundings, and changes the physics of burn product confinement. Diagnosing peak fuel magnetization is essential to understanding target performance and the viability of any experimental MIF concept. In pure deuterium fusion, 1.01 MeV tritons emitted via the aneutronic branch of the reaction can be confined in the fuel long enough to undergo secondary DT reactions. Novel techniques are presented to estimate the fuel magnetization during burn using the overall ratio of DD to DT neutrons emitted by the target as well as the energy spectra of the DT neutrons. Secondary reactions can also place constraints on the amount of pusher material mixed into the fuel during burn. The analysis is applied to the first integrated experiments testing the MagLIF concept[1], demonstrating significant magnetic confinement of charged burn products in a low-mix environment was achieved, both of which are essential features of future ignition-scale MIF designs.

*This research was supported in part by an appointment to the Sandia National Laboratories Truman Fellowship in National Security Science and Engineering, which is part of the Laboratory Directed Research and Development (LDRD) Program, and sponsored by Sandia Corporation (a wholly owned subsidiary of Lockheed Martin Corporation) as Operator of Sandia National Laboratories under its U.S. Department of Energy Contract No. DE-AC04-94AL85000.

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[1] S. A. Slutz *et al*., "*Pulsed-power-driven cylindrical liner implosions of laser preheated fuel magnetized with an axial field*", Physics of Plasmas **17**, 056303 (2010).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Using High-Z layers in directly driven targets*

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Previous theoretical and experimental work[1] at NRL has shown that very thin (100's of Å) of high-Z (e.g., Au or Pd) layers coated onto targets can be used to suppress early-time laser imprint and RM growth of hydrodynamic instabilities during the low-intensity foot of directly-driven targets. This work has been extended recently[2] to include the use of higher intensity laser spikes that are used for adiabat-tailoring of the target. In these studies, it was shown that a minimum layer thickness (dependent upon the material) was needed before the suppression was observed. Additionally, it was noticed that the conditions of the layer immediately prior to the primary laser onset can be crucial to the accurate simulation of the physics. We will address here the physics behind the imprint suppression effects and explore the some of the limitations of this method. We also investigate the implications and limits of using even thicker layers to extend the effect further into the laser drive and discuss the challenges of accurately modeling such experiments.

*This work Supported by U.S. DoE/NNSA

[1] S.P. Obenschain et al., "*Effects of thin high-Z layers on the hydrodynamics of laser-accelerated plastic targets*", Phys. Plasmas **9**, 2234 (2002); M. Karasik, et al., to be published.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Predictions of secondary reactions, areal densities and hot-spot radii for Omega capsule implosions*

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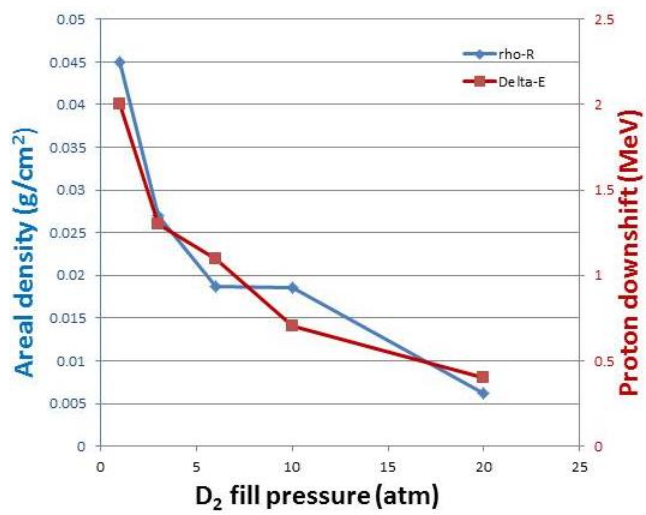
The radial density profile of an imploding capsule at the time of fusion burn is an important factor in determining the characteristics of the imploded shell and the conditions in the hot burning core. We have simulated a set of deuterium-filled Hoppe glass (SiO_2) capsule implosions using Hydra[1] and predicted the fraction of secondary protons (^3He+D →p[14.7MeV] + ^4He) and neutrons (T+D →n[14.1MeV] + ^4He) that are generated. The importance of using the downshift of secondary reaction protons for diagnosing capsule areal density is well known.[2] We show how the conversion efficiency changes with variations to the capsule gas fill. A strong correlation between the downshift of the secondary protons with respect to the areal density of the shell, i.e. the *ρR*, at the time of peak burn is predicted as shown in Figure 1. Predictions for primary and secondary yield variations for alternate gas fills including binary mixtures of H_2, D_2, ^3He and ^4He also will be shown. Synthetic self-emission diagnosis of the implosion trajectory will be compared to the radial temperature profile to assess the accuracy of hot spot measurement at the time of nuclear burn. The variation in the temporal burn profile, including the variation of three burn peak components will be discussed.



* This research was supported by the US DOE/NNSA, performed in part at LANL, operated by LANS LLC under contract number DE-AC52-06NA25396.

[1] M.M. Marinak, G.D. Kerbel, N.A. Gentile, O. Jones, D. Munro, S. Pollaine, T.R. Dittrich, and S.W. Haan, Phys. Plasmas, **8** 2275 (2001).
[2] F.H. Seguin, C.K. Li, J.A. Frenje, D.G. Hicks, K. M. Green, S. Kurebayashi, R.D. Petrasso, J.M. Soures, D. D. Meyerhofer, V.Y. Glebov, P.B. Radha, C. Stoeckl, S. Roberts, C. Sorce, T.C. Sangster, M.D. Cable, K. Fletcher and S. Padalino, Phys Plasmas **9** 2725 (2002).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

High-energy x-ray imaging and backlighting with spherical crystals*

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Laser-driven x-ray self-emission imaging or backlighting of High Energy Density Physics experiments requires brilliant sources with keV energies and x-ray crystal imagers with high spatial resolution of about 10 μm. Spherically curved crystals provide the required resolution when operated at near-normal incidence, which minimizes image aberrations due to astigmatism. However, this restriction dramatically limits the range of suitable crystal and spectral line combinations. We present a survey of crystals and spectral lines for x-ray backlighting and self-emission imaging with energies between 6 and 16 keV. Ray-tracing simulations including crystal rocking curves have been performed to predict the image brightness and spatial resolution. Ray-tracing results have been benchmarked to experimental data from Zr K-alpha (15.7 keV) x-ray backlighting using a Ge (220) crystal and self-emission imaging using a Quartz ($31\bar{4}0$) crystal, driven by the 200 J Z-Petawatt shortpulse laser.

* Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Ad- ministration under Contract No. DE-AC04-94AL85000.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Design of Magnetized Liner Inertial Fusion (MagLIF) Experiments Using the Z Facility*

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The alternative MagLIF approach to ICF has been presented as a path toward obtaining substantial fusion yields using the Z facility[1]. The direct magnetic implosion of a solid metal liner containing pre-heated and pre-magnetized fusion fuel reduces the stagnation pressure required to reach fusion conditions, and related experiments have begun in earnest at Sandia National Laboratories. We present integrated numerical magneto-hydrodynamic simulations of the MagLIF concept, which self-consistently include the laser preheating of the fuel, the presence of electrodes, and end loss effects[2]. These simulations have been used to design thermonuclear neutron-producing experiments on Z for the capabilities that presently exist, namely, DD fuel, peak currents of I_{max}=18-20 MA, pre-seeded axial magnetic fields of B_z^0=10 T, and laser preheat energies of about E_{laser}=2 kJ delivered in 2 ns. The first experiments based on these simulations have occurred, resulting in thermonuclear neutron yields $Y_n^{DD}=1\text{-}2\times10^{12}$ and inferred $\langle T_{ion}\rangle$=3-4 keV from imploded liners reaching peak velocities around 70 km/s over an implosion time of about 60 ns[3]. In principle, fusion yields comparable to the absorbed fuel energy may be possible with upgrades on Z, and high-gain MagLIF[4] may be possible using cryogenic fuel, substantial preheat energy, and a future facility capable of ≥60 MA.

* Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the National Nuclear Security Administration under contract DE-AC04-94AL85000. Support provided in part by the Laboratory Directed Research and Development Program at Sandia.

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[1] S. A. Slutz, M. C. Herrmann, R. A. Vesey, A. B. Sefkow, *et. al.*, "*Pulsed-power-driven cylindrical liner implosions of laser preheated fuel magnetized with an axial field*", Phys. Plasmas **17**, 056303 (2010).
[2] A. B. Sefkow, S. A. Slutz, J. M. Koning, M. M. Marinak, *et. al.*, "*Design of magnetized liner inertial fusion experiments using the Z facility*", submitted to Phys. Plasmas (2014).
[3] M. R. Gomez, S. A. Slutz, A. B. Sefkow, D. B. Sinars, *et. al.*, "*Experimental demonstration of fusion-relevant conditions in magnetized liner inertial fusion*", submitted to Phys. Rev. Lett. (2014).
[4] S. A. Slutz and R. A. Vesey, "*High-gain magnetized inertial fusion*", Phys. Rev. Lett. **108**, 025003 (2012).

Interplay of stimulated Brillouin and Raman scattering and two-plasmon decay in spherical interaction experiments on OMEGA*

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Spherical high-intensity laser–plasma interaction experiments on OMEGA with and without smoothing by spectral dispersion (SSD) show clear spectral evidence of stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), and two-plasmon decay (TPD) in the corona below $n_c/4$. SBS and SRS are reduced significantly in the presence of 0.3-THz SSD, while TPD is not affected in these experiments. All time-resolved spectra show distinct features when hydrodynamic ablation rates change rapidly. SRS appears to be significantly reduced when SBS is present in spatial proximity. There also appears to be evidence for multibeam SRS sidescattering. No equivalent multibeam SBS has been observed apart from cross-beam energy transfer, a low-gain SBS process that is observed in almost all direct-drive inertial confinement fusion experiments.

*****This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Absolute and convective two-plasmon decay driven by multiple laser beams*

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It is now well established that for direct-drive geometries, two-plasmon decay (TPD) is a collective process, in which a given set of decay waves is driven by several laser beams.[1,2] The single-beam decay is maximized on a hyperbola in *k* space lying in the beam's plane of polarization so that maximum convective gain for the multibeam process occurs near the intersection of the hyperbolas corresponding to the beams involved. All the hyperbolas intersect at the origin in *k* space so TPD tends to be most strongly driven in this small-*k* region. Depending on beam orientation and polarization, the second branches of the hyperbolas may or may not also intersect at a larger value of *k*. However, the instability can only be convective in this large-*k* region, whereas it can be absolute in the small-*k* region, and in fact it is found that the absolute threshold for TPD is in general lower than the convective threshold. Therefore, the small-*k* absolute instability is expected to dominate the linear phase of TPD growth, consistent with Zakharov simulations.[3] Two types of absolute mode are found in the small-*k* region, with the dominant mode depending on the relative angles between the beams. Results for the absolute TPD threshold as a function of beam geometry and polarization will be presented and the consequences for direct-drive experiments will be discussed.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] C. Stoeckl *et al.*, "*Multibeam effects on fast-electron generation from two-plasmon-decay instability*," Phys. Rev. Lett. **90**, 235002 (2003).
[2] D. T. Michel *et al.*, "*Experimental validation of the two-plasmon-decay common-wave process*," Phys. Rev. Lett. **109**, 155007 (2012).
[3] J. F. Myatt *et al*, "*Multibeam laser–plasma interactions in inertial confinement fusion*," to be published in Physics of Plasmas.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

New results and insight into the Asymptotic Self-Similar Solutions of Rayleigh-Taylor and Richtmyer-Meshkov Instabilities at any Dimensionality and Density ration

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The asymptotic self-similar evolution of the bubble front of the RT and RM instabilities for immiscible fluids is evaluated in 2 and 3 dimensions, using a new formulation of Haan[1] and Ofer- Shvarts[2] mode-coupling modal models. For the RT case the model does result in a self-similar coefficients of α_{RT} ~0.04 in 2D (h_{RT}~$\alpha_{RT}Agt^2$), consistent with full 2D numerical simulations, and ~0.05 in 3D, consistent with the LEM experiments[3] but a factor of ~2 higher than the results of full 3D numerical simulations[4]. This last result is attributed to the fact that only for miscible fluids, that is the case in full numerical simulation, the entrainment of the two fluids in the bubble caused by a 3D small scale turbulent flow, is reducing the effective Atwood number by about ~2. As for the RM case, it is shown that Θ_{RM} =2/5 in 2D (h_{RM}~$\alpha_{RM}t^{\Theta_{RM}}$), consistent with the Alon-Shvarts prediction and full 2D numerical simulations[5], and Θ_{RM}=1/3 in 3D, independent of density ratios and therefore not affected by entrainment. The smaller power law exponent, Θ_{RM}~0.25±0.05, in the LEM 3D experiments[4] and full 3D numerical simulations[6], is shown to result from the lack of enough mode-coupling generations, needed to reach the asymptotic self-similar stage.
Newly proposed experiments on NIF, using very long laser pulses, in order to confirm the above conclusions regarding the asymptotic self-similar behavior of miscible fluids in the 3D RT case, and getting enough (3-4) generations in the 3D RM case, will be describe and discuss.

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[1] S. W. Haan, Phys. of Fluids **B 3**, 2349 (1991).
[2] D. Ofer, U. Alon, D. Shvarts, R. L. McCrory and C. P. Verdon, Phys. of Plasmas **3**, 3073 (1996); D. Shvarts, U. Alon, D. Ofer, R. L. McCrory, C. P. Verdon, Phys. of Plasmas **2**, 2465 (1995).
[3] G. Dimonte and M. Schneider, Phys. of Fluids **12**, 304 (2000).
[4] G. Dimonte, D. Youngs et al., Phys. of Fluids **16**, 1668 (2004).
[5] U. Alon, J. Hecht, D. Ofer and D. Shvarts, Phys. Rev. Lett. **74**, 534 (1994).
[6] B. Thornber, D. Drikakis, D. L. Youngs, R. J. R. Williams, Phys. of Fluids **23**, 095107 (2011).

44th Annual Anomalous Absorption Conference
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June 8-13, 2014

Upcoming indirect drive, high-foot beryllium campaign on the National Ignition Facility*

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For indirect drive inertial confinement fusion, beryllium (Be) ablators offer a number of important advantages[1,2] as compared with other ablator materials, such as plastic and high density carbon. In particular, the low opacity and relatively low density of Be lead to higher rocket efficiencies allowing for thicker fuel layers for a given X-ray drive; and to broader ablation fronts and higher ablation velocities providing more ablative stabilization and reducing the effect of hydrodynamic instabilities on the implosion performance. Thus, Be ablator advantages provide a larger target design optimization space and can significantly improve the National Ignition Facility (NIF) ignition margin.

While this has been realized for a long time, and Be has been considered the primary NIF ablator, no NIF Be targets have been used so far. Recently we designed a number of such modern targets optimized for hydrodynamic stability, including the low-foot ignition Rev. 6[1] and several high-foot[2]. The targets employ the standard NIF 5.75 mm gold hohlraum, with the high-foot ones allowing for a range of the laser drive powers and energies and fuel ice thicknesses and scaling towards ignition. The latter targets will be used in the first NIF Be experimental campaign scheduled to begin in August of this year. The goal of the campaign is to obtain near one-dimensional α-heated implosions while quantifying Be target performance uncertainties, cross-comparing with other ablators to elucidate main limitations of our predictive capabilities, and testing superior Be ablator properties near high-foot plastic performance cliffs. Herein, we will summarize the results of this work and outline the upcoming NIF Be experiments.

*This work was performed at LANL, operated by LANS, LLC for the U.S. DoE under Contract No. DE-AC52-06NA25396; and at LLNL, operated by LLNS, LLC for the U.S. DoE under Contract No. DE-AC52-07NA27344.

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[1] A. N. Simakov et al., "*Optimized beryllium target design for indirectly driven inertial confinement fusion experiments on the National Ignition Facility*", Phys. Plasmas **21**, 022701 (2014).
[2] S. A. Yi et al., "*Hydrodynamic instabilities in beryllium targets for the National Ignition Facility*", Phys. Plasmas, submitted (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Fluid description of a collisional plasma with multiple ion species*

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A fluid description of a collisional plasma with multiple ion species is of interest for inertial confinement fusion (ICF) applications. Indeed, a standard ICF capsule usually contains thermonuclear fuel made of hydrogen or helium isotopes at the center, which is surrounded by a pusher shell made from beryllium, carbon, plastic, aluminum or even gold. The pusher is normally doped with copper, germanium, silicon or other materials. Possessing different charges and masses, various ions of the ICF capsule plasma can respond to the electric field and density, temperature and pressure gradient drives differently. This can result in various important plasma physics effects on the capsule implosion and performance that cannot be accurately taken into account with a single-fluid description.

While a multiple ion species plasma fluid description exists in principle[1], it is extremely cumbersome and hard to employ in practice. Herein, we attack the problem by appropriately generalizing the classical *electron* treatment of Braginskii[2]. Reference 2 obtains fluid equations for the electron density, flow velocity and temperature and provides expressions for electron heat flux and electron-ion friction force for a plasma with a single ion specie of a charge Z_i=1,2,3,4, and +∞, but no expressions are given for an arbitrary Z_i. Moreover, electron viscosity is only derived for the case of Z_i=1. We resolve these deficiencies by deriving the *electron* description in a collisional plasma containing arbitrary atomic fractions of arbitrarily charged ions[3]. In addition, we show how these electron fluid equations can be applied to obtain a description of plasma *ions with disparate masses*. A general ion description is left for future work.

*This work was performed under the auspices of the Thermonuclear Burn Initiative at Los Alamos National Laboratory, operated by Los Alamos National Security, LLC for the U.S. Department of Energy under Contract No. DE- AC52-06NA25396.

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[1] V. M. Zhdanov, *Transport Processes in Multicomponent Plasma*, (Taylor & Francis, New York, 2002).
[2] S. I. Braginskii, in *Reviews of Plasma Physics*, edited by M. A. Leontovich (Consultants Bureau, New York, 1965), Vol. 1, p. 205.
[3] A. N. Simakov and K. Molvig, "*Electron transport in a collisional plasma with multiple ion species*", Phys. Plasmas **21**, 024503 (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Challenges for scaling laser heating of MagLIF targets to high yields*

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Numerical simulations [S.A. Slutz et al Phys. Plasmas 17, 056303, 2010] predict that significant fusion yields (>100 kJ) could be obtained with the MagLIF (Magnetized Liner Inertial Fusion) concept driven by the existing Z accelerator, which can provide up to 25 MA of current. Simulations further predict that much higher yields could be possible with future accelerators delivering higher currents [Slutz and Vesey PRL 108, 025003, 2012]. Magnetized liner implosions have been demonstrated using external coils to provide the initial axial field [Awe et al. PRL 111, 235005, 2013]. However, the fuel must be heated before compression to obtain significant fusion yields due to the relatively slow implosion velocities (~100 km/s) of magnetically driven liners. Lasers provide a convenient means to accomplish this pre-compressional heating of the fusion fuel. The Beamlet laser,which presently provides 2 kJ of energy, is being used to test the MagLIF concept. This laser energy is sufficient to demonstrate the concept but much higher energies (20-40 kJ) will be required for high yield and gain. The laser must penetrate a foil covering the laser entrance hole and deposit most of its energy in the fuel within the length of the liner. Analytic scaling and numerical simulations of this process are presented which indicate that energies as high as 40 kJ could be deposited in the fuel if challenges such as refraction and laser plasma interactions can be overcome.

*This work conducted under the auspices of Sandia National Labs. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Simulations of integrated fast-ignition experiments on OMEGA*

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Integrated fast-ignition experiments on OMEGA benefit from improved performance of the OMEGA EP laser, including higher contrast, higher energy, and a smaller focus. Good agreement with the 2-D radiation–hydrodynamic simulations using the code *DRACO* was found with 8-keV Cu K_α flash radiography of cone-in-shell implosions and cone-tip breakout measurements. *DRACO* simulations show that the fuel assembly can be further improved by optimizing the compression laser pulse, evacuating air from the shell, and adjusting the material of the cone tip. This is found to delay the cone-tip breakout by ~250 ps and increase the core areal density from ~80 mg/cm^2 in the current experiments to ~500 mg/cm^2 at the time of the OMEGA EP beam arrival before the cone-tip breakout. Integrated experiments on OMEGA using cone-in-shell targets with copper dopant added to the plastic shell have been performed. Cu doping is used to probe the transport of fast electrons generated by the OMEGA EP beam via their induced Cu K-shell fluorescent emission. A spherical crystal imager (SCI) was used to image the Cu K_α radiation, visualizing the fast-electron transport. SCI images show the maximum K_α emission from the regions of the shell around the cone, indicating plasma prefilling the cone as a result of the prepulse and the cone tip being smaller than the OMEGA EP beam spot size. *LSP* simulations of the fast-electron transport and Cu K_α emission have been performed using the implosion plasma profiles predicted by *DRACO* simulations. The simulations reproduce the spatial distributions of Cu K_α emission observed in the experiments and explain the fast-electron transport. The coupling efficiency of 4% to 7% of the fast-electron beam energy to the compressed core is inferred.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the U.S. Department of Energy under Cooperative Agreement Nos. DE-NA0000854 and DE-FC02-04ER54789, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Taming Rayleigh-Taylor mix via a combination of magnetic, ablative, and viscous stabilization*

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Rayleigh-Taylor instability (RTI), an interchange instability commonly observed in inertial confinement fusion (ICF) capsules, has been known to play a key role in inhibiting ignition on the National Ignition Facility (NIF). The recent success of the high-foot campaign on NIF suggests that mix reduction holds the key to high performance in ICF. In order to achieve ignition, however, a high-convergence ratio target design is still the most promising approach, which begs the question of how to mitigate mix with high-convergence ratio targets, especially at the gas-ice interface.

The results presented here show that a combination of magnetic, ablative, and viscous stabilization can complement each other for adequate mix control at the gas/ice interface in a range of magnetic field strengths that are experimentally accessible. Large externally applied magnetic fields mitigate mix by damping short wavelength RTI for **k** parallel to the magnetic field, **B**, due to the energy required to bend the field lines. In contrast, magnetic fields have no effect on **k** perpendicular to **B**. Ablative stabilization relies on electron thermal conductivity to ablate fuel into the hot-spot and thus mitigate short-wavelength RTI. Since magnetic fields additionally reduce electron thermal conductivity by forming an insulating layer across the mix interface, it results in a competing, as well as complementary, effect when ablative and magnetic stabilization are acting together. Here we show that, in an ICF target, magnetic and ablative stabilization can work together for overall mix mitigation for a range of appropriately chosen magnetic field strength. In addition, we will also show that as hot-spot ions reach multi-keV temperature, ion viscosity also stabilizes short-wavelength RTI and short-wavelength Kelvin-Helmholtz instabilities.

*This work was conducted under the auspices of Los Alamos National Laboratory.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Inline Cross-Beam Energy Transfer and Backscatter in Hohlraum Simulations*

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Ignition experiments at NIF with gas-filled hohlraums have used significant cross-beam energy transfer (CBET) to control the polar and azimuthal symmetry of capsule implosions. These shots also display substantial stimulated Raman backscatter (SRS) from the inner laser beams, and associated energetic or "hot" electrons. We have extended the laser package in the radiation-hydrodynamics code HYDRA to include inline (self-consistent) CBET and SRS. For both processes, coupled-mode equations in the strong damping limit are solved along the entire ray paths of the incident laser beams. Cross-beam and Raman coupling (with linear, kinetic gain coefficients), driven ion-acoustic and Langmuir wave production, and inverse-bremsstrahlung absorption are calculated based on local plasma conditions.

CBET and SRS both change the plasma properties and target dynamics in important ways. CBET deposits energy into ion waves, which heat the ions and deposit momentum[1]. In addition, inner-beam SRS developing inside the target leads to more heating of the underdense hohlraum fill – and more depletion of the inner beam power reaching the hohlraum wall – than simply removing the escaping SRS light from the incident laser power. CBET and SRS both modify the plasma conditions in the laser entrance hole so as to limit CBET. We compare inline results with post-processing (or "offline") CBET calculations on plasma conditions from simulations that do not include CBET or SRS. Resulting changes to hohlraum plasma conditions and target performance will be discussed.

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

[1] P. Michel et al., Phys. Rev. Lett. 109, 195004 (2012)

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Numerical Investigation of a New Kinetically Enhanced Mix Mechanism for an Omega Plastic Ablator Capsule*

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In ICF, mixing of a high-Z ablator material into the fuel can be detrimental towards achieving ignition. The primary mix mechanisms considered so far by the ICF community are hydrodynamic processes such as Rayleigh-Taylor and Richtmeyer-Meshkov instabilities. However, recent experiments[1,2] on both the National Ignition Facility (NIF) and the Omega facilities indicate that mix is happening both deeper and earlier than what the hydrodynamic instability models predict. Additionally, there have been observations[3] of a strong electric field within the ICF capsule on the Omega facility that cannot be explained by fluid/quasi-neutral theory alone.

A recent theoretical study[4] of a new kinetic mix mechanism for an Omega plastic ablator capsule has predicted a mix amount and electric field strength that are consistent with some experiments. The new mechanism relies on the early formation of an electrostatic double-layer field at the fuel-pusher interface, which cannot be obtained from a quasi-neutral model, and which can cause significant pusher ion acceleration into the fuel.

We have pursued a careful computational study to further refine and expand these theoretical results. In particular, we seek to obtain a better estimate of the strength of the double-layer electric field and its effect on mix on an Omega plastic ablator capsule. We do so by performing a self-consistent, fully kinetic 1D1V (one dimensional in configuration space and one dimensional in velocity space) Vlasov-Fokker-Planck-Ampère simulation of the fuel-pusher interface in a slab geometry.[5] Here, we model electron and multiple ion species kinetically with charge separation effects. We show numerically the existence of the postulated double-layer electric field, and quantify its impact on mix by performing a sensitivity study of the field strength and mix number as a function of initial conditions. We also provide comparison with theory.

*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 LANS, LLC under contract DE-AC52-06NA25396.

[1]R.C. Shah, F. Wysocki, Private communication, (2013).
[2]T. Ma et al., *"Onset of Hydrodynamic Mix in High-Velocity, Highly Compressed Inertial Confinement Fusion Implosions"*, Phys. Rev. Lett. 111, (2013) 085004.
[3]C.K. Li et al., *"Monoenergetic-Proton-Radiography Measurements of Implosion Dynamics in Direct-Drive Inertial Confinement Fusion,"* Phys., Rev. Lett., 100 (2008) 225001.
[4]D.A. Knoll et al., *"Plasma Double-Layer Initiated Mix in ICF Implosions,"* Phys. Rev. Lett., (2014), in review.
[5]W.T. Taitano et al., *"Charge-and-Energy Conserving Moment-Based Accelerator for a Multi-Species Vlasov-Fokker-Planck-Ampere System, Part II: Collisional Aspects,"* J. Comp. Phys., (2014), submitted.

Strong-shock generation and laser–plasma interactions for shock-ignition inertial fusion*

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Recent experiments and target design work at the Laboratory for Laser Energetics, in collaboration with CELIA and CEA, have been carried out to validate the shock-ignition (SI) concept and to develop a target design for ignition experiments at the National Ignition Facility (NIF). Since SI relies on launching an ignitor shock at pressures $\geq$300 Mbar, the demonstration of such strong shocks is crucial to the validation of the SI concept. Among the most recent experiments, solid spherical targets have been used to demonstrate the generation of ultrastrong shocks. The timing of the x-ray flash from shock convergence in the center of the solid ball target is used to infer the shock velocity and pressure. Very recent experiments have demonstrated the generation of convergent shocks launched by an ablation pressure approaching 300 Mbar. Another set of experiments was devoted to study the laser–plasma instabilities (LPI's) at SI-relevant intensities of about 3 to 5×10^{15} W/cm^2. Those LPI experiments are used to assess the level of reflectivity and hot-electron generation. It is found that for SI-relevant intensities, the hot-electron temperature is moderate (<100 keV), instantaneous conversion efficiencies of laser energy into hot electrons reach ~10% in the intensity spike, and the reflectivity stays below 30%. The results indicate that hot-electron preheat and laser-energy coupling can be controlled within acceptable levels at spike intensities relevant to ignition but with a plasma scale length that is significantly shorter than in ignition targets. A full validation of LPI for SI would require long-scale-length, high-intensity experiments at the NIF.

*This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-NA0001944, the OFES Fusion Science Center grant No. DE-FC02-04ER54789, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

A Reduced Model for Relativistic Electron Beam Transport in Solids and Dense Plasmas - Application to Kα Photons Diagnostics*

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A hybrid reduced model for relativistic electron beam transport based on the two first angular moments of the relativistic Vlasov-Fokker-Planck equation with a special closure is presented. It takes into account the plasma heating, the collective effects with the self-generated electromagnetic fields as well as the collisional effects with the slowing down of the relativistic electrons by plasmons, bound and free electrons and their angular scattering on both ions and electrons. This M1 model allows for fast computations of relativistic electron beam transport in solids or dense plasmas while describing their energy distribution evolution.
The study presented here is motivated by an experimental campaign conducted on the UHI100 laser (CEA Saclay). In these experiments, a linearly polarized laser pulse with a wavelength λ = 800 nm, a total energy E_L = 0.7 J and a τ = 26 fs Full Width Half Maximum (FWHM) time duration has been focused with a peak intensity of $I_L = 3.10^{19}$ W.cm^{-2} with a 45 degrees of normal incidence on different targets. The targets are composed by three successive layers of 1 μm of Aluminium, 3 μm of Copper and 1, 6, 10 or 15 μm of Aluminium. The experimental results show that the thinner the target is, the larger the Copper Kα emission of radiation spot size FWHM is. Indeed, Kα photons are produced as electrons reflux laterally across the target and the thinner the target is, the more electrons spread laterally, enhancing the Kα spot size.
Our hybrid model does not calculate the electron source but the latter has been computed thanks to a 2D fully PIC simulation of the laser plasma interaction. The refluxing of the electron beam by electrostatic fields at both the irradiated and the rear side of the target is taken into account via the specular reflections of the electron beam.
It is shown that a standard computation of the Kα emission assuming a relatively small amount of excited atoms does not allow to reproduce the experimental results. The calculated spot size is several times smaller than the observed ones. It is found that the reason of this striking discrepancy is the saturation of the density of the K-shell emitters. A good agreement with the experiment is obtained when the saturation is taken into account. This effect could be also important in other experiments with high intensity laser pulses, especially in what concerns the measurements of the electron beam divergence.

*This work conducted under the auspices of the French Agency for Research and the joint competitiveness cluster Alpha Route des lasers through project TERRE ANR-2011-BS04-014, and the EURATOM within the "Keep-in-Touch" activities.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Toward a Nonlinear Stimulated Raman Scattering Fluid Model in Inhomogeneous Plasmas

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Recent experiments conducted on the NIF[1] and LIL[2] facilities exhibited very large levels of stimulated Raman backscattering (SRS). Understanding the mechanisms at the origin of such reflectivity in long, inhomogeneous and hot plasmas is challenging, mainly because of the nonlinear kinetic behavior of the electron plasma waves. In particular, nonlinear kinetic effects such as electron trapping result in nonlinear Landau damping and nonlinear frequency shift, and lead, in some cases, to an increase of the SRS reflectivity[3,4,5]. Moreover, the combination of the nonlinear frequency shift and plasma inhomogeneity is crucial because it can lead to the autoresonance mechanism, possibly enhancing SRS reflectivity[3].

The investigation of SRS with PIC simulations is out of reach in large plasmas on long time scale, particularly when a multi-dimensional model is required. Nevertheless, it can be expected that the nonlinear evolution can be analyzed by means of a nonlinear wave coupling model describing the energy exchange between the incident and daughter waves.

In this context, we will present and discuss the first 2D results obtained with our three wave coupling solver which integrates a nonlinear frequency shift model taking into account the nonlinear evolution of the electron distribution function due to trapping[6]. Our results compare well to PIC simulations, and experimental data gathered during the last LIL campaign. This Raman model is to be incorporated in the 3D paraxial and parallel code HERA[7,8].

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[1]S.H. Glenzer *et al*, *Plas Phys and Contr Fus*, 54, 045013, (2012)

[2]P. Loiseau *et al*, *IFSA*, (submitted 2013)

[3]T. Chapman *et al*, *Phys of Plasmas*, 17, 122317, (2010).

[4]H. X. Vu *et al*, *POP*, 9, 1745, (2002).

[5]P-E. Masson-Laborde *et al*, *POP*, 17, 092704, (2010).

[6]L. Divol, *IFSA*, (2003)

[7]P. Loiseau *et al*, *Phys Rev Lett*, 97, 205001 (2006).

[8]P. Ballereau *et al*, *J. Scient. Computat*, 33, 1, (1997).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Simulations of Laser Plasma Interactions Relevant to IFE via the Hybrid Cylindrial Algorithm*

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Recently we have implemented a hybrid cylindrical code (PIC in the (r,z) direction and gridless in f) [1] and have applied this scheme successfully on a large number of problems relevant to plasma based accelerators (including both LWFA's and PWFA's). Here we report the progress in applying this scheme to the problem of laser plasma interactions relevant to IFE. We will discuss our efforts in adding new particle and field boundary conditions for the LPI problem and demonstrate the potential of this scheme to efficiently study 3D LPI's of a single laser speckle under NIF relevant conditions.

* Prefer Poster Session

*This work is supported by NNSA.

[1] A. Davidson *et al*, "Implementation of a hybrid particle code with a PIC description in r-z and a gridless description in ϕ", submitted to *Jour. Plas. Phys.* (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Polarimetry on ICF Experiments*

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Polarimetry of backscattered light and dedicated probe beams was recently implemented on experiments at the National Ignition Facility (NIF), the Titan Laser at the Jupiter Laser Facility, and OMEGA EP at the Laboratory for Laser Energetics. These measurements have yielded quantitative understanding of crossed -beam energy transfer (CBET) on NIF and the demonstration of laser-generated magnetic fields at the other facilities. Polarimetry is commonly used to diagnose B fields in magnetic fusion experiments; its use on inertial confinement fusion experiments has been rare. This talk will highlight the NIF results.

Polarimetry was added to the NIF Full Aperture Backscatter (FABS) system used to assess laser-target coupling. We discovered that the time-averaged polarization of the backward Stimulated Brillouin Scattering light can differ substantially from the known injected beam polarization. The magnitude and reproducibility of the difference and its correlation with other observables suggested that crossed-beam energy transfer (CBET) can account for most of the observed variation. This motivated the development of a revised model including the effect of polarization on CBET in NIF hohlraums. Initial results show good agreement between the calculations and the experimental results. Polarimetry may thus provide quantitative feedback about CBET on the majority of indirect-drive ICF experiments at NIF.

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

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Nonlinear Development of the Two--Plasmon Decay Instability in Three Dimensions*

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Most recent experiments on the excitation of the two plasmon--decay instability (TPD) involve a three-dimensional (3D) array of overlapping laser beams. Our recent two dimensional (2D) simulations suggested that Langmuir cavitation and collapse are important nonlinear saturation mechanisms for TPD. There are important quantitative differences in the Langmuir collapse process in 2D and 3D. To address these and other issues, we have developed a 3D Zakharov code. It has been applied to study the evolution of TPD from absolute instabilities (arising from 3D laser geometries) to the nonlinear state (J. Zhang et al., " Multibeam Two-Plasmon Decay From Linear Threshold To Nonlinear Saturations," Phys. Rev. Lett., submitted (2014)). The present paper concentrates on the nonlinear saturated state excited by the collective action of two crossed laser beams with arbitrary polarizations. Remarkable agreement between 3D and 2D simulations is found for several averaged physical quantities when the beams are polarized in their common plane. As in previous 2D simulations we find: (a) the collective, initially convectively unstable *triad modes* dominate after a sub-picosecond burst, (b) Langmuir cavitation and collapse are important nonlinearities, and (c) that the statistics of intense cavitons are characteristic of a Gaussian random process. The 3D steady-state saturated Langmuir energy level is about 30\% higher than in 2D. The auto-correlation function of the Langmuir envelope field, and of the low-frequency electron density field, yield the spatial shape of the strongest collapsing cavitons which are 3D ellipsoids whose orientation depends on the laser polarizations. This tilting of the caviton's strongest electric field direction away from the normal to the target surface is a major new 3D result. This tilting may deflect the hot electron flux and thereby mitigate target preheat.

* This material is based upon work supported by the Department of Energy (DOE) National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Quasi-monoenergetic Electron Bunch Acceleration from Laser Driven Double-layer Ultrathin Films for X-ray Generation

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Coherent x-ray beams with a subfemtosecond pulse duration will enable measurements of fundamental atomic processes in a completely new regime. Recently, dense bunches of electrons generated through high intensity laser-plasma interactions at the plasma-vacuum interface have also been observed to generate harmonic x-ray beams through thin film targets via coherent synchrotron emission.

Numerical particle-in-cell simulations have predicted that bright and coherent x-ray sources can be obtained from Thomson scattering of a layer of dense electrons, and more uniform electron bunches, and then much higher frequency of x-rays generation from double layer of thin films. Although, the electron bunches has been measured from the Trident laser driven out a layer of diamond-like-carbon (DLC) films, no direct measurements of generating such electron bunches from double layer thin films has so far been shown.

Here we report the measurement of high electron density quasi-monoenergetic electron (e-) bunches from relativistic laser interaction of UT's GHOST laser producing 1.5J, 150fs, 10TW laser pulses, with ultrathin solid DLC film targets with varying thickness down to 5nm. Using double layer targets, we obtained 35× higher current and more uniformly distributed electron bunches compared to a single foil target. The measured several MeV mono-energetic electron bunch from a single 5nm thick DLC target has a narrow energy spread comparing to which a 20 nm thin DLC film target. The measured angular distribution of electron spectra from a single-layer and a double-layer target shows that (1) more energetic electrons with energy larger than 3 MeV are distributed at the laser incident direction, and most lower energy electrons with energy less than 1 MeV are distribute in the large collection angles; (2) The higher the angle from the target normal, the lower the electron cutoff energy; (3) The increase of the cutoff energy at larger angles (~3x) from a double-layer target shows the enhancement of the uniformity in energy of measured electron bunches. This experiment represents a first step towards a coherent, inverse Thomson source of bright x-ray sources to satisfy a strong demand of x-rays in a variety of different fields.

This project is supported by the DOE's NNSA via the LANL, LDRD program.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Simulation of a magnetically driven "Quasi-spherical" Al liner using the Eulerian AMR code Roxane"*

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In a 1995 experiment using the Shiva* capacitor bank at AFWL in Albuquerque, NM, Degnan et. al. imploded a "Quasi-spherical" liner down a 42 degree glide-plane using a 12.5 MA, 9 μs quarter-cycle risetime sinwave current pulse[1]. This Al liner was designed such that initially the mass of the liner per unit arc length along the spherical surface increased with angle off the equatorial plane in such a way that the driving magnetic pressure, which scales as $(I/R)^2$ and is consequently twice as high at 45 degrees as on the equator, was compensated for by an increase in mass. This $\csc^2$ thickness distribution produced, at least initially, a uniform acceleration radially along the arc, which was intended to produce a spherical inner surface after some convergence. Radiographs of the resulting shape after 12.7 μs showed that the inner surface was essentially spherical at that time, after a convergence of around a factor of 3. The Eulerian AMR code Roxane, which utilizes the Rage AMR code for the initial geometry setup, was utilized to simulate this experiment. The results of the simulation were compared to the data reported in Degnan's paper. Within the uncertainty in the data shown in the paper, the results from the Roxane code agreed well with the data for the radial trajectory in time. A synthetic radiograph was generated from Roxane and compared to radiographs taken at 300 keV from a flash x-ray source, again with in apparent agreement with the data. Results from the simulations and speculation about later evolution in the experiment will be shown. Possible extrapolations of the "Quasi-spherical" liner concept to different drive currents and liner materials will be discussed.

* Work performed by Los Alamos National Laboratory under contract DE-AC52-06NA25396 for the National Nuclear Security Administration of the U.S. Department of Energy

1. J. H. Degnan, F, M. Lehr, J. D. Beason, et. al.,*Electromagnetic implosion of a spherical liner*, PRL 74(1), 1995(98).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

*Laser Plasma Instabilities Driven by the Nike KrF Laser**

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Studies of laser plasma instabilities (LPI) at the Nike laser facility at NRL have previously concentrated on low-Z planar targets irradiated with their surface normal aligned to the central axis of the laser. These data have shown an increase in the instability threshold for quarter critical instabilities as expected due to shorter drive wavelength. Shots with planar targets rotated up 60° to the laser show alterations to the emission from the two-plasmon decay instability and stimulated Raman scattering near the quarter critical region. For low-Z targets, emission shifted to lower wavelength and were substantially stronger in the visible and ultraviolet spectral ranges as the rotation angle increased. The low-Z target data also show growth at an incident intensity slightly below the threshold values observed at normal incidence. A rapid rise in signal level over the same laser intensities was also observed in the hard x-ray data which serve as an overall indicator of LPI activity. Shots with rotated planar high-Z targets showed that the visible and ultraviolet emissions dropped significantly when compared to low-Z targets in the same geometry. Shots with widely separated laser beams are also planned to explore cross beam energy transport at Nike.

*Work supported by DoE/NNSA

1. RSI, Inc., 2. Berkeley Research Associates, Inc.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Kinetic Effects at Material Interfaces in ICF Implosions*

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The mixing of materials at an interface during an ICF implosion, for example the DT-Carbon interface in an ICF capsule, is a complex process. In general, radiation hydrodynamics codes do an excellent job of modeling the important processes during an ICF implosion. However, there are certain times during the implosion when kinetic effects of the ions may play a role in how two materials mix across the interface between them, even in the absence of shocks moving through them. The Knudsen layer effect is one such example[1]. We will describe results of multi-ion species hybrid LSP[2] simulations where the ions are treated kinetically and the electrons are treated in the fluid approximation. We observe that the DT and carbon ions diffuse across the interface in a self-similar manner, at a rate proportional to the square root of time, in agreement with diffusion theory. The resulting ion distributions for each species (on both sides of the interface) will be presented, and the result of this mixing on the yield will be discussed for both a standard ICF capsule, and double shell capsules. Preliminary results of a related mixing that occurs at the gas-hohlraum wall interface will also be presented.

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

[1] K. Molvig, N. M. Hoffman, B. J. Albright, E. M. Nelson, and R. B. Webster, "*Knudsen Layer Reduction of Fusion Reactivity*", PRL, **109**, 095001 (2012)
[2] D. R. Welch, D. V. Rose, B. V. Oliver, and R. E. Clark, "*Knudsen Layer Effect*", Nucl. Instrum. Methods Phys. Res. A **464** 134-139 (2001).

LLNL-ABS-653679

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Plasma conditions, cross-beam energy transfer, and laser backscatter expected in the first NIF high-foot beryllium target hohlraums*

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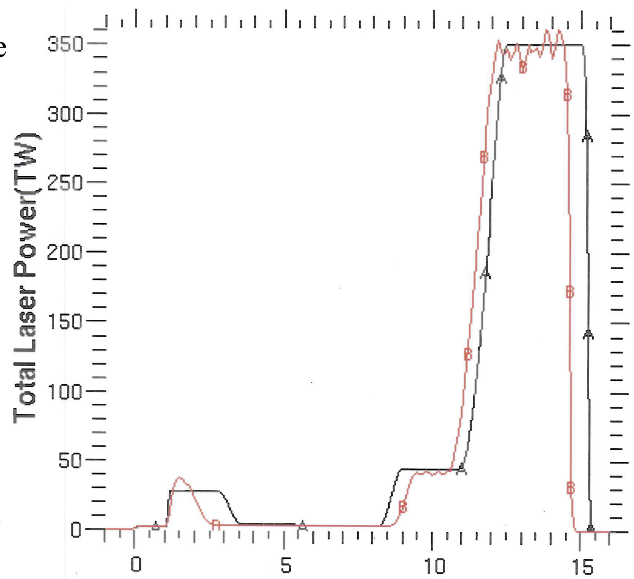
The first NIF implosions using beryllium capsules are based on the highly successful hi-foot experiments fielded using plastic (CH) capsules[1]. The hohlraum length, diameter, composition, and helium gas fill will be identical. The first beryllium high foot implosion laser pulse (black) is very similar to the first cryogenically layered CH high-foot DT shot at NIF, N130501(red). In the DT the first shock has the same pressure. By design the laser power is the same in the trough and the second pulse, and has an identical rise to the same 350 TW peak power. Less shock transmission across the beryllium/DT interface than CH/DT requires a higher shock velocity in beryllium leading to a higher hohlraum temperature and more laser energy in the picket. This early higher temperature and the lower opacity of beryllium cause greater mass ablation of beryllium, as compared with CH, expanding into the hohlraum throughout the laser pulse. To accommodate the greater beryllium mass ablation, the laser entrance hole has been widened. This allows more energy to reach the hohlraum waist, producing more symmetric capsule drive with less cross-beam energy transfer. It also reduces LEH closure late in time. We will discuss how the greater ablated mass of beryllium and the widened LEH change hohlraum conditions, which in turn affect expected cross-beam energy transfer, laser energy backscatter, and capsule drive symmetry.



*This work was performed at LANL, operated by LANS, LLC for the U.S. DoE under Contract No. DE-AC52-06NA25396; and at LLNL, operated by LLNS, LLC for the U.S. DoE under Contract No. DE-AC52-07NA27344.

[1]O.A.Hurricane, D. A. Callahan, D. T. Casey, *et al.*, “Fuel gain exceeding unity in an inertially confined fusion implosion”, Nature, **506**, 343 (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

PIC Simulations of Multi-Speckle Stimulated Raman Scattering in Inhomogenous Plasmas*

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Stimulated Raman scattering (SRS) is deleterious for laser-driven inertial confinement fusion because it leads to light being reflected backwards, absorbed where it was not intended to be, and absorbed into energetic electrons that can preheat the fuel. While particle-in-cell (PIC) simulations of SRS in single laser speckles for plasma conditions close to those at the National Ignition Facility (NIF) have shown SRS to be bursty in space and time, with localized plasma wave packets for sub-speckle-length scales and bursts of light on the sub-picosecond time scale, collective effects are possible in multi-speckled laser beams. SRS in multi-speckled laser-plasma interactions has been studied by our group in controlled simulations of two neighboring speckles and ensembles of several tens of speckles, as well as by others in large-scale simulations[1,2]. Large-scale simulations additionally afford the opportunity to investigate the nonlinear evolution of SRS in inhomogenous plasmas. Here we present 2D PIC simulations of multi-speckle SRS showing its sensitivity to both the density gradient scale length and the density value (location along the profile) at which SRS grows. We discuss the spectrum of scattered waves generated by multi-dimensional and multi-speckled SRS and the spectrum of hot electrons generated by the resulting nonlinear electron plasma waves, following which we discuss the dependence of SRS evolution on the density profile and speckle distribution.

*This work was supported by the DOE under Grant Nos. DE-NA0001833 and DE-FC02-04ER54789 and by the NSF under Grant Nos. NSF-Phy-0904039 and OCI-1036224. Simulations were carried out on the Hoffman2 and Dawson2 clusters at UCLA, Edison at NERSC, and BlueWaters at NCSA.

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[1] L. Yin *et al, Phys. Rev. Lett.* **108**, 245004 (2012).
[2] L. Yin *et al, Phys. Plasmas* **20**, 012702 (2013).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Verification and Convergence Properties of a Particle-In-Cell Code*

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Particle-in-cell (PIC) codes have been widely used throughout plasma physics for over 50 years, yet there still does not appear to be a consensus on the mathematical model that PIC codes represent. We argue that the model behind PIC codes is the Klimontovich equation with finite-size particles, as opposed to the Vlasov equation or a statistical model such as the Vlasov-Boltzmann equation. Our hypothesized model is represented by a gridless code with finite-size particles. For both the electrostatic and electromagnetic case, we present the convergence properties of a spectral gridless code as the number of Fourier modes, the particle size, and the time step are varied. We then compare a conventional, spectral PIC code to the gridless code, showing the convergence of electrostatic and electromagnetic PIC codes to the gridless code, i.e., to the model for the Klimontovich equation with finite-size particles, as the cell size is varied and the particle size is kept constant. We further verify the conditions for which electron plasma waves have the proper dispersion relation. Our convergence tests suggest that when using PIC codes with Gaussian-shaped particles, convergence can occur when using grid sizes less than half the electron Debye length and a particle size of approximately one Debye length.

*This work was supported by NSF Grant No. ACI-1339893 and DOE Grant Nos. DE-NA0001833, DE-SC0008491, DE-SC0008316, and DE-FC02-04ER54789. Support also provided by the UCLA NSF-REU and UCEAP programs and by the Foreign Affairs Office at Fudan University. Simulations were performed on the UCLA Hoffman2 and Dawson2 Clusters.

Intermittent laser–plasma interactions and hot-electron generation in shock ignition*

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We study laser–plasma interactions and hot-electron generation in the ignition phase of shock ignition through 1-D and 2-D particle-in-cell simulations in the regime of long density scale length and moderately high laser intensity. These long-term simulations show an intermittent bursting pattern of laser–plasma instabilities, resulting from a coupling of the modes near the quarter-critical surface and those in the lower-density region via plasma waves and laser pump depletion. The majority of the hot electrons are found to be from stimulated Raman scattering and of moderate energies. However, high-energy electrons that threaten to preheat the fuel can still be generated by the two-plasmon decay instability.

*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority; by DOE under Grant No. DE-FC02-04ER54789; by NSF under Grant No. PHY-1314734; and by NSCF under Grant No. 11129503. The research used resources of the National Energy Research Scientific Computing Center. The support of DOE does not constitute an endorsement by DOE of the views expressed in this abstract.

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Path to ignition for indirect drive beryllium implosions on the National Ignition Facility*

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Beryllium (Be) ablators offer an attractive path to ignition on the National Ignition Facility (NIF). Experimental measurements[1] at NIF-relevant radiation temperatures indicate that Be is a higher performance ablator than plastic (CH) and high density carbon (HDC), with significantly higher mass ablation rate, ablation pressure, and ablation velocity. These superior ablation properties allow for a larger target design space. On one hand, high foot Be target designs with relatively thick DT fuel layers achieve moderate areal densities and 1D yields at relatively low convergence ratios, while effectively suppressing ablation front instabilities. On the other hand, low foot Be targets with thinner fuel layers achieve higher compression, areal densities and 1D yields, but are less stable. Thus, there is a broad spectrum of Be target designs, with varying degrees of trade off between 1D yield and hydrodynamic stability.

We have designed targets that utilize the advantages of Be ablators to balance this trade off and scale to higher yields and ignition. We present a high foot target for the first Be experiments on NIF (to begin in August of this year), which is designed to produce a yield close to 1D predictions at the expense of absolute yield (~ 10^{15} neutrons) and compression. A tailored high foot pulse shape is used to propagate a strong but decaying (9 to 6 Mbar) first shock through the Be layer, to control the ablation front instabilities while placing the DT fuel on a moderately high adiabat. We also present strategies for scaling this high foot target to higher yields, through a combination of higher energy/power drives, thinner fuel layers, and lower feet laser pulses. The trade offs between hydrodynamic stability and higher yield in such designs are quantified. Finally, we present a low foot Be ignition target (Rev. 6)[2] which still suppresses ablation front instabilities more efficiently than the high foot CH designs shot so far.

*This work was performed at LANL, operated by LANS, LLC for the U.S. DoE under Contract No. DE-AC52-06NA25396; and at LLNL, operated by LLNS, LLC for the U.S. DoE under Contract No. DE-AC52-07NA27344.

[1] R. E. Olson et al., "*X-ray ablation rates in inertial confinement fusion capsule materials*", Phys. Plasmas **18**, 032707 (2011).
[2] A. N. Simakov et al., "*Optimized beryllium target design for indirectly driven inertial confinement fusion experiments on the National Ignition Facility*", Phys. Plasmas **21**, 022701 (2014).

44th Annual Anomalous Absorption Conference
Estes Park, CO
June 8-13, 2014

Stimulated scattering in laser driven fusion and high energy density physics experiments*

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In laser driven fusion and high energy density physics experiments, one often encounters a $k\lambda_D$ range of $0.15 < k\lambda_D < 0.5$ where stimulated Raman scattering (SRS) is active (k is the initial electron plasma wave number and λ_D is the Debye length). Using particle-in-cell simulations, the SRS reflectivity is found to scale as $\sim (k\lambda_D)^{-4}$ for $k\lambda_D \geq 0.3$ where electron trapping effects dominate SRS saturation; the reflectivity scaling deviates from the above for $k\lambda_D < 0.3$ when Langmuir decay instability (LDI) is present. The SRS risk is shown to be highest for $k\lambda_D$ between 0.2 and 0.3. SRS re-scattering processes are found to be unimportant under conditions relevant to ignition experiments at the National Ignition Facility (NIF). Large-scale simulations of the hohlraum plasma show that the SRS wavelength spectrum peaks below 600 nm, consistent with most measured NIF spectra, and that nonlinear trapping in the presence of plasma gradients determines the SRS spectral peak. Collisional effects on SRS, stimulated Brillouin scattering (SBS), LDI, and re-scatter, together with three dimensional effects are examined. Mitigation of SRS in the strongly nonlinear trapping regime is discussed.

*This work was performed under the auspices of the U.S. Dept. of Energy by the Los Alamos National Security, LLC Los Alamos National Laboratory.

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