UNIVERSITY of ROCHESTER
LABORATORY FOR LASER ENERGETICS

2011 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS
Wednesday, 24 August 2011
LLE Coliseum

1:30–1:35	Welcome	Dr. R. S. Craxton
1:35–1:45	Presentation of the 2011 William D. Ryan Inspirational Teacher Award	Dr. R. S. Craxton
1:45–2:00	Introduction	Felix Jin
2:00-2:10	Two Techniques for Array Generation with Applications in Grid Imaging Refractometry	Kevin Mizes
2:10-2:20	Image Processing and Analysis of 4ω Grid Image Refractometry Data	Andrew Zhao
2:20-2:30	X-Ray Fluorescence as an Imploded Shell Diagnostic	Sean Hamlin
2:30-2:40	Optimizing LLE Information Operations through Natural Language Processing	Brandon Avila
2:40-2:50	Modeling Tritium Removal From Metal Surfaces	Jefferson Lee
2:50-3:00	Water-Stimulated Tritium Release from Metals	Andrew Boyce
3:00-3:10	Design of a new Master Timing Generator	Dana Gretton
3:10-3:20	Automation of Vibration Measurement and Characterization of Cryogenic Deuterium-Tritium Target Motion	Matthew DeCross
3:20-3:35	Break	
3:35-3:45	Dynamic Defocusing in Streak Tubes	Harrison Xiao
3:45-3:55	Optical Time-Domain Reflectometry for the Transport Spatial Filter on the Omega Extended Performance Laser	Troy Thomas
3:55-4:05	Optimization of Beam Configurations for Shock Ignition Experiments on the NIF and OMEGA	Patricia Olson
4:05-4:15	Surface Grinding and Polishing to Remove Etch-Induced Noise Pitting in CR-39 Samples	Sean Reid
4:15-4:25	Characterization of Magnetic Coils for the Magnetoinertial Fusion Energy Delivery System	Felix Jin
4:25-4:35	Abrasion-Resistant Anti-Reflection Sol-Gel Coatings	Madeline Rutan
4:35-4:45	Photoaligned Liquid Crystal Wave Plate	Avery Gnolek
4:45-4:55	Generation of Radially Polarized Beams Using Optically Patterned Liquid Crystals	Michael Statt
5:00-5:30	Tour of the OMEGA and OMEGA EP lasers	David Canning, Mark Labuzeta

UR LLE
250 East River Road
Rochester, New York 14623–1299
(585) 275-5101

2011 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

LABORATORY FOR LASER ENERGETICS
UNIVERSITY OF ROCHESTER

Wednesday, 24 August 2011

Two Techniques for Array Generation with Applications in Grid Imaging Refractometry

Kevin Mizes
Pittsford Sutherland High School
LLE Advisors: Robert Boni, Dustin Froula, and Steven Ivancic

A small-scale optical system was implemented to model grid imaging refractometry (GIR) in the fourth-harmonic probe beam being built for OMEGA EP. GIR is a method for measuring gradients in refractive index. GIR is based on finding the deflection of grid beamlets from a refractive medium and using the deflection to back calculate the phase front. The optical system included a method for array generation, a refractive element to be probed, and an imaging relay to a scientific camera. Two different methods of array generation were tested: a physical copper grid and a three-beam interferometer. Different refractive media were used to distort the array beamlets so that distorted images could be collected at different object planes along the beam axis. The resultant images were put through an image processing system.

Image Processing and Analysis of 4ω Grid Image Refractometry Data

Andrew Zhao
Webster Thomas High School
LLE Advisors: Robert Boni, Dustin Froula, and Steven Ivancic

The Grid Image Refractometry (GIR) system is being developed to measure the plasma electron density in experiments planned for OMEGA EP. A fourth-harmonic GIR probe beam is propagated through a plasma region, where rays in the beam are refracted according to gradients in the local index of refraction, which depends on the electron density. Different object planes in the plasma are imaged onto a CCD camera. The images produced by the probe beam contain the information necessary to determine the electron density. Images are processed using a MATLAB code that automates data processing and analysis. The code was tested using real and simulated data to determine the effectiveness of the GIR system and the analysis process. Results show that the GIR system is capable of accurately measuring index gradients in a refractive medium.

X-Ray Fluorescence as an Imploded Shell Diagnostic

Sean Hamlin
Fairport High School
LLE Advisor: Reuben Epstein

When an imploded target shell is irradiated from within by hot-core x-ray emission, inner-orbital vacancies appear due to photoionization of atoms doped into the shell. Atomic electrons then fill these vacancies, resulting in characteristic Kα line fluorescence in the x-ray spectrum. Due to the sensitivity of the amount of photoionization to the shell areal density, this fluorescence is a potential shell compression diagnostic. To explore this diagnostic concept, a simple model was developed to represent the spectrum of the target. This model was compared with spectra from the detailed radiation-transport codes PrismSPECT and Spect3D for aluminum-doped target shells. Simplifying assumptions of the model, such as optically thin Kα emission from the target shell, were investigated, clarifying how this diagnostic should be interpreted. The results of this work show that x-ray fluorescence is a viable diagnostic for experiments on the National Ignition Facility involving germanium-doped target shells.

Optimizing LLE Information Operations through Natural Language Processing

Brandon Avila
Allendale Columbia High School
LLE Advisor: Richard Kidder

Research in natural language processing (NLP) was conducted to determine the feasibility of its use in optimizing information processing for large-scale laser facility operations. The Laboratory for Laser Energetics (LLE) maintains several decentralized knowledge repositories that are used during daily operations in order to operate and maintain the OMEGA and OMEGA EP laser systems. The information contained in the current repositories is vital to the safe and efficient operations of the facility, but is primarily accessed manually, often through cumbersome search methods requiring experienced users who are experts on individual laser sub-systems. The primary area of study was in using NLP for the extraction and linking of information from several sources used to house operational knowledge. A vocabulary of common terms found in LLE's documentation was created and used for developing increasingly complex data relationships among the data in the decentralized knowledge base.

Modeling Tritium Removal From Metal Surfaces

Jefferson Lee
Canandaigua Academy
LLE Advisor: Walter Shmayda

A program was written to numerically model the diffusion of tritons through a metal bulk. The program calculates the time evolution of a concentration profile based on specified diffusion constants. It has been used to accurately model how particles will flow out of a system with a concentration of zero at the surface. It has also been used to model how a change in diffusion constant, such as the one between the metal oxide layer and the metal bulk, affects the diffusion of particles. Work has started on a more complex program that will model the removal of tritons from the surface of the metal, and be used in conjunction with the diffusion model.

Water-Stimulated Tritium Release from Metals

Andrew Boyce
McQuaid Jesuit High School
LLE Advisor: Walter Shmayda

Experiments have been carried out to understand how tritium, a radioactive isotope of hydrogen, desorbs from, or leaves, metal surfaces. A tritium-contaminated metal coupon is exposed to a gas stream and the radioactivity removed from the coupon is carried by the gas stream and bubbled into a liquid scintillation cocktail to measure this activity. From this measurement the rate of tritium outgassing is calculated and plotted as a function of time. The outgassing rate was measured as a function of variations in the humidity of the gas stream, the temperature of the oven in which the coupon is held, and the chemical composition of the metal coupon used. A goal of the experiments was to measure the steady desorption rates at a given temperature and humidity. These experiments demonstrated that the rate of tritium desorption is temperature and humidity dependent.

Design of a New Master Timing Generator

Dana Gretton
Honeoye Falls Lima High School
LLE Advisors: Robert Peck, Eryk Druszkiewicz

A complex network of electronics serves to direct and monitor the operation of the OMEGA laser system. However, some of these components, like the Master Timing Generator (MTG), are aging and incompatible with modern technology. The MTG, first introduced in the 1990s, is a logic device responsible for keeping all of the laser system triggers to diagnostics hardware such as computers, cameras, and sensors tightly synchronized to the laser pulse. To replace the old device's 20-year-old technology, a new MTG was designed on a modern Complex Programmable Logic Device chip known for its low power consumption and high reliability. An Ethernet interface was also developed so that the LLE network can talk directly to the MTG, integrating neatly with existing protocols and speeding error diagnosis. Oscilloscope traces verify that the new MTG faithfully reproduces all of the behaviors of its predecessor. Meanwhile, the device's new Web page adds to its utility as LLE gradually proceeds with its systems renewal.

Automation of Vibration Measurement and Characterization of Cryogenic Deuterium-Tritium Target Motion

Matthew DeCross

Pittsford Sutherland High School

LLE Advisor: Lance Lund

Knowledge of target motion characteristics is important for maximizing the efficiency of cryogenic target implosions, since off-center targets will not be shocked and compressed evenly by a laser pulse. Presently, the vibration of the target is characterized by manually testing empty targets on a shaker apparatus and determining resonance frequencies and damping. This process, however, is time consuming. A program was developed using Visual Basic that automates the process of performing the shaker test, displays the resultant data in a graphical interface, and outputs the data into a database. Several programs were also written in MATLAB to plot and analyze data taken by two high-speed video cameras that monitor the target position inside the OMEGA target chamber up to 15 ms before the laser shot. A time-domain model of low-frequency target motion was created that can predict the target location at the time of a shot. Comparison of target vibration characteristics with shaker data also gives insight into the effects of DT fuel on target motion.

Dynamic Defocusing in Streak Tubes

Harrison Xiao
Pittsford Sutherland High School
LLE Advisor: Paul Jaanimagi

Streak cameras are used at LLE to measure the time histories of the laser pulse and the optical and x-ray emissions from OMEGA targets. A streak camera operates by applying fast-risetime voltage transients to a pair of parallel plates to deflect or streak electron trajectories across a phosphor screen. At high streak speeds, the foci of the electrons move behind the screen, thereby blurring the image on the screen. A program was written in C# to model electron deflection in streak cameras. The model uses the fourth-order Runge-Kutta method to integrate the Lorentz equation of motion and trace the path of electrons through the deflection plates as the voltages change. Data from the model was collected and extrapolated to calculate adjustments needed to refocus the electrons. A common-mode focusing voltage was applied to the deflection plates to shift the focal plane back to the screen.

Optical Time-Domain Reflectometry for the Transport Spatial Filter on the Omega Extended Performance Laser

Troy Thomas
Webster Thomas High School
LLE Advisor: Brian Kruschwitz

An Optical Time-Domain Reflectometer (OTDR) is a diagnostic that measures light that has been reflected back towards the laser's origin. The Transport Spatial Filter (TSF) OTDR is a device that measures these reflections in the latter half of the laser system. A MATLAB computer program has been created that imports and analyzes OTDR data files. These data files contain information on the voltage of the return signal at specific times, the time scale used, and the shot type. The time that the light takes to return to the OTDR has been determined through the use of ray trace charts. These charts have been used to trace the beam's path to the optic and back to the TSF OTDR. These times are used to create labels on the graph for the most important optics. The program then plots the data on a graph of voltage vs time. This graph allows easy interpretation of the data, allowing the user to diagnose any optic malfunctions or unexpected return signals.

Optimization of Beam Configurations for Shock Ignition Experiments on the NIF and OMEGA

Patricia Olson
Brighton High School
LLE Advisor: Stephen Craxton

Beam configurations have been optimized for shock ignition experiments at both the National Ignition Facility (NIF) and the OMEGA laser facility. Shock ignition involves two different laser pulses, one to compress the target, and the other to ignite it. On the NIF, to compensate for the configuration of the laser beams, the beams were repointed towards the equator of the target in a method known as polar drive. The NIF experiment uses 96 out of 192 beams for the compression pulse, and the other 96 for the ignition pulse. The compression beams have been optimized to provide a 3.5 μm rms deviation in the center of mass after implosion through 465 μm. The OMEGA experiment delivers the compression pulse to 40 of the 60 beams, and the shock pulse to the other 20. Adjustments to the compression beams have led to an energy deposition uniformity of 1.2% rms, while adjustments to the shock beams resulted in uniformity of 3.9% rms. These results were achieved by running numerous 2-D hydrodynamic simulations using the code *SAGE* in which various parameters were adjusted.

Surface Grinding and Polishing to Remove Etch-Induced Noise Pitting in CR-39 Samples

Sean Reid
Fairport High School
LLE Advisors: Michelle Burke, Robert Boni, Stephen Jacobs

Solid-state nuclear track detectors, such as the polymer CR-39, are used to measure and analyze ions produced by fusion implosions on the OMEGA and OMEGA EP laser systems. A time-efficient surface grinding and polishing procedure was developed to remove noise pitting associated with the etching of CR-39. Using CR-39 thickness measurements acquired during the grinding process, surface removal rates of 68 μm/min and 5 μm/min were determined for 15 μm and 9 μm-grade abrasive pads, respectively. Removing 7.7 μm of surface material eliminated noise pits, as well as 1 MeV and 2 MeV proton-induced pits. Exposing the CR-39 sample to UV radiation before etching was investigated as a method to deepen data pits. UV irradiation using a fluorescent bulb setup increased 1 MeV proton pit diameters by 12.6%, suggesting an increase in pit depth. The combination of CR-39 UV irradiation and surface grinding and polishing was shown to eliminate noise while preserving data.

Characterization of Magnetic Coils for the Magnetoinertial Fusion Energy Delivery System

Felix Jin
Brighton High School
LLE Advisor: Gennady Fiksel

The Magnetoinertial Fusion Energy Delivery System (MIFEDS) is used to provide a strong pulse of magnetic field required for a broad range of fusion and astrophysical applications. A magnetic coil was designed, fabricated, and calibrated for a collisionless shock experiment on OMEGA. A method for monitoring the coil arcing based on frequency analysis of the coil current oscillation was developed. Two programs were written in MATHEMATICA to calculate and map the magnetic field and to calculate the coil inductance. Results from these calculations suggest that the current coil design for the shock experiment is inefficient and an alternative was suggested that increases the magnetic field several-fold. Finally, the dynamics of the coil resistive heating, including the current skin effect and temperature diffusion, was investigated. These calculations, modeling, and analysis will assist in efficient coil design for future experiments.

Abrasion-Resistant Anti-Reflection Sol-Gel Coatings

Madeline Rutan
Penfield High School
LLE Advisor: Kenneth L. Marshall

Anti-reflection sol-gel coatings are deposited on many of the UV optical surfaces in both the OMEGA and OMEGA EP laser systems. One issue with these coatings is their lack of abrasion resistance. An unmodified sol-gel coating will scratch after an applied mass of only 6 g. Therefore, all sol-gel coated optics must be handled with extreme caution during installation and alignment. In an effort to increase the abrasion resistance of sol-gel coatings, organosilane-modified sol-gel particles have been cross-linked with dithiols. This method increases abrasion resistance because the dithiol cross-linkers create more bonds between the sol-gel particles resulting in a robust sol-gel network. The most promising results have been demonstrated by the use of a 15 mol% solution of the modifier 3-methacryloxypropyltriethoxysilane in combination with the cross-linker pentanedithiol. Substrates coated with this solution withstood an applied mass of 36 g while maintaining 96% transmission. An inverse relationship between maximum transmission and abrasion resistance has been observed.

Photoaligned Liquid Crystal Wave Plate

Avery Gnolek
Webster Thomas High School
LLE Advisor: Kenneth L. Marshall

Liquid crystal (LC) wave plates were produced using a photosensitive polymer to generate alignment. Currently, alignment of liquid crystals is achieved through the use of mechanical buffing, although this process is relatively imprecise and inherently dirty. However, photoalignment of LC wave plates using a coumarin-based photopolymer resolves many of the fundamental problems with buffing. Because photoalignment of LC wave plates is a noncontact process, it displays improved LC alignment and does not introduce unwanted particles on to the substrate. For the low-birefringence LC materials used for waveplate fabrication, the alignment quality produced using coumarin-based photopolymers is most greatly impacted by the surface finish and optical uniformity of the substrates. When substrates with relaxed scratch/dig, wedge and flatness tolerances were used, LC alignment was poor with numerous disclinations (defects). When substrate quality was improved, the number of disclinations was vastly reduced. Wave plates produced had retardance values well within the error specifications set for OMEGA.

Generation of Radially Polarized Beams Using Optically Patterned Liquid Crystals

Michael Statt
School of the Arts
LLE Advisors: Kenneth L. Marshall, Christophe Dorrer

Radially polarizing liquid crystal (LC) devices aligned optically were investigated for applications in laser technology. Presently, radially polarized beams are generated through complex laser resonator configurations or buffing of liquid crystal alignment layers. Optically aligned LC devices offer several advantages over these present methods, including their simple fabrication, low cost, high damage threshold, and scalability. This project researched the fabrication of the LC devices using a coumarin-based photopolymer irradiated on a rotating stage coupled with a slit. Radially polarizing LC devices have been fabricated and characterized. This will lead to more research to improve the fabrication technique and make larger devices.