CFTA Fill Rate Study*

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As the size of the fill tube in Capsule Fill Tube Assemblies (CFTAs) continues to get smaller, the time it takes to fill the capsule with fuel for an ignition shot increases significantly. Foreknowledge of the fill rate of the capsule is both useful for NIF operations and difficult to determine experimentally. By leveraging the existing X-Ray Fluorescence (XRF) process used to check for plugs in the CFTA fill tube, LLNL Target Fab has developed a method to determine the flow rate for CFTAs prior to being built into a target. Obtaining this information 2 weeks or more earlier than previously available can help NIF more effectively prepare for the shot. The theoretical foundation and experimental results enabling this early communication will be presented.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Oral

Presenter: Matt Aggleton, aggleton1@llnl.gov, 925-341-9897

Overview of Hohlraum Fabrication at General Atomics*

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In ICF experiments, the hohlraum is a crucial component for converting laser light into X-rays. Over the past years, modifications have been made to the shape of the hohlraum to better direct X-rays into the capsule. In addition to altering the shape, different inner surface materials, such as gold and depleted uranium, have been utilized to influence the drive energy. Various features have also been added for diagnostic purposes. In addition to traditional cylindrical hohlraums, non-cylindrical designs such as frustraums with new diagnostic features have been introduced in the recent past and are now regularly fabricated. This presentation will cover the hohlraum fabrication process and characterization capabilities at General Atomics.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Presentation Type: Oral

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Femto-Second Laser Hole Drilling of Target Capsules

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One of the most important features of femtosecond (fs) Laser processing is to control chemical reactions and ablation in the femtosecond time range without significant creation of heat damages. A second advantage of fs Laser processing is that strong absorption can be induced only at the focus position inside transparent materials due to nonlinear multiphoton absorption. We have developed a high precision Laser drilling and processing platform using femto-second Laser Technology, 3D metrology capabilities and novel holographic optics. We have successfully applied this technology to reliable capsule hole drilling with hole diameters smaller than 2um and neglectable heat affective hole lining, as verified by Confocal Raman 3D Scanning.

Presentation Type: Oral.
Presenter: Joachim Ahner, PhD, ahner1@llnl.gov, 1-925-422-3058

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IM release number: LLNL-CONF-862111

Overview of Capsule Fill Tube Assembly (CFTA) articles and qualifying processes*

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The National Ignition Facility (NIF) requires Targets to be assembled in a very precise and complicated format. These Targets contain many special components, one of them being a capsule fill-tube assembly (CFTA). The Capsule is a hollow sphere that can be of various sizes and materials, and the fill tube is needed to deliver fuel into the capsule in a completed target. Before the CFTA can be assembled into a target it must pass several qualifying tests. The outcome will either lead to further analysis or to continue build of a Cryogenic Target that theoretically would achieve the intended goal experiment. This poster will provide an overview of various capsule types, the tests used to qualify them and common failures.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

Presenter: J. Alcala, Jiro.Alcala@ga.com

Wetted Foam Target Production for Inertial Fusion Energy*

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Production of wetted foam capsules for inertial fusion energy (IFE) is a priority research opportunity listed in the DOE Basic Research Needs for IFE workshop report[1]. A wetted foam target typically consists of, or includes, a spherical polymer shell with a layer of low-density polymer foam just inside the shell. The foam layer would be used to wick in and create a layer of liquid DT filling the foam. Lower density foams are wanted in this application since the carbon and other high atomic number elements in the foam are mixed with the DT, increasing radiative losses in DT fuel during the implosion of the target, making ignition of the target more difficult. Polymers with just carbon and hydrogen (or deuterium) are preferred over those that also contain some oxygen or nitrogen for this same reason. Faster filling of liquid DT via wicking into a foam shell (10's of seconds expected) would greatly lower tritium inventory of the IFE DT target fill system compared to kg tritium quantities that would be required for permeation gas filling targets[2].

We are developing spherical foam shells with density ≤50mg/cm^3. Two different approaches to the manufacture of these shells are being pursued: microencapsulation and additive manufacturing via two photon polymerization (2PP). We report on our progress towards making the low-density foam shells by these two approaches. Accomplishments include using 2PP to make a foam shell at a density of 27mg/cm^3 which withstood re-wetting with Novec™ 7100 fluid (surface tension of 13.6 nN/m; more than liquid DT <4 mN/m), which indicates survival when rewetting with liquid DT is possible. We have developed techniques to microencapsulate our GACH pure CH or CD foam. In the previously available cast or cast and machine techniques, GACH foam has been made in billets with density from 5 to 200 mg/cm^3 and submicron pore size[3]. We have made microencapsulated GACH foam shells with a nominal density of 25mg/cm^3, diameters of 3 to 4 mm and wall thicknesses of ~100 to 200 µm. We continue to improve wall uniformity and drying processes for these foam shells.

Initial work to prepare dicyclopentadiene (DCPD) foam for micro-encapsulation will be discussed. Methods for deterministic symmetry control in micro-encapsulated capsules/foam shells will also be outlined.

[1]REPORT OF THE FUSION ENERGY SCIENCES 2022 BASIC RESEARCH NEEDS WORKSHOP ON INERTIAL FUSION ENERGY, https://science.osti.gov/-/media/fes/pdf/workshop-reports/2023/IFE-Basic-Research-Needs-Final-Report.pdf

[2]Schwendt et al, Fusion Sci. &Tech. 43:2, March 2003, 217-229, DOI: 10.13182/FST03-A262

[3]M. J.-E. Manuel, et al, Matter and Radiation ant Extremes 6, 206904 (2021), https://doi.org/10.1063/5.0025374

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Presentation Type: Oral (preferred)

Presenter: Neil Alexander, Neil.Alexander@ga.com, 858-455-2391

Capsule Laser Drilling Historical Progress*

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High density carbon (HDC) capsule ablators are of primary interest for National Ignition Facility (NIF) Deuterium-Tritium (DT) experiments. Reducing the fill tube perturbation has been a driver for requiring smaller fill tubes. Successful ignition shots (including record-to-date yield N240210) were performed with 2-µm fill tubes, down from the standard nominal 5 µm and 10 µm-diam fill tubes. Development for a standard specification for 2 and 5 µm fill tubes has led to a greatly improved yield of successful capsules from the mandrel removal and fill tube attachment stages. Improvements to the drilling operation includes GUI interface, data logging for machine learning trials, focal plane diagnostics, and a secondary laser for reducing drilling times and energy subjected to the capsule. Drill hole analysis has been improved by 3D tomographic analysis (Dragonfly software). Stage fixturing has been developed to allow precise position drilling (e.g., relative to the P1 nonuniformity). Recent processing changes have also allowed smaller fill tube holes (2 and 5 µm fill tubes) to be drilled in GDP capsules as interest in this ablator becomes prevalent again.

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Presentation Type: Poster

Presenter: Noel Alfonso, noel.alfonso@ga.com, 858-455-3929

Effects of Pyrolysis on Glow Discharge Polymer Capsules*

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Glow discharge polymer (GDP) capsule ablators are of primary interest for the National Ignition Facility (NIF) experiments. One integral process in the fabrication of GDP capsules is pyrolysis to remove the mandrel. To better understand the capsule behavior in inertial confinement fusion (ICF) it is imperative to understand the capsule's properties and have an established design requirement. An investigation into how pyrolysis affects the capsule's properties has been conducted, and how they change quantitatively. This information allows for proper prediction of the capsule's final properties, ensuring that the capsule meets the shot or design requirements.

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Presentation Type: Oral

Presenter: Anthony Allen, anthony.allen@ga.com, 858-455-2189

Engineering of Thiol-Michael Resins for Two-Photon Printing*

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[2] Laboratory of Laser Energetics, University of Rochester, Rochester NY
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Fast and highly accurate direct laser writing of polymeric structures with sub-micron resolution is rapidly benefiting applications ranging from biomedical scaffolds to photonics to inertial confinement fusion targets. Two-photon polymerization (2PP) is a direct laser writing method that whereby the focus of a pulsed, femtosecond laser is translated through a 3D volume element within a droplet of resin to create a desired structure. The vast majority of 2PP resins are polymerized by uncontrolled free radical polymerization. Although overwhelmingly useful, this chemistry suffers from rapid and unpredictable chain propagation and termination through radical combination and chain disproportionation reactions, leading to print error and poorly defined network topologies and dangling chain ends.

We have developed novel 2PP resins that utilize base-catalyzed thiol-Michael hydrothiolation reactions to form highly uniform polymer network with improved print resolution. Resin formulations include mixtures of commercially available multifunctional monomers, photosensitzers, with a light-sensitive photobase initiator. We apply Raman microscopy to study the photogeneration of guanidine base molecules, and 2PP of the resulting resin shows higher resolution than comparable free-radical formulations.

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Presentation Type: Oral
Presenter: Mitchell Anthamatten, mitchell.anthamatten@rochester.edu, 585-273-552

Abstract Title: Target Fabrication Machining Facility Upgrades

Author(S) Matthew Arend

Date 2/20/24

Abstract: The LLNL target fabrication machining facility was relocated to be more integrated with the rest of NIF target fabrication efforts. The relocation provided an opportunity to upgrade much of the outdated equipment and invest in some of the latest ultra precision machining technology. This poster will present some of these upgrades and some of the work involved in moving precision machining and assembly capability. The move, which began in August 2021, included facility renovations and careful staging. As soon as the first three pieces of equipment were installed and qualified, three precision machinists followed to continue their work on the new equipment. The move continued over the next few months in stages, with a few pieces of equipment installed followed by a few machinists moving their work. A coordinated effort between project managers, LLNL riggers, the NIF FINS team, machine tool services, ES&H, the NIF logistics team, and many others made this move happen on schedule.

LLNL-ABS-861650

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Tape Targetry to Enable High Repetition Rate High Power Laser Experiments.

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The development of lasers towards ever higher repetition rates and power has seeded an explosion in the number of user facilities and experimental shots that are available to the laser user community. These experiments are carried out across a broad range of plasma physics and material science areas from ion acceleration to the structure of materials. In addition, the integration of free-electron lasers (FEL's) with high power lasers opens up areas of research that were not previously accessible.

All of these developments need to be supported by robust targetry assembly and delivery solutions that are able to accommodate shot rates of up to 10Hz, comprising positioning systems, production methodologies and characterisation capabilities. In response to this demand the Central Laser Facility in collaboration with its user community has developed a tape target strategy that is being fielded on a wide range of facilities and experiments. Positional accuracy of <2um in the laser focus direction has been achieved, removing the need for shot to shot alignment of the target position. Manufacturing techniques have been developed to provide structured and patterned substrates and a strategy has been developed to produce up to 1km of target substrate per day; equivalent to 100,000 shots.

We present the development of a range of these systems based on a standard architecture and control software.

Presentation Type: Poster

Presenter: S. Astbury, sam.astbury@stfc.ac.uk, Tel :+44 1235 446357

Abstract Title: Improvements to high density carbon capsule quality and availability for the inertial confinement fusion program

Author(S): (LLNL) S. Baxamusa, S. Hayes, X. Lepro, T. Braun, T. Parham, J. Biener, A. Nikroo (GA) A. Allen, C. Kong, M. Ratledge, J. Crippen, N. Alfonso, A. Foresman (DM) T. Fehrenbach, C. Wild

Date: 3/15/24

Abstract: Routinely fielding targets with yield >1 MJ on the National Ignition Facility (NIF) is the capstone of decades of effort. But it has also allowed the Inertial Confinement Fusion program to focus capsule manufacturing improvements on those attributes observed to drive NIF performance in this regime. Reductions in bulk inclusions and voids, surface pits, and capsule non-concentricity, as well as improvements to metrology capability and capacity, have increased the quality of capsules selected for NIF shots. These improvements have also increased the importance of improving the yield of downstream capsule processing. This presentation will cover the impacts of improvements to capsule processing including hole drilling, mandrel removal, dimensional culling of sub-components to capsule availability.

LLNL-CONF-861984

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Progress and Perspectives in LMJ Target Fabrication *

Virgile Bernigaud[1]

[1] CEA, DAM, Valduc, F-21120 Is-sur-Tille, France

The French target fabrication department located in Valduc Center supplies all the targets used for HEDP experiments and Inertial Confinement Fusion (ICF) campaigns performed by CEA Military Applications Division. Currently, a large panel of HEDP experiments are carried out on the LMJ facility, while consolidation of the ICF target design with dedicated experiments moves forward.
This presentation is an overview of state of the art and progress performed by the French team on selected examples related to these experiments. We first remind the department organization and then detail some updates about fabrication, assembly and characterization capabilities.
Among the topics covered, new production and characterization devices recently purchased by the lab are presented (X-Rays CT Scan, laser for welding applications, femtosecond laser for machining, etc.).
A more in-depth study of glue characteristics, used in the target fabrication process, is also addressed, involving the use of dedicated devices on representative samples.
Concerning ICF targets, a first non-cryogenic target equipped with a 30 µm fill tube has been experimented in 2022 on the LMJ facility. Since then numerous feasibility studies are in progress and the latest developments concerning cryogenic targets are also discussed in this presentation. This includes cryogenic tritium target lab under study and assembly progress.
Finally, as an introduction to other oral communications from French target fab colleagues; a quick focus is given on PAMS mandrel synthesis, development of gold boron thin liner, capsule with controlled roughness fabrication and thin-walled holhraum electroplating process. More specifically, in the field of Equations Of State experiments, we developed a new instrument dedicated to micro-thickness measurement of samples, which is of prime importance for optimized target design.

Presentation Type: Oral
Presenter: Virgile Bernigaud, virgile.bernigaud@cea.fr, +33 3 80 23 40 00

Overview of Helium Leak Detection and Testing for Capsule Fill Tube Attachments*

B. Berry, J.W. Crippen, M. Ratledge

General Atomics, P.O. Box 85608, San Diego, California 92186-5608

Helium mass spectrometer leak detectors provide the most precise and reliable means of locating and measuring leaks in systems and products. In support of Inertial Confinement Fusion (ICF) campaigns General Atomics strives to use leak detection techniques to provide the high-resolution data on capsule fill tube assemblies (CFTA) to understand if they are ready to integrate into experiments at the National Ignition Facility (NIF). By incorporating these tests into the assembly process, we can reduce time-to-market for historically time-consuming target builds. This data can be used to give us feedback on new assembly designs, capsule coating methods, and allows us to troubleshoot and repair multipart assemblies. To meet the increasing demand for CFTA delivery, General Atomics has developed and implemented several standards, tests, and specifications to ensure we are producing high quality assemblies. This poster will introduce the leak detection and testing techniques used for CFTA production and the recent improvements to the processes.

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Presentation Type: Poster

Presenter: Brandon Berry, Brandon.berry@ga.com, 858-455-4673

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Visar Mirrors _n Bhandarkar

N. Bhandarkar

March 12, 2024

25th Target Fabrication Specialists Meeting
San Diego, CA, United States
August 25, 2024 through August 29, 2024

Abstract Title: Optimization of VISAR Mirror for NIF Targets

Author(S): Neal Bhandarkar (bhandarkar2@llnl.gov)

Date:

Abstract:

VISAR (Velocity Interferometer System for Any Reflector) is a critical diagnostic used for measuring shock propagation through a sample for several campaigns at the National Ignition Facility (NIF). To support simultaneous measurements with VISAR and other diagnostics, optical mirrors are implemented so that when the target line of sight matches the primary diagnostic, a VISAR measurement can be taken from an angle off-axis to the shock path through the physics package. A variety of factors have required Target Fabrication to work on improving these mirrors, including complex new target geometries, variance in VISAR signal as the system ages, and experiments requiring more challenging polling rates. This presentation lays out a few of the efforts to help mitigate these issues by improving both the flatness and reflectivity of these commonly used mirrors.

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

Correlation of Macroscopic and Microscopic Properties of Tungsten Doped Nanocrystalline Diamond Coatings

Tom Braun[1], Rajeev Kumar Rai[2], Tobias Fehrenbach[3], Tian Lee[1], Warren L. York[1], Mike Nielsen[1], Wenyu Sun[1], Chantel Aracne-Ruddle[1], Sean M. Hayes[1], Monika M. Biener[1], Leonardus Bimo Bayu Aji[1], Wes Nieveen[4], Jack Li[4], Eric A. Stach[2], Christoph Wild[3], and Juergen Biener[1]

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Macroscopic properties of tungsten-doped nanocrystalline diamond (W-NCD) ablator shell coatings that are critical for ignition target design and/or target characterization/quality control include density and IR transparency. Characterization of production batches revealed that these macroscopic material properties depend in a non-linear fashion on the tungsten doping level and deposition temperature. This work attempts to correlate macroscopic properties like density, IR transparency, electrical conductivity, and elastic modulus with microscopic material properties such as grain size and texture, content of graphitic carbon and hydrogen, and tungsten coordination. Microscopic material properties were obtained using a suite of state-of-the-art microscopy and spectroscopy techniques including high-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM), energy-dispersive X-ray spectroscopy (EDS), electron energy loss spectroscopy (EELS), carbon K-edge X-ray absorption spectroscopy (XAS), X-ray diffraction (XRD), and secondary ion mass spectroscopy (SIMS). The results suggest that the non-linear density / IR absorption / W-doping correlations are a consequence of grain size refinement and changes in the graphitic carbon content.

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Machining Process for LANL Bosque Shells

C.A. Blough, P.M. Donovan, T.E. Quintana, B.M. Patterson, D.W. Schmidt, B.Y. Farhi, B.M. Haines, Y. Kim.

Abstract

The Bosque campaign is a 2pp printed lattice foam inside of a Rexolite outer shell. It explores the use of 2PP Foam (3-D printed foam) encapsulated in two semi-finished Rexolite shells that are subsequently machined to finished dimensions. The machining process for Bosque shells include a coordinated multistep process to ensure the quality of the parts. This is done while maintaining the best achievable concentricity of all components throughout the manufacturing process.

Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218NCA000001).

Presentation: Poster

Presenter: Casey Blough, cblough@lanl.gov 505-667-6507

LA-UR-24-23652

Development of a specific electroplating process for the manufacturing of thin-walled hohlraum.

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In order to optimize the implosion symmetry for indirect drive experiments carried out on the LMJ facility, the CEA uses a new diagnosis thanks to the development of a hohlraum thin-walled platform. With a gold wall thickness of only 6 µm, the thickness is thick enough to keep the soft X-ray albedo equal to a standard thickness hohlraum, but is thin enough to have good X-ray transmission signal to quantify the laser power of internal and external laser beam cones.

The main challenge for the manufacture of these thin-walled Hohlraum targets is to ensure a wall thickness of 6 µm ± 2 µm. A technical solution could be to electroplate a thick layer of gold on the surface of a copper mandrel and then machine it to achieve the required final thickness. Nevertheless, as gold is a very soft material, machining the gold layer to obtain a thickness less than 10 µm with such precision becomes very difficult or even impossible depending on the geometry of the parts.

For these reasons, we chose to obtain the requested gold hohlraum thickness directly by electrolytic deposition. For this, CEA has developed a specific electroplating process to optimize the uniformity of the current density distribution on the surface of the mandrel during electrolytic deposition. Thickness measurements obtained using the X-ray fluorescence technique show that the thickness of the deposited gold on the mandrel surface is uniform with a standard deviation of less than 0.5 µm, whether for a cylindrical or for a rugby shape hohlraum.

Recently, CEA designed and manufactured a new version of this process including an automated electroplating station entirely dedicated to the fabrication of future thin-walled hohlraums that will be experimented on the LMJ.

Presentation Type: Oral
Presenter: Ronan BOTREL, ronan.botrel@cea.fr, +33 3 80 23 40 00

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LLNL-ABS-863641

Technology Advancements Enabling Fusion Ignition on the National Ignition Facility

G. K. Brunton

April 25, 2024

Title: Technology Advancements Enabling Fusion Ignition on the National Ignition Facility

Author: Gordon Brunton (Lawrence Livermore National Laboratory, Livermore, CA)

Abstract:

The National Ignition Facility (NIF) stands as a pinnacle of scientific and technological excellence, supporting frontier advancement of High Energy Density (HED) science in support of the National Nuclear Security Administration's (NNSA) Stockpile Stewardship Program (SSP). Recent technological enablers have accelerated the NIF's successes and were instrumental in the historic laboratory fusion ignition accomplishment and four subsequent repeats since December 2022.

This presentation delves into four key science and engineering advancement areas that have propelled the NIF towards these accomplishments. Optics improvements have strengthened the facility against extreme conditions enabling an increase in the maximum laser energy delivered by the NIF. Laser precision and accuracy enhancements have empowered researchers to fine-tune experimental parameters with unprecedented control, ensuring greater repeatability of the fusion process. Additionally, target fabrication quality improvements have played a pivotal role in achieving higher fusion yields and experimental reproducibility. Furthermore, advancements in diagnostic capabilities provided quantitative data crucial to understanding the key adjustment levers contributing to the rapid increase in performance over the past few years.

These collective advancements have not only enabled validation of the feasibility of fusion ignition but have also established a robust foundation for continued scientific exploration and enhanced performance.

Looking forward, we will address near-term priorities concerning facility degradation and equipment obsolescence, and a proposal to implement a modest NIF upgrade to maximize its full potential, thereby ensuring NIF remains a premier experimental capability for the NNSA and the broader scientific community for decades to come.

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

LLNL-ABS-863641

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LLNL-CONF-862189

Buried Layer Campaign_Chopra

J. Chopra

March 26, 2024

25th Target Fabrication Specialists Meeting.
San Diego, CA, United States
August 25, 2024 through August 29, 2024

Abstract Title: Fabrication and Handling of a Novel Physics Package for Buried Layer Campaign

Author(S): Jaymin Chopra

Date: 3/20/22

Abstract: The Buried Layer Campaign aims to measure the emissivity and ionization of gold under hohlraum-relevant conditions in order to benchmark NLTE (non-local thermal equilibrium) models. To accomplish this physics goal, the physics package comprises a novel low-density CH foam, weighing 20mg/cc, internally tamping Au foam to establish uniform plasma conditions. This paper will provide detailed insights into the fabrication and handling of the physics package, as well as outline the next steps for this campaign.

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Release#: LLNL-CONF-862189

Advances in Fabrication Methods for Evolving Target Needs

R. Chow, N. Nijem, T. Bernat, N. Cahayag, A. Pastrnak, T. Siv, D. Skilling

ManTech Livermore Laboratory

ManTech Livermore Laboratory applies extensive capabilities in precision machining, physical vapor deposition, organic coatings, materials development, precision assembly, and characterization to meet target fabrication customers' evolving target designs and specifications. Specific targets illustrate the wide range of targets ManTech Livermore Lab provides and techniques developed to overcome fabrication challenges.

Presentation Type: Poster

Presenter: Rida Chow, rida.chow@mantech.com, 510-305-3438

Double Shell Development with Emphasis on Fill Tube Assemblies

N. Christiansen[1], D. Schmidt[1], P. Donovan[1], J. Martinez[1], C. Wilson[1], B. Patterson[1], T. Quintana[1], E. Loomis[1], S. Palaniyappan[1]
C. Shuldberg[2], J. Crippen[2], W. Sweet[2], M. Ratledge[2]
N. Roskopf[3], B. Ferguson[3], H. Robey[3], C. Choate[3], T. Briggs[3], N. Hash[3], J. Kroll[1]

[1] Los Alamos National Laboratory (LANL)
[2] General Atomics (GA)
[3] Lawrence Livermore National Laboratory (LLNL)

Abstract

The double shell campaign was designed with the purpose of pursuing a platform that would foster an improved understanding of the role mix has on a volume burn target. The double shell target consists of an outer aluminum ablator with a foam cushion and an inner capsule. The double shell assembly needs to be filled with liquid DT at the inner capsule. That necessitates the need of a fill tube to be inserted into the inner capsule. The outer joint and fill tube in the aluminum ablator both create imperfections in the implosion that techniques have been developed to minimize the impact. This talk will highlight the processes used in the development of the first double shell fill tube assemblies as well as open discussions on the results and lessons learned from the initial target shots at the National Ignition Facility.

Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218NCA000001).

Presentation Type: Oral
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LA-UR-24-23753

Multi-MJ target designs for Inertial Fusion Energy

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In laser driven inertial confinement fusion (ICF), a spherical capsule filled with deuterium and tritium (DT) is accelerated inward by direct irradiation of the laser energy (direct drive) or by X-rays generated from the laser interacting with the hohlraum (indirect drive). At stagnation, the fuel is compressed to ~ 100-200 x its initial density and has been heated to temperatures larger than ~ 10 keV. The DT atoms fuse to produce a 3.6 MeV alpha particle and a 14.1 MeV neutron. On December 5, 2022, the National Ignition Facility (NIF) achieved "breakeven" for the first time, where 2.6 MJ of fusion energy output were generated from 2 MJ of laser energy input. This represented a significant milestone after 50 years of research. The goal of the emerging inertial fusion energy (IFE) community is to commercialize ICF for the purpose of creating a fusion pilot plant (FPP) and eventually, a first of a kind (FOAK) GW nuclear reactor.

Xcimer Energy Inc is designing a novel class of low cost, high energy (~10 MJ) laser systems enabled by the development of gas optics. This is a huge step forward given the present inability of solid optics to survive large beam fluences. The chamber design is based on the well studied HYLIFE concept which uses molten eutectic salt to collect the radiation from the target output, serving as a coolant, Tritium breeder, and a shield for the chamber wall. The target containing the DT fuel must survive injection into the chamber, irradiation from two sides, and achieve gains >100-150 (the requirements for which depend on repetition rate and wall plug efficiency). For a target concept to be viable and credible, it also must exhibit robustness to the Rayleigh Taylor instability which severely limited the performance of early NIF experiments predicted to achieve high yields. In this presentation, we discuss the target design opportunities that are enabled by high energy lasers for producing robust implosions that are both high gain and hydrodynamically stable.

Presentation Type: Oral,

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New Challenges for Cryogenic NIF Target (TMP) Assembly done at GA*

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Over the years the National Ignition Facility (NIF) increased the shot rate and complexity of experiments necessitating General Atomics (GA) to standardize the fabrication, metrology and TMP Sub-Assembly processes to meet the demand of precision machined components such as Thermal Mechanical Packages (TMP), Diagnostic Bands (DB), Laser Entrance Hole Washers (LEH Washer), Shields (SH), and Window Washers (WW).

The implemented standardized processes allow sufficient complexity within each component type enabling GA to maintain weekly deliveries of several different components to meet the demand for NIF.

In the past three years new challenges arose with the demand of “standardized” targets consisting of new materials, such as plastics and ceramics. In addition, new design scales were implemented such as MTMP, MagNIF and HU.

This presentation will highlight some of these challenges, the R&D effort, and the impact to the overall target delivery schedule.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Poster

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Tape Drive Target Delivery System Commissioning on GALADRIEL at General Atomics*

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GALADRIEL, the General Atomics Laboratory for Developing Rep-rated Instrumentation and Experiments with Lasers, provides a platform built around a 1 TW laser for developing rep-rated diagnostics, database frameworks, feedback systems, and target delivery methods for HED science experiments. Presently, a tape drive system built using a design developed for use at ELI Beamlines provides rep-rated solid target delivery on GALADRIEL. This tape drive can deliver targets, spooled on a tape-type substrate to target chamber center (TCC) with a precision along the axis of laser focus of ~10 μm, and a rate of up to 10 Hz (the max operating rate of GALADRIEL), depending on the target type. Initial shakedown tests of the tape drive at GALADRIEL delivered 75 μm thick Cu tape at rates of 0.2 – 10 Hz to study the tape drive operational capabilities, the X-ray output from the laser-target interaction, and the ablation plasma density as a function of time after the laser struck the target. Campaigns in the near future aim to streamline the accurate delivery of more complex targets machined and deposited onto the tape system leveraging cutting-edge target fabrication capabilities at General Atomics.

*This work performed under the auspices of General Atomics Internal R&D funding.

Presentation Type: TBD
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Techniques for Fielding Kr-doped Deuterium Ice and Ice Shells in ICF Targets*

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Cryogenic ice fills offer higher fuel densities than can be achieved with gas or liquid fills in ICF targets. Fielding such targets with dopants, however, is difficult since the deuterium fusion fuel freezes and diffuses at different temperatures and rates than the high-Z dopant. Initial attempts indicated that effectively all of the Kr was stripped from the fuel prior to filling the target. Computational Fluid Dynamic analysis coupled with repeated attempts has enabled the development of techniques for successfully fielding Kr-doped D2 ice and ice shell targets. By using two different techniques to form cryogenic fuel of doped deuterium, we obtained significant D-D neutron yields on two ICF campaigns, consisting of six shots. This work marks the first time that a Kr-doped D2 ice shell fuel has been fielded on Z as well as the first time Kr-doped ice has been fielded in ICF.

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

Presentation Type: Oral
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The Advancement of a Cationic Capsule Fill Tube Assembly for The National Ignition Facility*

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A Capsule Fill Tube Assembly (CFTA) is comprised of an ablator type hermetically sealed to a fill tube. At the National Ignition Facility (NIF) demands and expectations of these CFTA's have increased. To meet these high demands an alternative glue bond with additional testing was required. A cationic bonding process requiring the use of both a focused laser beam with an external LED heat source was implemented. Extensive engineering experiments were performed at both General Atomics and Lawerance Livermore National Laboratories (LLNL) to qualify this process. These experiments ensured a fully cured glue mass and optimal bond strength between the capsule and fill tube. General Atomics has also developed new techniques and methods within the assembly process to ensure optimal quality. This talk will cover the CFTA experiments performed and process improvements that have led to the increase delivery yield to NIF.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Presentation type: Oral

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Oral
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Title: Manufacturing and Characterization Techniques for Double Cylinder Experiments at the National Ignition Facility

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Manufacturing and Characterization Techniques for Double Cylinder Experiments at the National Ignition Facility

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Progressing from single cylinder direct drive experiments, a double cylinder implosion experimental platform has been developed for and fielded at the National Ignition facility. The experimental package design requires a thin-walled outer cylinder, 35-40 mg/cc CH aerogel between an outer and inner cylinder, a bi-layer thin-walled inner cylinder made from two materials with sufficiently contrasting density with or without external perturbations, or a copper aluminum gradient, and an inner 200 mg/cc foam. Fabrication of the experimental package comes with many similar fabrication challenges to single cylinder experiments, predominantly maintaining uniform wall thickness on thin-walled cylinders and providing accurate characterization of the final parts and assembly. Unique challenges to the double cylinders fabricated is maintaining concentricity between the inner and outer cylinders and fabrication of a thin-walled cylinder made from gradient density material. This presentation will give an overview of the double cylinder fabrication process, discuss contactless on tool gauging techniques aimed at reducing wall thickness non uniformities, and show tooling developed to produce uniform gradient density coatings on a cylinder.

This work used resources provided by Los Alamos National Laboratory, operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218NCA000001).

Presentation Type: Oral
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X-ray Sagometer Process for Cryogenic Targets*

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Cryogenic inertial confinement fusion targets are used in experiments at the National Ignition Facility (NIF). These targets come in many variations, and consist of a capsule with fill tube, a hohlraum, and a diagnostic band, which form a thermal mechanical package that is precisely assembled to within a few microns and sealed to be leak tight. Once the Target is fully assembled, it needs to go through final qualification checks. Some of these checks are done in the X-ray Sagometer test box.

The X-ray Sagometer test box is a lead-lined, inter-locked test chamber used to test for Ignition Target Sag with a low power x-ray source. It has the capability to image the capsule though starburst cutouts in the Hohlraum to calculate capsule sag. It can view the capsule through LEH windows which allows the operator to observe a xenon fill and determine if there is a plug. If it passes the sagometer qualification checks the Target will move on to the National Ignition Facility.

This poster will provide an overview of the sagometer process of the cryogenic NIF precision targets.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

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2PP Printing of 3D Deuterated Plastic Lattices: Challenges and Optimization

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Although 2PP resins are readily available for fabricating lattice structures, many applications within ICF require materials with high levels of deuteration and low oxygen content. To address this need, General Atomics has developed materials and processes which enable 2PP printing of highly deuterated structures with minimal shrinkage and good mechanical properties. Various experiments were conducted to investigate the relationship between solvent properties and the rate of polymerization. Additionally, the research highlights the optimal quantity of solvent and cofactors within the resin to produce printable targets while maintaining a high deuterated percentage. Furthermore, a range of laser parameters, including stitching, power gradients, slicing, hatching, and scanning rates, were explored to optimize the printing process and reduce printing time while ensuring high-quality production. As a result, the fabricated targets achieve low densities ranging from 16 to 25 mg/cc and consistent dimensions, with a shrinkage rate of 1 to 3%. This research contributes to the advancement of 3D printing techniques for the production of deuterated materials for LANL's Bosque campaign and others.

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Presentation Type: Poster

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LLNL-ABS-862516

Diamond-like carbon (DLC) coatings prepared by pulsed plasma physical vapor deposition

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25th Target Fabrication Specialists Meeting, August 25-29, 2024

Though in widespread industrial use as a high-wear tribological coating, amorphous diamond-like carbon (DLC) is also a material of interest as a next-generation ablator for high energy density and inertial confinement fusion experiments. However, robust DLC films with high density (> 2 g/cm^3) and minimal defects are difficult to achieve without incurring penalties of high intrinsic stress, which precludes the thick film growth necessary for ablator coatings. We will discuss our process to deposit ultrathick (>50 microns), highly uniform coatings with minimal hydrogen incorporation using high power impulse magnetron sputtering (HiPIMS) as well as our ongoing research aimed toward increasing film density while minimizing stress.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and was supported by the LLNL-LDRD Program under projects 22-FS-027 and 23-ERD-040.

Cryogenic Planar Ablation: Testing and Fabrication

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Abstract

The CryoAblation program is studying ablative and shock characteristics of heterogeneous deuterium. Target fab has worked in collaboration with the experimental designers to produce a feasible design platform. The experiment involves a cryogenic target, retrofitted to work with the current LLE cryogenic system, and a warm target which mirrors the cryogenic targets. The design involves 2 um and 20 um thick high density carbon front windows, and a 2pp printed lattice. The warm targets include an aerogel that is casted into the lattice to mirror the mass of the deuterium. This poster will cover the survivability testing of the front windows, and the manufacturing method to cast aerogel into a 2pp printed lattice.

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Presentation: Poster

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Ultra-Low-Density Metal Aerogels in Emerging Target Designs

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Target Fabrication Meeting
Oral Presentation
August 25-19, 2024
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LLNL-ABS-862188

Ultra-low-density materials (1-50 mg/cm^3 foams and aerogels) are critical components in a variety of experimental platforms for High Energy Density Physics (HED) campaigns. Sub-critical-density metal foams can be heated uniformly to generate shockless plasmas which are frequently used as integrated X-ray sources, both as heaters and high-intensity backlighters. These materials can also be used for generating uniform plasmas of controlled density and geometry. This presentation will focus on the use of ultra-low-density metal foams in some recent campaigns at NIF and Omega: cocktail foams for broadband X-ray sources and Au non local thermodynamic equilibrium (NLTE) at high and low densities. Advancements and challenges in foam fabrication, handling, and assembly for these targets will be discussed.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344.

Printed Targets with Sub-micron Feature Patterns for the Study of Ablator Defects *

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As per present implosion models, laser imprint and implosion symmetry are insufficient to account for observed performance degradation of direct-drive cryogenic implosions. To investigate this, a series of OMEGA experimental campaigns is underway to study isolated target defects, such as domes or voids, as a source of hydrodynamic instability and mix. Key requirements are systematic variation of the laser intensity, defect size, and geometry. Given the need for micron-scale feature resolution and precise registration, the LLE's Target Fabrication additive manufacturing team identified two-photon polymerization (TPP) as an ideal method to fabricate these targets. TPP printing enables controlled formation of designed domes and voids to investigate the combined effect of size and proximity of these features on the hydro performance – something that is not currently feasible with other fabrication techniques.

Primary targets for this campaign consisted of 1-mm outer diameter, 0.8-mm clear aperture, 16-µm thick, TPP-printed planar ablators with and without defect patterns. Designed defects consisted of hemispherical domes and divots of 1-µm height or depth, respectively, and ranging in lateral size from 1- to 10-µm, as well as a line feature of 300-µm length and 1-µm semicircular cross-section. A Nanoscribe PPGT+ TPP printer was used to fabricate these targets to a high degree of repeatability and design fidelity, but not without challenges. The print processes were qualified and targets characterized using a suite of techniques including optical, confocal, atomic force, x-ray, and scanning electron microscopy. Ablator surface roughness < 50-nm rms for stitchless regions was achieved, as well as stitching defects < 150-nm peak-to-valley.

In this poster, the design, fabrication, metrology, challenges and results are presented in greater detail, along with fabrication improvements for future TPP-printed targets.

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

Presentation Type: Poster

Presenter: Sarah M. Fess, smul@lle.rochester.edu, 585-273-3010 (office)

Improving geometrical uniformity of ablator capsules using monitoring during coating process *

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Geometrical uniformity in inertial confinement fusion ablator capsules plays a critical role in successful ignition experiments at the National Ignition Facility (NIF). Yet, the mechanism underlying the wall thickness non-uniformity, often referred to as "mode 1", remains poorly understood. Utilizing object detection and particle tracking techniques on recorded video, we tracked and monitored the trajectories that high-density carbon (HDC) ablators undergo during coating process. We investigated the effect of coating parameters such as the number of capsules and the rotation speed of the racetrack to inform about the frequency of substrate reorientation as well as collision and other events with the aim to improve wall thickness uniformity.

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

Presentation Type: Poster
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LLNL-ABS-863647

Tender X-ray tomography at the Advanced Light Source*

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Characterization of materials with low atomic number (Z) and low density pose challenges for conventional tomographic techniques, which predominantly operate within the higher energy spectrum of X-rays (>10 keV). Shifting the X-ray range towards the tender regime offers a compelling solution by increasing contrast and enhancing visibility of such low-density materials without using the complications of phase-contrast techniques. This adjustment facilitates comprehensive studies of morphology and metrology with higher precision. In this context, a dedicated movable tender X-ray tomography capability has been developed, strategically utilizing infrastructure of beamline 3.3.2 at the Advanced Light Source (ALS), which operates within 4-12 keV energy range. This unique capability facilitates quantitative attenuation contrast imaging and tomography, covering a range of low-Z materials including all the transition metal K-edges. Here, we highlight current achievements, challenges and discuss the future potential of tender X-ray tomography at beamline 3.3.2 of the ALS.

* This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. This research used resources of the Advanced Light Source, a DOE Office of Science User Facility under contract DE-AC0205CH11231.

Presentation Type: Oral or Poster
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LLNL-ABS-863849

High-entropy alloys for next-generation hohlraums

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After LLNL's inertial confinement fusion (ICF) program achieved ignition in December 2022, and more recently in October 2023, the next goal is to increase the amount of energy generated to tens of megajoules. This requires further improvement in the x-ray drive of the hohlraum. We are developing heavy-metal high-entropy alloys (HEAs) that have optimum x-ray drive and can also be used in magnetically assisted implosion schemes. These hohlraums are fabricated by magnetron sputtering. They must balance design constraints including mechanical stability, laser-to-x-ray conversion efficiency, and electrical resistivity. Here, we present results of combinatorial magnetron co-sputtering studies aimed at developing a family of Ta-W-Pt-Au-Bi high entropy alloy films. Effects of the alloy composition and deposition process parameters on the microstructure, residual stress, mechanical properties, and electrical transport will be considered, as well as implications for ICF applications.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344 and was supported by the LLNL-LDRD Program under Project No. 23-ERD-005.

STARFIRE: Building towards inertial fusion energy with multi-institution collaboration

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Demonstration of ignition on the National Ignition facility propelled Inertial Fusion Energy (IFE) from a far-away concept to a tangible reality. However, IFE still requires significant advances to become viable. An integrated program will necessarily include may different science areas, technology development efforts, infrastructure needs, private industry involvement, and workforce recruitment and development. In this talk, we will describe the IFE landscape before focusing on the Science and Technology Accelerated Research for Fusion Innovation and Reactor Engineering (STARFIRE) program funded by Office of Science. Under that program, collaborations with many partners from private companies, academia and other national laboratories have been forged to advance the current knowledge in IFE. STARFIRE focuses on several key technical areas, including target development and engagement, that are essential to reach a first fusion power plant design. Prepared by LLNL under Contract DE-AC52-07NA27344, LLNL-ABS-865242.

Presentation Type: Oral
Presenter: C. Goyon, goyon1@llnl.gov

Advances in 2 Photon Polymerization for Target Fabrication at General Atomics*

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General Atomics' (GA) developments and capabilities with 2 Photon Polymerization (2PP) additive manufacturing have been utilized for ICF and HEDP target fabrication. A historical perspective of GA developments and involvement in establishing 2PP for target fabrication is a case study on how private industry can adopt and develop new advanced manufacturing technology through collaboration and building a foundational understanding. An overview of GA 2PP capabilities spans laser lab infrastructure with custom optical systems to material preparation and post processing and is run by highly capable staff members fluent in target fabrication as well as photoreactive system design. 2PP has proven to be a viable way to produce current targets as well as enabling an entirely new class of targets that expand the boundaries of ICF and HEDP physics. Multiple areas of research and development in 2PP are being pursued at GA to enhance speed and resolution, reduce defects, introduce new materials, and to offer greater applicability to the target fabrication enterprise.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract LANL LDRD, NNSA main contract, IFE-STAR contract, and General Atomics Internal Research and Development Funds

Presentation Type: Oral

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DU Hohlraum Leaching Improvements*

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Collaborating with LLNL, process improvement concepts to improve variability reduction and improve cycle time resulted in three primary changes. 1) process temperature uniformity, 2) agitation uniformity, 3) leach chemistry variation control. As a result, opportunities for variability reduction were identified with the leaching process (removal of the aluminum internal hohlraum mold "mandrel" from the hohlraum). The process improvements consist of thermal confinement and assuring a more uniform agitation. This was accomplished by purchasing a containment shaker system as being the primary process tool with the option to use a thermally contained heated magnetic stir-bar system. We also moved away from masking mandrels in leach to implementing a more precise detachment. This reduced variation in the amount of material in leach and removed the potential for contamination from the masking materials. The result is reduced process time variation and a slight reduction in labor content.

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Presentation Type: Poster

Presenter: Martin Havre, martin.havre@ga.com , 858.455.3219

Accelerometer-Based *in-situ* monitoring of HDC Capsule Polishing

Author(S) Sean Hayes, Akash Tiwari, Monika Biener, Satish Bukkapatnam, Shashank Galla, Kshitij Bhardwaj, Antony Alexos, Suhas Bhandarkar

Aug 25, 2024

Abstract: HDC polishing is an important aspect of the fabrication process to reach the final thickness and surface finish of the capsule design. Challenges in polishing include both uniform defects such as surface roughness, sphericity, and final mass as well as isolated defects such as surface pits. The process of polishing shells currently requires large amounts of operator intervention to ensure that material removal rates are within normal levels and that the surface quality remains satisfactory. The addition of accelerometer sensors coupled with metrology data provides a unique opportunity to utilize machine learning techniques to determine acoustic signals that can provide real-time process monitoring to enhance polishing speed and yield. This talk will give an overview of both experimental and analytical techniques as well as preview results from domain adaptation machine learning models.

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Improvement of Capsule Mode 1 through Experimentally Enhanced Monte Carlo Modeling

Author(S) Sean Hayes, Juergen Biener, Tom Parham, Tom Braun, Xavier Lepro, Jean-Baptiste Forien, Liam Sohngen, Christoph Wild, Sal Baxamusa

Aug 25, 2024

Abstract: The wall thickness nonuniformity (mode 1) has been identified as one of the main degradation mechanisms of ICF implosions. High-yield ignition experiments require selecting capsules with Mode 1 values of 0.18% or lower. Targeting capsules with very low M1 has a significant effect on HDC batch yield. Due to the long processing times, it is necessary to reduce the overall magnitude of M1 to allow for more viable shells to be selected for targets, thus having a positive effect on overall yield. Experiments to determine the instantaneous coating non-uniformity (ICNU) were performed to provide inputs for Monte Carlo modeling to elucidate the effects of different parameters on the batch average M1. Results indicate that both agitation time and the FWHM of the coating have a strong effect on M1 and provide an effective screening tool for tuning parameters and optimizing batch yield.

LLNL-CONF-862043

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Smooth High at% SiCH and Ultra-thin SiCH Capsules*

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The strong interest in developing silicon doped plasma polymer capsules, either as single layer or as dual layers, with increased silicon content is driven by record performance of silicon doped CH capsules as measured by increased yield (up to 50% higher than expected) in Cryo DT experiments on OMEGA. In support of this interest, relatively smooth coatings up to 9at% Si are demonstrated as free-standing single layer capsules. (Actually, 11 at% Si was achieved in a single layer capsule but its properties – strength and smoothness, were not investigated). It is also shown that for dual layer capsules, it is possible to deposit up to 9 at% SiCH onto a SCD capsule, but only after completion of the PAMS pyro process, with final low order mode smoothness limited by the inner SCD layer. These developmental experiments also resulted in the thinnest free-standing SiCH capsule successfully manufactured to date with an aspect ratio exceeding 1000. This talk will discuss the development of highly silicon doped SiCH layered capsules, their surface finish and strength properties.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063.

Presentation Type: Oral

Presenter: Martin Hoppe, hoppe@ga.com, 858-455-2793.

Fabrication and Characterization of NIF Lithium Salt Targets

Chantel Aracne-Ruddle, Parminderdeep Singh, Corie Horwood, Suhas Bhandarkar, Soojin Stadermann, Alec Schwartz, Jean-Baptiste Forien, Gino Mercado, Rick Vargas, Ariel Lighty, and Curtis Walters.

We will discuss the many challenges and successes in fabricating lithium salt targets for the National Ignition Facility (NIF). Lithium salts require highly specialized handling and fabrication techniques, owing to their highly hygroscopic and air sensitive nature. We have developed techniques for hot-pressing ca. 1 mm sized cylindrical pellets, including the design and fabrication of custom molds and machining capabilities, all in an argon glovebox. Eary work focused on improving the grain size and uniformity, and reducing the oxidation of the lithium salt. Contaminants of the starting salt, including metals and oxygen, were quantified, and pellets were analyzed by radiography and tomography to assess the grain size and uniformity. We have expanded this fabrication capability to include doping the pellet with other metals and forming pellets with solid objects implanted inside.

LLNL-ABS-862127 This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Capsule Metrology*

H. Huang, P.N. Lapa, K. Sequoia, M. Yamaguchi,

S. Pajoom, C. Kong, N. Tomlin, and M.P. Farrell

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High precision, highly complex targets are central to the Inertial Confinement Fusion (ICF) program, which demand continuous innovations in both target fabrication and metrology technologies. In this talk, we will go through key examples of new metrology techniques developed by General Atomics. The 12-axis 4Pi system at the center of capsule metrology brings the national ICF program into the new era of “integrated metrology”, where multiple instruments complement each other to probe different aspects of the targets to gain deeper insight than possible with any individual instruments. In 4Pi, we use a five-axis translational stage system to allow up to 8 instruments to engage (in sequence) a capsule with 2 µm positional repeatability, use a five-axis rotational and translational stage system to precisely orient the capsule in (theta, phi) while maintaining the shell wobble and focus to submicron precision, and use a two-axis rotational and translational stage system to enable shell flipping such that the entire 4Pi surface of a capsule can be measured. Aided by a robotic system which enables 24/7 operation, we are able to perform 100% inspection, on 100% of the 4Pi surface, of incoming ablator capsules used by the National Ignition Facility (NIF). 4Pi selected the best capsules for NIF shots, and contributed to the historical fusion ignition on Dec 4th, 2022, and the subsequent fusion ignition repeats. Two instruments on the 4Pi system were specifically responsible for solving the top-two capsule metrology problems in NNSA's ICF program: (a) Digital holographic microscope for 100% HDC capsule surface pits quantification, linked to the “meteor” problem that radiates heat away from the hot spot, thus quenching the fusion yield. (b) Compact FTIR system for whole surface wall thickness variation mapping, linked to the mode-1 wall nonuniformity problem that caused the hot spot to drift, thus depriving the energy from deeper compression and higher yield. Other instruments on 4Pi include (c) Near-IR reflectometer to support thin-wall measurement of transparent or translucent targets of interest to the direct drive program (d) Second generation digital holographic microscope with 3-wavelengths that enables discrete step height measurement on EOS targets, lens-mount AFM to maps out individual surface defects. (e) Darkfield microscope to quantify defects in PAMS, PS, GDP ablator capsules to 0.1um dimensions for direct drive ICF program. (f) Lasik system to systematically remove protruding defects from capsule surface, or write engineering defects onto the capsule surface to study the effect. We deliberately kept the 4Pi design modular, so that its architecture can be future proof for tomorrow's ablator types and utilizing sensors not-yet-invented. With 2 µm positional repeatability and <1 µm wobble and focus control, the 4Pi system is precise and robust enough for heavy-duty production use. With all instruments sharing the same (theta, phi), we make performance simulation a reality, and shot control & offset a distinct possibility. It suffices to say the 4Pi system embodies the current state-of-art in capsule metrology that will keep driving fusion ignition to higher and higher yield in the foreseeable future. Other novel metrology techniques will also be discussed.

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Presentation Type: Oral

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How we got thermonuclear fusion, without fission

O. A. Hurricane[1]

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For many decades, the running joke in fusion research has been that ‘fusion’ is thirty years away and always will be. Yet, these past few years we find ourselves in a position where we can now talk about the milestones of burning plasmas, fusion ignition, and target energy gain greater than unity (scientific breakeven) in the past tense. Fusion is no longer a joke! Yet getting to fusion ignition, the tipping-point of thermonuclear instability resulting in an explosive increase in ion thermal temperature and fusion reaction-rate, and scientific breakeven (yield > deposited laser energy) has not been easy. In this plenary talk, I will discuss our present understanding of the physics and technological challenges surrounding ignition and Gain as well as highlight some outstanding problems that still need resolution.

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Oral presentation

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Target Manufacture for Shock Tube Geometries and Astrophysical Shock Experiments.

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Manufacture techniques are presented to produce complex high power laser targets used in a range of experimental parameter studies including the understanding of Rayleigh-Taylor instabilities and the experimental verification of astrophysical phenomena. Some of the complex components that are produced include multi-layer drive packages with doped plastic that are precision machined with complex modulations (single and multi-mode), foam filled target cavities, foams produced with embedded nano-particulates to simulate astronomical ‘dust’ and precision machined target components as shields and alignment features. Experimental examples are shown with some initial results and characterisation techniques to verify target quality. We discuss the challenges of manufacture and the developments to improve target quality as well as future plans for the development of the range of capabilities in this area.

Presentation Type: Poster
Presenter: S. Irving, sam.irving@stfc.ac.uk, Tel :+44 1235 445415

Nanostructured Targets*

A.A. Jara, A.C. Basaran, N.M. Vargas, F.H. Elsner, and C. Monton

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Targets are one of the main components of high repetition rate experiments. Their design must be specific to the phenomena investigated, the laser parameters, and the diagnostic setup. Due to this, they range in size from micrometers to millimeters and in shape from a layered planar structure to complex 3D structures combining multiple shapes and materials. Another point to consider is that the laser–solid interactions are sensitive to perturbations in the order of the laser wavelength. In this regard, recent experiments showed that targets with textured surfaces, with feature sizes that match the wavelength of the laser, can considerably improve the laser-target coupling efficiency up to five hundred times.

In this presentation, we describe the characteristics of a new set of nanostructured targets fabricated at General Atomics aimed to provide improved laser-target coupling. These targets are made of CH and CD nanowires, nanoparticles embedded in CH nanowires, and nanowires made of metal and non-metal doped CH. We will also describe a fabrication method that allows the PIs control of micro-scale wires arrange design and, therefore, its filling factor (i.e., the ratio between diameter and density of microwires per unit area) for control of the laser-target coupling.

*This work performed under the auspices of General Atomics Internal R&D funding

Presentation Type: Poster

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Characterisation Capabilities of Target Fabrication at Orion

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AWE Target Fabrication capabilities support campaigns that take place within Orion, international collaborations for example with NIF, and are utilised for non-laser components. In this talk I will discuss the techniques and protocols that we apply based on customer requirements. Future characterisation needs and how to meet challenges from principal investigators will be discussed.

Our current capabilities in metrology consist of a Coordinate Measurement Machine, CMM by QVI and white light interferometry with the Zygo Nexview. These provide accurate measurements of assemblies with high accuracy and repeatability. The CMM is predominantly employed to verify complex target assemblies for laser experiments. White light interferometry enables nanometre resolution for depth, surface, and flatness measurements. Ideal for examining features with small depths or surfaces with required surface finish tolerances.

The imaging capabilities currently consists of light microscopy, electron microscopy and X-ray microscopy (XRM). Light microscopy is used for a quick inspection, providing a guiding step for further characterisation. Electron microscopy with the Zeiss Ultra Plus, field emission gun scanning electron microscope (FEG-SEM), is capable of nanometre resolution. The stability of this microscope along with the charge compensator enables imaging of non-conductive samples without the need for coating. The FEG-SEM also has two other detectors for chemical compositional and crystallographic studies. EDS, energy dispersive spectroscopy can reveal changes in chemical constituents or highlight any contaminants that are present. EBSD, elemental backscatter diffraction shows the crystal orientation within a sample. For sub-surface inspection sample preparation would be required. XRM removes the need for sample preparation for sub-surface inspection of samples. XRM reveals voids and density variations in samples. As each technique is complimentary and have their own strengths and weaknesses, a characterisation workflow is designed with customer requirements in mind.

Presentation Type: Oral
Presenter: Jebin Jestine, Jebin.jestine@awe.co.uk, 01189858616

Investigations into PolyHIPE contamination and analysis of low chlorine content foam

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PolyHIPE, a low-density foam doped with chlorine, is manufactured in house at AWE, for use in plasma physics experiments. The foam is produced by making an emulsion which is then heat cured before using Soxhlet extraction to leave a foam billet requiring further analysis and machining. The specification for this material is that pore sizes are no larger than 30 µm therefore, we inspect using X-ray microscopy (XRM) to assess and analyse.

Trails were conducted to produce a PolyHIPE with <30 µm pores however, initial XRM analysis revealed contaminants present in some of the billets after synthesis preventing accurate pore assessment. Work has been conducted to investigate mechanisms to remove the contamination post synthesis, and to investigate low chlorine content PolyHIPE. Both sonication and critical point drying (CPD) were investigated to remove the residual salts. Initial data on analysis of low chlorine systems is presented. We also present use of the Dragonfly ORS software for segmentation of contaminants and identifying voids within the samples.

Presentation Type: Poster
Presenter: Jebin Jestine, Jebin.jestine@awe.co.uk, +441189858616

Hoppe Glass Shell Properties Synopsis*

J. Murray, C.M. Shuldberg, M.L. Hoppe, R. Luo, I. Ruiz, D. Guzman, B. Serrato, L. Aghaian, and F.H. Elsner

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Drop Tower (DT) and Hoppe Glass (HG) shells are frequently used in Inertial Confinement Fusion (ICF) experiments as primary and auxiliary targets. Glass capsules are desirable due to their high strength and low permeability to deuterium/tritium gas mixtures at room temperature. DT glass capsules have been produced and experimentally used for over 40 years. However, they suffer from certain limitations. Larger DT glass shells must travel further down the drop tower tube to reach their full size, and GA's drop tower dimensions restrict the maximum size to 1500 µm. As a result, they cannot be used for the experiments that require glass capsules with larger diameters. Additionally, DT shells suffer from high elemental composition variation capsule to capsule. Discovered in the 1990s by Dr. Martin Hoppe, Hoppe Glass shells introduced new capabilities that made it possible to fabricate capsules with diameters greater than 1mm and more tightly controlled dimensions and chemical properties. After careful consideration, GA has moved away from DT shells to HG shells to supply targets to ICF experiments. The fabrication, metrology, and advantages and disadvantages of HG shells will be discussed in the poster.

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Presentation Type: Poster

Presenter: Joshua Murray, joshua.murray@GA.com, 858-455-3867

Advancements of Complex Target Manufacturing Efforts at the Laboratory for Laser Energetics*

M. J. Bonino, R. F. Earley, T. Cracium, S. Karim, K. J. Lintz, and D. R. Harding

Laboratory for Laser Energetics, University of Rochester

The Target Fabrication Group at the Laboratory for Laser Energetics (LLE) produces approximately 2600 targets annually, with a third classified as complex. Complex target designs from a production perspective are qualified by factors such as the number of components per assembly, multiple process steps per component, and overall assembly time. The demand for complex targets continues to increase year to year, requiring new assembly and metrology processes and forethought to procure innovative systems and equipment, if necessary. With an increased number of requests with complex specifications and longer vendor delivery times for parts, the strategy is to add in-house manufacturing capabilities to not only bridge the gap, but increase our knowledge base within the group to better meet design requests.

This poster describes building and measuring a complex target, using the cone and shell design as an example. The work focuses on techniques for each step per component, including 3D printing, micromachining, metrology, metal depositions, and final assembly—all processes completed in-house at LLE.

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Presentation Type: Poster
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Developments of Gold Boron Thin Liner for LMJ Hohlraum

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In order to prevent Brillouin backscattering during inertial confinement fusion (ICF) experiments at the Laser Mégajoule (LMJ) facility, a gold-boron (AuB) liner hohlraum was developed. In this work, we studied the addition of a gold-boron (AuB) layer inside hohlraum by physical vapor deposition (PVD). This technique called "moulding PVD" consists to directly coat the liner on a two-part half-hohlraum from co-pulverization of gold and boron targets in order to obtain the adequate alloy composition. The objective is to elaborate an AuB liner of about 1.0 µm thick with a controlled and uniform composition of respectively 60%at.-40%at. In this study, we present the first results obtained with this method. In order to achieve the required specifications, various studies had been started, acting on several PVD parameters (pressure, power, sample localization, etc.) and sample preparation for the thickness determination by Scanning Electron Microscopy (SEM). Surface and depth profile compositions were measured by X-Ray Photoelectron Spectroscopy (XPS).

Presentation Type: Oral
Presenter: S. Khieu, sarah.khieu@cea.fr, +33380234000

HDC Leaching Cleaning Experiments*

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High density carbon (HDC) capsules are the primary ablator material used for inertial confinement fusion experiments at the National Ignition Facility (NIF). Recently, HDC capsules have given the highest yields ever achieved at the NIF, including multiple demonstrations of fusion ignition in the laboratory. A key enabler of these experiments has been the development of the 2 µm capsule fill tube assembly (CFTA). Leaching of the silicon mandrel through the 2 µm drill hole is a critical process step in the production of these high yield targets. Improvements have been made to turn what was originally a developmental process into a production process.

Greater understanding of the leaching process has been accomplished through development of a new leaching chamber, reduction in contamination sources, and detailed examination of the effects of drill hole profiles on leaching success. Implementation of a revised low temperature cleaning process has resulted in a yield of effectively 100%. Future work is focused on better understanding of the bubble dynamics inside the capsule during the cleaning process to enhance efficiency. This talk will highlight the experiments and improvements that have led to a >90% yield for the HDC leaching and cleaning process.

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Presentation Type: Oral

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Ignition Target Baseline Design for Indirect Drive Ignition Experiments on the National Ignition Facility (NIF)

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With the achievement of ignition on the NIF, LLNL target fabrication is updating the documentation of physics and engineering requirements for the ignition targets. The ignition target is described as three critical subsystems; the physics package, the thermal-mechanical package and the cryogenic base. The ignition physics package consists of the capsule filltube assembly (CFTA) and the hohlraum, which includes openings for viewing the ice layer within the capsule. The thermal-mechanical package and the cryogenic base support electrical, thermal and gas fill connections to the ignition insert cryostat (ITIC). We will discuss ignition target requirements and how these have been met with current target design, fabrication, assembly and metrology.

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LLNL-ABS-862115

Presentation Method: Oral or Poster

Presenter: Jeremy Kroll, kroll4@llnl.gov, (925)-422-6437

TFM 2024

San Diego, August 25-29, 2024

Boron carbide coatings for internal confinement fusion ablators

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Amorphous boron carbide is an attractive ablator material for next-generation inertial confinement fusion targets. However, the fabrication of boron carbide ablators by physical vapor deposition has proven to be challenging. Here, we describe our recent progress toward the development of a robust process of the fabrication of boron carbide ablators by magnetron sputter deposition. We demonstrate the deposition of ultrathick (20-100 microns) coatings of amorphous boron carbide with close-to-zero residual stress. Our current research focus is on solving the following remaining challenges: relatively low deposition rates and the nucleation of nodular growth defects. We will present results illustrating approaches to solving these challenges.

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Presentation Type: Oral

Presenter: Sergei Kucheyev, kucheyev@llnl.gov, (925) 422-5866

LLNL release number: LLNL-ABS-862126

Abstract Title : Developing Manufacturing Techniches for the Equation of State Campaign

Author: Mark Lament1, Suzanne Ali1, Emma Floyed1, Anna Murphy1, Henry Wong1, Nam Le1, Gino Mercado1

Date 3/21/24

Abstract: Target-Fabrication Team has been developing manufacturing techniques for High Energy Density materials. The Equation of State (EOS) campaign study helium implanted Pb (PbImp) ramp compression experiments.

These targets contribute to in-depth studies of the impact helium bubbles have on the compressibility of materials.

Limitations in the implantation process mean this target is thin in comparison to previous Pb samples as well as two-piece PbImp step sample targets.

The latest Equation of State step samples are manufactured from a single piece of PbImp that is machined down to an incredibly thin and accurate step sample making manufacturing and assembly quite challenging.

The machining and handling of pure Pb at that level of precision and size is crucial and requires special handling techniques. The Equation of State step targets hold the tightest specification for any target build shot at National Ignition Facility (NIF).

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4Pi Wall Thickness Measurement of HDC and GDP Capsules*

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Capsule wall thickness variation is directly linked to hot spot drift and hot spot distortion, both of which redirects energy otherwise available for compression, thus significantly suppressing the neutron yield in ICF implosions. Xray imaging-based wall thickness measurement has uncertainty (150 nm) that is a large fraction of the capsule rejection criteria (350 nm), therefore, a higher precision method is desired. General Atomics utilizes a set of middle- and near-infrared spectrometers on the 4PI system for metrology of wall variation and direct determination of asymmetry between inner and outer surfaces of capsules with respect to its center (P1 parameter). The technique yields high precision (~10 nm) and can be applied to various ablators (HDC, GDP, DLC, plastics). In this talk, we will cover: (1) The difference in metrology approaches and data analysis depending on a capsule's material; (2) Factors affecting the accuracy of measurements; (3) A technique which enables aligning a capsule's P1 with respect to the fill tube.

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Presentation Type: Oral

Presenter: Pavel (Pasha) Lapa, pavel.lapa@ga.com, 858-455-3624

The Development of Compound Parabolic Concentrators (CPC)

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High energy and high intensity lasers are desired for high energy density applications such as particle acceleration and x-ray generation. Steep laser requirements on laser beam quality led to increased facility costs and large beam size propagating through complex amplifier systems caused significant aberrations degrading the focal spot quality and reducing the intensity target. To reduce the cost and enhance the performance of large F/# systems, miniature compound parabolic concentrators (CPC) were implemented in the target design acting as non-imaging focusing optics and are built into the laser target. To compensate for the large ARC spot size, CPC cone targets were utilized at the National Ignition Facility Advanced Radiographic Capability (NIF-ARC) laser to enhance the acceleration of electrons and production of high energy photons.

A series of experiments with CPC cone targets were introduced using the NIF-ARC laser to determine the enhancement to MeV photon generation with CPC cone targets, as compared to flats. From these experiments, a new target design was developed where the CPC cones were used as a new backlighter source to guide ARC beams. Being able to provide high-resolution x-ray radiography is crucial to study hydrodynamic instabilities in the high-energy density regime at the National Ignition Facility (NIF).

The introduction of CPC cones on new target designs brought challenges to assembling microscopic components where the 500 μm opening entrance for the ARC beams are critical to delivering optimal results.

This poster will provide an overview of the CPC cone targets, the assembly challenges involved, and the solutions to overcome these challenges.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

Presenter: N. Lau, Nancy.Lau@ga.com

Omega CylDRT Fabrication Process

J. Lavelle[1], D. Schmidt[1], T. Day[1], N. Christiansen[1], J. Sauppe[1], K. Flippo[1], J. Dowd[1], L. Kot[1], J. Martinez[1], T. Quintana[1], C. Wong[1], D. Ross[1], C. Wilson[1]

[1]Los Alamos National Laboratory

Abstract

LANL is producing single-cylinder implosion targets for use on the Omega chamber at the Rochester LLE. The design of these target are recommended by the physics team, with appropriate approval from the target fabrication team. The construction of the target consists of an internal aluminum plating, with an external coating of Epon, then back-machined into the correct 'cylinder' form. Once produced, these targets are then sent to Rochester LLE where the shot experiment can take place. The poster will cover the manufacturing of the cylinder targets.

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Presentation: Poster

Presenter: Joseph Lavelle, jlavelle@lanl.gov, 505-667-2481

LA-UR-24-23568

Cryogenic Target Diagnostic Band Subassemblies and Target Shielding for Laser Experiments at the National Ignition Facility*

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The target diagnostic band (DB) is a key component to a cryogenic target. Multiple types of cryogenic targets require a diagnostic band subassembly (DBSubA), to complete the assembly for a NIF laser experiment. Targets may also require additional shielding and backlighters to be installed to complete the intended target design. Utilizing precision tooling, Optical Coordinate Measuring Machines (OCMMs) and various adhesive or bond types, components are deterministically assembled.

This poster will present the complex builds, assembly improvements including tooling developed and verification through metrology.

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Presentation Type: Poster

Presenter: L. Leal, Luis.Leal@ga.com

Changes in Fill Tube Curvature during Target Assembly

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NIF targets used for ICF experiments are marvels of design and manufacturing precision, composed by a myriad of components carefully and precisely assembled with accuracies no larger than few micrometers in most cases. When individual components deviate from these strict specifications during the assembly process, they can induce target failure. An integral component essential to ICF targets is the capsule-fill-tube assembly. This assembly involves bonding the capsule to an ultra-thin fused silica tube, through which the T_2+D_2 mixture fuel is injected into the capsule prior to the NIF shot. The filling tube is bonded to a larger fused silica capillary, about 150 O.D. coated with a few micrometers thick polymeric coating. Only tubes with the utmost straightness are suitable for assembly. Even slight curvatures can lead to unwanted stresses, potentially causing misalignment of the capsule and resulting in clogging or leaks during the filling process. Despite manually qualitatively sorting each tube for straightness prior assembly, it has been found that the treatments the tubes undergo once attached to the capsule can alter their curvature. Filling tubes initially deemed perfectly straight may become too curved, making them unsuitable for targets. Here, we propose a metric to assess the degree of curvature of filling tubes and gauge their changes in curvature caused by the standard thermal processing methods employed in target assembly. In addition, we suggest alternatives to mitigate tube curvature, ensuring they conform to specifications following assembly in the final targets.

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Preferred method of presentation: Poster

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92-5424-2047

Capsule with controlled roughness for turbulence laser experiments

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In prevision of future experiments at the Laser Mégajoule (LMJ) facility dedicated to the study of turbulence phenomena during implosion of a DT target, we develop a hydrogenated amorphous carbon (a-C:H) capsule with a controlled roughness on its inner surface.
To achieve this goal, we use a plasma treatment to etch outer surface of a poly-α-methylstyrene (PAMS) mandrel in order to degrade its roughness. The second step consists in synthetizing a plasma polymer (GDP) on this rough surface before the thermal depolymerization of the mandrel.
In order to validate this approach, we have first studied the effect of a plasma treatment made by a plasma furnace on PAMS thin films realized on silicon wafer thanks to an atomic force microscope imaging the surface of samples. This study was done for different etching gas (argon, air, argon/air) and treatment conditions (pressure, RF power and duration). After the selection of the best parameters, the etching process was transferred in a GDP coater to study its effect on PAMS mandrels. The adjustment of plasma treatment has permitted to obtain translucid PAMS showing a high roughness of several hundred nanometers on the outer surface. Finally, after the GDP step and the thermal removal of mandrel first a-C:H capsule with a high roughness inner surface is obtained.

Key words: Plasma etching, atomic force microscopy, glow discharge polymerization.

Presentation Type: Poster

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Use of Dragonfly Software for HDC Drill Hole Analysis*

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Tomographs of HDC capsules is a primary metrology technique used to gain important information on the inside of capsules. The Dragonfly software utilizes this information and has proved useful to produce a high-resolution three-dimensional representation of the drill hole. Based off the representation, that data is then ran through code to do a more in-depth quantitative analysis of the drill hole profile. Data from this can be helpful for a multitude of reasons, from giving physics a better mass deficit for shot simulation, to assisting the build team when doing a fill tube attachment.

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Presentation Type: Poster

Presenter: Benjamin LeVay, benjamin.levay@ga.com, 858-455-3105

Title: Development of Mixed Foams for NIF Hohlraum Wall Heating Experiments

Authors: Christine Liberatore, Ted Baumann, Monika Biener, Massimiliano Ferrucci, Lauren Hobbs, Peter Graham*, Kevin Driver, Warren Garbett*, Steve Langer, Dean Rusby, Shon Prisbrey

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ABSTRACT

The Hohlraum Wall Heating Campaign is investigating the interaction of radiation and mix relevant to hohlraum physics. After 27 shots over 3.5 years, they have recently expanded their data set on planar and RT mix (rippled) interfaces to include mixed interfaces. This new physics package design required the fabrication of novel hybrid foam structures ("chunk" mix and "atomic" mix) in which a high-Z foam component is mixed into a low-Z foam matrix to create two distinct types of inhomogeneities in the bulk foam architecture. In the chunk mix foams, Ta_2O_5 foam particles (or "chunks") of known size are uniformly dispersed into a low-density CH foam, while, in the atomic mix foams, the Ta_2O_5 is deposited as a conformal layer on inner surface area of the CH foam using atomic layer deposition. Both types of hybrid foams were characterized by SEM and radiography to determine the uniformity of the dispersed high-Z phase and its interaction with the low-Z support matrix. Billets of both foam types were also tested for machinability as these components are part of a larger foam physics package assembly. This presentation will detail the fabrication processes and analysis performed to successfully meet the physics requirements of this campaign.

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Presentation Method: Oral/Poster

Presenter: Chris Liberatore, Liberatore1@llnl.gov

Two-photon polymerization and coherent anti-Stokes Raman spectroscopy for developing fusion targets

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Laser-direct-drive (LDD) inertial confinement fusion (ICF) involves the implosion of a spherical-shell target containing a thermonuclear fuel layer of cryogenic deuterium–tritium. 3D printing via two-photon polymerization (TPP) provides a unique capability of flexibly fabricating complex structures over 1D-3D dimensions and μm-cm scales with resolutions below 100 nm. In the past years, we have developed practical TPP approaches to fabricating various target structures for ICF, including low-density foams, plastic capsules, ablators, target filling tubes, plasma lenses, *etc.*, with controlled geometries, profiles, and qualities. At the same time, we need to overcome several challenges, including mechanical (e.g., stage shift, vibration, resonance, backlash, mirror inertial, and resin viscosity), optical (e.g., aberrations, beam quality, scattering and absorption, photobleaching, optical alignment, and thermal effects), digital (e.g., aliasing), and chemical errors (e.g., incomplete polymerization, residual monomers, formation and diffusion of radicals).

At the same time, fuel capsules for ICF experiments should be inspected for surface and wall-embedded defects. Plastics materials [e.g., for example polystyrene (PS)] are the common materials used to make fuel capsules. However, during their manufacturing, capsules usually contain defects (vacuoles) embedded inside the shell walls, which may distort the implosion processes and influence the ICF performance of the capsules. The size of vacuoles is usually in a range from 100 to 2000 nm. Coherent anti-Stokes Raman scattering (CARS) microscopy offers the capabilities of inspecting and characterizing the capsule defects. The CARS process involves the interactions of four waves designated as pump (p), Stokes (s), probe (p'), and anti-Stokes, where pump and probe waves are usually fixed at the same frequency ($\omega_p = \omega_{p'}$). When the beat frequency (ω_p-ω_s) between the pump and the Stokes beams is matched with resonant vibrational frequencies Ω_{vib} of molecules, a resonant enhancement of the third-order nonlinear optical process occurs and greatly promotes the imaging sensitivity with chemical selectivity. CARS imaging has been used for analyses of the fuel capsules with advantages of 1) 3D sectional imaging capability with no requirement of fuel capsule rotation; 2) high sensitivity to PS capsules which have rich C-H vibrational groups; 3) no additional capsule preparation required; 4) high spatial resolution down to 300 nm; 5) fast imaging within minutes; and 6) no damage to the fuel capsules inspected. The CARS imaging is also being extended to image the distribution of the hydrogen isotopes (hydrogen and deuterium at icing temperature) inside the fuel layer of the capsules, which is expected to provide greater resolution and sensitivity than the previously used technique, tunable infrared diode laser spectroscopy, to address an important question that could not be diagnosed until now.

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

Presentation Type: Oral

Presenter: Yongfeng Lu, E-mail: ylu2@unl.edu, Tel: 402-617-3509

Fabrication and Characterization of Shimmed Capsules for OMEGA Experiment*

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In a recent polar-direct-drive (PDD) experiment conducted on the OMEGA laser system, deuterium gas-filled, shimmed CH capsules were utilized. These capsules are designed with a unique structure, featuring a thinner wall at the equator and thicker wall at the poles. This design, under uniform laser intensity applied to the target, leads to faster acceleration of the thinner wall compared to the thicker one. Consequently, this results in asymmetric compression and nonuniformity during the implosion process. Understanding and addressing the causes of this asymmetry is crucial for developing strategies to correct implosion asymmetries. In this poster, we provide a comprehensive overview of the process involved in fabricating and characterizing the shimmed capsules. This includes the challenges encountered in utilizing a glow discharge polymerization coating process alongside a laser marking method. Additionally, we delve into the enhancements made to deuterium gas retention in the capsules by introducing an atomic layer deposition (ALD) gas barrier layer. A noteworthy feature of the shimmed capsules is the inclusion of a 200 nm laser fiducial mark, which remains visible through the ALD layer, ensuring accurate capsule orientation during the target mounting process for fill and shot in the OMEGA system.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Poster

Presenter: Rain Luo, rain.luo@ga.com, 858-455-2265

LLNL-CONF-862130

Abstract Title: Measuring bond strength of Capsule to Fill Tube Assembly (CFTA) at cryogenic temperatures

Author(S): Daniel Malone, Chantel Aracne-Ruddle, Parminderdeep Singh

Date: March 18, 2024

Abstract:

Recent unexpected failures of capsule to fill tube assemblies fielded for NIF have prompted a revisit to study the behavior of alternative glue options and surface pretreatments to increase adhesion strength and decrease failure. The bond strength of adhesives used in NIF targets have historically been tested by a lap sheer method on Instron. However, the behaviors of materials may differ when used in such small amounts as on a CFTA as well as at different temperatures. A method and fixturing has been developed to mount a CFTA to an Instron for more accurate measurements and the ability to cool the bond with liquid nitrogen. CFTAs with 2, 5, and 10 um diameter fill tubes have been tested at 20 C and -196 C. The CFTA bond has been measured to be stronger at cryogenic temperatures. This newly developed method has shown reproducible results for measuring the bond strength of NIF target CFTAs.

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Evolution of Equation of State (EOS) Target Design and Assembly*

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The EOS (Equation of state) targets provide a way to measure the basic properties of matter at the highest pressures possible in a repeatable way. Hundreds of materials have been measured using EOS targets. This has provided a way to test and prove theories about different materials essential to the study of many applied science programs at LLNL including white dwarf stars, black holes, and aging plutonium for the nuclear deterrent program.

The design of the EOS has changed to accommodate the location of the catcher within the NIF. A few variations have been produced and assembly has evolved. Techniques and challenges will be presented in this poster.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

Presenter: T. Marcotte, Thomas.Marcotte@ga.com

LLNL-ABS-862375

Overview of GA Component Fabrication Supporting Ignition Targets*

M.P. Mauldin, K. Clark, L. Aghaian, J. Stutz, A.C. Forsman, T. Nunn, M.O. Havre, J.R. Wall, L.J. Inandan, W.A. Vakki , J. Gaut, R. Espinosa, V. Ho, A. Castillo, J.C. Villanueva, E.L.Alfonso, W. Sweet, J.W. Crippen, N.G. Rice, C. Kong
E. Marin,T. Phipps, B. Cates, J.A. Robles, E. Gaut, M.P. Farrell, F.H. Elsner

General Atomics (GA) supplies a variety of components and subassemblies to Lawrence Livermore National Laboratory (LLNL) in support of cryogenic targets fielded at the National Ignition Facility (NIF). These components are fabricated through novel precision fabrication techniques including but not limited to precision machining, electroplating, physical vapor deposition, laser machining, and precision assembly. There have been several process changes to improve efficiency, consistency, and robustness of processes and delivered components. Ignition has driven a focused effort between LLNL and GA to further these improvements so experiments on NIF perform as expected. This presentation is an overview of many GA processes and associated components that have been delivered to LLNL on the road to successful ignition experiments on NIF.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Presentation Type: Oral
M. Mauldin; michael.mauldin@ga.com; 858-455-3118

Fully additively manufactured wetted foam capsule for inertial confinement fusion

W.P. Moestopo[1], Y. Rho[1], M. Mettry-Yassa[1], J.J. Schwartz[1], T.R. Prisk[1], J. Sater[1], G.E. Kemp[1], J.S. Oakdale[1], X. Xia[1]

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As the societal need for more sustainable sources of energy increases, the recent demonstration of the first-ever fusion ignition in a laboratory has renewed interests in scaling up the inertial confinement fusion (ICF) technology for commercial energy generation. To address the technological gap that exists in mass-producing high quality ICF fuel capsules, we demonstrate the fabrication and testing of fully additively manufactured (AM) foam-lined capsules using a commercial two-photon lithography machine. We will present our recent advancements in improving printing speed and printing foam lining inside our capsules, and we will discuss results from metrology and foam wetting experiments. AM foam capsules were fielded for polar-direct drive experiments on the National Ignition Facility, and we will discuss the unique design considerations involved. The capabilities enabled by our process will shorten the turnaround time between each target design iteration and enable the exploration of more complex physical interactions between the laser, capsule, and fuel.

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Presentation Type: Oral
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LLNL-CONF-862119

Abstract Title: Fabrication of the First Lead and Depleted Uranium Laser Entrance Hole (LEH) Inserts for the Viewfactor Campaign

Author(S): Weston Montgomery, Scott Vonhof, Joe Burke, Zachary Rodriguez, Marilyn Schneider, Hui Chen

Date: 2024-MAR-22

Abstract:

The hohlraums used in inertial confinement fusion (ICF) experiments at the National Ignition Facility (NIF) typically utilize two annulus-shaped parts. The inner diameter of these annuli functions as the diameter of the LEH, so these components are called LEH inserts. Typically, LEH inserts are made of Au to match the hohlraum material. In 2022, the rise to peak power and the Au bubble growth were both studied in a pair of experiments. These experiments utilized a Viewfactor target design with an open side and an LEH side. The "open side" facing an xray diagnostic called DANTE-1. The other side utilized an LEH insert made out of Pb and it had two Pb-coated polyimide windows. The Au bubble growth was observed through these coated windows, and it was compared between the two experiments (nominal rise and slow rise). These experiments yielded good results. The Pb LEH insert was laser cut by target fabrication at Lawrence Livermore National Laboratory (LLNL). The polyimide windows were Pb coated by the vacuum processing laboratory (VPL) at LLNL. Later experiments instead utilized DU LEH inserts which were laser cut and polished by target fabrication at LLNL, and the polyimide windows were DU coated by the VPL.

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

Developments in HiZ PP Fabrication

Anna Murphy, Henry Wong, Nam Lee, Gino Mercado, Matt Arend, Jeff Stanford, Todd Matz, Sullivan Figursky, Jeremy Kroll

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ABSTRACT

The High Energy Density (HED) Materials Physics program consists of a series of subcampaigns to investigate the structure and strength of relevant materials at high pressure regimes. Within the program there are a series of targets using Plutonium as the material of interest. The fabrication and assembly process we typically use for the production of lower-Z physics packages require several adjustments to accommodate safety requirements of working with Plutonium.

Improvements in the machining capabilities allow increased precision in thickness of the sample, and improvements in coating robustness allow removal of the sample/pusher glue bond which has allowed the physics drive to maintain better control and probe new regions of the equation of state. We have also successfully implanted helium into the metal matrix, based on an adjusted procedure used for Pb samples previously, which will allow investigation into the effects of aging plutonium in material structure and strength.

We will discuss HiZ HED target requirements and how these have been met with current target design, fabrication, assembly and metrology.

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Release #: LLNL-ABS-862274

Presentation Method: Oral/Poster

Presenter: Anna Murphy, Murphy78@llnl.gov

ManTech Livermore Target Fabrication Overview

N. Nijem , T. Bernat , N. Cahayag, R. Chow, A. Pastrnak , T. Siv , D. Skilling

ManTech Livermore Laboratory

ManTech Livermore Laboratory provides target components and assemblies that enable ignition and high energy density experiments. ManTech's extensive capabilities for target fabrication includes precision machining, physical vapor deposition, organic coatings, materials development, precision assembly, and characterization. These capabilities are continuously developed to meet target fabrication customers' evolving target designs and specifications. Target fabrication examples will be presented to illustrate the wide range of targets ManTech Livermore Lab provides.

Presentation Type: Oral

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LLNL-ABS-862994

LAWRENCE LIVERMORE NATIONAL LABORATORY

Nikroo A - HiZ and Petals Abstract.pdf

A. Nikroo, S. Hayes, J. Hackbarth, W. York, D. Behne

April 12, 2024

25TH TARGET FABRICATION SPECIALISTS MEETING
San Diego, CA, United States
August 25, 2024 through August 29, 2024

High Z and Petal Defect Identificaiton and Metrology in High Density Carbon Capsules for Ignition Shots on NIF

A.Nikroo, S. Hayes, J. Hackbarth, D. Behne, W. York

Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA, USA 95550

Capsule quality is a major parameter in obtaining the desired ICF implosions. Improvements in capsule quality in terms of voids and surface pits combined with changes in the implosion drive allowed the seminal achievement on NIF of 1.3MJ of neutron yield from the N210808 implosion at 1.9 MJ laser energy. However, attempts to repeat this result and subsequent changes to the drive and ice layer were unsuccessful for more than a year due to defects in subsequent batches. We describe here the systematic examination and metrology focused effort that led to the proper identification of these defects and their eventual elimination. Capsules free of such defects have been since used to achieve ignition at 1.9MJ laser drive as well as record yields (up to 5 MJ netron yield) on NIF at 2.05MJ and 2.2 MJ of laser drive.

ABSTRACT

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-765894.

Method of presentation: Oral

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Keywords: NIF, Target Fabrication, Manufacturing, Metrology

LLNL-ABS-863529

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Nikroo_sub micron glue thickness measurements and uncertainty Abstract

A. Nikroo, J. Mcnaney, J. Eggert, C. Kumar, S. Schiaffino

April 24, 2024

25TH TARGET FABRICATION SPECIALISTS MEETING
San Diego, CA, United States
August 25, 2024 through August 29, 2024

Sub-micron Glue Thickness Measurement and Uncertainty Determination for Dynamic Material Experiments on NIF

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ABSTRACT

Dynamic materials experiments at the National Ignition Facility require targets which include precision planar components in the so-called physics package. The physics package contains the sample material of interest usually sandwiched between the ablator or the pusher, and the window. These components are glued together at ~<500-1000 nm tolerance in thickness and uniformity to allow such experiments to that drive the sample on the intended trajectory in the density/pressure phase space, providing invaluable information for the stockpile stewardship program. Failure to produce samples with such small glue gaps, or samples that do not meet stringent, sub-micron, tolerances, can have a detrimental impact on the experiment. Such thin glue layers and dimensional tolerances need to be verified by precision measurements with uncertainty, much better than the allowed <500-1000 nm for each glue gap or dimensional tolerance. In this paper, we review the double sided interferometric technique developed for measuring the form of individual parts as well as glue layers between such opaque stacked samples, and then discuss in detail the effort to quantify and validate the uncertainty in the measurement which is in general~ 100 nm dependent on the details of the sample stack.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-765894.

Method of presentation: Oral

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Keywords: NIF, Target Fabrication, Manufacturing, Metrology

High Precision Machining of Hard-to-Cut Material with the Ultrasonic Tooling Systems*

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This study investigates the machining method of ultra-precision diamond turning techniques applied to hard-to-cut material such as stainless steel, iron and tungsten. These materials are traditionally challenging to machine to a high precision specification due to the wear and tear of the conventional machine tools used. However, with the application of a specified kilohertz (kHz) ultrasonic vibration in conjunction with a single crystal diamond tool, aka Ultrasonic tooling system, we successfully achieved very fine surface "mirror like" finish on a flat and cylindrical surface. In addition, patterning a sine wave on the material was also achieved. The difficulties encountered in machining hard-to-cut materials are primarily attributed to their exceptional hardness, abrasion resistance, high strength at various temperatures, superior thermal conductivity, and resistance to oxidation and corrosion.

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Presentation Type: Poster

Presenter: Alberto Nunez, alberto.nunez@ga.com, 858-455-2816

Direct laser drive approach that enables sub-megajoule IFE targets*

S. P. Obenschain[1], M. W. McGeoch[2], A, J. Schmitt[3], and M, C. Levy

[1]LaserFusionX Inc., [2]Plex LLC, [2]Naval Research Lab (retired), [4]AE Blue Capital

The combination of direct drive and the deep UV (193 nm) broad bandwidth light (10 THz) from the argon fluoride (ArF) laser is predicted to enable the fusion energy gains (>100) needed for power production with less than 1 MJ of laser energy. Laser fusion power plants using 1/3 of the laser energy demonstrated by the National Ignition Facility appear to be feasible. We will discuss the high gain target physics, the required targets, and advances in the high energy ArF laser technology needed for inertial fusion energy (IFE).

*This work is presently supported by LaserFusionx Inc. It was previously supported by the U.S. Department of Energy.

Presentation Type: Oral
Presenter: Stephen Obenschain, StephenObenschain@LaserFusionX.com

Capabilities and Challenges of the Target Fabrication Science team at AWE/Orion

C, O,Connor[1], L, Brimble[1], E, Hancox[1], J, Jestine[1], J Milton[1], R, Sealey[1], R, Taylor[1], T, Tipler[1]

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The Science Team in Target Fabrication works to deliver high class capabilities to support campaigns in internal (Orion) and external facilities (e.g. NIF, CLF). The team is comprised of Characterisation, Chemistry and Coatings specialists and technicians with a range of equipment to deliver against customer requirements. Recently efforts have been out into re-establishing knowledge on existing capabilities, commissioning new equipment and investigating novel materials. This poster will present the current capabilities of the Orion TF Science team, show where we are planning to take the team in the future and what challenges we are actively researching.

Presentation Type: Poster
Presenter: Dr. Colum O’Connor, colum.o’connor@awe.co.uk, +441189858307

Re-establishing and Improving Chemistry and Coatings Capabilities at AWE/Orion

C, O'Connor[1], E, Hancox[1], R, Taylor[1], T, Tipler[1]

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In recent years the Science team in AWE's Target Fabrication Group has undergone a number of significant personnel changes while being challenged by our customer to deliver more complex products. We are working to re-establish the team as a center for expertise in this area while also advancing beyond our minimum expected capabilities. This presentation will discuss the current team capabilities, the challenges we have been set by our customer, and improvements the team is investigating.

Our chemistry team have had well established long running processes fail to work, the coatings and characterization teams had experienced staff move onto other roles. In this presentation I will discuss what happened when the colloidal silica process we rely on to provide a coating for optics fails without a clear explanation. Alongside investigating such a critical process, the chemistry team has been investigating production of low-density foams and utilizing new critical point dryers. The coatings team has been mainly focused on re-establishing capability due to the loss of established staff members. We are able to confidently perform gold coating processes and are investigating more complex systems such as multi-layered and more adventurous coating materials. The Science team are working hard to meet current and future challenges and we are keen to share our successes and seek help with the things we cannot solve ourselves.

Presentation Type: Oral
Presenter: Dr. Colum O'Connor, colum.o'connor@awe.co.uk, +441189858307

Defect Detection for ICF Capsules using Deep Neural Networks*

D. Orozco, M. Quinn, B. Sammuli, C. Kong, A. Allen, S. Pajoom, K. Sequoia, M. Ratledge, and M.P. Farrell

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In the pursuit of achieving optimal implosion mechanics, the type, size, and distribution of capsule defects play a pivotal role in maximizing neutron yield in inertial confinement fusion (ICF). Capsule metrology produces high quality image datasets that require effective analysis to guide capsule selection. Manual review of these images by human operators proves to be challenging and labor-intensive. To address this challenge, we have successfully applied deep convolutional neural networks (CNNs) to the problem of defect classification on interferometer data. However, generating the labeled data required for training these models can be costly and poses its own challenges. Unsupervised machine learning methods are employed to assist in the initial labeling of these datasets and transfer learning is used to reduce the amount of data required, thus mitigating the associated costs. By integrating trained CNNs into the analysis pipeline, our implemented solution streamlines the defect detection process, reducing intensive labor requirements and accurately producing capsule defect statistics.

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Presentation Type: Poster
Presenter: David Orozco, orozcod@fusion.gat.com

Target Production in Support of Z Pulsed Power Experiments*

R.R. Paguio, K. Tomlinson, J.L. Taylor, G.E. Smith, R.R. Holt, W.D. Tatum, M. Rich, K. Perkins, J.D. Vocke, T. Neal, H. Huang, C. Monton, G.M. Wier, W.S. Sweet, N. Langley, M.P. Mauldin, J.T. Tomlin, M.P. Farrell

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Pulsed-power accelerator technology offers an efficient, robust, and cost-effective approach to achieving high-energy-density states of matter. By directly driving targets with mega-amp generated magnetic fields, experiments can probe material behavior at millions of atmospheres of pressure and also generate conditions suitable to study inertial confinement fusion. These targets pose unique fabrication challenges in terms of their size, tolerances, and the materials involved. They share many similarities with indirect and direct drive laser targets and advances made for one platform are relevant to the others. This talk will present an overview of several classes of Z-Machine targets, the advancements made to fabricate them, and the experimental results they enabled. These targets include cylindrical and planar targets for dynamic material property (DMP), MagLIF, MagLIF Cryo, Double Cylinder, DECEL, Radiation Effects Science (RES), Opacity, PDV (Photonic Doppler Velocimetry), PECOS Laser, and Inertial Confinement Fusion (ICF) experiments.

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Presentation type: Oral

Presenter: Reny R. Paguio, rrpagui@sandia.gov, ph 505-845-7762

4PI Pre-Screen Process Improvements*

S. Pajoom, P. Lapa, D. Orozco, C. Kong, K. Sequoia, M. Quinn, M. Ratledge

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Capsule selection is critical in Inertial Confinement Fusion (ICF) research aimed to reduce hydrodynamic instabilities and asymmetry of implosion during laser ablation of the target. Hydrodynamic instabilities lead to the degeneration of the hot spot that effects yield amplification empowered by alpha particle heating. A hollow shell made of High-Density Carbon (HDC) is amongst the most popular ablators due to the higher density, sphericity, and chemical and physical stability of the ablator. In these targets, defects usually emerge on the surface as hollow conical intrusions or pits, or cavities inside the ablator's wall known as voids. Moreover, the wall thickness variation of the ablator is another cause of the asymmetry of implosion leading to hydrodynamic instabilities. General Atomics' Diagnostic Center of Excellence designed and executed a metrology 4PI station with 11 axis and several instruments to allow coordinated integrated metrology on fusion targets. Pre-screening is a process change that was adopted to focus efforts in processing and metrology on targets meeting specifications rather than the entire batch of capsules. In this pre-screen process, capsules are measured and ranked upon arrival based on physical specifications before laser drilling process. Therefore, only favorable targets would go through laser drilling, leaching, and metrology steps. This poster reviews the improvements in the pre-screening process such as robotics, automation, and use of machine learning in defect analysis in 4PI metrology in capsule selection for production of ICF targets.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Presentation Type: Poster

Presenter: Shahin Pajoom, Shahin.pajoom@ga.com, 858-455-4550

Overview of Diagnostic Assemblies in a Complex Hydro Target*

D. Paras[1], S. Stadermann[2], D. Martinez[2], S. Khan[2], C. Santos[2]
M. Arend[2], R. Vargas[2], D. Casaray[2]

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With the rising complexity of target assemblies built for the National Ignition Facility (NIF), targets are constantly evolving by developing new target designs and diagnostics to meet new experimental goals and requirements.

Target experiments for the HED Complex Hydro program, study complex hydrodynamics phenomenon using Advanced Radiographic Capability (ARC). Target assembly consists of several precision components, challenging machining requirements, and highly complicated assembly processes. These target experiments require micron accuracy in metrology and alignment to meet precise specifications for ARC.

This poster will focus on the process of specific diagnostic assembly requirements that involves installing a 13 μm diameter tungsten wire that will image the driven physics package, precision alignment, and delicate handling installation of the physics package in a hohlraum and improving ARC performance by implementing diagnostic configurations on the target assembly.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster
Presenter: D. Paras, Danilo.Paras@ga.com

Fabrication of Metal-to-Metal Interface Targets for Material Strength Experiments*

A. Pastrnak, R. Cahayag, R. Chow, T. Siv, D. Skilling, J. Streit

ManTech Livermore Laboratory

Dynamic strengths of materials at high temperatures and pressures are inferred from the Rayleigh-Taylor instability growth at an accelerated rippled interface between a lower and a higher density material. Mechanically bonding machined rippled surfaces often results in an uneven glue bond with defects due to the machined interface imperfections, and for the case of two opaque metals the bond is difficult to characterize. Thick and uneven glue bonds with voids at the interface may lead to shock wave reverberation, energy loss, and heating during compression.

Physical vapor deposition (PVD) was utilized to deposit up to 12 microns of one metal directly onto the rippled surface of the other, filling the machined perturbation. The excess coating is machined flat, and an additional layer of the same material is bonded to the flat surface. The resulting target has two metals in intimate contact with a sub-micron glue bond that is spaced away from the interface. This method also allows characterization of each layer's thickness and the morphology of the interface that is more accurate than characterizing two mechanically mated layers.

*In collaboration with Lawrence Livermore National lab

Presentation Type: Poster

Presenter: Austin Pastrnak, 925-239-1337 (Office), 925-297-5693 (Cell)

Working to Improve the Dimensional Quantification of Target Metrology from X-ray CT Imaging

Brian M. Patterson, Derek W. Schmidt, Theresa E. Quintana, Nikolaus S. Christiansen, Patrick M. Donovan

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Dimensionally accurate measurements using X-ray CT to the accuracy and precision needed for Target Fabrication is an extremely challenging problem. Many in this community have been exploring various aspects of these challenges. These challenges include investigating X-ray attenuation variations (lack of compositional analysis or accuracy), interaction of polychromatic X-ray sources upon the specimen, phase contrast artifacts, resolution and voxel reconstruction accuracy, segmentation issues and far many others.

As the schedule for most pieces/parts used require that they are quickly assembled, shipped, and shot, little time is available to perform a more thorough analysis of the metrology process. Recently, we machined outer ablator parts for a double shell target with intentionally, less than ideal specifications to enable our exploration of our capabilities in identifying and measuring these intentional issues. We will also report on initial efforts in the use of a phase contrast artifact reduction process.

LA-UR-24-23598

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Presentation Type: Oral
Presenter: Brian M. Patterson, bpatterson@lanl.gov, (505) 606-0831

Thin Film Metrology and Processing Improvements at Luxel Corporation

B. Paul, B. Zeiger, R. Smith, I. Brown, T. Ayers[1]

[1] Luxel Corporation

Thin polymer, metalized polymer, and metal-only membranes provide crucial optical and gas barrier components for laser targets. Evolution of the target design space, both with tighter tolerances and into complex geometries, has increased the need for precision metrology and manufacturing of these components. To meet these needs, Luxel has added a suite of new metrology instruments and laser machining capability. New instruments include a white light interferometer for measuring 3D profiles and areal surface roughness, a scanning electron microscope with energy-dispersive spectroscopy capability for high-resolution imaging and material analysis, an optical ellipsometer for non-destructive mapping of membrane thicknesses, and pressurization test capability up to 20 atm. In addition to summarizing the new instruments, we present examples of designs enabled by the new capabilities.

Presentation Type: Poster
Presenter: Brett Paul, brett.paul@luxel.com, 360-378-4137

Thin film (tent) preparation and Target Tenting in Support of Production and R&D Efforts*

A. Perez, K. Bigelow, J. Jensen, J. Florio, M. Aggleton

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The tent line is one of multiple unique production lines employed to produce extremely delicate and repeatable subassemblies for laser targets. Thin formvar "tent" films are made to specification and applied to Thermal Mechanical Packages (TMPs) used to cradle the target capsule between two hohlraums halves. More recently tent films are also used in both cryo and warm targets to support components such as foam cylinders. The assembly line equipment must be substantially maintained to minimize the likelihood of particles from being present or landing on the formvar tents. The poster being presented will provide an overview of the tasks performed to ensure the highest quality of tents are used in each target, common challenges and tent applications to support R&D and novel targets.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

Presenter: A. Perez, April.Perez@ga.com

Overview of New GA Machined Target Component Designs*

T. Phipps, M. Mauldin, E. Gaut, F. Silva, V. Ho, J. Robles, C. Helmlinger, J. Shepler, M. Stapleton, R. Espinosa, A. Nuñez, M. Vu, E. Peterson

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Precision-machined components have played a critical role in experiments related to inertial confinement fusion (ICF) and high energy density physics (HED) experiments at Lawrence Livermore National Laboratory's National Ignition Facility (NIF), The Laboratory for Laser Energetics OMEGA and OMEGA-EP laser facility, and Sandia National Laboratory's Z Facility. CPM's current capabilities include 4-axis lathe turning, 5-axis milling, electro-plating, and casting of pure and doped plastics. These capabilities have produced a variety of parts furthering multiple fields of study. These components include materials such as: Cu, Au, Al, Boron Nitride, Stainless Steel, Pb, Shapal, SiO_2, LiF, as well as aerogels and foams. This presentation will highlight recent novel components that have been fabricated and delivered in support of the ICF and HED community.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Poster
Presenter: Taylor Phipps, Taylor.Phipps@ga.com, 858-909-5097

Assembly of Visar and 1DConA ESPADA targets for the HED ESPADA Campaign

D. Ponce[1], J. Jensen[1], K. Bigelow[1], S. Stadermann[2]

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In 2023 the target fabrication assembly team began fielding target requests for a new high energy density (HED) campaign, delivering precisely built target assemblies for demonstrating and measuring confined plasma jets to validate code predictions. The VISAR and 1DConA Espada targets are two of the more challenging targets to assemble with extremely delicate components. This poster will present the challenges and solutions including tooling and techniques utilized to provide a viable target to the National Ignition Facility in support of the ESPADA campaign.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation Type: Poster

Presenter: D. Ponce, Darrold.Ponce@ga.com

Overview of Machine Learning Applications in ICF Capsule Metrology*

M. Quinn, D. Orozco, B. Sammuli, C. Kong, A. Allen, S. Pajoom, K. Sequoia, M. Ratledge, W.S. Sweet, K.J. Boehm, and M.P. Farrell

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The amount of capsule metrology data continues to expand in size and complexity due to ever-increasing experimental shots and advancements in inspection techniques. The data is necessary to maximize fusion yield, but the amount of daily acquired information is outpacing the ability for scientific staff to review the statistics, necessitating high throughput automated analysis. These methods need to be exceedingly accurate, flexible in variations to data quality, and robust to changes in interpreting results. There have been several opportunities to leverage machine learning algorithms to enhance fabrication procedures, improve characterization, and monitor equipment health. This talk provides an overview of the machine learning methodologies that have been applied by General Atomics, such as Bayesian Regression, Shellnet's object detection, k-means clustering, feature classification, and dimensionality reduction. Additionally, these algorithms are used with case examples throughout different areas of target fabrication, including high density carbon tomography and topography data, plastic mandrel synthesis data, atomic force microscopy data, and laser drilling data.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and General Atomics Internal Research and Development Funds

Presentation Type: Oral

Presenter: Matthew Quinn, Quimat@ga.com, 858-455-4105

Foam Characterization at LANL Using Computed Tomography

Theresa E. Quintana, Brian M. Patterson, Jason Benkoski, Camille Wong

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Foam characterization is constantly requested at Los Alamos National Laboratory (LANL). X-ray Computed Tomography (CT) is used to check for foam consistency, voids, placement, volume fraction and particle size. Foams are CT imaged and then rendered with 3D software. The process of 3D rendering is a multi-step process that can be labor intensive depending on the information requested. CT is used to quantify porosity and assure foam consistency. Ultimately, CT characterization gives the Principal Investigator a clearer understanding of end performance.

Presentation Type: Poster
Presenter: Theresa E. Quintana theresa@lanl.gov, 505-665-1336
LA-UR-24-23754

ASSEMBLY AND CHARACTERIZATION OF EOS TARGETS FOR LMJ EXPERIMENTS

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Poster communication

The CEA target department develops materials experimented on high energy laser facilities such as Laser MegaJoule (LMJ). These materials are developed and assembled with dedicated glues to form *Equation of State* (EOS) targets, which are then experimented to obtain precise Hugoniot data. This type of targets requires very precise and delicate manufacturing steps from materials fabrication to physics package assembly.

To non-destructively characterize them, some commercial devices based on optical or mechanical technics are used to measure their thickness and surface roughness. However, device capabilities can be exceeded when characterizing thin membranes of few microns thick. Indeed, for the thinnest samples, roughness, local defects as bumps or sample's curvature can introduce a significant error in the results of the measurements.

In order to measure thin membrane thickness in a non-destructive way, a dedicated equipment has been developed. Its main components are two chromatic confocal probes placed on both sides of the sample to measure local thickness. A set of motorized stages extends the device capabilities with a whole sample thickness mapping.

Each probe is able to determine the surface sample position with a theoretical resolution better than 100 nm. By combining these surface position determinations and those obtained from the measurement of a referee gauge, the sample local thickness is computed by software. The measurement precision depends on several parameters like the confocal probes alignment. To improve this alignment, a dedicated measurement protocol has been developed. The other main sources of error and the measurement uncertainties have also been studied.

This poster gives details on the last developments about assembly and characterization of EOS targets.

Overview of HDC Capsule Processing*

M. Ratledge[1], C. Kong[1], A. Allen[1], S. Pajoom[1], J. Hund[1], M.P. Farrell[1], S. Baxamusa[2], M. Stadermann[2] and C. Choate[2]

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In ICF target design, high density carbon capsules (HDC) are the current ablator type of choice for producing high neutron yielding experiments at the National Ignition Facility (NIF). The HDC material is deposited via chemical vapor deposition onto Si mandrels in a variety of different shell designs varying diameter, wall thickness, and dopant concentration. To be usable in an ignition style target, the Si mandrel needs to be removed leaving the final HDC shell. The shell has its interior rinsed, is characterized with several techniques, and finally is attached to a fill tube for gas fill in target build. In this presentation, we discuss recent changes and improvements to HDC capsule processing and their effects on NIF target assemblies.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Presentation Type: Oral

Presenter: Mark Ratledge, mark.ratledge@ga.com, 858-455-3850

Laser-Direct-Drive (LDD) Experiments on OMEGA Contributing to Ignition*

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LDD is an attractive approach to ignition because the laser energy couples directly to the capsule, without an intervening x-ray conversion step. This allows larger targets and potentially increased ignition margin and improved target stability in future designs, which could provide a path to robust high yields (i.e., repeatable fusion yield above 200 MJ).

In the last decade on OMEGA improvements in the precision of the laser, advancements in targets, the implementation of innovative diagnostics, statistical modeling, and a focus on ab-initio modeling have led to significant improvements in performance to achieve record fusion yields and a Lawson triple product χ that hydrodynamically scales to about 90% of the value required for ignition at the National Ignition Facility (NIF) laser energies. This extrapolated performance indicates that if drive conditions (laser coupling, radiation and hot-electron preheat) were hydrodynamically scaled to spherical direct drive (SDD) on the NIF, LDD would likely achieve ignition.

With the proof-of-principle demonstration of ignition on NIF, LLE has put greater emphasis on the achievement of robust high yield. LLE has shown through combinations of LPI and radiation-hydrodynamics simulations that broad bandwidth lasers ($\Delta\omega/\omega$ ~1% at 3ω) can mitigate cross beam energy transfer, hot-electron preheat, and laser imprint for the LDD approach, and provide a path to high yield. Consequently, LLE is adding an independent, high bandwidth, 150 J beam line to the OMEGA target chamber called the Fourth-Generation Laser for Ultra-Broadband Experiments (FLUX) to study the effects of laser bandwidth on LPI and laser imprint. Benefits of these broad bandwidth drivers to LID will be evaluated with FLUX as well.

Progress in the determination of the limit of χ on OMEGA with the current laser system configuration and the path forward for broad bandwidth lasers will be presented. LDD target advancements will be emphasized.

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

Presentation Type: Oral
Presenter: Sean P. Regan, sreg@lle.rochester.edu, 585-275-7077

Techniques for Increasing Foam, Plastic, and Foil Yield*

T.A.G. Reuter, N.G. Langley, W.S. Sweet, R.I. Jimenez, G.D. Lovelace, J.C. Williams, R. Santana, F.H. Elsner

General Atomics, P.O. Box 85608, San Diego, California 92186-5608

General Atomics (GA) has continued supporting inertial fusion experiments by fabricating foams and doped plastics with a range of densities and geometries. To increase production yield, GA has developed new procedures and techniques in handling, fabrication and synthesis of various parts. This poster will elaborate on the key improvement steps in the manufacture of foams, films, and foils over the past 2 years. The most notable developments include precision alignment tactics for micromachined parts and foam tubes, enhanced contact radiography efficiency, and higher foam and foil yields.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063.

Presentation Type: Poster
Presenters: Tina Reuter, Tina.Reuter@ga.com, 858-455-3076

Identification of Voids & Inclusions in Z Targets*

M. Rich, K. Tomlinson, R. Holt, and R.R. Paguio

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To simulate voids and inclusions found in Z target bodies, parts were created with voids and inclusions of known size and location. The intent is to use computed tomography (CT) to detect and characterize these defects. The inclusions were stainless steel microspheres ranging in size from 20 µms to 180 µms. These microspheres were then pressed in between two cylinders to imitate the iron inclusions found in Z target bodies. All the inclusions were detected during the CT scan, however there was a significant amount of X-Ray scattering that occurred which led to the inclusions appearing larger than they are. Additional adjustment of CT scan parameters (current and energy) should provide a more accurate sizing detection of inclusions. Instead of pressing microspheres between two cylinders, small divots will be machined into the end of one cylinder to imitate voids within the target bodies and the same CT process will follow. The findings of this study will be applied to the CT process of Z targets for more thorough characterization.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Poster

Presenter: Magdelyn Rich, magdelyn.rich@ga.com, 505-844-6944

Impedance Match and Hohlraum development

Callum Richardson[1]

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AWE Target Fabrication supports multiple experiments both in Europe as well as the US. These campaigns range in materials, design, and complexity. This poster focuses on the Impedance Match EOS campaign fielded on the Orion laser. This poster covers the targets being designed, developed, and manufactured. It also highlights the expected challenges and the solutions which are used or are being developed for these targets. Similar targets have been made previously for the initial iteration of this campaign, this provided learning opportunities which has helped identify potential challenges with the new target designs - However there is a new requirement for a more complex hohlraum concept, which is a new request for AWE target fabrication. This poster also covers the design of this hohlraum.

Presentation Type: Poster
Presenter: Callum Richardson, Callum.Richardson1@awe.co.uk, 011898 24134

Abstract Title : Target Fabrication of Colliding Planar Shock Targets

Author(S) : Jacob Riddles, Mike MacDonald, Matt Arend, Chris Santos, Jean Jensen, Nancy Lau, Josh Ponce, Danilo Paras, Rick Vargas, Zac Rodriguez, Liam Sohngen, Joe Burke

Date: 3/21/24

Abstract: **The target fabrication team at Lawrence Livermore National Laboratory (LLNL) undertook the design, manufacturing, and assembly of three Colliding Planar Shock (CPS) targets. These targets marked the first test of a novel design aimed at quantifying carbon ionization at extreme densities, essential for benchmarking ionization models in the warm dense matter regime. Each CPS target was comprised of a meticulously crafted physics package in a symmetrical arrangement of components, including two gold halfraums, gold washers, planar high-density carbon (HDC), and plastic washers that were fit to either end of an HDC cylinder (1.5mm tall, 0.75mm diameter). Adhering to stringent physics requirements, the team did not use a bonding agent, opting instead for an interference fit between the HDC planar part, gold washer, and HDC cylinder, a key innovation that was made possible by target fabrication's highly skilled precision machining team. The extensive use of gold dimpled shielding necessitated further development of a specialized process that utilized a heated hydraulic press in tandem with a rigorous metrology routine that ensured compliance with dimpled shield specifications outlined by the National Ignition Facility (NIF). The targets were successfully fielded on the NIF and delivered data with enhanced clarity to the physics team.**

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

LLNL-CONF-862267

Abstract Title Enhancing Yield and Performance Through Process Engineering in Target Fabrication

Author(S) Katherine Rivadeneira Velasco, Marcus Monticelli

Date 03/22/2024

Abstract:

Process engineering plays a pivotal role in elevating yield and performance in target fabrication processes. This poster highlights the indispensable contributions of a multidisciplinary process engineering group in target assembly at NIF. This group refines production processes, designs, and methodologies to optimize target performance and yield. Emphasis is placed on meticulous assessment of equipment, procedures, and risk factors to propose effective mitigation strategies. All steps of THD target production process are evaluated, including challenges such as off-normal events, capsule and hohlraum leaks, and depleted uranium oxide slivers in starbursts found during target inspection. Complex studies and analyses are conducted to explore innovative bonding processes and sliver mitigation by acid etching processes. Additionally, best practices are evaluated based on operator expertise and historical target data. Ultimately, process engineering emerges as a driving force in advancing technology and shaping the future of target development.

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

Release #: LLNL-ABS-862273

Abstract Title: Utilizing Creo Parametric IGES Files to Automate Target Specification Sheets

Author(S): Nicholas Roskopf

Date:

Abstract: Accurate specification sheets are essential for efficient production and precise qualification of Targets. I established a labeling system for Creo Parametric points to facilitate the interpretation of measured and reported values such as distances between points, surface angles, vector angles, and the center position and angles of planes. Through leveraging Initial Graphics Exchange Specification (IGES) files containing custom notated Creo Parametric point clouds, I automated the generation of warm target and subassembly specifications. The automation was built in two standalone MATLAB applications made available to Target Fabrication Engineers (TFEs). In these applications TFEs import IGES files containing custom notated points, select the target positioner, base type, and other relevant fields that provide the applications information to solve for and translate measured and reported values from the Target-based MET coordinate system into the Target Chamber Coordinate System (TCC). A single click generates a meticulously formatted and equation-based Excel sheet, seamlessly integrated with our database system LoCoS. These applications eliminate human error and significantly reduce time expenditure by automating the arduous tasks of Excel sheet formatting and data entry for top level warm targets and sub-assemblies.

Release Number: LLNL-ABS-861622

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

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Approved for public release; distribution is unlimited.

Title: Gradient Coating of Cylindrical Targets

Author(s): Ross, David John
Usov, Igor Olegovich
Day, Thomas H.

Intended for: Target Fabrication Meeting, 2024-08-25/2024-08-29 (San Diego, California, United States)

Issued: 2024-04-19

Los Alamos
NATIONAL LABORATORY

Gradient Coating of Cylindrical Targets

D, Ross, T. Day, I. Usov

Los Alamos National Laboratory

Compositional and geometric specifications for high energy density targets are frequently shifting to align with emerging experimental needs. These novel target designs require precise distributions of materials across length scales which are difficult to achieve via standard machining and assembly methods. Physical vapor deposition (PVD) provides a convenient and straightforward technique for augmenting many target fabrication platforms. However, coating complex geometries creates additional challenges for production and characterization of the final target.

In this work we present our efforts to create and characterize high quality cylindrical targets with a copper to aluminum gradient layer. These targets were produced using magnetron sputtering with custom mandrel fixtures and characterized using multiple methods before assembly. Analysis showed that the desired gradient was achieved, in addition to revealing important information regarding density and physical structure.

Presentation Type: Poster
Presenter: David Ross, dross@lanl.gov, 505-667-3640

Reducing Oxygen Absorption in Si-Doped GDP Capsules by Improving Storage Conditions*

I. Ruiz, D. Guzman, W. Sweet, R. Luo, B. Serrato, F.H. Elsner, J. Murray, C.M. Shuldberg and M.L. Hoppe

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Infrared heating is required for layering smooth D2 in cryogenic target shells. It's known that oxygen absorption in CH and Si-doped CH is a major contributing factor in reducing the infrared transparency, resulting in the disruption of the smoothing of the D2 layer. Here in this work, we test different storage conditions for Si-doped CH thin films and measure their oxygen absorption over time. We measure the mass increase, capsule wall thickness and outer diameter, as well as spectroscopic information using Fourier Transform Infrared Spectroscopy. We demonstrate that oxygen absorption can be reduced by storing samples under vacuum or under inert gas, but more interestingly it is shown that photo-oxidation plays a major contributing role in oxygen absorption. A significant decrease in oxygen pick-up by the Si-doped CH films was demonstrated by storing the samples under dark conditions, even when stored in atmosphere.

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Presentation Type: Poster

Presenter: Isaac Ruiz, isaac.ruiz@ga.com, 858-455-4077

Development of Soft X-Ray Metrology Equipment for X-Ray Opacity Database Revision

R. Santana, H. Huang, K. Sequoia, J. Tomlin, M. Farrell

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High Energy Density (HED) research from the Solar Opacity program motivated General Atomics (GA) to innovate in the ways HED targets are characterized to allow the measurement of the target areal density and room temperature x-ray opacity to higher precision and accuracy. This allows benchmarking of the hot opacity values at the solar convection zone base, now accessible at the premium HED facilities run by Department of Energy (DOE)'s National Laboratories, to the room temperature values to better understand the opacity increase at extreme temperature and pressure. Comparison of the room temperature measurements to existing databases led to the realization that the mass attenuation coefficient, or opacity, tabulated in existing x-ray opacity databases are consistent only to ~10 percent, sometimes far worse, even for common elements. This presents a fundamental barrier to obtaining ~1-2% accuracy in the areal density determination. Previously GA developed a tool, named "AutoEdge", to refine the x-ray opacity to ~1-2% accuracy in the energy range from 3-17 keV.

In this work, we have created the next generation equipment that expands the effective measurement range down to 400eV by incorporating a windowless x-ray source and detector design. The new design enhances the accuracy of areal density measurements of important low-Z elements like Si, Mg, and Al, all of which are integral to National Ignition Facility (NIF) and Z Pulsed Power Facility (Z) HED experiments.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Poster

Presenter: Ruben Santana, ruben.santana@ga.com, 858-455-3143

Fabrication of Thick Oxide and Metal Foils for Solar Opacity Motivated High Energy Density Experiments*

R. Santana, C. Monton, H. Huang, K. Sequoia, J.N. Tomlin, M.P. Farrell

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Large-scale High-Energy Density (HED) facilities provide a unique platform for astrophysicists to conduct controlled laboratory experiments, replicating extreme conditions found in white dwarf stars and solar interiors. General Atomics (GA) has been at the forefront of this endeavor, researching and developing cutting-edge material science processes. This involves producing freestanding thick oxide and metal foils with precise areal densities required for experiments at facilities such as the National Ignition Facility (NIF) and the Z Facility. The top two contributors to solar opacity are (1) oxygen (2) iron. The effect of Fe has been extensively studied since 2004 using Fe/Mg comix targets (and contrast against Ni/Mg targets) where GA contributed photolithography-based target production and x-ray transmission-based metrology known as AutoEdge. The effect of oxygen is unknown due to the lack of HED targets with sufficient oxygen areal density. In this work, we have created thick oxide targets to enable the experimental investigation of the oxygen contribution on NIF and Z.

Addressing the challenge of obtaining high-density oxygen, we utilize SiO_2 to immobilize a significant amount of oxygen, while using the broadening of the Si k-shell emission line as a local plasma condition sensor. Improved plasma condition determination is achieved with Mg k-shell emission lines when Mg is incorporated into SiO_2. The high areal density required, typically 3 µm to 6 µm of SiO_2 deposition, leads to high stress buildup, resulting in issues like delamination and cracking. Stress management becomes an integral aspect of our coating design, especially for mixed coatings where the stress build-up is significantly worse.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Oral
Presenter: Ruben Santana, ruben.santana@ga.com, 858-455-3143

Overview of Target Fabrication and Development at Los Alamos National Laboratory

D. Schmidt[1], C. Blough[1], N. Christiansen[1], T. Day[1], P. Donovan[1], B. Farhi[1], J. Lavelle[1], J. Martinez[1], B. Patterson[1], J. Porto[1], T. Quintana[1], D. Ross[1], V. Siller[1], K. Sims[1], S. Stringfield[1], C. Wilson[1], C. Wong[1]

M. Farrell[2], H. Huang[2], C. Shuldberg[2], M. Mauldin[2], T. Nunn[2], T. Phipps[2], W. Sweet[2]

[1]Los Alamos National Laboratory
[2]General Atomics

Abstract

This talk goes through the complex target fabrication designs being fabricated and assembled at LANL for the Omega, Z, and NIF campaigns over the last two years. Our campaigns require a mixture of capabilities including micro-machining, coatings, foam synthesis, precision assembly, and metrology. Developments in individual campaigns will be overviewed including Double Shell, Double Cylinders, and experimental campaigns investigating 2pp foam impacts. LANL has a partnership with General Atomics for the delivery of varying types of capsules, micro-machined components, and 2pp printed components for imbedded experiments.

Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218NCA000001).

Presentation: Oral

Presenter: Derek Schmidt, dwschmidt@lanl.gov (505)667-6009 LA-UR-24-23570

Examining the Degradation of Depleted Uranium Layered Hohlraums

Authors: Alexander Schwartz, Suhas Bhandarkar, Martine Havre, Loosineh Ahaian, Chantel Aracne-Ruddle, Abbas Nikroo, Sergei Kucheyev, Corie Horwood

Depleted uranium (DU) hohlraums are used to convert laser energy into X-rays in Inertial Confinement Fusion (ICF) experiments at NIF. Over the past year, we have seen a new failure mode where certain sections of the cutouts in the hohlraum where the DU edge is exposed form sliver-like features in the final target. We found that these slivers are comprised of an oxide of uranium. If a DU sliver flakes off and causes particulate debris on the capsule surface, the quality of the implosion can be substantially compromised. This risk caused several targets to be rejected which significantly impacted the overall yield of ICF targets. In this poster, we will present key details of the slivers and the effect of machining and environmental conditions. We will also discuss different mitigation strategies including one using acid etching.

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

IM No. LLNL-ABS-862367

Digital Holographic Surface Metrology for HED Capsules*

K. Sequoia, H. Huang, P. Lapa, M. Yamaguchi, J. Walker, K.J. Boehm, K.C. Engelhorn

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Laser fusion experiments rely on adiabatic compression to reach High Energy Density (HED) conditions. Any imperfection on the capsule surface would grow exponentially via the Rayleigh-Taylor (RT) process to cause meteor-like jetting into the hot spot, thereby quenching the neutron yield. High precision metrology is required to locate then quantify the biggest defects to inform the target fabrication and capsule selection. The same data is also used to support post-shot performance evaluation to advance the Inertial Confinement Fusion (ICF) program.

The development of the 4Pi-integrated digital holography method for capsule inspection was motivated by many factors: (1) Previous generation equipment for GDP dome inspection had been aging and no longer supported. (2) Confocal microscope alternatives are too slow in certain applications. (3) The majority of the interferometer or confocal based methods are very sensitive to vibration, which in a slow process, is hard to mitigate. (4) The shell coordinate system is difficult to maintain from instrument to instrument, forcing redundant measurements.

We integrated a digital holographic microscope into our 11-axis 4Pi metrology station, and developed custom data acquisition, analysis and rendering programs. Since its deployment, significant progress has been made. Advanced statistical analysis ensures height measurement reliability, machine learning enables defect classification, and AFM spot checks enhance defect characterization. These improvements signify a substantial step forward in supporting the evolving needs of the national ICF program through comprehensive and efficient metrology solutions. In this presentation, we will discuss how we use the digital holographic microscope to solve metrology problems in support of the rapidly evolving needs of the national ICF program.

*This work performed under the auspices of General Atomics Internal R&D funding.

Presentation Type: Oral
Presenter: Kevin Sequoia, kevin.sequoia@ga.com, 858-692-1053

LLNL release number: LLNL-ABS-862121

TFM 2024

San Diego, August 25-29, 2024

Precision milling of ablator materials with ion beams

S. J. Shin, L. B. Bayu Aji, D. C. Goodelman, E. Kim, J. B. Forien, and S. O. Kucheyev

Lawrence Livermore National Laboratory, Livermore, California 94550, USA

The fill-hole in an ablator shell is one of the major yield degradation sources of an inertial confinement fusion (ICF) experiment. It is important to precisely control the dimensions and geometry of the fill-hole to mitigate yield degradation and, at the same time, to preserve mandrel leaching and fueling capabilities. We aim to achieve this goal with focused ion beams. Here, we present our findings on the correlation between the major ion beam bombardment conditions (i.e., ion mass, energy, flux, and impact angle) and the hole milling behavior and discuss approach to high-resolution, high-throughput x-ray imaging of fill-holes.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344 and was supported by the LLNL-LDRD Program under Project No. 23-ERD-033.

Overview of Capsule Fabrication for Direct Drive at General Atomics*

C.M. Shuldberg, M.L. Hoppe, J. Murray, R. Luo, I. Ruiz, D. Guzman, B. Serrato

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Over the past several years the variety of capsule designs experiments have increased to meet the needs of various ICF experiments and academic users. This overview focusses on capsules fabricated by General Atomics for direct drive experiments at Omega. These targets include capsules fabricated for LLE Cryo experiments where the target design changed from single layer to multilayer targets to decrease the preheat; metal buried layers to provide emission; and new CH dopant and higher at% achieved.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063

Presentation Type: Oral

Presenter: Claudia Shuldberg, claudia.shuldberg@ga.com, 858-455-2605

Polymer Selection for Target Fabrication

R. Smith, B. Paul, I. Brown, T. Ayers, B. Zeiger[1]

[1] Luxel Corporation

The high strength and light element composition of LUXFilm® Polyimide make it a staple of target design for inertial confinement fusion and high energy density physics experiments. One product, however, cannot be simultaneously optimized for all applications. In an effort to meet evolving target needs for composition, deformation, and other properties, Luxel has expanded its suite of polymers. A notable addition is LUXFilm® EL, which offers a high-elongation polyimide for three-dimensional targets and non-planar windows. To aid in target design, we present characterization data for Luxel polymers, including mechanical properties, infrared and x-ray spectroscopy, composition analysis, helium permeation, and burst failure data.

Presentation Type: Poster

Presenter: Ryan Smith, ryan.smith@luxel.com, 360-378-4137

LAWRENCE
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LABORATORY

LLNL-ABS-862376

Investigation of Titanium as a Surrogate Material for Magnetron Sputtered Beryllium

L. Sohngen

March 28, 2024

25th Target Fabrication Specialists Meeting.
San Diego, CA, United States
August 25, 2024 through August 29, 2024

TFM 2024

San Diego, August 25-29, 2024

Investigation of Titanium as a Surrogate Material for Magnetron Sputtered Beryllium

L. Sohngen(1), G.V. Taylor(1), S. J. Shin(1), L. B. Bayu Aji(1), X.Lepro-Chavez(1), and S. O. Kucheyev(1)

1) Lawrence Livermore National Laboratory, Livermore, California 94550, USA

The current use of beryllium as an ablator platform in ICF/HED experiments is due to its many advantageous properties which include high density, high tensile strength, dopability, and high thermal conductivity at cryogenic temperatures. Despite these favorable characteristics, research and development of Be ablators using magnetron sputtering is impeded because of its toxicity. Thus, the use of a non-toxic surrogate material with similar growth characteristics is critical in facilitating the advancement of Be as an ablator platform. Here, we investigate the use of titanium as a beryllium surrogate material. This work will focus on the effects of direct current magnetron sputtering parameters and high-power impulse magnetron sputtering on major films properties of residual stress, mechanical properties, areal density, and microstructure on substrates deposited on at normal and oblique angles.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-765894.

Current and Future Capabilities in Target Fabrications

Andy Spencer[1] James Cooper[1] Colum O'Connor[1] Liam Jenvey[1]

[1] Target Fabrications Group, AWE plc, Aldermaston, Reading, Berkshire, RG7 4PR, UK

The capabilities in Target Fabrications within the Orion Laser Facility involve people, plant, and process. Target Fabrications support the Orion Laser Campaigns and the international collaborative work for overseas campaigns. This oral presentation will discuss the current and future capability of Target Fabrication within the Orion Laser facility.

Presentation Type: Oral,
Presenter: Andy Spencer, E-mail - andy.spencer@awe.co.uk, Telephone +44 11898 50483

UPLiFT: UK Targetry Strategy for IFE

C. Spindloe[1], R. Scott[1], M. Tolley[1]

[1] UKRI-STFC, Rutherford Appleton Laboratory, Harwell Campus, Didcot, Oxfordshire, OX11 0QX, UK

UPLiFT is an ambitious Laser Fusion science and technology development programme based in the UK which has just received initial funding. The objective is to develop the technological path that leads from this scientific breakthrough to the realisation of safe, sustainable, and secure laser-driven Inertial Fusion Energy.
The UK's Central Laser Facility (CLF) is a world-leader in the development of the type of high efficiency, high repetition-rate lasers required for Laser Fusion. CLF also has extensive skills, capabilities, and expertise in the development of the complex targets required for laser experiments.
A major enabler of IFE is Target Mass Manufacturing; Laser Fusion energy will require approximately one million targets per day. Each target is ~2 mm in diameter and of exquisite surface quality which is vital for high fusion-energy-gain and hence for energy production. Moreover, target cost is a major driver in the economic viability of energy-production. Mass manufacturing of targets at such high quality creates many technical challenges and the programme will demonstrate:

1. The development of a UK conventional target capsule manufacturing capability based on triple orifice technology.
2. Target capsule mass-manufacturing with sufficient quality and at costs commensurate with economically viable fusion energy. This deliverable will further develop novel micro-fluidics methods initially pioneered during the HiPER project.
3. Rapid, automated, characterisation of targets, demonstrating the quality required for fusion energy. Along with developing advanced imaging and post-processing methods it will employ machine learning for automation of image analysis.
4. Initial prototyping of rapid methods to assemble cryogenic fuel, either as solid fuel layers, or using foams wetted with liquid fuel. Again, this will build upon novel methods developed during the HiPER project.
5. The development of enhanced low density foam capabilities for implosion targets focussing on novel 3D printing methods using two-photon polymerisation.

Presentation Type: Poster
Presenter: C. Spindloe, christopher.spindloe@stfc.ac.uk, Tel :+44 1235 446357

Target Fabrication after Ignition

M. Stadermann
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ABSTRACT

For over three decades, target fabricators have been working towards targets that will ignite and produce a burning plasma on NIF, signified by an energy output that is greater than the laser input. On December 5th 2022, this goal was finally achieved, and has been repeated multiple times since.

Ignition is a scientific and technical triumph that required tremendous advances in the areas of lasers, optics, and target fabrication. An ignition target requires a capsule that is virtually flawless, containing no defects larger than bacteria, and it is filled through a filltube that is 50 times thinner than a hair. The target is assembled under a microscope to maintain micron tolerances, and has to be leak tight at room temperature and 18K, where a single crystal fuel layer is formed inside the shell.

In this presentation, I will review the technical accomplishments in target fabrication that have enabled this milestone. I will describe the impact that ignition has had on daily work as well as the research and development work going forward, and conclude with the future directions for ignition experiments and how they affect target fabrication.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-765894.

Method of presentation: Oral

Presenter:
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Keywords: NIF, Target Fabrication, Manufacturing, Metrology

LLNL-ABS-862275

Metrology of shielded ARC targets using mirror reflection in OCMM

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ABSTRACT

The Advanced Radiographic Capability (ARC) laser system provides an experimental platform for high intensity X-ray imaging of High Energy Density (HED) plasmas, such as imploding ICF capsules. For high-resolution X-ray imaging, the ARC beamlets are focused onto a metal microwire. The microwire backlighter is typically 10-30 um in diameter and required to be inside a cone shaped shield to protect it from the unconverted light of the National Ignition Facility (NIF) laser drive. For high X-ray conversion efficiency, the ARC beamlets need to be aligned to the target within 10 um accuracy; however, the small size and the shield surrounding it make the metrology challenging. The stability of the ARC backlighter has also been in question due to the shield assembly added after the final target metrology. In this presentation, we will discuss the metrology of the microwire using a mirror to reflect the distance measuring laser light on to the microwire and back to the Optical Coordinate Measuring Machine (OCMM). The mirror reflection measurement provides supplementary data to the direct laser beam measurement and confirms the target stability by allowing measurement after the shield assembly.

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Presentation Method: Slides/Poster

Presenter: Soojin Stadermann, stadermann3@llnl.gov

Release#:LLNL-CONF-862124

Development of 2PP Lattices and AR Coatings for use in Bosque Shock Imprint and Bosque Preheat

S. Stringfield[1], N. Christiansen[1], B. Farhi[1], Y. Kim[1], P. M Kozlowski[1], J. Lavelle[1], J. Martinez[1], B. Patterson[1], T. Quintana[1], D. Schmidt[1], K. Sims[1], R. W. VanDervort[1], C. Wilson[1]

T. Phipps[2], C. Shuldberg[2], W. Sweet[2]

[1] Los Alamos National Laboratory
[2] General Atomics

Abstract

This talk goes over the target fabrication and assembly process used to develop targets for Bosque Shock Imprint and Bosque Preheat. Bosque SI studies the expansion of a 2PP lattice structure from hot electron preheat and radiative heat, while Bosque PH measures the imprint of a 2PP lattice structure onto a shock front velocity. The techniques used to fabricate and assemble components in these campaigns were developed and further optimized to enhance the quality of the shot. Most notably, the 2PP structures were created using various design techniques and software to increase print quality, a process for coating windows with an anti-reflective coating was developed and tested in house, and custom vacuum tips were designed to improve assembly.

Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218NCA000001).

Presentation Type: Oral
Presenter: Samuel Stringfield, sstringfield@lanl.gov, (505)695-3581

LA-UR-24-23656

Laser Micromachining Process for Pinholes Used for X-ray Diagnostics*

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Pinholes are used as an x-ray diagnostic in all of Nation Ignition Facility (NIF) target shots. The pinhole components are custom for each individual shot based on the data that is wanted. These pinhole arrays can have anywhere between a single hole to hundreds of holes with sizes between 0.01 mm to larger than 3.0 mm in diameter. The materials used in these arrays also vary between 0.05 mm up to 0.75 mm in thickness depending on if it is being used as the final aperture (pinhole) for the x-rays or as a shield (collimator). GA has the equipment to fabricate these custom pinhole components and to measure each feature of the components. Capabilities of the equipment and the processes used in fabrication and measurements of these custom pinhole components are presented.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Presentation type: Poster
Presenter: Jordan Stutz, Jordan.stutz@ga.com, (858) 455-4184

Observation of Proton-Boron Fusion Reaction from the Decaborane Target Irradiated by LFEX Laser

A. Sunahara[1], M. Wong[1], H. Matsubara[2], Y. Karaki[2], R. Yamada[2], F. Nikaido[3,2], T. Yasui[3,2], T. Minami[3,2], K. F. F. Law[2], R. Takizawa[2], A. Yogo[2], Y. Abe[3,2], Y. Kuramitsu[3,2], Y. Fukuda[4,2], T. Hayakawa[4,2], M. Kanasaki[5], K. Honda[2], K. Yamanoi[2], K. Takahashi[2], T. Johzaki[6,2], H. Maruta[1], T. Trottier[1], S. Iizuka[1], H. Ohta[1], S. Fujioka[2], and S. Nakamura[1]

[1] Blue Laser Fusion Inc.
[2] Institute of Laser Engineering, Osaka University
[3] Graduate School of Engineering, Osaka University
[4] National Institutes for Quantum Sciences and Technology (QST)
[5] Graduate School of Marine Science, Kobe University
[6] Graduate School of Advanced Science and Engineering, Hiroshima University

We conducted the Proton-Boron (p-B^{11}) fusion reaction experiment with targets made of decaborane ($B_{10}H_{14}$), which was irradiated by the ultra-intense laser pulse with 1ps duration, order of 10^{19} W/cm^2 laser intensity pulse of LFEX laser at the ILE, Osaka University. We successfully obtained the gamma-ray signal of 511 keV due to β^+ decay of C^{11} produced from p-B^{11} fusion reactions as (p + B^{11} → neutron + C^{11}) by the radio-activation measurement.

The temporal decay rate of the gamma-ray signal confirmed the production of C^{11} from the Proton-Boron reactions and showed an increased p-B^{11} reaction compared to that of the Boron Nitride (BN) target.

Also, we tested the plastic (CH)-pitcher/decaborane catcher type target in which the target sheath normal acceleration (TNSA) mechanism accelerates the proton to a higher energy than the proton directly accelerated by the ultra-intense pulse and obtained a significant increase in the number of p-B^{11} reactions than the bulk decaborane target.

Furthermore, we conducted the inner irradiation-type heating experiment with a CHBN composition shell target to compare the number of p-B^{11} reactions with the planar targets. The results show that the inner-irradiated CHBN target gives a larger number of p-B^{11} reactions than the planar target, which implies that the inner-irradiation-type heating allows the effective coupling of the energy of the ultra-intense laser to the target.

Based on the high potential of the decaborane targets as a fusion fuel and the inner irradiation heating method, we are going to develop the Proton-Boron target for the fusion experiment.

Presentation Type: Oral
Presenter: Atsushi Sunahara, asunahara@bluelaserfusion.com, Telephone +1-(812) 614-5731

IM #1094625

Boron carbide coatings deposited with HiPIMS

S. Graiser[1,2], S. J. Shin[1], L. B. Bayu Aji[1], X.Lepro-Chavez[1], G.V. Taylor[1], and S. O. Kucheyev[1]

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2) Binghamton University SUNY, Binghamton, New York 13902, USA

Boron carbide possesses many key properties that make it particularly well suited as a next generation ablator platform for inertial confinement fusion research. The deposition of high density, low residual stress amorphous boron carbide coatings has been demonstrated with conventional magnetron sputter deposition with both radio-frequency and direct-current driven plasmas. However, fine control of growth modes, including nodular growth defects and columnar growth at oblique angles, remains a challenge. Here, we investigate the deposition of amorphous boron carbide films using high power impulse magnetron sputtering (HiPIMS) with a full-face erosion magnetron source. Emphasis is on the effect of Ar working pressure and substrate bias on the major film properties of residual stress, mechanical properties, atomic density, and the columnar microstructure.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344.

Z-Machine Cryogenic Target Performance Advances and Innovations*

J.L. Taylor[1], G.E. Smith[1], R.R. Paguio[1], J.A. Crabtree[2]

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Several campaigns supported by the Z-Machine at Sandia National Laboratory require cryogenically cooled targets for advancement of fusion science. Recent innovations on cryogenic targets for the Z-Machine have improved performance in the areas of cryogenic cycling robustness and delivery of shot-ready targets. This poster will highlight the advancements in the mechanical design and bonding techniques for these types of assemblies that have improved the success rate for cryogenic targets fielded at Z.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063.

Presentation Type: Poster

Presenter: Jerry Taylor, jltayl@sandia.gov, (505)284-4428

Prospectus on Inertial Fusion Energy*

C. A. Thomas

Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623-1299, USA

The achievement of ignition [Phys. Rev. Lett. **129**, 075001 (2022)] represented the culmination of an extraordinary effort by an even more impressive team. In an instant, it also signaled the start of a new era, and what will become a race to realize the immense potential of inertial fusion energy (IFE). We can expect success to require new discoveries and inventions, and teamwork, and just like ignition, the best solutions will be a surprise. For motivation, we revisit lessons from the National Ignition Facility and other institutions, and discuss how they are shaping efforts on IFE. The emphasis will be on developments in targets and drivers, and supporting technologies, and how they might overcome issues in physics and economics. We also summarize the status of the field, its growing momentum, and the many new and exciting ventures in the space both public and private.

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

Presentation Type: Oral

Presenter:
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Keywords:
Inertial fusion energy (IFE), inertial confinement fusion (ICF), ignition, gain, targets, drivers, NIF, OMEGA

Abstract Title: **(Re)Development of a CFTA Production Station at LLNL**

Author(S) : **N. Thompson[1], M. Aggleton[1], D. Barker[1], N. Farmer[1], C. Heinbockel[1], C. Henning[1], J. Nguyen[1], S. Winters[1]**

[1]Lawrence Livermore National Laboratory (LLNL)

Date: **3/18/2024**

Abstract:

Recent improvements in the quality and performance of components assembled into a Capsule Fill Tube Assembly (CFTA) for an inertial confinement fusion target mean that each finished product represents a substantial investment of resources. The advent of features like 2 micrometer diameter fill tubes have also dramatically increased CFTA sensitivity to the environments experienced during the production lifecycle – with some designs incapable of surviving transport between General Atomics (GA) and LLNL facilities. LLNL Target Fabrication seeks to reduce the environmental loads generated during handling of finished CFTAs between production and assembly. This need motivated LLNL Target Fab to re-establish the capability of producing CFTAs on-site. The LLNL CFTA Production Station is based on the proven platform that evolved over nearly two decades of CFTA production at GA. Improvements are intended to increase the reliability of fabricating challenging CFTAs in a production environment.

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

Release #: LLNL-CONF-862045

4-Axis Milling of Planer Targets For Dynamic Materials Properties Experiments*

K. Tomlinson[1], W.D. Tatum[1], and B.R. Morgan[2]

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[2]Sandia National Laboratories, PO Box 969, Livermore, California 94551-0969

A new method has been developed and instituted for diamond machining critical components used in approximately half of the targets for the Z machine at Sandia National Laboratories. By employing an ultra-high precision, 5-axis milling machine and a novel fixture design instead of a diamond lathe, total processing times have been reduced by 25%, or 400 man-hours annually at current shot rates, while improving quality and accuracy. The time savings is due to cutting the number of setups and machines from 2 to 1, use of screws instead of glue for fastening to fixtures, 10x spindle speed increase, and automatic tool changing vs. manual tool changing. The accuracy improvements are due to the increased thermal stability resulting when machining times are reduced as a consequence of higher spindle speeds. This poster will illustrate the process changes which lead to these efficiency enhancements.

*This work performed under the auspices of the U.S. Department of Energy by General Atomics under Contract 89233119CNA000063 and by Sandia National Laboratories under Contract DE-NA0003525.

Presentation Type: Poster

Presenter: Kurt Tomlinson, ktomlin@sandia.gov, 505-284-1350

Micro CT Applications in Fabrication of ICF Targets

Lance Ulrich and Neil Redden
University of Rochester,
Laboratory for Laser Energetics

Abstract

A Bruker Skyscan 2214 micro CT scanner was employed to analyze different ICF targets, investigating a foam & pusher target and 2-photon-printed targets to assess the equipment's suitability for our applications. Utilizing software provided by the vendor, we obtained comprehensive 3D visualizations of foam targets, isolating regions-of-interest for further analysis. Custom-written scripts were developed to analyze large datasets, assessing filament and pore dimensions across vertical regions. Statistical analysis revealed a significant variation in mean filament thickness, up to 0.2µm (representing a 13% difference) across 20µm vertical regions. Additionally, custom scripts were written to analyze the inner surface roughness of 2pp-printed shells provided by the University of Nebraska, Lincoln. Findings indicated a peak surface roughness of 18µm and revealed that the target was on average 2.2µm smaller than designed, with the most significant variation at the poles due to print block overlaps. These insights offer valuable guidance for improving the 2-photon printing process.

3D visualizations

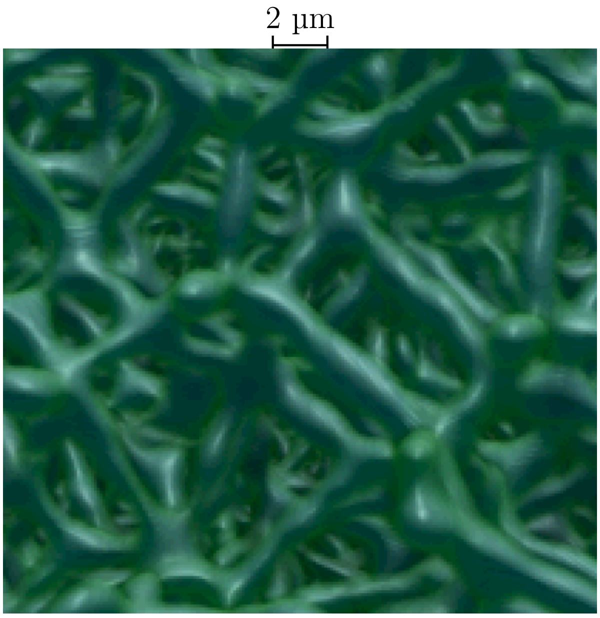

Figure 1: Image at the center of a 2 photon printed foam target

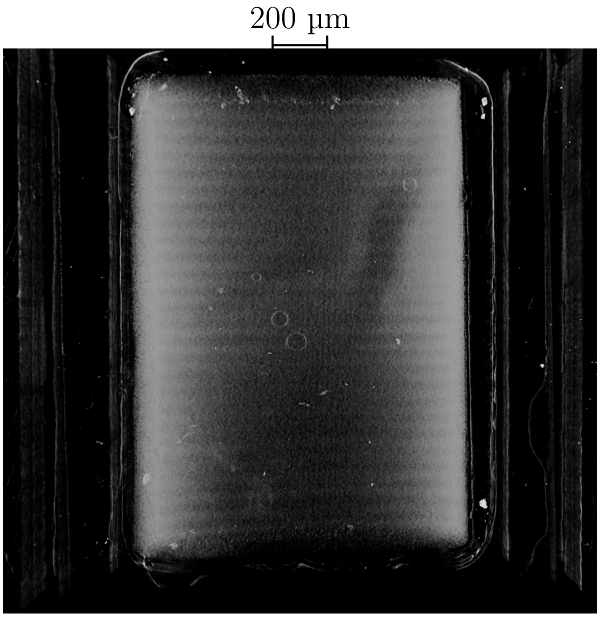

Figure 2: Image of voids in the glue at the interface between the shock tube and the modulated pusher

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

Presentation Type: Oral
Presenter: Lance Ulrich, lulrich2@u.rochester.edu, 571-926-7743

Innolite 500 Sinewave Project

T, Uphill[1]

[1] AWE

Presentation on the machining of metallic sinewave target samples using the Overdrive 20 Attachment and ILCam3D Software on the Innolite 500 Diamond Turning Lathe. During the presentation I will first discuss the Set-up of the Overdrive 20 and programming sinewave forms with the ILCam3D software. I will then detail each form machined, the accuracies achieved, and what was learned at each stage. At the end of the presentation, I will discuss plans for future development with the IL500.

Presentation Type: Oral
Presenter: Thomas Uphill, Thomas.Uphill@awe.co.uk, 01189857552

Precitech 250 Sinewave Development

T, Uphill[1]

[1] AWE

A poster detailing the steps taken to machine a simple sinewave with static tooling on the Precitech 250 Nanoform Diamond turning Lathe. This poster will contrast the difference in process between machining sinewave forms on this machine and the Innolite 500, giving the advantages and disadvantages of each strategy in simple terms. Photographs of the fixturing and setup will be included, along with diagrams, a description of each machining stage and the results achieved.

Presentation Type: Poster

Presenter: Thomas Uphill, Thomas.Uphill@awe.co.uk, 01189857552

Detailed analysis of opacity foils areal density uncertainties determined by Rutherford Backscattering Spectrometry

I. Usov [1], D. Ross [1], M. Chancey [1], H. Huang [2], R. Santana [2], K. Sequoia [2]

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Comprehensive characterization of materials and components used in the building of High Energy Density (HED) targets is crucial for collecting reliable and reproducible experimentally measured atom-specific datasets. Modern manufacturing and diagnostics instruments enable the production of complex targets with well-defined geometric dimensions. Whereas there has been a long-standing concern about poorly known accuracy of elemental areal density values of thin foils used for opacity measurements at Z- and NIF-facilities. Such foils typically consist of two atomically mixed elements (such as Fe and Mg) with a wide range of stoichiometric variations. The foils are fabricated by Physical Vapor Deposition (PVD) methods on a Parylene coated Si wafer and subsequently overcoated with another Parylene layer. Most of the quantitative analytical techniques suitable for thin film chemical composition analysis rely on calibration standards with a predetermined chemical composition, which in our case is essentially the object of the measurement. Consequently, Rutherford Backscattering Spectrometry (RBS), which does not require a material specific standard, has traditionally been used for opacity foils elemental areal density measurements. RBS is an exceptional technique because with a single measurement one can identify the main elements and impurities, quantitatively measure stoichiometry, and obtain concentration depth profiles of each element. This wealth of information permits straightforward calculation of areal densities of each element constituting the thin foil. Rigorous RBS measurements of ion implanted dopants in Si wafers, developed to meet ever growing semiconductor industry standards, have approached accuracy and precision in the 1-2% range. In this study, we will present analysis of areal density measurements uncertainties obtained with the new RBS capability recently installed at the Ion Beam Materials Laboratory (IBML) at LANL. Additionally, the RBS results will be compared to the areal densities determined by X-ray absorption technique.

Presentation Type: Oral
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Spherical polyalphamethylstyrene (PAMS) mandrels synthesis improvements

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For the French Simulation Program, ICF targets are made of several assembled elements, including spherical Glow Discharge Polymer (GDP) capsules with perfectly controlled geometrical characteristics.

PAMS mandrels are used as deposition templates for all the capsules produced by the French target fab department. Mandrels synthesis implies a microencapsulation process followed by different fabrication and characterization steps. The first step of this process is liquid shells production using a triphasic emulsion, followed by a curing step with a progressive solvent evaporation under a controlled atmosphere designed to solidify the mandrel without generating surface or sphericity defects. Mandrels washing and emptying by reverse osmosis complete the fabrication. This long and multi-step synthesis enables to master mandrels geometrical characteristics.

This presentation will detail production process and optimizations that have recently been brought on injection, curing and characterization steps.

Presentation type: Oral

Presenter: Pauline Valois, pauline.valois@cea.fr, +33 3 80 23 40 00

Overview of Diamond Like Carbon Coatings*

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On December 5, 2022, after 4 decades of technical improvements, NIF reached "ignition" for the first time, achieving a 150% energy yield. Although, the current ablators improve energy efficiency and ablation pressure, challenges persist. Diamond Like Carbon (DLC) material has captured the interest of the laser fusion community due to its unique properties. DLC’s amorphous microstructure, high density, and ability to be doped makes it an attractive choice for ablator material. At General Atomics, we developed a Hollow Cathode Radio Frequency Plasma Assisted Chemical Vapor Deposition (HC-RF PACVD) system to deposit DLC coatings on both flat and spherical substrates.

Our DLC capability, with precisely tuned hydrocarbon and carrier gas compositions, enables the deposition of thick, dense, and smooth Diamond-Like Carbon coatings for experiments in Inertial Fusion Technology. In this presentation, we will provide an overview of our major results to create free-standing DLC capsules, including the fabrication, characterization, and post processing techniques.

*This work performed under the auspices of General Atomics under Internal Research and Development.

Presentation Type: Poster

Presenter: Nicolas M. Vargas, Nicolas.vargas@ga.com, (858)455-3613

3D PRINTING CAPABILITIES USED BY TARGET FABRICATION AT THE LABORATORY FOR LASER ENERGETICS

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Three-dimensional printing for rapid prototyping and manufacturing is a technology that benefits most engineering disciplines. Printing in this manner not only allows a reduction in the development cycle time, but also offers an alternative to producing complex geometries from a wide range of commercially available materials. The Target Fabrication Group at The Laboratory for Laser Energetics is applying this technology to streamline existing production processes and develop new fabrication capabilities. The group uses two printers, each having different print resolutions, meeting different needs. The first of these (Form3 by FormLabs) uses stereolithography technology to mass produce centimeter-scale parts with resolution less than 100um. The second instrument (Photonic Professional GT2+ by Nanoscribe) uses two-photon polymerization technology to achieve millimeter-scale parts with sub-micron features.

The poster discussion shows system specifications for each instrument, examples of real designs that emphasize print capability related to fusion science and identifies a possible solution to a size and resolution gap between printers.

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

Presentation Type: Poster
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Overview of Coating Fabrication Capability Expansion at General Atomics

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Over the past several years the diversity of thin film deposition requirements has increased to meet the needs of various ICF experiments and academic users. This overview focuses on three new capabilities that have been established and show potential for expansion. The first is freestanding thick film generation by additive manufacturing, opening the door to new geometries and alloys. The second new proven capability is interior deposition of films into hohlraums, expanding hohlraum liner diversity. And the third is lithium extrusion and passivation, allowing solid lithium to be utilized in experiments without oxidation concerns.

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Presentation Type: Poster

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Fabrication of Robust Pure Metal Aerogels From the Plasma Phase*

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The evolution of aerogel fabrication techniques has led to the utilization of dusty plasmas generated by striking metal plasmas within a controlled, high-pressure environment. In this study, we present a novel approach to fabricating pure metal aerogels by directing the flow of dusty plasmas onto a motion-controlled stage. This method enables precise control over the deposition process, allowing for the creation of aerogels with tailored geometries and compositions. By harnessing dusty plasmas, we eliminate the need for solution-based synthesis and nanoparticle doping, simplifying the fabrication process while expanding the range of achievable compositions. The resulting metal aerogels exhibit low densities and intricate structures, making them promising candidates for applications in nuclear fusion and high-energy density physics. This advancement represents a significant step forward in aerogel technology, offering new opportunities for the design and fabrication of targets optimized for demanding experimental conditions.

*This work performed under the auspices of General Atomics Internal R&D funding

Presentation Type: Oral

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Target Engineering post-Ignition

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ABSTRACT

For a couple decades, Target Fabrication has been aggressively working towards target designs that will ignite and produce a burning plasma on NIF, with a primary focus on achieving performance. Since the December 5^{th} 2022 ignition results and repeat ignition shots, emphasis has expanded to improving target robustness and reliability while maintaining performance. Ignition targets have repeatability demonstrated they meet the stringent performance requirements of NIF experiments, but need improvements in robustness and reliability to meet the needs of a sustained experimental program. In 2023, approximately one-half of the ignition targets delivered to NIF had issues that resulted in delays or missed shots. These deficiencies resulted in implementation of several Target Engineering related changes to improve target robustness and reliability. In this presentation, I will highlight several of the changes employed, including organizational, process and tactical.

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Method of presentation: Oral

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Keywords: NIF, Target Engineering, Ignition Target

Release#: LLNL-ABS-862770

Development of Aerogels and Foams for LANL Target Assembly

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LA-UR: 24-23670

Abstract

This study focuses on several methodology developments of aerogels and other target foams at Los Alamos National Lab which provides target assembly parts for both the Omega and National Ignition Facility. The main foams and gels used in targets include a variety of different silica aerogels, doped aerogels and Divinylbenzene (DVB) foams. The aerogel and foam formulations and processes were and are currently being investigated and developed extensively to obtain optimal conditions for density accuracy and repeatability. Using the developed methods, the gels and foams than both use a CO_2 supercritical dryer at temperatures from 10-45°C to bypass the critical point and solidify. Running the CO_2 supercritical dryer weekly allows for a focused study of the dryer's impact on product's density and physical properties. Examples of this drying method are showcased with characterization for quality assurance.

Presentation Type: Poster

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Capsule Data Improvements*

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A long-term goal for the National Ignition Facility (NIF) is how to achieve fusion ignition consistently. Physicists at Lawrence Livermore National Laboratory (LLNL) use data to predict capsule performance in upcoming shots and use experimental results to understand shot performance. Given the recent increase in ignition breakthroughs, there is now more data about capsules that reached fusion ignition successfully. This has led to an increased scrutiny over the metrology data that General Atomics (GA) collects and transfers to LLNL. Historically, after data generation the data transfers were done manually, causing a delay between data generation and data delivery. This poster describes how GA transformed the data transfer system by automating transfers and developing a new tracking system to ensure all data reaches LLNL in a timely fashion.

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Presentation Type: Poster

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Double Shell and PSS Shell Development*

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Metal capsules are an essential part of LANL double shell and LLNL pushered single shell (PSS). The double shell inner shell employs Mo, W, Bilayers of Mo-Be and W-Be, and W-Be gradient capsules. They require a smooth surface and to be leak tight. In support of the double shell HDC experiments we have fabricated some smoother and leak tight metal coatings using magnetron sputtering on various mandrels, such as GDP and PAMS etc. Some of the leak tight coatings were achieved by using a leak tight Be liner. We are continuing to develop leak tight coatings of Mo and W. PSS shells employ Cr-Be and Mo-Be gradient capsules for stable and higher mass implosion. The gradient needs to follow hyperbolic tangent function profiles to achieve a stable implosion front. We have fabricated leak tight PSS capsules on PAMS and GDP mandrels with different density profiles. Microstructure analysis indicates a morphology variation with profile composition, changing from mostly amorphous to a Be crystal structure. This talk will overview the progress in making double shell inner shells and PSS shells.

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Presentation Type: Oral

Presenter: Hongwei Xu, hongwei.xu@ga.com.com, 858-455-3936

Fabrication of cupper containing deuterated material target for laser plasma diagnostics

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In the fast ignition which is an advance concept of Inertial Confinement Fusion, the understanding the mechanisms of the energy transfer from fast electrons to the compressed plasma core is critical for efficient fusion fuel heating. In these experiments, characteristic X-rays produced by the laser-accelerated fast electrons are utilized to understand the mechanisms of the electron transport in dense plasma and neutrons generated during the IFE experiment are utilized to investigate the fusion reaction as well as the temperature of the core compressed. Characteristic X-rays and neutrons are measured by using fuel targets containing tracer atoms that generate a specific signal during a fusion reaction. The amount of tracer is important to avoid resonant self-absorption of the X-ray. The deuterated ratio of target materials is also essential for efficient fusion reaction. For these purposes, several targets such as high deuterium concentration, metal foams, and low Z materials had been developed. It has been pointed out that experiments involving X-rays and neutrons require different experimental conditions mainly because inorganic materials such as Cu and organic materials with deuterium are generally incompatible with each other. However, the simultaneous achievement of Cu doping, deuterated polymer, mechanical toughness and chemical robustness for the fabrication process is not so simple. The glow discharge polymer (GDP) method was applied for a Cu-doped deuterated target. However, this method has a problem that the complicated shape of the target is difficult to be fabricated, because it requires a base part to deposit the target. Therefore, there is no bead target that contains both Cu and deuterium and no simultaneous measurements involving both characteristic X-rays and neutrons. In this regard, we report the fabrication of Cu-doped deuterated methyl methacrylate and methacrylic acid targets (Cu-dMA targets) as a novel target. The Cu-dMA is soluble in the solvents to facilitate processing into various shapes. Our results suggest that the Cu-dMA targets can be used as targets to provide valuable insights in the IFE experiments.

Presentation Type: Oral
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Characterization of solid hydrogen isotopologues mixture by refractive index measurement experiments and thermo-fluid simulations

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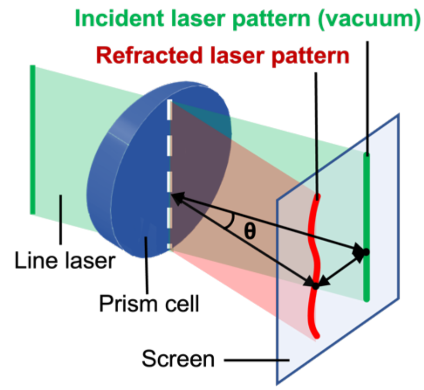

Fig 1. Schematic of optical measurements

Inertial confinement fusion target designs are generally based on a spherical ablator containing a solid D-T fuel layer surrounding a D-T vapor core. However, because of the isotope effect, the fractionation of hydrogen isotopologues has been noticed during the solidification process. Inhomogeneity of the solid D-T layer may result in the deterioration of the fusion reaction. Thus, solid D-T layer needs effective methods to characterize the isotopologues distribution and the homogeneity by means of both experiments and numerical simulation. We aim to develop a dedicated refractive index detection system at cryogenic temperature. The refractive index of solid D-T gives the composition of isotopologues, and the mapping of the refractive index in the solid D-T shows the homogeneity. The line laser is refracted after passing through a prism cell containing solid D-T –Figure 1. By measuring the angle of refraction, the refractive index is evaluated with Snell's law. The temperature dependence of the refractive index and the refractive index as a function of the D/T ratio were observed. Then, by mapping the refractive index in the solid D-T, the distribution of D-T was cleared. To confirm the influence of tritium beta decay, the refractive index distribution measurement of the solid protium (H) - deuterium (D) mixture was completed at first. The inhomogeneity in the solid H-D mixture was observed. Isotopologue distribution of the solid Hydrogen isotopologues mixture also be numerically simulated using computational fluid dynamics. Thermo-fluid simulations of the mixture solidification process were performed to study the mechanism of component distribution. The H-D prism cell has been 3D modeled and simulated. Figure 2. indicates the good agreement between the experiment and simulation. In addition, the influence of the decay heat and the decay product (helium-3) of tritium will be studied by experiments and numerical simulations. The study of D-T uniformity will encourage the study of the higher-quality D-T fuel pellets.

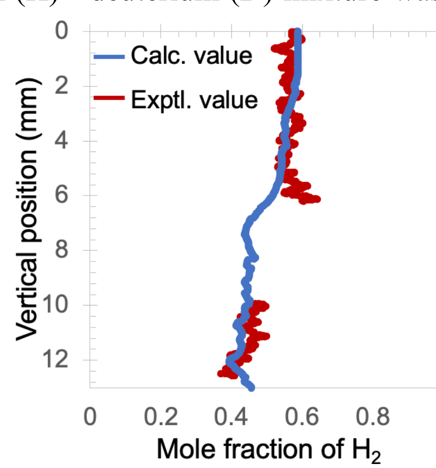

Fig 2. Refractive index vertical distribution

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