2014 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

Wednesday, 27 August 2014
LLE Coliseum

1:30–1:35  Welcome
1:35–1:45  Presentation of the 2014 William D. Ryan Inspirational Teacher Award
1:45–2:00  Introduction
2:00–2:10  Optimization of Wavefront Control using a High-Resolution Wavefront Sensor
2:10–2:20  Isotopic Exchange on a Platinum-Coated Molecular Sieve
2:20–2:30  Analyzing the Sensitivity of a Hard X-Ray Detector using Monte Carlo Methods
2:30–2:40  Computational Modeling of Azobenzenes for Optically Addressable Liquid Crystal Alignment
2:40–2:50  Statistical Investigation of Cryogenic Target Defects
2:50–3:00  The Use of Rosseland- and Planck-Averaged Opacities in Multigroup Radiation Diffusion
3:00–3:10  Display of Scientific Image Sources with Mobile Devices
3:10–3:20  Polar-Driven X-ray Backlighter Targets for the National Ignition Facility
3:20–3:35  Break
3:35–3:45  Effects of Alpha-particle Stopping-Power Models on Inertial Confinement Fusion Implosions
3:45–3:55  Capturing Hydrogen on a Chilled Molecular Sieve
3:55–4:05  Limits on the Level of Fast Electron Preheat in Direct-Drive Ignition Designs
4:05–4:15  Creating an Open Source LLE-based Ethernet to LonTalk adapter
4:25–4:35  Next Generation Polymers for High-Power UV Optics
4:35–4:45  Optimizing Beam Profiles for Polar Drive Implosions on the National Ignition Facility
4:45–4:55  Evaluation of a Collaborative Networking Environment for Experimental Configurations
5:00–5:30  Tour of the OMEGA and OMEGA EP lasers
Optimization of Wavefront Control using a High-Resolution Wavefront Sensor

William Franceschi
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LLE Advisors: Brian Kruschwitz, Adam Kalb

Deformable mirrors, used to correct the wavefront of the OMEGA EP laser beams, currently rely on information provided by a wavefront sensor with 77 resolution elements. A new high-resolution wavefront sensor (HRWS) containing 19,044 resolution elements promises more accurate wavefront measurements and potentially improved wavefront correction. Previous software was modified and new MATLAB code was written to incorporate the HRWS. The calibration algorithm was altered to account for problems associated with a changing pupil area. The HRWS control algorithms were tested first in the Deformable Mirror testbed, and then on a beamline of the OMEGA EP laser. They outperformed the existing Wavefront Control System with an 8% decrease in RMS wavefront and a 5% decrease in focal spot size (80% encircled energy).

Isotopic Exchange on a Platinum-Coated Molecular Sieve

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LLE Advisor: Walter Shmayda

Tritium is a radioactive isotope of hydrogen that is used regularly in experiments at LLE. To minimize emissions to the environment, capture and containment of tritium released from process systems is very important. Air detritiation systems oxidize elemental tritium to form tritiated water (HTO) and then collect all HTO on a molecular sieve drier. Tests were conducted to determine whether or not a platinum-coated molecular sieve (Pt/4A MS) loaded with light water (H_2O) could serve as an alternative to the classical ‘burn and dry’ approach of capturing tritium. In these tests, deuterium was used as a surrogate for tritium. Deuterium gas in a helium carrier was converted to heavy water over hot copper/zinc and flowed over a platinum-coated 4A molecular sieve preloaded with light water. The heavy water displaced the light water in the molecular sieve and did not appear in the exhaust of the Pt/4A MS bed until the light water was consumed.
Analyzing the Sensitivity of a Hard X-Ray Detector using Monte Carlo Methods

Junhong (Sam) Zhou
Victor Senior High School
LLE Advisor: Christian Stoeckl

Data gathered from the nine-channel HERIE and the four-channel HXRD hard x-ray detectors revealed a discrepancy in the inferred x-ray spectrum between the two diagnostics. To better understand this discrepancy, Monte Carlo simulations of the x-ray interactions in the HERIE setup were performed using the Geant4 framework. Geant4 was chosen because the HXRD had historically been modeled on this framework. The geometry of the HERIE was first recreated in Geant4. Simulations were then run with the image plate, the component that records incident x rays, to compare the x-ray transmission and the sensitivity of the image plate with published experimental data, effectively validating the accuracy of the model. Then the detector's sensitivity was calculated at various energy levels, allowing experimental data from the HERIE to be interpreted and the spectrum of the incident x rays to be inferred. Using this sensitivity data, which incorporated the full geometry of the detector, the difference between the HERIE and HXRD inferred spectra was significantly reduced.

Computational Modeling of Azobenzenes for Optically Addressable Liquid Crystal Alignment

Kyle Xiao
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LLE Advisor: Kenneth L. Marshall

Photoisomerization of azobenzene between its straight trans and bent cis forms can be used to control liquid crystal alignment. This property makes azobenzenes useful in optically addressable liquid crystal beam shapers. Rather than using the costly trial-and-error synthesis method to analyze a large array of compounds in order to identify unique characteristics of certain azobenzenes, computational modeling was performed. Density functional theory (DFT) and time-dependent DFT calculations were performed in this study using Schrodinger’s Jaguar program to model azobenzenes tethered to a polymer backbone. The length of the spacer chain tether was shown to affect the energy difference between the trans and cis states. The addition of terminal groups was also explored and yielded interesting results. A chloromethyl acetamide terminal group increased the configurational energy difference between isomers by 40% and an aminoester group decreased the energy difference significantly. Adding heteroaliphatic rings increased the wavelength of light required to isomerize trans molecules significantly.
Statistical Investigation of Cryogenic Target Defects

Robin Zhang
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LLE Advisor: Colin Kingsley

After hollow cryogenic targets are filled with a frozen layer of DT, images of them are taken and analyzed for quality control. Often, imperfections with an appearance of either cracks (dendrites) or dark spots (darks) appear on the surface of the target. Many aspects of these defects, including origin, composition, and impact on target performance, are not well understood. In order to work towards elimination of these defects, more needs to be known about their nature. Images and information pertaining to a large sample of targets were drawn from a database and different properties were analyzed using various statistical techniques. The numerous tests performed resulted in many small pieces of information about the nature of the defects that rule out some theories and support others. However, much is still not well understood, and additional analysis is necessary in order to discover more about the defects.

The Use of Rosseland- and Planck-Averaged Opacities in Multigroup Radiation Diffusion

Pranav Devarakonda
Brighton High School
LLE Advisor: Reuben Epstein

Opacity quantifies how strongly radiation is absorbed while passing through a material. Hydrocodes at LLE and elsewhere use opacity values averaged over large intervals of the radiation spectrum to calculate radiation energy diffusion transport within plasmas. This work compares two-opacity modeling, where Planck averages are used for emission and absorption and Rosseland averages are used for transport, with the treatment in LLE hydrocodes where a single opacity (typically the Planck average) is used. Planck and Rosseland interval-averaged opacities for Si were obtained by running the Prism detailed atomic model PROPACEOS. An analytic solution was then derived for the radiation diffusion equation in a slab-source problem in which separate opacities were used for absorption and transport. Results for the emitted spectral flux were compared for the preferred two-opacity case and for the case where a single, Planck opacity was used. Even when the Planck and Rosseland averages differed, the differences in flux were minimal except for spectral intervals where the optical depth was approximately one.
Display of Scientific Image Sources with Mobile Devices

Ryan Dens
Allendale Columbia School
LLE Advisor: Doug Jacobs-Perkins

Software infrastructure is being developed for mobile devices to enable scientists and technicians to view images captured by cameras in the experimental areas of LLE. Mobile devices are desirable because users can see the images wherever wireless connectivity is available. However, they present significant software design challenges for efficient bandwidth management, visual presentation and ease of use. The initial software is for devices running the Android operating system such as smartphones and tablets. First, a method was developed to download an image specified by a URL as a bitmap image. Next, features were added to render text, such as captions or other metadata transmitted with the image, and create graphs. The graph displays the intensity in a given column or row. This application provides the foundation to acquire and display live images from sources such as the SI-800 scientific-grade camera and provide basic image analysis tools. The availability of live image display on mobile devices would allow the result of any repair or adjustment to be viewed nearly instantaneously.

Polar-Driven X-ray Backlighter Targets for the National Ignition Facility

Roger Zhang
Webster Schroeder High School
LLE Advisor: Stephen Craxton

Imploding x-ray backlighter targets on the National Ignition Facility (NIF) can be used to gather information about a primary target; an initial proposal involves measuring the opacity of heated materials. The backlighter targets radiate x rays that are absorbed as they pass through the primary target to a detector. An optimized beam configuration has been developed to maximize the implosion uniformity of the backlighting target (a SiO$_2$ shell with diameter 2.1 mm and thickness 10 µm) using only the four most polar rings of beams (rings at 23.5° and 30.0° from the poles). Optimization was performed by adjusting parameters such as beam aim points and defocus distances in SAGE, a hydrodynamics simulation code. The uniformity was measured using the rms variation in the center-of-mass radius of the shell, calculated when the target had imploded to approximately half of its original size. This was reduced from 26.2% in the initial design to 5.4% in the optimized design. This was achieved primarily by directing 75% of the beams beyond the equator and decreasing their defocus distances to maximize energy deposition near the equator.
Effects of Alpha-particle Stopping-Power Models on Inertial Confinement Fusion Implosions

Nathan Xu
Pittsford Sutherland High School
LLE Advisor: Suxing Hu

An important issue for the design of inertial confinement fusion implosion experiments is the rate at which the $\alpha$-particles resulting from fusion reactions deposit their energies as they travel through the plasma. In this work, four different models of stopping power (energy deposition), based on different physics approximations, have been examined: the Skupsky model (currently used in LLE’s hydro-codes), the Li-Petrasso model, the Quantum Molecular Dynamics model, and the Brown-Preston-Singleton model. These models have been tested for different deuterium-tritium (DT) plasma conditions such as temperature, density, and initial $\alpha$-particle energy. The models have been implemented into LLE’s one-dimensional hydro-code (LILAC), allowing their effects on National Ignition Facility-scale ignition implosions to be investigated through hydro-simulations. Contrary to what was expected, the results show significant changes in the overall target performance depending on which model is used; changes in target gain varied by a factor of two. Finally, an experiment has been suggested to verify which model, if any, is truly valid.

Capturing Hydrogen on a Chilled Molecular Sieve

Krishna Patel
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LLE Advisor: Walter Shmayda

LLE studies inertial confinement fusion using deuterium-tritium fuel mixtures. Tritium released from processing equipment is re-captured with ZrFe getter beds. These devices need to be unloaded annually to recover their tritium collection efficiency. One approach to collecting the tritium released from ZrFe getter beds utilizes a cryotrap, a coil filled with crushed molecular sieve chilled to liquid nitrogen temperatures (90 K). The performance of a compact cryotrap was evaluated using hydrogen-helium mixtures. The hydrogen capacity of the cryotrap has been measured to be 5.84 sL, or 60 scc of hydrogen per gram of molecular sieve. At one-fifth of the total capacity, the mean residence time of the hydrogen in the cryotrap is 169.6 minutes for a helium purge flow rate of 0.1 L/min. The residence time decreases as the helium purge rate through the cryotrap increases.
**Limits on the Level of Fast Electron Preheat in Direct-Drive Ignition Designs**

Christopher Ye  
Webster Schroeder High School  
LLE Advisor: Jacques Delettrez

Inertial confinement ignition designs are characterized by their gains (energy produced over energy input), which can be reduced by preheat of the fuel. High intensity lasers like the ones used in direct-drive ignition create plasma instabilities, producing fast electrons. These electrons can reach temperatures of 60 million degrees K, compared to 3 million degrees K in the corona of the target. When fast electrons penetrate the cold fuel shell, they preheat the target, increasing the adiabat (a measure of the preheat) and decreasing the gain. The one-dimensional hydrodynamic code LILAC was used to simulate target implosions affected by the fast electrons. The optimizing code TELIOS adjusted the picket timings and levels in the laser pulse for the implosions in an attempt to decrease the preheat and counteract the decrease in gain caused by fast electrons. Optimization with TELIOS was able to partially recover the gain by varying the picket timings and powers.

**Creating an Open Source LLE-based Ethernet to LonTalk adapter**

Jeremy Weed  
Victor Senior High School  
LLE Advisors: David Hassett, Robert Peck, Dustin Axman

The OMEGA Laser System is currently controlled by a LonWorks distributed control system that includes over 1,600 Neuron 3150 chips running at 10 MHz. Communicating on more than 20 twisted pair channels, the Neurons control over 3,000 A/D channels, 2,000 DC servo motors and 4,000 digital I/O channels. All communications entering or exiting the network travel through LENA servers across an RS-232 serial bus to a Serial to LonTalk adapter and onto the LonTalk network. Creating a direct Ethernet to LonTalk adapter would allow for the retirement of the LENA PCs used, provide physical connections to the LonTalk network, allow the servers to reside on virtual machines, and minimize any errors caused by high traffic volumes through the current RS-232 interface. Using a Netburner board and a Neuron card, a proof-of-concept Ethernet to LonTalk adapter was attempted. Using Neuron-to-Neuron network variables, data communication from the current firmware to an updated system was demonstrated. However, SPI data communication between the Netburner and Neuron was not achieved due to hardware limitations, so different protocols will be explored.
Optimization of Uniformity for Current Polar-Drive Implosion Experiments on the National Ignition Facility

Emma Garcia
Penfield High School
LLE Advisor: Stephen Craxton

Two alternative designs for the current series of polar drive implosions on the National Ignition Facility (NIF) have been developed using the hydrodynamics simulation code SAGE. Polar drive is a method of repointing the NIF beams, which are configured for indirect drive, away from the poles and towards the equator to create a uniform direct-drive implosion. The current design produces implosions that are close to spherical but still show some nonuniformities. The design is calculated to have a center-of-mass rms nonuniformity of 1.30% averaged over the whole sphere when the shell has compressed to approximately half its initial diameter. The first alternative design, the “defocused” design, utilizes greater defocuses than the current design on all of the beams along with small changes to the pointing shifts. This design has a lower nonuniformity of 0.64%. The second alternative design, the “oblique” design, uses large pointing shifts so that all beams encounter the target at oblique incidence. It is speculated that this may help to reduce the nonuniformity associated with laser speckle that is not modeled in the simulations. The oblique design has a nonuniformity of 0.57%.

Next Generation Polymers for High-Power UV Optics

Jack Gumina
The Harley School
LLE Advisor: Kenneth Marshall

Several polymers were evaluated as candidate materials for UV laser optics. Glass optics such as distributed phase plates and diffractive axicons can be costly and time consuming to make by conventional optical fabrication techniques. The use of moldable polymers instead of glass in these applications would greatly decrease cost and production time. For a polymer optic to be viable, it would need to have high transmission and a high laser damage threshold (>2 J/cm²) at 351 nm. Polymers were bar coated onto glass substrates at film thicknesses of ~100-200 µm, and transmission was measured in the UV. Two polymers (Master Bond EP21LSCL-1 and Resin Design 071607-D2) were found to have over 98% transmission at 351 nm. These materials have 1-on-1 laser damage thresholds of 2.8 ± 0.5 J/cm² and 0.14 ±0.01 J/cm², respectively. It was also determined that both polymers release cleanly from Teflon®. Future research will look more closely at the moldability of current materials and expand the search for new materials.
Optimizing Beam Profiles for Polar Drive Implosions on the National Ignition Facility

Felix Weilacher
Penfield High School
LLE Adviser: Radha Bahukutumbi

In polar-drive geometry, beams are displaced closer to the equator from their original on-target positions to achieve better implosion symmetry. Current direct-drive polar drive implosions for the National Ignition Facility use phase plates - optics which define the laser beam profiles - designed for indirect drive, limiting the implosion uniformity achieved. Optimal laser beam profiles have been identified using the hydrodynamics code DRACO. Using a combination of spherically symmetric and elliptical beam profiles, adjustments to laser temporal power histories can achieve nearly uniform implosions, greatly improving target performance. The optimal beam profiles are also robust to model variations. For example, designs with different heat conduction models can be optimized using relatively minor variations in laser power histories. The neutron yield increased by more than 50% using the optimized beam profiles.

Evaluation of a Collaborative Networking Environment for Experimental Configurations

Liam Smith
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LLE Adviser: Richard Kidder

A three-dimensional model of the OMEGA target chamber has been developed for web-based services to emulate interaction with large-scale laser facilities, specifically the 60-beam OMEGA laser. This design was created with the purpose of allowing OMEGA users to collaborate in an interactive and visually intuitive environment to set up experimental configurations. Work has been done to expand the network collaborative capabilities of the web-based service to include tools that allow users to directly interact with one another in a real-time situation. Users can interact with the target chamber by toggling diagnostics and ten-inch-manipulators (TIMs). Users can also interact with other online users by sending messages or even watching the actions of another user in real-time. The expanded three-dimensional virtual model of the OMEGA target chamber can be used as an interactive platform for configuration creation and display as an alternative to the traditional text-based proposal tools.