UNIVERSITY of ROCHESTER

LABORATORY FOR LASER ENERGETICS

2024 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

Wednesday, 28 August 2024
LLE Coliseum
Zoom: https://rochester.zoom.us/j/99021333710

1:30–1:35	Welcome	Dr. R. S. Craxton
1:35–1:45	Presentation of the 2024 William D. Ryan Inspirational Teacher Award	Dr. C. Deeney
1:45–2:00	Introduction	Chloe Chen
2:00–2:10	An Improved OMEGA Statistical Model for Fusion Experiments	Aria Banks
2:10–2:19	Characterizing Nanoscale Roughness of Hafnia and Silica Thin Film Coatings	Chelsie Odenbach
2:19–2:29	Evolutionary Optimization of Target Designs to Enhance the Predicted Ignition Metric on OMEGA	Evan Hoefen
2:29–2:38	Quantitative Analysis of Digital Film Scanning Techniques	Sophia Fietkiewicz
2:38–2:48	Developing Reflectivity Standards for High-Energy-Density Applications	Alexis Anauo
2:48–2:57	Injection Throttle Transmission on the OMEGA EP Laser	Ty Badre
2:57–3:07	Defocused Beams for Cryogenic Target Implosions on OMEGA	Noah Rose
3:07–3:16	Development of Waterproof Protective Optical Coatings for Laser Glass in Actively Cooled Disk Amplifiers	Prathiksha Mangalasubaskaran
3:16–3:30	Break	
3:30–3:40	Measurement of Palladium Hydride Isotherms at Cryogenic Temperatures	Samuel Cohen
3:40–3:49	Use of ChemCrow in Predicting the Optical Properties of Liquid Crystals	Isaac Allen
3:49–3:59	Double-Plate Lateral Shearing Interferometer for a Short-Coherence-Length Laser Source	Justin Chan
3:59–4:08	Non-Classical Heat Conduction in Laser-Produced Plasmas	Timothy Seo
4:08–4:18	Measurement of Nonlinear Refractive Index in Laser Materials	Colton Perry
4:18–4:27	Exploration of Better and Safer Solvents for Cleaning KDP Crystals Using Solubility Parameter Theory	Malachi Falco
4:27–4:37	Extracting Implosion Velocity and Compression from X-Ray Self-Emission Images in Direct-Drive Inertial Confinement Fusion	Forrest Li
4:37–4:46	Development of Laser Beam Configurations for Gold-Shell Targets on the National Ignition Facility	Chloe Chen
4:46–4:56	Implementation Feasibility Study of CMOS Sensors as Replacements for CID-based X-ray Pinhole Cameras in OMEGA Laser Systems	Johnny Piermarini
5:00–5:30	Tour of the OMEGA and OMEGA EP Lasers	Mark Labuzeta, David Canning, Jason Puth

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An Improved OMEGA Statistical Model for Fusion Experiments

Aria Banks
Pittsford Mendon High School
LLE Advisor: William Trickey

One-dimensional simulations of OMEGA cryogenic implosions are highly idealized and cannot account for experimental complexities on their own. These complexities can be represented with terms in a statistical model. Analyzing hundreds of implosions with this model has produced the most accurate predictions of implosion performance to date. The terms in the model have some correlation with each other but, ideally, would have no correlation. This work reduces the correlation between two terms by modifying the term representing instability. This modification improves the predictive capabilities of the statistical model.

Characterizing Nanoscale Roughness of Hafnia and Silica Thin Film Coatings

Chelsie Odenbach
Honeoye Central School
LLE Advisor: Brittany Hoffman

Thin film dielectric coatings are used for various optics in high-power, high-intensity laser systems. The most common dielectric coating materials are hafnia and silica due to their high laser-damage threshold. In order to understand how an optic might perform, a deep understanding of the material and coating properties is required. One aspect of this understanding is the nanoscale roughness of the films. Different factors such as materials, layer thickness, and deposition method could affect the roughness of the film, and thus the optical performance and laser damage mechanisms. In order to understand which factors affect the roughness, many different types of sample were measured using atomic force microscopy (AFM) and an optical profilometer. The AFM results showed that the nanoscale roughness increased as a function of thickness, especially for hafnia films.

Evolutionary Optimization of Target Designs to Enhance the Predicted Ignition Metric on OMEGA

Evan Hoefen
Brighton High School
LLE Advisor: Ka Ming Woo

An evolutionary algorithm was used to optimize the ignition metric χ (a measure, ranging from 0 to 1, of proximity to ignition) for OMEGA cryogenic implosions by identifying multiple target and laser pulse designs. The algorithm was also used to optimize the areal density (density-radius product) and neutron yield. In earlier work, the algorithm has been shown to be a viable process for generating successful designs. It includes multiple laser pulse shape parameters and five target design parameters: DT gas radius, DT ice radius, plastic thickness, CHSi layer thickness, and silicon doping fraction. Applied machine learning techniques include genetic evolution algorithms, multilayer perceptron neural networks, and Gaussian Process regression. Contributions of this work to the laser pulse and target design database have increased the prediction accuracy of evolutionary models by providing a wider range of input variables. This work could lead to the development of improved target and laser pulse designs that further increase χ.

Quantitative Analysis of Digital Film Scanning Techniques

Sophia Fietkiewicz
Our Lady of Mercy High School
LLE Advisors: Steven Ivancic and Michael Michalko

The currently existing methods of digiting x-ray films from OMEGA experiments include the Photometric Data Systems microdensitometer and the Epson 12000XL scanner. With the fast capture time and available user resources of charged-coupled devices (CCD), a new method of digitization was developed utilizing a CCD. A standard step wedge was digitized using the microdensitometer, scanner, and CCD to compare each instrument's response via optical density, with high-dynamic-range imaging applied to the CCD. This method provides optical density values with a root-mean-square error of 7.91% over the range 0.5-2.0 when compared to the microdensitometer, resulting from variations in spectral and optical collection between the systems. Similarly, the resolutions of the microdensitometer, scanner, and CCD were found to be 32, 8, and 16 line pairs/mm, respectively, by digitizing a resolution target and noting the line spacing at which contrast dropped below 50%. Finally, a laser-cut grid was digitized, and it was found that the CCD was the only technique that contained a slight barrel distortion, which can be corrected.

Developing Reflectivity Standards for High-Energy-Density Applications

Alexis Anauo
Eastridge High School
LLE Advisor: Danae Polsin

High-energy-density (HED) physics is studied by exploring the behavior of matter at extreme conditions using laser-driven experiments with the Omega EP laser. While the behavior of matter at one atmosphere has been well-characterized, material properties at HED conditions—pressures greater than one megabar, or approximately one million atmospheres—are largely unexplored. This work characterizes the reflectivity of aluminum and titanium coatings, from one atmosphere to 4 Mbar, for use as reflectivity standards to detect changes in electronic properties at HED conditions. The reflectivities and velocities of compressed Al and Ti are recorded with an instrument known as VISAR by reflecting a probe beam off the target. The interference pattern from this reflected light can be used to analyze reflectivity. The titanium reflectivity increases by only ~5% to a peak pressure greater than 2 Mbar, while the aluminum reflectivity continuously decreases by over 24% to the same pressure. This work concludes that titanium is an excellent reflectivity standard for HED applications.

Injection Throttle Transmission on the OMEGA EP Laser

Ty Badre
Pittsford Sutherland High School
LLE Advisor: Nicholas Black

The OMEGA EP laser system utilizes polarizers to configure the energy of the laser beams. The beams pass through three different optical elements known as the injection throttle, which contains a waveplate between two polarizers. Each optical element changes the output energy when rotated. However, errors were found to occur in the waveplate causing it to produce light travelling with an incorrect polarization. The injection throttle was simulated in MATLAB using Jones Calculus, which uses matrices and arrays to provide a mathematical representation of different polarizations and optical elements. The MATLAB simulation analyzed the laser beam before and after passing through each optical element. An experimental setup was used to gather data comparing the waveplate's impact on output energy when rotated and tilted by various amounts. One of the causes of this error from the waveplate was found to be the waveplate being placed at an incorrect angle with respect to the laser beam. Other factors that impact the waveplate's performance such as mechanical stress still need more testing.

Defocused Beams for Cryogenic Target Implosions on OMEGA

Noah Rose
Geneseo High School
LLE Advisor: Stephen Craxton

LLE's OMEGA laser is operated with phase plates that determine the beam spot size at best focus. Two sets of phase plates are available, known as the SG-850 and the SG-650 because they are designed for nominally 850 μm and 650 μm diameter spots, respectively. Generally, a larger beam spot better distributes the energy across the target surface to create a more uniform implosion, but at the expense of lower absorption. This work proposes the use of the SG-650 phase plate in combination with defocusing the laser to create implosions that have both improved uniformity and increased energy absorption compared with SG-850 phase plates used in best focus. Numerous simulations were run using the hydrodynamics code *SAGE* to find the optimal focal distance with the SG-650 phase plate for targets of varying dimensions. For a 950-μm-diam target and a 2-mm defocus, the rms deposition uniformity was 0.25% with an absorption of 78.6%, compared with 0.45% and 76.1%, respectively, for the in-focus phase plate. Use of this technique could improve the neutron yield of cryogenic target implosions on OMEGA.

Development of Waterproof Protective Optical Coatings for Laser Glass in Actively Cooled Disk Amplifiers

Prathiksha Mangalasubaskaran
Pittsford Mendon High School
LLE Advisor: Kenneth Marshall

The proposed EP OPAL laser is dedicated to the study of ultrahigh-intensity laser matter interactions. The laser may utilize heavy water as a coolant to dissipate the heat generated by the flashlamps. Coatings will therefore be applied onto the laser glass via dip coating to shield from water erosion. Dip coating involves dipping a sample into a polymer solution with varying concentrations and withdrawal speeds. The polymer studied was polyvinyl butyral in 2-butanone. This work found that the polymer produced a coating with minimal defects as viewed through a microscope, strong hydrophobic properties verified by examining contact angles, homogeneity in the topography of the surfaces, and a high transmission of 92.47%. Other materials such as Filmtronics P102f in ethanol and Dow-Corning Sylgard 184 in toluene were also capable coatings that merit further testing. The coatings that were researched demonstrate promising results and will be further evaluated with immersion tests and measurements of the laser damage threshold of the material.

Measurement of Palladium Hydride Isotherms at Cryogenic Temperatures

Samuel Cohen
Brighton High School
LLE Advisor: Matthew Sharpe

The metal palladium has a strong affinity for hydrogen and its isotopes. They react to form compounds such as palladium hydride and palladium deuteride. Palladium is being researched due to its ability to store large volumes of hydrogen gas in its latticed structure. Currently, there is little data for this reaction at temperatures below 170 K. This work measured the vapor pressure of hydrogen and deuterium gas over palladium as a function of time to create adsorption curves. Isotherms were also obtained that measure the equilibrium pressures at fixed temperatures as a function of the Q/Pd ratio, where Q is the hydrogen gas. This study examined the behavior of the reaction at cryogenic temperatures (<170 K) where the reaction shifts from hydriding to adsorption on the surface of the palladium bed. Analyzing the adsorption curves and isotherms for the reaction at cryogenic temperatures, it was determined that the reaction occurs at a slower rate. This suggests that the reaction begins to adsorb only rather than hydride and adsorb at lower temperatures.

Use of ChemCrow in Predicting the Optical Properties of Liquid Crystals

Isaac Allen
Brockport High School
LLE Advisor: Kenneth L. Marshall

The unique optical properties of liquid crystals (LC's) and the ability to tailor their properties through chemical synthesis to meet device requirements make them highly useful for polarization control of light in laser systems. Because the design and synthesis of LC's can be costly and time-consuming, it becomes imperative to develop new computational methods to design LC's with enhanced properties. One key tool in this effort is *ChemCrow,* a software package that uses prompt-engineering and tools to modify existing artificial intelligence models, orientating them towards scientific use. *ChemCrow* was used to assemble a dataset of relevant optical properties, fine-tuned to train a model to predict molecules' refractive index, and used to plan syntheses for molecules with potential optical use. This work demonstrates *ChemCrow*'s prospective use in future optical and machine learning applications, as its predictive capabilities can be applied to numerous other molecular properties.

Double-Plate Lateral Shearing Interferometer for a Short-Coherence-Length Laser Source

Justin Chan
Webster Schroeder High School
LLE Advisor: Seung-Whan Bahk

Wavefront measurement using a short pulse laser can provide important information on the dynamics of a fast moving plasma. Specifically, measuring the critical plasma surface of an ablating inertial confinement fusion target provides information about the uniformity of the converging target surface. Among many wavefront diagnostics, the use of lateral shearing interferometers (LSI), which operate based on the interference between spatially shifted replicas of a laser beam, is convenient due to its simplicity and self-referencing principle. However, most LSI are unable to be used for short pulse lasers because they have unequal path lengths or are too bulky. A proposed solution is to use a double-plate LSI which can provide equal path lengths for two short pulse beams, enabling the creation of interference patterns. These patterns can be used to calculate the phase of the wavefront sampled by the short pulse laser. This concept was modeled in Zemax and was experimentally demonstrated, with results showing a strong agreement between the measured phase and the known test phase.

Non-Classical Heat Conduction in Laser-Produced Plasmas

Timothy Seo
Pittsford Mendon High School
LLE Advisor: Nathaniel Shaffer

Absorption and heat conduction are the two most important energy-balance mechanisms for inertial-confinement-fusion (ICF) plasmas. This work studied heat conduction in the presence of a laser to explore novel effects, such as reduced heat flow due to two causes: plasma density gradients and the absorption of laser energy. Using Vlasov-Fokker-Planck simulations to model the electron distribution function (the probability of electrons having different velocities), a series of temperature and heat flux profiles were analyzed to create a fit for the thermal conductivity. A recently proposed model for how absorption reduces thermal conductivity was validated, and a new model for heat flow due to density gradients was developed. Multiple laser intensities and different charge states were analyzed, including consideration of electron-electron collisions. This work lays the groundwork for developing a practical model of how lasers affect the heat flow in the absorbing regions of an ICF plasma.

Measurement of Nonlinear Refractive Index in Laser Materials

Colton Perry
Bloomfield High School
LLE Advisor: Douglas Broege

When a light beam travels through a medium at a high intensity, it has the ability to change the refractive index of the material. This creates an issue when using powerful lasers, as this change in refractive index causes nonlinear refraction, wherein the light bends more or less than it would at a lower intensity, leading to problems such as unintentional hotspots, which can damage optics. Thus, it is paramount to the studies of laser optics and the evaluation of prospective laser materials to quantify this property, determined by a quantity known as the nonlinear refractive index, or n_2. To measure n_2, an optical setup was used that focuses a laser beam onto a sample material and collects camera images of the emerging beam for various locations of the sample. Changes in refraction result in changes in the images, allowing n_2 to be calculated. A set of software packages—one that gathers data and another that analyses it to obtain the n_2—was created.

Exploration of Better and Safer Solvents for Cleaning KDP Crystals Using Solubility Parameter Theory

Malachi Falco
Churchville-Chili High School
LLE Advisor: Nate Urban

Potassium dihydrogen phosphate (KDP) crystals are critical optics for laser frequency conversion in high-power laser systems conducting inertial confinement fusion research. As these crystals are water-soluble, finishing the surfaces to an optical quality involves either diamond turning or polishing in oil-based fluids. Residual oils and abrasives must be thoroughly cleaned off the crystal surfaces before they can be coated and deployed, yet the current process of hand-wiping with the hazardous and environmentally detrimental xylene solvents is inefficient as well as potentially damaging to the crystal. In this work, a list of solvents that are both safe and environmentally friendly was compiled and then Hansen Solubility Parameters (HSP) were used to predict their cleaning efficiency as compared with xylenes. HSP uses the cohesive energy density of the dispersive, polar, and hydrogen bonding components of molecules to predict their solubility. A number of promising solvents (and blends) were predicted to have superior cleaning efficiency over xylenes. This work is anticipated to make the process of cleaning KDP crystals both significantly safer and more efficient.

Extracting Implosion Velocity and Compression from X-Ray Self-Emission Images in Direct-Drive Inertial Confinement Fusion

Forrest Li
Webster Thomas High School
LLE Advisor: Luke Ceurvorst

In direct-drive inertial confinement fusion implosions, benchmarking simulations is critical for ensuring their reliability. In this work, an automated program was developed using MATLAB to determine the position of the target shell at various times during the implosion. Using images of the x rays emitted by the target at different times, an Abel inversion—a function used in image analysis to extract profiles of emission as a function of radius from a scanned image—was applied. These profiles were further used to extract the emission edge position of the target by taking the midpoint of the emission profile's rising edge. Previous 1D *LILAC* simulations were then benchmarked by comparing the experimentally determined positions with the simulated positions, confirming the validity of the program. This program can be used when new simulations are made for alternative target materials as it is important to understand how much laser energy is converted into target kinetic energy. By comparing experimentally determined positions from the program to simulated positions, the accuracy of the alternate material simulations can be inferred.

Development of Laser Beam Configurations for Gold-Shell Targets on the National Ignition Facility

Chloe Chen
Penfield High School
LLE Advisor: Stephen Craxton

Experiments utilizing gold-shell targets are planned on the National Ignition Facility (NIF) to provide scientists with a greater understanding of gold x-ray emissions. The proposed targets are constructed of a 10-μm gold outer shell coated onto 1090 μm of solid CH plastic. These targets require uniform irradiation by the 192 NIF beams. Optimized laser beam pointings have been developed using the 2-D hydrodynamics code *SAGE* to simulate the laser energy distribution across the target surface. Compared with a previous design, which produced nonuniformities at the target's poles and equator, improved uniformity was obtained by increasing the size of the laser spots on the target using defocused laser beams, and by varying the location of the beam aimpoints in both the latitudinal and longitudinal directions. The deposition nonuniformity was calculated to be 1.4% root-mean-square, compared with 5.8% from the previous design. The design was optimized for the middle of the pulse and provided comparable consistency throughout the entire pulse. Utilizing these configurations will provide improved uniformity for the planned NIF experiments.

Implementation Feasibility Study of CMOS Sensors as Replacements for CID-based X-ray Pinhole Cameras in OMEGA Laser Systems

Johnny Piermarini
Red Jacket High School, Manchester-Shortsville
LLE Advisors: Daniel Slakes and Steven Ivancic

CID sensors used in x-ray pinhole cameras facilitate efficient data acquisition and analysis for the OMEGA 60 and OMEGA EP laser systems. However, with the discontinuation of CID sensors, there is a need for alternatives. This study evaluated two CMOS sensors: the Finger Lakes Instruments Kepler KL400 and the Hamamatsu S-11685. The Kepler KL400 was thoroughly assessed by mapping its response to visible (~570 nm) and Ti Kα x-ray emissions (4.51 keV), and generating a photon transfer curve to evaluate its sensitivity and performance. The Hamamatsu sensor encountered significant hardware and software integration challenges, which limited its feasibility for analysis in the scope of this study, but it still remains a desirable option due to its design. The Kepler KL400 showed promising performance and will undergo further testing in the upcoming months to ensure its effectiveness and compatibility with the facility's requirements. If successful, it will provide a suitable replacement for CIDs and ensure the continued operational integrity of x-ray pinhole camera diagnostics.