2009 SUMMER HIGH SCHOOL STUDENT RESEARCH PRESENTATIONS

LABORATORY FOR LASER ENERGETICS UNIVERSITY OF ROCHESTER

Wednesday, 26 August 2009

The Effect of Alcohol Hydroxide Solutions on the Bulk Etch Rate of CR-39

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The bulk etch rate properties of NaOH/ethanol solution as a CR-39 etchant were investigated. It was discovered that NaOH/ethanol is an aggressive etchant that has a bulk etch rate greater than the standard etchant NaOH. The bulk etch rate properties of NaOH/ethanol were tested by etching CR-39 in NaOH/ethanol solutions of various temperatures and molarities. It was found that as temperature increased the bulk etch rate increased. However, the molarity of the NaOH/ethanol solution did not have a significant effect on the bulk etch rate. 1.5M, 60°C NaOH/ethanol yielded the fastest bulk etch rate of 27.3 μm/hr. The results obtained in this experiment will support a new CR-39 processing method that will include a background noise subtraction technique intended to enhance the accuracy of CR-39 diagnostics.

X-ray Phase-contrast Characterization of Cryogenic Targets

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In order to obtain ignition and high gain in an implosion, a cryogenic target's ice layer must be almost perfectly spherically symmetric. The Cryogenic Fill-Tube-Target Test Facility (CFTF) can be used to create and characterize cryogenic target ice layers. X-ray phase contrast imaging on the CFTF uses a small-spot-size x-ray source to irradiate the target with x rays that are recorded by an x-ray camera on the opposite side of the target. X rays that pass through the ice layer at nearly tangential angles undergo strong refraction, resulting in light and dark rings in the camera image. Asymmetries and imperfections in the ice surface are characterized by analyzing these rings. To better understand the behavior of these rings, the ray-tracing code *Icarus* was used to simulate the rings. In particular, the effects of a finite spot size and the energy distribution of the x-ray source were studied and compared with experimental measurements of the rings.

UV Probe Beam for Plasma Characterization and Channeling Experiments

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The OMEGA EP laser system will be used to study long-scale-length plasmas and the channeling of an ultra-intense infrared short-pulse beam through these plasmas. One of the primary plasma diagnostics will be grid image refractometry (GIR). In GIR a collimated UV beam illuminates a grid that breaks the beam into a two-dimensional array of probe-beam ray bundles. These rays pass through a plasma, where they are affected by refraction. Analyzing the images of the grid then allows one to determine the plasma density. In the standard GIR approach the grid has a large stand-off distance from the plasma and the grid is imaged into the plasma. A new approach is studied here in which the grid is in close proximity to the plasma. The goal of this project was to study the basic optical properties of this GIR system, including the diffraction effects from the grid but ignoring the refraction due to the plasma. A PV-Wave program was written based on a simple ray-trace algorithm that included diffraction from the grid. The image quality was studied for various object planes and grid periods. An optimal position for the grid was found that resulted in crisp images, showing that this approach is viable.

Abrasion-Resistant Anti-Reflective Silane Sol-Gel Coatings

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Many optics in the OMEGA and OMEGA EP lasers are coated with anti-reflective (AR) silane sol-gel to maximize their transmittance. Although these coatings are highly resistant to both airborne contaminants and laser damage, they are susceptible to mechanical damage by abrasion, and thus require extra care during the handling, installation and alignment of sol-gel optics. Previous "hardened" sol-gel AR formulations achieved physical robustness through exposure to ammonia, but were highly susceptible to degradation by atmospheric contaminants. In this work, alternate cross-linking agents for improving both mechanical robustness and contamination resistance were studied. The effectiveness of acryloyl chloride and glyoxal as "hardening" agents was evaluated through both solution and vapor-phase exposure. A drag-wipe testing protocol was developed for these chemically modified sol-gel ARs to determine their abrasion resistance as a function of hardening agent and exposure time. Results showed that glyoxal modification of AR coatings is effective in improving abrasion resistance, while contamination resistance needs to be evaluated further.

Water Desorption from Copper at Room Temperature

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Water adsorption and desorption is a major issue in industries that handle ultra-pure gases. For example, in the semiconductor industry, water desorption into pure gas streams can contaminate the entire stream and reduce the yield and lifetime of large-scale integrated devices. An experiment has been performed to understand the process by which water adsorbs and desorbs from metallic surfaces. Tritium, which is a radioactive isotope of hydrogen, was used in this experiment as a tracer to label water molecules attached to metals and monitor the rate at which desorption occurs. Tritium is an ideal tracer because, as an isotope of hydrogen, it can replace hydrogen in water (H_2O) to form tritiated water (HTO). In this experiment, copper with HTO bound to its surface was exposed to a helium carrier with varying amounts of humidity and the rate of exchange between the carrier-borne H_2O and the surface-bound HTO was measured as a function of carrier humidity. It was found that two processes control the rate of exchange: the arrival rate of water vapor to the surface when the metal is first exposed to the humidity and the rate of tritium diffusion from the metal when the upper oxide layers are tritium deficient in the later phase.

A Graphical Network Interface to Oscilloscopes

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A graphical user interface (GUI) was created that allows the user to modify the settings of and display data from an oscilloscope by communicating across a network. The GUI provides a convenient way to observe signals throughout the laser system. The GUI displays a graph of the data received from each channel of the oscilloscope, showing the signal's shape as well as other attributes. The user is able to continuously update the display with the most recent data or, at any time, acquire a single trace. The user is also able to arm the oscilloscope or force its trigger. The GUI communicates with the server program using ICE (Internet Communication Engine), a software package used for network communications. The results of this effort will allow remote viewing and control of virtually any oscilloscope in the laser system.

Using Networked Data Services for System Analysis and Monitoring

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By connecting instruments to a networked data service rather than a single output, it is possible to make the instrument data available to an entire network. This can enhance experimental capabilities by allowing data from multiple instruments to be combined in real time in a computer program and used to adjust an experimental system. This project demonstrates the combination of data from two experimental diagnostics in one program and the use of this data to automate the process of optimizing a pulse stretcher on OMEGA EP. The program, coded in Java, Matlab, and the Ice language, receives data from the Time-Expanded Single Shot Autocorrelator (TESSA) service and a spectrometer on an OMEGA EP front-end laser via the Internet Communications Engine's (ICE) IceStorm and IceGrid services, uses the data to predict the pulse shape, and then automatically adjusts a pulse stretcher, a process that is currently performed manually.

Exploration of the Feasibility of Polar Drive on the LMJ

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The Laser MegaJoule (LMJ), a laser system being constructed in France, is very similar to the U.S. National Ignition Facility (NIF) and will, therefore, operate using an indirect drive configuration. However, it is desirable that the LMJ, like the NIF, have the capability to operate using direct drive, despite its less favorable geometry. Currently two types of direct drive experiments are planned for the NIF: initial implosions of glass targets with low energy (≤350 kJ) to produce neutrons to test diagnostics, and later implosions of cryogenic targets with higher energy (1.5 MJ) to obtain break-even. These experiments employ a method known as polar drive in which beams are repointed toward the equator. The possibility of doing these experiments on the LMJ has been explored using the two-dimensional simulation code SAGE. Optimum designs for both experiments were created by adjusting parameters including the beam defocus distance and the beam pointings, and by using a new asymmetric beam shape. The levels of uniformity obtained are comparable to those expected for the NIF, proving that polar drive is feasible on the LMJ.

Resonance and Damping Characterization in Cryogenic Fusion Targets

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In direct-drive fusion experiments on OMEGA, a centered and stationary cryogenic fusion target is required for maximum radiation uniformity. Various sources of vibrational excitation are present in the target chamber, resulting in a need to understand target resonance and damping behavior. Frequency response functions were used to analyze resonance, and damping was estimated by the half-power bandwidth and logarithmic decrement methods. The Type 1 targets tested have two distinct primary resonance frequencies around the 130-150 Hz range, one for each target axis, and damping was estimated to be around 1% of critical damping. Transmissibility was generally within the 300-400 μm/gn range. Variability tests show that while frequency response functions return repeatable resonance frequency values, amplitude and damping values at resonance are more precise when calculated from a transient excitation in the time domain. A program, *Damping Estimator*, was written to estimate damping by the half-power bandwidth method and to visualize 3-dimensional target motion at high frame rates to investigate cross-coupling, the excitation of target axes transverse to the direction of applied acceleration.

Electron Reflection in Monte Carlo Simulations with the Code GEANT

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Target preheat is a significant concern in inertial confinement fusion experiments because, when the temperature of the target becomes too large, the areal density (density times radius) required for ignition cannot be attained. Part of the preheat comes from fast electrons produced when the laser interacts with the target. When these energetic electrons are slowed by collisions, they release high-energy x rays. The energy profile of these x rays is thus a very useful diagnostic of the preheat problem. This energy profile has been obtained from Monte Carlo simulations using the code GEANT. The GEANT code simulates electron transport in the target ending either with the electron's loss of all kinetic energy through collisions or with its escape. In reality, only a negligible number of electrons escape before the target becomes charged enough to reflect the remaining electrons back into the target. A FORTRAN program was written to model the specular reflection of these electrons back into the target. The results of this program are then used as input for another GEANT run with the reflected electrons. This allows for more accurate simulation of electron transport and of the profile of the x rays generated.

Laser Beam Shaping with Optically Patterned Liquid Crystals

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Current laser beam shapers such as those used in the OMEGA EP laser system for spatial gain precompensation are made of small metal pixels arranged in a pattern to create a beam shaping device. Laser beam shapers can also be made from liquid crystals (LCs). Because of their unique properties, LCs can be oriented so that they transmit, block, or change the phase of incident light when viewed with the aid of polarizers. This orientation is controlled by a polymer alignment layer in close contact with the LC material. If a linearly photopolymerizable polymer (LPP) is irradiated with polarized UV light, the LC molecules will align along the polymer chains. Irradiating the LPP through a mask, followed by rotating the substrate and irradiating again without the mask, allows the orientation of LCs in different regions of the substrate to be controlled. This process can be used to produce pixilated LC devices that function similarly to metal beam shapers, with both a greater variety of optical effects and a substantially higher laser damage threshold. Future applications of these devices could include erasable and rewriteable beam shapers and apodizers.

Computational Modeling of Optically Switchable Azobenzenes

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Azobenzenes have a unique ability to undergo reversible isomerization between two geometrical isomer forms (the straight *trans* and the bent *cis*) when irradiated with the correct wavelength of UV or visible light. These systems are of interest because of their numerous potential applications as reversible photoswitchable absorbers. To reduce the need to synthesize a large number of materials in order to establish structure-properties relationships, computational chemistry was used to model the absorption spectra of these materials as a function of molecular structure. Time-dependent density functional theory (TDDFT) was used in this study to model the absorption spectra of azobenzene derivatives, and the process was refined to produce results closer to observed spectra than previous research. An alternative method, Zerner's Intermediate Neglect of Differential Overlap (ZINDO), was also investigated and the results were compared with those obtained with TDDFT. The TDDFT approach was found to give consistently better agreement with experimental data than the semiempirical ZINDO approach.

Neutron Detection with High Bandwidth and High Dynamic Range

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The success of an inertial confinement fusion (ICF) implosion is determined by the areal density (ρr) of the imploded target. During implosions, the areal density of the imploded targets increases and the fusion neutrons, generated at the target center, lose more energy as they escape. Neutron diagnostics measure the neutron spectrum and thus provide a good measure of the implosion ρr. A neutron diagnostic for ICF experiments was created and is suitable for both the OMEGA and National Ignition Facility (NIF) laser facilities. The neutron detector exhibits high bandwidth and an exceptional and unprecedented dynamic range of 10^{10}, which is ideal for measuring neutron spectra from implosion experiments. Because neutrons are electrically neutral particles and thus do not respond to electric fields, they are detected by transferring energy to charged particles. The neutron detector uses a foil of polyethylene as a source of protons, with which the neutrons can exchange energy by elastic collisions. The detector also utilizes tungsten as a shield for x-ray radiation emitted from the target.

Automated Injection for High-Power Fiber Amplifiers

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Large-mode-area photonic crystal fibers (PCFs) when used as amplifiers have made possible kilowatt laser systems producing millijoule pulses, power and energy levels previously prevented by the detrimental effects of nonlinearities in smaller optics. However, the utility of these fibers is limited since they cannot be spliced using normal methods. The rigid structure of the fibers necessitates the use of free-space injection. In addition, the output beam quality of PCFs degrades with significant injection site misalignment. These characteristics of PCFs make injection site accuracy critical to maintaining optimum performance. The misalignment can be observed and measured using a microscope objective focused on the end face of the fiber. Software has been written that analyzes end face microscope (EFM) images and automatically calculates the site misalignment. The software corrects the misalignment by communicating with a motorized mirror mount that controls the path of the injected light, and thus the location of the seed-pulse injection site.

Analysis of Implosion Radiographs

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In order to achieve ignition conditions in inertial confinement fusion experiments, it is necessary for the imploding target to reach very high densities. X-ray radiography is employed to measure the properties of the target while it implodes. The target is backlit, and the resulting radiograph is recorded using a pinhole camera. The optical thickness profile of the target is then inferred from the intensity profile recorded in the radiograph. In previous analyses, the target was treated as an absorbing sphere, with no emissivity. However, it is necessary to account for a significant amount of self-emission from the target. By including both an emitting center and an emitting outer shell in our model, estimates of the optical depth can be improved, allowing more-accurate determinations of the projected radial density distributions.

Optimization of 1-D Multiple-FM SSD Designs for OMEGA EP and the NIF

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This work investigates 1-D Multiple Frequency Modulation (Multi-FM) Smoothing by Spectral Dispersion (SSD) proposed for the National Ignition Facility (NIF) and demonstrates that a high level of uniformity can be achieved using Multi-FM. The laser non-uniformity that directly drives an inertial confinement fusion target can imprint on the target's shell during the ablation process, leading to the exponential growth of non-uniformity followed by the shell's destruction. The SSD system mitigates imprint by causing the laser’s speckle pattern to evolve continuously, creating many statistically independent patterns that average over time. The 1-D Multi-FM SSD system uses multiple phase modulators with different frequencies, dispersed in a single dimension. The parameters of 1-D Multi-FM SSD were optimized using a MATLAB-based algorithm that intelligently varies the parameters to minimize a metric based on time-integrated laser non-uniformity and laser system constraints. The optimized designs have lower levels of non-uniformity than single modulator designs with comparable bandwidth. The OMEGA EP laser will be used as a test bed for the new designs.