2008 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

LABORATORY FOR LASER ENERGETICS UNIVERSITY OF ROCHESTER

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High-Speed Measurements of Target-Support Vibrations using Linescan Cameras

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Target vibrations are a critical source of error in OMEGA fusion experiments. Deviations in target location as little as 20 microns from target chamber center can seriously impact the implosion. Linescan cameras capture images that represent displacement in one dimension as a function of time, and can therefore be used to capture target movement. Displacement data extracted from the images are analyzed using a Fast Fourier Transform technique to identify resonant frequencies of the target. This provides valuable information about the target support structure, its responses to various vibration sources, and the possible effects of engineering improvements. Optical measurement techniques are superior to other possible options because they do not directly contact the target. However, camera resolution and image quality limit the camera's ability to capture data for targets that are resonating at high frequencies with small displacements.

Characterization of a Cryogenic Target in a Transparent Cylindrical Hohlraum

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Characterization of a spherical cryogenic target in a cylindrical hohlraum is important for indirect-drive inertial-confinement-fusion implosions, as the targets must be as uniform as possible. Shadowgraphic image analysis techniques developed for spherical targets have been adapted to evaluate the uniformity of targets in hohlraums. An existing ray-trace code was extended to add the hohlraum and predict the apparent outer target radius and bright ring radius as a function of angle around the viewing direction. These predictions were confirmed by data obtained under a microscope using a surrogate target (a thick, spherical plastic shell) in a hohlraum. By subtracting the predicted distortions from the measurements of the bright ring radius, the uniformity of the inner surface of the target can be assessed. The uniformity of targets in hohlraums can now be evaluated to a degree of accuracy constrained primarily by the uniformity of the hohlraum.

Development of the Cryogenic Target Information System

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Part of the inertial confinement fusion research at LLE entails the production and implosion of cryogenic targets filled with deuterium or tritium. Prior to this project, the databases containing relevant data were dispersed and excessive amounts of time were required to search for simple data. This project involved the creation of a new Web-based comprehensive query that serves as the starting point of an information search. The query allows a user, for the first time, to search for information online based on a variety of target characteristics, such as ice thickness or target outcome. To complement this database, a Layer Analysis Table (an exhaustive target quality database) was also created to focus solely on the layering cycle of cryogenic targets. These new online database features are essential to LLE's future work because researchers are now able to easily connect the characteristics of cryogenic targets to the shot result. This effort has improved data management and will simplify analysis of cryogenic data.

Investigation of the Causes of and Possible Remedies for Damage to Sensors Used on the OMEGA Laser System

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When a target is imploded using the OMEGA laser system, various types of radiation, including neutron radiation, are produced. Cameras using charge-coupled devices (CCDs) are used to record these implosions. However, the CCDs are vulnerable to neutron irradiation. The CCD used on the Neutron Temporal Diagnostic shows significant increases in dead pixels in conjunction with high neutron yield shots. The high energy neutrons collide with the sensitive structure of the CCD, causing physical damage to the device. These physical defects are reflected in the images produced by the CCD as noise, dead pixels, saturated pixels, and hot pixels that lead to line defects. The CCD soon becomes unable to function. Research into solutions for this problem has shown that little can be done to prevent or reverse the damage. While a polyethylene shield decreases the damage by a factor of two, a significant amount of radiation is still able to reach the CCD. Scientists can learn to work with the damage and develop a system to determine when the CCDs should be replaced.

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Contamination-Resistant Sol-Gel AR Coatings by Vapor-Phase Silylation

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Silica-based sol-gel optical coatings are critical components of the OMEGA and OMEGA EP laser systems. Water vapor and volatile organic compounds in the target bay and laser bay areas contaminate these coatings, reducing their antireflective efficiency and laser-damage resistance. Earlier work has shown that alkylation of free hydroxyl groups on the sol-gel with organosilicon compounds in solution can improve the contamination resistance of currently used sol-gels. In this work, alkylation with organosilanes in the vapor state was studied as a simple alternative to solution-based methods. Sol-gels based on tetraethylorthosilicate (TEOS) were vapor-phase treated with TMDS (tetramethyldisilazane) and FTMDS (bis (trifluoropropyl)-tetramethyldisilazane) at room temperature and at elevated temperatures. Contact angle measurements were taken to discern the degree of silanization after various periods of treatment. The resistance to contamination of these vapor-phase treated sol-gels was determined by exposing them to machine oil at 60°C and 80 mTorr. Results suggest that elevated temperatures enable higher degrees of silanization and therefore increased contamination resistance.

Development of an Optical Pulse Characterization Device Based on Spectral Shearing Interferometry

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Ultrashort optical pulses are integral to various fields in which extremely rapid events are investigated. Thus, the characterization of these pulses is crucial in understanding the results of experiments and applications using them. A diagnostic was created to determine the shapes of ultrashort optical pulses using the principle of spectral shearing interferometry (SSI). By strongly chirping an optical pulse using a double-pass two-grating compressor and overlapping it with two replicas delayed by 1.8 ps in a lithium triborate LiB_3O_5 (LBO) nonlinear crystal, sum harmonic generation of the input laser beam was achieved. The SSI interferogram at 2ω was then characterized by a spectrometer to determine pulse characteristics. The diagnostic was tested on the diagnostic compressor of the Multi-TeraWatt (MTW) laser, determining the compressor distance for which the optical pulses were shortest.

Optimization of Cone-in-Shell Implosions

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Fast ignition, one method of laser-driven fusion, employs an energetic short pulse laser beam that irradiates an imploded target. Cone-in-shell targets, in which a gold cone is embedded in a shell of deuterium-tritium fuel, are one design proposed for fast ignition. Laser beams arrayed uniformly around the target implode the fuel to high densities. Energy from the short pulse laser is then funneled through the cone to ignite the dense fuel. Fast ignition is most effective when high fuel densities are achieved. The implosion of cone-in-shell targets that have been shot on OMEGA was simulated using the hydrodynamics code SAGE including laser ray tracing. It was found that portions of the shell near the cone were imploded with slower velocities, negatively impacting the uniformity of the implosion and the density of the fuel. By altering beam pointings and energies, improved implosions were found with higher fuel densities. This enhances the attractiveness of fast ignition.

Minimization of the Tritium Contamination of Surfaces

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Tritium is a radioactive hydrogen isotope used in fusion reactions. Plasma decontamination is one of the methods used to remove tritium from the surface of objects. Although plasma decontamination is very efficient at removing surface activity, it cannot easily remove tritium beneath the surface of a material. To improve the process, the properties of the plasmas used in this process are being studied by varying the operating pressure of the plasma. The results of these experiments will be used to find the optimal settings for plasma decontamination so that the temperature of the item being decontaminated is at its highest. Hydrogen mobility increases with increasing temperature, enabling hydrogen present in the bulk to migrate more freely to the surface where it is removed by the plasma.

Controlling a PC-Based Data Acquisition System with Java

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PC-based data acquisition systems have the capability to replace oscilloscopes, signal generators, and certain digital input/output communications in laboratory diagnostics setups. Though proprietary software exists for controlling these systems, this software has no flexibility to be adapted for LLE use. Instead, Linux Control and Measurement Device Interface (COMEDI) has been used. This is an open-source C library for Linux machines that supplies functions for communicating with a PC-based data acquisition system. The goal of this project was to adapt ScopeControl, a preexisting program written in Java for controlling oscilloscopes, to monitor and save data from a PC-based data acquisition system using the COMEDI library. Programs were written in both C and Java and the Java Native Interface was used to allow these programs to communicate. Once ScopeControl had been sucessfully modified, additional hardware and software features present in the data acquisition systems were explored, including analog waveform generation and remote data monitoring through the network.

Counting System for the Carbon Activation Diagnostic

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Nuclear reactions in the core of an OMEGA implosion can be used to infer the density of the deuterium-tritium (DT) fuel at peak compression. A three-step process leads to the production of “tertiary” neutrons with energies up to 30 million electron volts (MeV), more than twice the energy of the primary neutron (14 MeV) from the direct fusion of DT. The tertiary-to-primary neutron yield ratio is proportional to the square of the fuel density and can be measured using a neutron-induced reaction in ^{12}C. This reaction leads to the emission of a positron that subsequently produces two back-to-back 511-keV gamma rays. LLE is developing a high-counting-efficiency detector system based on standard nuclear spectroscopy techniques to measure the number of activated ^{12}C atoms in a sample of graphite exposed to the tertiary neutron flux from the OMEGA laser. As part of this development process, measurements were made of the background sensitivity to determine the detector shielding requirements and the counting efficiency in normal and “Compton” coincidence modes. The first activated Cu-graphite mixtures to be used for an absolute calibration of the detector sensitivity were counted.

Exploring Metadata for Laser Diagnostics and Control Systems

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For this project, an application was made that illustrates the advantages of an ontology over the current databases in use at LLE. An ontology is a way of organizing the data of a system based on the data's characteristics (i.e., the metadata). The strength of an ontology is that it creates a model of the system by connecting the data via their properties. This project focuses on the gain that an ontology provides by allowing programs to simulate "cause and effect", something that would be much harder to do under the current data organization. The application implements an ontology of the OMEGA EP laser system and uses it to predict the effects on laser diagnostics timing of making changes to the system, such as switching between long pulse and short pulse and adding or removing subsystems. All of this is done without any reference to the actual parts of the laser system, and thus the program functions the same regardless of how the ontology is configured.

Automated Determination of Crystal Reflectivity in the X-ray Laboratory

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LLE Advisor: Frederic Marshall

The University of Rochester's OMEGA laser is used to create plasmas with temperatures high enough to emit x rays. One method of observing such x-ray emission is diffraction by a crystal. In order to accurately measure x-ray emission using crystal diffraction, the integrated reflectivity of the crystal must be known. X ray diffraction was observed and measured with stepper-motor-driven positioning stages and a photon detector in the X-ray Laboratory at LLE. Stepper motor controllers were programmed to automate the process of measuring the integrated reflectivity of a crystal. Results are presented for a KAP (Potassium Acid Phthalate) crystal at an energy of 1.48 keV (Al Kα radiation).

K-Shell Emission-Line Backlighter Source Optimization

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X-ray backlighting is an important diagnostic technique used in laboratory experiments conducted on the OMEGA laser system. To obtain images of imploding cryogenic targets, short-pulse, high-energy laser beams are directed at a thin slab of solid material, creating plasma x-ray line emission that projects the shadow of the target onto a photographic film. For ample image contrast, x-ray intensities of backlighters must exceed the continuum intensity of targets. Therefore, high-intensity lines in a plasma's spectrum are desirable. The K-shell lines of He-like species hold particular interest due to the strength of their emissions, as well as the sharpness of the line. Moreover, using Al as a backlighter source positions these He-α lines within a photon energy range where about 1/e of the light is absorbed by the target. PrismSPECT, a spectral analysis code simulating the atomic and radiative properties of plasmas, can reveal the effect of certain parameters on He-α line emission. With the program, the optimal temperatures were obtained for x-ray emissions of steady-state Al plasmas at given mass densities and thicknesses, as well as the times required for the plasmas to reach steady-state.

The Effects of Space Charge on Electron Pulse Broadening in Streak Cameras

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Streak cameras are used to record the time history of laser pulses at LLE. However, space charge effects can distort images recorded on the phosphor screen of streak cameras, making it difficult to impossible to accurately interpret the image. Space charge effects are caused by the interaction between electrons when they pass through the streak camera. These interactions cause the electrons to repel, making the entire pulse broaden. Streak cameras cannot surpass a certain resolution before space charge begins to distort the recorded image. For this project, a computer program was written to simulate the movement of electrons through the streak camera. This program enables one to accurately predict the amount of space charge broadening that would occur with given initial conditions. This prediction capability will lead to improvements in streak cameras in the future, allowing streak cameras to record pulses at sub-picosecond levels.

Investigation of Brushless DC Motor Commutation Techniques

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Brushless DC (BLDC) motors are cleaner and more reliable than their brushed counterparts. For this reason, a number of BLDC motors are used in the OMEGA laser system. Because of the extreme conditions these motors are exposed to during a laser shot, including a powerful electromagnetic pulse (EMP), the Hall effect sensors that govern the motors' commutation cycles sometimes sustain serious damage. This damage may render the motors inoperable using the installed motor drivers. This necessitates a difficult extraction process to recover the motors for repair. This project investigated sensorless motor commutation as a potential solution to this problem. With a sensorless commutation scheme, the motors could be extracted without the use of the damaged Hall sensors. Therefore, a test fixture has been developed that is capable of driving a BLDC motor sensorlessly. This will aid in extracting the target positioner and the off-axis parabola inserter/manipulators after Hall sensor damage has occurred.