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# LLE Review

## Quarterly Report

## Contents

# In Brief

This volume of the LLE Review, covering July–September 2008, features "Optimizing Electron–Positron Pair Production on kJ-Class High-Intensity Lasers for the Purpose of Pair-Plasma Creation" by J. Myatt, J. A. Delettrez, A. V. Maximov, D. D. Meyerhofer, R. W. Short, C. Stoeckl, and M. Storm. In this article, the authors report that expressions for the yield of electron–positron pairs, their energy spectra, and production rates have been obtained in the interaction of multi-kJ pulses of high-intensity laser light interacting with solid targets (p. 161). The Bethe–Heitler conversion of hard x-ray bremsstrahlung is shown to dominate over direct production (trident process). The yields and production rates have been optimized as a function of incident laser intensity, by the choice of target material and dimensions, indicating that up to $5 \times 10^{11}$ pairs can be produced on the OMEGA EP Laser System. The corresponding production rates are sufficiently high that the possibility of pair-plasma creation is shown to exist.

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

- S. X. Hu, P. B. Radha, J. A. Marozas, R. Betti, T. J. B. Collins, R. S. Craxton, J. A. Delettrez, D. H. Edgell, R. Epstein, V. N. Goncharov, I. V. Igumenshchev, F. J. Marshall, R. L. McCrory, P. W. McKenty, D. D. Meyerhofer, S. P. Regan, T. C. Sangster, S. Skupsky, V. A. Smalyuk (LLE), and D. Shvarts (Nuclear Research Center, Negev) describe neutron yields of direct-drive, low-adiabat ($\alpha \simeq 2$ to 3) cryogenic $D_2$ target implosions on OMEGA have been systematically investigated using the two-dimensional (2-D) radiation hydrodynamics code *DRACO* (p. 172). Low-mode ($\ell \leq 12$) perturbations, including initial target offset, ice-layer roughness, and laser-beam imbalance, were found to be the primary source of yield reduction in implosions for thin-shell (5-$\mu$m), low-$\alpha$, cryogenic targets. Overall, our 2-D simulations of thin-shell implosions track experimental measurements for different target conditions and peak laser intensities ranging from $2.5 \times 10^{14}$ to $6 \times 10^{14}$ W/cm$^2$. Simulations also indicate that fusion yield is sensitive to the relative phases between the target offset and the ice-layer perturbations. These 2-D numerical results provide a reasonably good guide to understanding the yield degradation in direct-drive, low-adiabat, cryogenic, thin-shell-target implosions. Thick-shell (10-$\mu$m) implosions generally give lower yield over clean (YOC) than low-$\ell$-mode *DRACO* simulation predictions. Simulations including the effect of laser-beam nonuniformities indicate that high-$\ell$-mode perturbations caused by laser imprinting play a role in further degrading the neutron yield of thick-shell implosions. Finally, for obtaining meaningful implosions to study ICF compression physics, these results suggest a target specification with a $\leq$30-$\mu$m offset and ice-roughness of $\sigma_{rms} < 3$ $\mu$m.

- H. Sawada, S. P. Regan, P. B. Radha, R. Epstein, D. Li, V. N. Goncharov, S. X. Hu, D. D. Meyerhofer, J. A. Delettrez, P. A. Jaanimagi, V. A. Smalyuk, T. R. Boehly, T. C. Sangster, B. Yaakobi (LLE), and R. C. Mancini (Department of Physics, University of Nevada, Reno, Nevada) present a time-resolved Al 1*s*–2*p* absorption spectroscopy used to diagnose direct-drive, shock-wave heating and compression of planar targets having nearly Fermi-degenerate plasma conditions ($T_e \sim 10$ to 40 eV, ~3 to 11 g/cm$^3$) on the OMEGA Laser System (p. 185). A planar plastic foil with a buried Al tracer layer was irradiated with peak intensities of $10^{14}$ to $10^{15}$ W/cm$^2$ and probed with the pseudocontinuum M-band emission from a point-source Sm backlighter in the range of 1.4 to 1.7 keV. The laser-ablation processes launch 10- to 70-Mbar shock waves into the CH/Al/CH target. The Al 1*s*–2*p* absorption spectra were analyzed using the atomic physics code *PrismSPECT* to infer $T_e$ and in the Al layer, assuming uniform plasma conditions during shock-wave heating, to determine when the heat front penetrated the Al layer. The drive foils were simulated with the 1-D hydrodynamics code *LILAC* using a flux-limited ($f = 0.06$

and $f = 0.1$), nonlocal thermal-transport model. The predictions of simulated shock-wave heating and the timing of heat-front penetration are compared with the observations. The experimental results for a wide variety of laser-drive conditions and buried depths have shown that the *LILAC* predictions using $f = 0.06$ and the nonlocal model accurately model the shock-wave heating and timing of the heat-front penetration while the shock is transiting the target. The observed discrepancy between the measured and simulated shock-wave heating at late times of the drive can be explained by the reduced radiative heating caused by lateral heat flow in the corona.

- C. D. Zhou (LLE and the Fusion Science Center for Extreme States of Matter and Fast Ignition Physics) and R. Betti (LLE, the Departments of Mechanical Engineering and Physics and Astronomy, and the Fusion Science Center for Extreme States of Matter and Fast Ignition Physics) describe how the ignition condition (Lawson criterion) for inertial confinement fusion can be cast in a form dependent on the only two measurable parameters of the compressed fuel assembly: the hot-spot ion temperature $\left(T_i^h\right)$ and the total areal density ($\rho R_{\mathrm{tot}}$) that includes the cold shell contribution (p. 204). A marginal ignition curve is derived in the $\rho R_{\mathrm{tot}}, T_i^h$ plane and current implosion experiments are compared with the ignition curve. On this plane, hydrodynamic equivalent curves show how a given implosion would perform with respect to the ignition condition when scaled up in the laser-driver energy. An approximate form of the ignition condition (typical of laser-driven ICF) is $\left\langle T_i^{\mathrm{no}\,\alpha}\right\rangle_{\mathrm{n}}^{2.6} \times \left\langle \rho R_{\mathrm{tot}}\right\rangle_{\mathrm{n}} > 50\ \mathrm{keV}^{2.6} \times \mathrm{g/cm}^2$, where $\langle \rho R_{\mathrm{tot}} \rangle_{\mathrm{n}}$ and $\left\langle T_i^{\mathrm{no}\,\alpha}\right\rangle_{\mathrm{n}}$ are the neutron-averaged total areal density and hot-spot ion temperature without accounting for $\alpha$-particle energy deposition, respectively. Such a criterion can be used to determine how surrogate $D_2$ and sub-ignited DT target implosions perform with respect to the one-dimensional ignition threshold.

- X. L. Cross, X. Zheng, P. D. Cunningham, L. M. Hayden, Š. Chromik, M. Sojkova, V. Štrbík, P. Odier, and R. Sobolewski (LLE) present an ultrafast THz-pulse time-domain spectroscopy (TDS) and femtosecond optical-pump THz-probe (OPTP) studies of Hg-Ba-Ca-Cu-O (HBCCO) high-temperature, superconducting thin films (p. 219). Our 500-nm-thick films were prepared by rf-magnetron sputtering of Re-Ba-Ca-Cu-O precursor films, followed by an *ex-situ*, high-temperature mercuration process. The resulting films were *c*-axis oriented with a predominant Hg-1212 (plus some Hg-1223) phase. Their transition temperature $T_{\mathrm{c}}$ had an onset at 123 K and zero resistance at 110 K. The THz TDS measurements demonstrated a sharp drop in the transmitted THz signal when the sample temperature was decreased below $T_{\mathrm{c}}$, which we directly related to a change in the imaginary component of the film's complex conductivity. Simultaneously, the peak of the temperature-dependent real part of the conductivity was shifted toward lower frequencies at lower temperatures. The time-resolved OPTP spectroscopy experiments showed that the quasiparticle relaxation process exhibited an intrinsic single-picosecond dynamics with no phonon bottleneck, which is a unique feature among superconductors and makes the HBCCO material very promising for ultrafast radiation detector applications.

- This volume concludes with a summary of LLE's Summer High School Research Program (p. 224), the FY08 Laser Facility Report (p. 226), and the National Lasers Users' Facility and External Users' Programs (p. 228).

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*Editor*