UNIVERSITY of ROCHESTER

LABORATORY FOR LASER ENERGETICS

2019 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

Wednesday, 28 August 2019
LLE Coliseum

1:30–1:35	Welcome	Dr. R. S. Craxton
1:35–1:45	Presentation of the 2019 William D. Ryan Inspirational Teacher Award	Dr. E.M. Campbell
1:45–2:00	Introduction	Simon Narang
2:00–2:11	Optimization of X-Ray Prepulse Geometry for Imprint Mitigation in Directly Driven Implosions	Adelyn Carney
2:11–2:22	Investigations of the Hydrogen-Palladium and Deuterium-Palladium Systems	Stephen Rosa
2:22–2:33	Optimization of the Uniformity of 12-Quad Targets for the National Ignition Facility	Hanna Wiandt
2:33–2:44	A Comparative Study of the Effects of Methanol and Ethanol Solutions on the Bulk Etch Rate of CR-39	Michele Lin
2:44–2:55	Using IRIS3D to Simulate the Effects of Smoothing by Spectral Dispersion on Cryogenic Implosions	Anthony Mazzacane
2:55–3:06	Evaluation of Fresnel Zone Plate X-ray Imagers for Inertial Confinement Fusion Applications	Christopher Kukla
3:06–3:17	Schlieren Diagnostic for the Imaging of Thermal Turbulence	Adam Mroueh
3:17–3:35	Break	
3:35–3:46	Design of a Single-Hit Neutron Spectrometer for Long-Duration Fusion Reactions	Henry Berger
3:46–3:57	Glassy Liquid Crystals Based on Natural Products for High-Peak-Power Laser Optics	George Morcos
3:57–4:08	Micro Raman Spectroscopy of Silica and Hafnia Laser Damage Sites	Ji-Mi Jang
4:08–4:19	Enhancements to the Calorimetric Measurement System on the OMEGA Laser	Max Neiderbach
4:19–4:30	Development of a Beam Configuration for the SG4 Laser to Support both Direct and Indirect Drive	William Wang
4:30–4:41	Comparative Analysis of Oxygen Uptake in Nickel and Copper-Zinc Beds	Ka-Hyun Nam
4:41–4:52	Application for Filling Cryogenic Targets at an Arbitrary Viewing Angle	Simon Narang
5:00–5:40	Tour of the OMEGA and OMEGA EP lasers	Mark Labuzeta, David Canning

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Optimization of X-Ray Prepulse Geometry for Imprint Mitigation in Directly Driven Implosions

Adelyn Carney
Webster Schroeder High School
LLE Advisor: Hans Rinderknecht

Laser imprint, when laser nonuniformities are imprinted onto the capsule at the beginning of the implosion, is a limiting factor in direct-drive inertial confinement fusion. One method to reduce imprint is x-ray pre-illumination, in which an additional x-ray source is used to “puff up” the outermost layer of the capsule before it is illuminated by the main laser pulse. In this project, the optimal placement of x-ray prepulse foils that will be driven by OMEGA EP beams to create the additional x-ray source is investigated. MATLAB functions were developed to generate 4-, 6-, and 8-foil geometries and verify that they satisfy beam clearance requirements. VisRad models were constructed for select foil configurations, and viewfactor simulations were run to optimize foil orientation. A six-foil geometry was found to provide the highest mean incident flux with nonuniformity below 10%, while an eight-foil geometry was found to provide the lowest nonuniformity (<8%).

Investigations of the Hydrogen-Palladium and Deuterium-Palladium Systems

Stephen Rosa
Eastridge High School
LLE Advisors: Walter Shmayda and Matthew Sharpe

Palladium is a metal that is used to store hydrogen and its isotopes. It can interact with hydrogen by either physically storing it in the spaces between palladium atoms, or by reacting with it chemically to form palladium hydride, which can later be separated to release the stored hydrogen. This project examines the change in vapor pressure over palladium as hydrogen is added to change the ratio of hydrogen atoms to palladium atoms, all while the temperature is held constant. Data has been collected on the formation of palladium hydride at temperatures ranging from 140 K to 393 K (-130°C to 120°C). Little data exists for temperatures below 0°C. Hydride formation appears to become temperature independent below 160 K.

Optimization of the Uniformity of 12-Quad Targets for the National Ignition Facility

Hanna Wiandt
Pittsford Mendon High School
LLE Advisor: Stephen Craxton

The National Ignition Facility has a total of 192 beams, divided amongst 48 quads located at 23˚, 30˚, 45˚, and 50˚ from the top and bottom of the target chamber. A proposed experiment requires the use of 24 quads to irradiate a cylindrical hohlraum and 12 quads to compress each of two spherical targets using direct drive. A sample would be exposed to the high fluxes of x rays and neutrons produced by the targets. Glass and plastic spheres of 1600 µm and 2000 µm diameter were considered for the direct drive targets. Individual beams were repointed in the theta (vertical) and azimuthal (horizontal) directions to increase the uniformity of the imploding targets, compensating for the uneven coverage provided by the use of only 12 quads. The beams were also defocused to spread out their energy. Nonuniformities as low as 3-4% rms were obtained in all cases.

A Comparative Study of the Effects of Methanol and Ethanol Solutions on the Bulk Etch Rate of CR-39

Michele Lin
Attica High School
LLE Advisor: Michelle McCluskey

CR-39 is a plastic polymer detector used in the Magnetic Recoil Spectrometer (MRS) diagnostic on the OMEGA laser system. Charged nuclear particles emitted from the implosion disrupt chemical bonds within the plastic, leaving tracks. The plastic undergoes a series of three chemical etching processes to reveal the tracks. The tracks are recorded using an optical microscope in conjunction with image processing software, which uses a coincidence counting technique to distinguish true tracks from background noise. This project investigates a new bulk etching technique using a methanol/sodium hydroxide solution with the goal of increasing the etch rate. Varied concentrations of methanol and sodium hydroxide were tested. A 2.5 N methanol/sodium hydroxide solution increased the bulk etch rate from ~17 microns removed/hour using the standard ethanol/sodium hydroxide solution to ~35 microns removed/hour. This promises to decrease the amount of time needed to process MRS and other data.

Using IRIS3D to Simulate the Effects of Smoothing by Spectral Dispersion on Cryogenic Implosions

Anthony Mazzacane
Pittsford Mendon High School
LLE Advisors: Radha Bahukutumbi, Owen Mannion, Samuel Miller

Smoothing by spectral dispersion (SSD), a technique of rapidly oscillating laser focus points to reduce the effect of speckle, has been shown to significantly increase target uniformity in simulated cryogenic implosions. A remapper program was developed for the radiation hydrodynamics code *DRACO* to reduce grid resolution for neutron transport calculations while conserving physical quantities. This remapper was demonstrated to produce accurate neutron spectra when *DRACO* simulations are post-processed by *IRIS3D,* while significantly reducing computation time. The program was then used to remap a set of simulations containing various amounts of SSD, which were post-processed to generate neutron energy spectra and inferred areal density values. These calculations enabled a comparison of simulated values with those from experiments performed on OMEGA, demonstrating the effectiveness of SSD in reducing the nonuniformity of cryogenic target implosions.

Evaluation of Fresnel Zone Plate X-ray Imagers for Inertial Confinement Fusion Applications

Christopher Kukla
Pittsford Mendon High School
LLE Advisors: Frederic Marshall, Steven Ivancic

Fresnel Zone Plates (FZPs) can increase the x-ray imaging spatial resolution on the OMEGA and OMEGA EP systems to a level approaching 1 micron. Current methods are limited to 5 to 10 microns, so FZPs are a significant improvement. A method using fast Fourier transforms (FFTs) has been developed to evaluate the resolution of FZPs. The frequency spectra of both an idealized grid image and real images obtained with a charge-coupled device (CCD) are determined by calculating the FFTs. An assumed Gaussian point-spread function (PSF) can then be forward-fitted to the ideal pattern to determine the resolution of the system. A MATLAB script was written to determine the range of Gaussian PSFs that could be fitted to the dataset to accurately predict the resolution. This is applied to FZP images of grids obtained both in the X-Ray Laboratory and on the OMEGA EP laser system.

Schlieren Diagnostic for the Imaging of Thermal Turbulence

Adam Mroueh
Pittsford Sutherland High School
LLE Advisor: Douglas Broege

Turbulence and index gradients arise from heat or gas flow through air and have long been an issue, disrupting the propagation of laser beams as well as their stability and ability to focus on a tight spot. Schlieren, a type of imaging used to visualize gradients in indices of refraction, has been proposed as a possible way to identify turbulence such as that occurring in CLARA amplifiers at LLE. In this experiment, through the setup of a Schlieren system consisting of a pinhole light source, a concave parabolic mirror, and a razor blade, it was possible to record the flow of heat and gas through air. Using the Schlieren system, a hot plate was analyzed at various temperatures ranging from 40-50 degrees Celsius. Videos were taken at a given temperature and a MATLAB script was devised to average these videos into a composite image. The script then finds the root-mean-square deviation between the averaged image and each individual frame in the video. The resulting image represents turbulence from the hot plate. This process was repeated for nitrogen flow at varying pressures. Upon comparing results from the hot plate and nitrogen, it was explored whether turbulence from nitrogen could be eliminated through heating it.

Design of a Single-Hit Neutron Spectrometer for Long-Duration Fusion Reactions

Henry Berger
Brighton High School
LLE Advisor: Chad Forrest

A novel neutron spectrometer was designed and simulated for use with 2.45 MeV neutrons from fusion reactions with durations beyond the limits of time-of-flight-based spectroscopy. This diagnostic will be used to infer the apparent temperature of fusing ions. The spectrometer consists of two parts: a deuterated plastic converter foil, in which an incident neutron can transfer its energy to a deuteron, and a silicon chip that measures the energy of deuterons. The shape of the observed deuteron energy spectrum was found to be strongly predictive of the shape of the incident neutron energy spectrum, enabling the determination of the fusing particles' thermal energy. Many design parameters, including the converter's material, thickness, and distance from the detector, were optimized, in order to maximize the detection rate and energy resolution. Simulations were used to determine the range of neutron yields and ion temperatures for which the spectrometer would be effective. The spectrometer is not efficient enough for use at FuZE, the reactor for which it was intended, but the spectrometer could function at other reactors. A spectrometer based on this work will be built and tested at LLE.

Glassy Liquid Crystals Based on Natural Products for High-Peak-Power Laser Optics

George Morcos
Rush-Henrietta Senior High School
LLE Advisor: Kenneth Marshall

Glassy liquid crystals (GLCs) are of interest for potential application as circular polarizers for high-peak-power lasers such as OMEGA. One new material based on a natural product (cholesterol), GLC-Bz3CholC5, is of particular interest because it shows a ten-fold increase in laser-induced damage threshold values as compared to previous materials – a prerequisite to large-scale laser optics applications. The feasibility of using this material for the fabrication of practical, large-area polarization control devices for high-peak-power laser applications was investigated by preparing mixtures of this material with nematic and long-pitch cholesteric GLC host materials and evaluating their liquid crystal phase behavior and optical properties by hot-stage polarizing microscopy. Near-planar alignment of these new materials in assembled devices was achieved by melt-processing and thermal quenching on glass substrates, although significant optical scatter, due to liquid crystal domain defects, remains.

Micro Raman Spectroscopy of Silica and Hafnia Laser Damage Sites

Ji-Mi Jang
Pittsford Mendon High School
LLE Advisor: Tanya Kosc

Micro Raman spectroscopy is a technique used to measure the Raman effect on microscopic samples. A microscope objective focuses the pump laser (excitation source) onto a micron-sized spot, and the absorbed photons provide energy to excite the electrons. Some of that energy can be lost to molecular vibrations; energy not lost is reemitted at a different wavelength, producing the Raman scattering signal. The goal of this project is to use Raman spectroscopy to characterize material modification as a result of laser-induced damage. The spectra of silica and hafnia, used to make multi-layer thin film coatings for laser optics, are similar, both showing Raman features and photoluminescence, but easily discernible. Photoluminescence helps differentiate between 1-on-1 and n-on-1 damage sites as well as between damaged and undamaged areas. This information could be applied to the future manufacturing of thin film coatings.

Enhancements to the Calorimetric Measurement System on the OMEGA Laser

Max Neiderbach
Geneseo Central School
LLE Advisors: Michael Sharpe, Vinitha Anand, and Robert Peck

Calorimeters are used to measure the energy of a laser beam. This is done by measuring the voltage output of the calorimeter over a period of time, and then integrating the graph of this measured signal. The calorimeter system that is currently being used can achieve a signal-to-noise ratio of 32:1. In order to improve measurement accuracy, the noise must be decreased. Different digitizers and calorimeter insulations were tested. The best performing system used a 24-bit digitizer that was controlled by a Raspberry Pi computer, and the calorimeter was insulated by two layers of foam separated by an air gap. This system can achieve a signal-to-noise ratio of between 316:1 and 1000:1, which is between a 10 and 32 fold improvement over the current system.

Development of a Beam Configuration for the SG4 Laser to Support both Direct and Indirect Drive

William Wang
Pittsford Sutherland High School
LLE Advisor: Stephen Craxton

Recent papers (e.g., Ke Lan *et al*.) have proposed "cubic," or six-hole, hohlraums for the planned SG4 laser. Cubic hohlraums aim to increase indirect drive uniformity on the target capsule (compared with the cylindrical hohlraums used on the National Ignition Facility). The SG4 target chamber uses 48 quads to drive the cubic hohlraum with 8 quads/hole. This work proposes an amended target chamber that will provide the option of direct drive along with indirect drive. A viewfactor program, *LORE*, has been created to calculate the target nonuniformity for indirect drive. *LORE* simulations have confirmed results obtained by Lan and others for cubic hohlraums and predict a nonuniformity ranging from 0.6% at early times (when the target is irradiated primarily by the laser spots) to 0.07% at later times (when the heated hohlraum wall dominates). Initial optimizations of the beam pointings for direct drive using the 2-D hydrodynamics simulation code *SAGE* indicate that an rms nonuniformity of ~1% in the deposited laser energy can be achieved while beams are repointed by less than 9° on the target surface. Further improvements to the uniformity are expected with additional optimization.

Comparative Analysis of Oxygen Uptake in Nickel and Copper-Zinc Beds

Ka-Hyun Nam
Brighton High School
LLE Advisors: Cody Fagan and Walter Shmayda

Oxygen must be removed from tritium processing systems to avoid irreversibly oxidizing the zirconium-iron (ZrFe) alloy used to capture tritium. Nickel (Ni) and copper-zinc (CuZn) alloy beds were compared for their efficiency in extracting oxygen from inert gas streams containing small concentrations of oxygen. Oxygen was loaded onto a Ni bed to form nickel oxide (NiO) at various temperatures and carrier-gas flow rates. This data was compared with previously collected data for copper-zinc alloy under similar operating conditions. A shorter mass transfer zone (MTZ), the region in the bed where the oxidation occurs, is indicative of a more effective use of the bed's capacity. It was found that the Ni bed has the shorter MTZ for carrier-gas flow rates between 0.1 and 5 liters per minute. Additionally, the MTZ was found to decrease in length as the Ni temperature increased from 350°C to 450°C.

Application for Filling Cryogenic Targets at an Arbitrary Viewing Angle

Simon Narang
Pittsford Sutherland High School
LLE Advisors: Mark Wittman, Dean Bredesen

Cryogenic targets are filled with a liquid mixture of deuterium and tritium (DT) which is subsequently frozen into a uniform solid layer on the interior of a polymer capsule. At present, DT gas is diffused into the capsule at high pressure. A new target-delivery system for OMEGA is being developed in which capsules are filled from a DT reservoir via a 10-µm-diameter tube. The amount of DT in the capsule, and thus the thickness of the frozen layer, will be determined from an x-ray image of the liquid meniscus viewed at an angle not perpendicular to gravity. A Matlab program was developed to analyze these x-ray images from an arbitrary angle. This program calculates the layer thickness as a function of the viewing angle and the semi-minor axis of the elliptical bubble above the liquid meniscus. The predictions were tested on the Cryogenic Fill-tube Test Facility using experimentally obtained x-ray images (taken at 90° to gravity) of initial liquid fills and the resulting solid-DT layers. The algorithm was able to predict the fuel thickness to an accuracy of 2 µm on uniform targets.