UNIVERSITY of ROCHESTER

LABORATORY FOR LASER ENERGETICS

2016 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

Wednesday, 24 August 2016
LLE Coliseum

1:30–1:35	Welcome	Dr. R. S. Craxton
1:35–1:45	Presentation of the 2016 William D. Ryan Inspirational Teacher Award	Dr. R. S. Craxton
1:45–2:00	Introduction	Grace Lenhard
2:00–2:12	Using Social Media Technologies for Online Scientific Analysis and Collaboration	James Hu
2:12–2:24	Characterization of the Electrical Properties of Contaminated Dielectric Oils for Pulsed Power Research	Sapna Ramesh
2:24–2:36	Simulations of Laser-Driven Magnetized-Liner Inertial Fusion	Leah Xiao
2:36–2:48	Measuring Hydrogen Pressure over a Palladium Bed	Joseph Mastrandrea
2:48–3:00	Design and Optimization of a Portable Wavefront Measurement System for Short-Coherent-Length Laser Beams	Archana Sharma
3:00–3:12	Beam-Pointing Optimizations for OMEGA Implosions	Webster Kehoe
3:12–3:30	Break	
3:30–3:42	Post-Shot Data Analysis Tools for Cryogenic Target Shots	Kyle Bensink
3:42–3:54	Characterizing a Cu/Mn Alloy for Extracting Oxygen from Inert Gas Streams	Grace Lenhard
3:54–4:06	Validating the Fast-Ion Energy Loss Model in the Monte Carlo Simulation Toolkit Geant4 and Simulating Laser-Driven Nuclear Reaction Experiments at OMEGA EP	Jonah Simpson
4:06–4:18	Impulse Response Calibration of a Neutron Temporal Diagnostic Using the Multi-Terawatt Laser	Matthew Wang
4:18–4:30	Development of a Standardized Saturn Ring for Proton Backlighter Targets on the National Ignition Facility	Lindsay Browning
4:30–4:42	Development of a Digital Microscope for the Characterization of Defects in Cryogenic DT-Filled Targets	Joy Zhang
4:42–4:54	OMEGA Frequency Conversion Crystal Designs for Improved Power Balance	Nathan Morse
5:00–5:40	Tour of the OMEGA and OMEGA EP lasers	Steven Stagnitto, David Canning

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Using Social Media Technologies for Online Scientific Analysis and Collaboration

James Hu
Brighton High School
LLE Advisor: Richard Kidder

A web page that provides a scientific analysis worksheet for data from experiments on the OMEGA and OMEGA EP lasers has been improved upon with the implementation of social features to create a more collaborative scientific environment for users. This interface was created with the purpose of allowing principal investigators and guest users to collaboratively analyze data in web-based live sessions and communicate with their peers through a group chat system. Users are able to connect with other principal investigators, diagnostic specialists and facility managers associated with scientific campaigns of interest. Collaborators are able to view and analyze data or develop code using Python functions. Principal investigators can invite remote colleagues to join a session to conveniently share data.

Characterization of the Electrical Properties of Contaminated Dielectric Oils for Pulsed Power Research

Sapna Ramesh
Pittsford Mendon High School
LLE Advisor: Kenneth Marshall

In the pulsed-power Z machine at Sandia National Laboratory, the high-voltage energy-storage capacitors are submerged in insulating oil to minimize thermal and electric losses. Over time this oil becomes contaminated with dielectric breakdown products from high-voltage discharges and extrinsic contaminants introduced during maintenance and cleaning activities. The effect of these contaminants on the electrical properties of the insulating oil was evaluated using impedance spectroscopy along with DC-regime measurements of resistivity. A process for purification of the oil using absorbants such as molecular sieves was developed and measurements of electrical and optical properties were used to evaluate the effectiveness of the absorbants. This work provides the framework for future studies of insulating oil lifetime and purification procedures for the Pulsed Power Laboratory being constructed at LLE.

Simulations of Laser-Driven Magnetized-Liner Inertial Fusion

Leah Xiao
Webster Schroeder High School
LLE Advisor: Stephen Craxton

Magnetized-liner inertial fusion (MagLIF) is being explored as a new method of achieving ignition. MagLIF uses a cylindrical shell containing deuterium fuel imploded using a high electrical current with a preheating beam fired down the axis. In this work various geometries and systems have been modeled for MagLIF experiments using the hydrodynamics simulation code *SAGE*. Simulations of small-scale laser-driven MagLIF experiments on OMEGA without the preheating beam have explored a variety of compression beam parameters. These simulations demonstrated agreement with data from experimental shots for quantities such as radius versus time, speed and shape. Simulations of upcoming shots with the incorporation of the preheating beam predicted temperatures of the heated deuterium as well as compression uniformity. Simulations of large-scale targets with dimensions appropriate to the Z machine at the Sandia National Laboratory show that a desired temperature profile can be achieved through the formation of a self-focusing density channel.

Measuring Hydrogen Pressure over a Palladium Bed

Joseph Mastrandrea
Webster Thomas High School
LLE Advisor: Walter Shmayda

An experimental setup that utilized a Pd bed connected to a heater and a cryocooler (which operates according to the Stirling Cycle) was used to collect data on the formation of palladium hydride. Palladium is a member of a group of metals that have been found to absorb the different isotopes of hydrogen and form metal hydrides. It is of great interest on account of its ability to collect and store large volumes of hydrogen, deuterium, and tritium. Measuring the change in hydrogen pressure above the palladium at equilibrium provides the amount of hydrogen absorbed into the palladium. Pressure data was recorded for H/Pd ratios between 0.0 and 0.8 and temperatures between 233 K and 453 K. This extends the prior minimum temperature of study from 293 K to 233 K and expands the upper bound of the H/Pd ratio studied from 0.6 to 0.8. The absorption data indicates that palladium is an effective absorber of hydrogen at lower temperatures and can deliver hydrogen over a broad temperature range.

Design and Optimization of a Portable Wavefront Measurement System for Short-Coherent-Length Laser Beams

Archana Sharma
Webster Schroeder High School
LLE Advisors: Adam Kalb, Christophe Dorrer, Kyle Gibney

A Hartmann mask-based method for judging the collimation of laser beams of any coherence length on the OMEGA EP system using existing imaging systems has been developed and optimized. Collimation, which can greatly impact laser performance by way of transport efficiency and focal spot quality, has typically been judged interferometrically using shear plates. In order for a shear plate to work well, its thickness must be much less than the coherence length of the laser beam being tested, making shear plates impractical for laser pulses with very short coherence lengths, such as those created by high-average-power fiber lasers or via optical parametric amplification. A test setup has been built and MATLAB code has been developed to process data in order to reconstruct the wavefront of a laser beam. A newly developed mask having apodized holes and a conventional Hartmann mask with flat-top holes have been used to measure known wavefronts introduced by test components. The apodized mask has been determined to be more accurate than the conventional flat-top mask.

Beam-Pointing Optimizations for OMEGA Implosions

Webster Kehoe
Joseph C. Wilson Magnet High School
LLE Advisor: Stephen Craxton

It is often desired to divert beams from the OMEGA laser to a secondary target used for x-ray backlighting. This secondary target emits x rays that pass through the primary target to create a diagnostic image. In one experiment, six beams were used to target the x-ray backlighter, leaving 54 beams to drive the implosion. As a result there was significantly worse compression uniformity: the root-mean-square (rms) irradiation nonuniformity increased from 0.40% for the perfect configuration with all 60 beams to 10.3%. Using the hydrodynamics simulation code *SAGE* the beam pointings of the remaining 54 beams were optimized to maximize uniformity, bringing the rms nonuniformity down to 0.67%. Since this method of optimization is very time intensive, an effort was made to explore whether it is possible to find an acceptable configuration in a short amount of time given any combination of missing beams. An algorithm was created to find the optimal configuration given any single missing beam. This algorithm produced an rms nonuniformity of 0.54%, equal to that of the non-algorithmic optimization.

Post-Shot Data Analysis Tools for Cryogenic Target Shots

Kyle Bensink
Victor Senior High School
LLE Advisor: Douglas Jacobs-Perkins

A series of Matlab programs were developed that can systematically parse and analyze data from multiple cryogenic-target positioning-control and sensor subsystems on OMEGA. The most involved analysis programs monitor the pressure and leak rate of helium exchange gas within the inner shroud, both of which must be relatively stable in order to tightly control the target temperature. Other programs monitor interrelated parameters that influence the condition of the deuterium-tritium ice layer within the target as well as the target position. Most data sources log data at dissimilar rates - for example, high-speed video logging of target position records rapidly and intermittently, in contrast to diagnostic equipment on the bridge and moving cryostat transfer cart. As a result, programs that incorporate multiple subsystem data sets correlate time logs in order to parse effectively. As more programs are developed, they will be integrated into the post-shot analysis cycle to generate statistical data, and ultimately will allow subsystem "health" to be closely monitored.

Characterizing a Cu/Mn Alloy for Extracting Oxygen from Inert Gas Streams

Grace Lenhard
Prattsburgh Central School
LLE Advisors: Walter Shmayda and Matthew Sharpe

Gloveboxes filled with inert gases are used to reduce the release of tritium, a radioactive isotope of hydrogen used for fusion experiments at LLE, into the atmosphere. A zirconium/iron (Zr-Fe) alloy is used to remove tritium accidentally released into the gloveboxes. However, oxygen and water, which leak into the gloveboxes through the gloves and seals, deactivate the Zr-Fe bed, so they must be removed from the gas stream. A copper/manganese alloy was investigated as an alternative to nickel, the current oxygen getter (absorber). Oxygen in a carrier stream of helium is flowed over the alloy, where it forms a surface oxide layer. The amount of oxygen exiting the bed is measured as a function of time to determine the bed capacity. When the amounts of oxygen entering and leaving the bed are nearly equal, the bed is considered full. This procedure was repeated for various alloy temperatures. As the temperature increased, the bed capacity increased but the bed efficiency (the percentage of the oxygen stream that is absorbed) stayed unchanged until the bed reached capacity. Flowing oxygen over the bed also produced a small quantity of water, even if the bed had been dried beforehand, suggesting water creation from hydrogen somewhere in the system.

Validating the Fast-Ion Energy Loss Model in the Monte Carlo Simulation Toolkit Geant4 and Simulating Laser-Driven Nuclear Reaction Experiments at OMEGA EP

Jonah Simpson
Brighton High School
LLE Advisor: Christian Stoeckl

Monte Carlo particle simulations are valuable because of their ability to accurately track multiple complex processes in specific geometries, but their applicability is constrained by the need to validate each physical process simulated in the code. The fast-ion energy-loss electromagnetic model in Geant4 was validated against the well-established dedicated ion-stopping simulation SRIM. The Geant4 toolkit was used to create a simple simulation of a deuterium or tritium ion beam with energies in the range 1-20 MeV incident on various target materials. Tracking the position into the material and the kinetic energy of individual ions over millions of simulated particles allowed a comparison of the slowing-down models. Geant4 and SRIM showed good agreement over the entire energy range in all target materials and with all the options for electromagnetic models available in the toolkit. A full geometry was set up in Geant4 to simulate neutron-time-of-flight spectra from a recent laser-driven nuclear reaction experiment at OMEGA EP. A comparison of the simulated and measured spectra will be used to validate newly implemented fusion cross sections in Geant4.

Impulse Response Calibration of a Neutron Temporal Diagnostic Using the Multi-Terawatt Laser

Matthew Wang
Pittsford Sutherland High School
LLE Advisor: Christian Stoeckl

In inertial confinement fusion experiments on OMEGA, the neutron production width is an important metric used to assess the quality of implosions. In order to measure this width accurately, the impulse response of the neutron temporal diagnostic (NTD) system must be known precisely. The NTD uses a plastic scintillator that converts neutron energy into light, which is recorded by an optical streak camera capable of resolving temporal history. An NTD system was designed and built for the Multi-Terawatt Laser, which produces short x-ray pulses to simulate neutron production, in order to develop techniques to optimize its impulse response. The performance of this system was evaluated by varying the setup of the laser, which included pulse duration, energy, focus condition, and target material, as well as by varying the NTD nose cone, which houses the scintillator. An important finding in this experiment was that the measured impulse response using an aluminum nose cone was twice as fast as that using a tungsten nose cone. Techniques developed during this experiment will be used to optimize the impulse response of the NTD system on OMEGA.

Development of a Standardized Saturn Ring for Proton Backlighter Targets on the National Ignition Facility

Lindsay Browning
Penfield High School
LLE Advisor: Stephen Craxton

Proton backlighter targets filled with D^3He are of interest at the National Ignition Facility (NIF). They are irradiated with a small number of laser beams, producing a burst of protons upon implosion that pass through a primary target. This provides a variety of diagnostics as the protons are either deflected or absorbed by the primary target. Due to the small diameter of the backlighter targets, unabsorbed light travels past the target and could potentially damage laser optics on the opposite side of the target chamber. Saturn rings have been proposed to be placed around the targets to minimize the effects of passing light. Designs for the NIF have been developed, using the hydrodynamics simulation code SAGE, with a Saturn ring that will fit all backlighter target diameters from 440 to 1100 μm. Adjustments have been made to laser pointings for larger targets to maintain a uniform implosion. This will allow for the manufacturing of a standardized Saturn ring that will prevent laser damage for a wide range of proton backlighter targets on the NIF while maintaining implosion uniformity.

Development of a Digital Microscope for the Characterization of Defects in Cryogenic DT-Filled Targets

Joy Zhang
Penfield High School
LLE Advisor: Roger Janezic

A digital microscope is being developed for the purpose of viewing submicron defects on the surface of cryogenic DT-filled targets. The existing target characterization system is obstructed by a protective shroud, limiting its resolution to 1.6 μm. The microscope under development will eventually operate in a cryostat where targets can be viewed directly without the limitations of a protective shroud. This will allow the microscope to operate from a shorter working distance, improving its resolution to approximately 0.5 μm. The illumination conditions, including the wavelength, current, exposure time, and propagation optics of the light-emitting-diode light source, were optimized at ambient conditions. A U.S. Air Force resolution target was used to generate pixel profile lineouts in order to quantify image quality during optimization. Under optimized conditions, a resolution of 0.5 μm was demonstrated with polymer microsphere standards and 0.5-μm-diameter defects on a polystyrene (CH) cryogenic shell. The digital microscope will undergo further optimization in order to ensure its functionality at cryogenic temperatures and pressures.

OMEGA Frequency Conversion Crystal Designs for Improved Power Balance

Nathan Morse
Allendale-Columbia High School
LLE Advisor: Mark Guardalben

A key element to achieving LLE's 100-Gbar implosion goal is improving the UV power balance of the OMEGA laser's 60 beams. The frequency conversion crystals (FCCs) on OMEGA convert an IR laser pulse to a UV laser pulse using a single doubler and two triplers, and were originally designed for higher laser input intensities and larger SSD bandwidth than are currently required. Less sensitivity of the UV laser power to beam-to-beam variations in the IR energy and FCC angular alignment might be possible by using a different FCC design. A Monte Carlo-based merit function was developed and used to characterize two different categories of FCC designs: 1) A reconfiguration of the current FCCs, and 2) FCC designs with alternative crystal lengths. Using a UV pulse designed for an 80-Gbar implosion campaign and beam-to-beam IR energy variations less than 0.8%, improved power balance was achieved by eliminating OMEGA's second tripler. For IR energy variations greater than 0.8%, the dual-tripler design had better power balance. Additional improvement to power balance was obtained in a single-tripler design by changing OMEGA's crystal lengths from the current 12.2 mm to 15 mm.