UNIVERSITY OF ROCHESTER
LABORATORY FOR LASER ENERGETICS

Volume 113
October–December 2008
DOE/NA/28302-804

# LLE Review

## Quarterly Report

## Contents

# In Brief

This volume of the LLE Review, covering October–December 2007, features "High-Intensity Laser–Plasma Interactions in the Refluxing Limit," by P. M. Nilson, W. Theobald, J. Myatt, C. Stoeckl, M. Storm, O. V. Gotchev, J. D. Zuegel, R. Betti, D. D. Meyerhofer, and T. C. Sangster. In this article (p. 1), the authors report on target experiments using the Multi-Terawatt (MTW) Laser Facility to study isochoric heating of solid-density targets by fast electrons produced from intense, short-pulse laser irradiation. Electron refluxing occurs due to target-sheath field effects and contains most of the fast electrons within the target volume. This efficiently heats the solid-density plasma through collisions. X-ray spectroscopic measurements of absolute $K_\alpha$ (x-radiation) photon yields and variations of the $K_\beta/K_\alpha$ emission ratio both indicate that laser energy couples to fast electrons with a conversion efficiency of approximately 20%. Bulk electron temperatures of at least 200 eV are inferred for the smallest mass targets.

Additional highlights of recent research presented in this issue include the following:

- M. Storm, I. A. Begishev, R. J. Brown, D. D. Meyerhofer, C. Mileham, J. F. Myatt, P. M. Nilson, T. C. Sangster, C. Stoeckl, W. Theobald, and J. D. Zuegel, along with C. Guo (The Institute of Optics) present the design of a high-resolution optical transition-radiation diagnostic for fast-electron-transport studies using the MTW Laser Facility. Coherent transition radiation is generated as relativistic electrons, generated in high-intensity laser–plasma interactions, exit the target's rear surface and move into vacuum. High-resolution images of the rear-surface optical emission from high-intensity ($I \sim 10^{19}$ W/cm$^2$) laser-illuminated metal foils have been recorded using a transition radiation diagnostic (TRD). The detector is a scientific-grade charge-coupled-device (CCD) camera that operates with a signal-to-noise ratio of $10^3$ and has a dynamic range of $10^4$. The TRD has demonstrated a spatial resolution of 1.4 $\mu$m over a 1-mm field of view, limited only by the CCD pixel size.

- V. N. Goncharov, T. C. Sangster, P. B. Radha, T. R. Boehly, T. J. B. Collins, R. S. Craxton, J. A. Delettrez, R. Epstein, V. Yu. Glebov, S. X. Hu, I. V. Igumenshchev, S. J. Loucks, J. A. Marozas, F. J. Marshall, J. P. Knauer, P. W. McKenty, S. P. Regan, W. Seka, S. Skupsky, V. A. Smalyuk, J. M. Soures, C. Stoeckl, R. Betti, R. L. McCrory, and D. D. Meyerhofer, along with D. Shvarts (Nuclear Research Center Negev), J. A. Frenje, R. D. Petrasso, C. K. Li, and F. H. Séguin (Plasma Science Fusion Center, MIT), W. Manheimer (RSI), and D. G. Colombant (Naval Research Laboratory) describe the performance of direct-drive cryogenic target implosions on OMEGA. The success of direct-drive-ignition target designs depends on two issues: the ability to maintain the main fuel adiabat at a low level and the control of the nonuniformity growth during the implosion. A series of experiments was performed to study the physics of low-adiabat, high-compression cryogenic-fuel assembly. High-areal-density (with $\rho R > 200$ mg/cm$^2$) cryogenic-fuel assembly has been achieved on OMEGA in designs where the shock timing was optimized using the nonlocal treatment of the heat conduction and the suprathermal-electron preheat generated by two-plasmon-decay instability was mitigated.

- W. Theobald, R. Betti, C. Stoeckl, K. S. Anderson, J. A. Delettrez, V. Yu. Glebov, V. N. Goncharov, F. J. Marshall, D. N. Maywar, R. L. McCrory, D. D. Meyerhofer, P. B. Radha, T. C. Sangster, W. Seka, V. A. Smalyuk, A. A. Solodov, B. Yaakobi, and C. D. Zhou, along with D. Shvarts (Nuclear Research Center Negev), J. A. Frenje, C. K. Li, F. H. Séguin, and R. D. Petrasso (Plasma Science Fusion Center, MIT), and L. J. Perkins (LLNL) present the results from initial experiments on the shock-ignition inertial confinement fusion concept. Shock ignition is a two-step inertial confinement fusion concept where a strong shock wave is launched at the end of the laser pulse to ignite the compressed core of a low-velocity implosion. Initial shock-ignition technique experiments used 40-$\mu$m-thick, 0.9-mm-diam, warm surrogate plastic shells filled with deuterium gas. These experiments showed a significant improvement in the performance of low-adiabat, low-velocity implosions compared to conventional "hot-spot" implosions. High areal densities with average values exceeding ~200 mg/cm$^2$ and peak areal densities above 300 mg/cm$^2$ were measured, which is in good agreement with one-dimensional hydrodynamical simulation predictions. Shock-ignition technique implosions with cryogenic deuterium and deuterium–tritium ice shells also produced areal densities close to the 1-D prediction and achieved up to 12% of the predicted 1-D fusion yield.

- W. Seka, D. H. Edgell, J. P. Knauer, J. F. Myatt, A. V. Maximov, R. W. Short, T. C. Sangster, C. Stoeckl, R. E. Bahr, R. S. Craxton, J. A. Delettrez, V. N. Goncharov, and I. V. Igumenshchev, along with D. Shvarts (Nuclear Research Center Negev) report investigations on time-resolved absorption in cryogenic and room-temperature, direct-drive implosions on OMEGA. Time-dependent and time-integrated absorption fractions are inferred from scattered-light measurements that agree reasonably well with hydrodynamic simulations that include nonlocal electron-heat transport. Discrepancies in the time-resolved scattered-light spectra between simulations and experiments remain for complex laser pulse shapes indicating beam-to-beam energy transfer and commensurate coupling losses. Time-resolved scattered-light spectra near $\omega/2$ and $3\omega/2$, as well as time-resolved hard x-ray measurements, indicate the presence of a strongly driven two-plasmon-decay (TPD) instability at high intensities that may influence the observed laser light absorption. Experiments indicate that energetic electron production due to the TPD instability can be mitigated with high-*Z*-doped plastic shells.

- J. R. Rygg, F. H. Séguin, C. K. Li, J. A. Frenje, M. J.-E. Manuel, and R. D. Petrasso (Plasma Science Fusion Center, MIT), along with R. Betti, J. A. Delettrez, O. V. Gotchev, J. P. Knauer, D. D. Meyerhofer, F. J. Marshall, C. Stoeckl, and W. Theobald (LLE) report on monoenergetic proton radiography of field and density distributions in inertial confinement fusion implosions. This unique imaging technique reveals field structures through deflection of proton trajectories, and areal densities are quantified through energy lost by protons while traversing the plasma. Two distinctly different types of electromagnetic-field configurations are observed during implosions and the capsule size and areal-density temporal evolution are measured. The first field structure consists of many radial filaments with complex striations and bifurcations that permeate the entire field of view with 60-T magnetic-field magnitudes, while another coherent, centrally directed electric field of the order of $10^9$ V/m is seen near the capsule surface. Although the mechanisms for generating these fields are not yet fully understood, their effect on implosion dynamics is expected to be consequential.

Jonathan D. Zuegel
*Editor*