December 2002 Progress Report on the Laboratory for Laser Energetics Inertial Confinement Fusion Program Activities

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Optimized Direct-Drive Illumination Uniformity: Recent calculations indicate that a new distributed phase plate (DPP) design can further minimize the OMEGA nonuniformities due to target positioning, beam energy balance, and pointing errors. Figure 1 shows Aitoff projections of the calculated energy absorption variation about the average for 60-beam OMEGA directly driven targets with varying DPP profiles. Two optimum circularly symmetric shapes have been identified. They are super-Gaussian profiles with a radial intensity dependence of $I = I_0 e^{-(r/r_0)n}$. Minimum variations occur for $n = 2.2$ and $n = 3.6$ if absorption is assumed to have a simple cosine dependence on angle to the target normal (cos θ). The first minimum at $n = 2.2$ is relatively insensitive to choice of absorption profile, whereas the second minimum varies from $n = 3.6$ to 4.6 as the absorption profile varies from cos θ to $\cos^3\theta$. The higher-order design is less sensitive to beam mispointing and beam-to-beam imbalance due to its flatter, wider shape. The current DPP's on OMEGA are an $n = 2.3$ design. A new $n \sim 4.2$ DPP has been designed and tested. With the new DPP design on all 60 OMEGA beams, and assuming precision beam pointing (<10 μm rms) and energy balance (<2%), it is estimated that the on-target nonuniformity will be reduced from a level of ~2.6% rms with the current DPP's to a level approaching 0.9% rms. A set of the $n = 4.2$ DPP's is currently in fabrication and will be implemented on OMEGA in 2003.

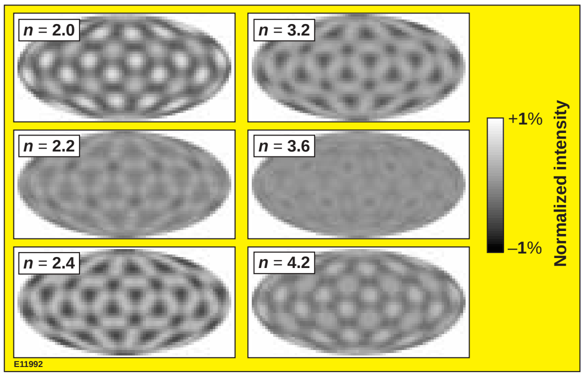

Figure 1. Aitoff projections of the spatial variation of absorbed energy on OMEGA spherical targets with DPP's producing a super-Gaussian intensity distribution of varying order, *n*. These calculations assume that the absorption varies as the cosine of the angle to the target normal.

Deuterium Equation-of-State Experiments: Knowledge of the equation of state (EOS) of hydrogen and its isotopes is essential for the study of condensed matter physics, planetary structure, and inertial confinement fusion (ICF). Deuterium EOS experiments have shown varying degrees of disagreement with each other and with the widely used *SESAME* EOS library[1] and various theoretical models.[2] An LLE/LLNL collaborative experiment was recently conducted on OMEGA to confirm the EOS measurements on liquid D_2 previously made on the Nova laser.[3] The campaign used the OMEGA planar cryogenic target positioner and the VISAR diagnostic to carry out re-shock measurements of the compressibility of deuterium in the pressure range of 0.8 to 2.2 Mb [80 to 220 Gpa]. The initial results (see Fig. 2) show that the D_2 compressibility in the pressure range covered in the experiment is in reasonable agreement with the Saumon–Chabrier model.[2] More-detailed studies planned for the future will include radiography and temperature measurements. Since July '02 the planar cryogenic target system has performed 33 shots on cryogenic deuterium. As many as 5 cryogenic shots were performed in one day with 7 warm-target shots interleaved.

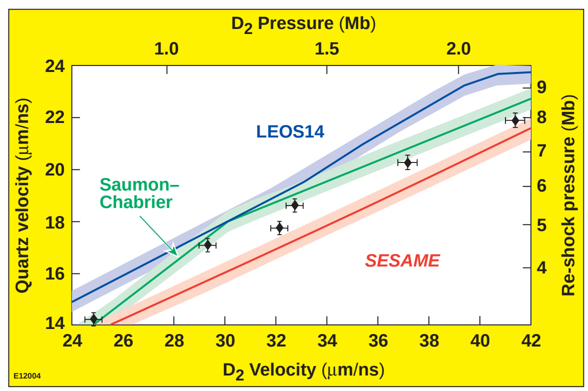

Figure 2. Plot of quartz shock velocity (re-shocked D_2 pressure) versus D_2 velocity (D_2 pressure) measured in the experiment. For comparison, note the *SESAME*[1] table predictions (solid red line), LEOS14 (a fit to the NOVA data[3]), and the Saumon–Chabrier model.[2] The measurements use quartz as a reference material; the bands represent anticipated excursions due to worst-case uncertainty in that reference.

OMEGA Operations Summary: A total of 90 target shots were taken on OMEGA in December. These included 52 integrated spherical and 1 cryogenic target shots for LLE; 9 LLNL shots for diagnostics development and the BLIMP experiment; 12 SNL shots for WBS-3 experiments; and 16 NLUF shots for three collaborations led by MIT, University of Michigan, and the University of Nevada, Reno, respectively. One week of December was dedicated to scheduled facility maintenance activities.

1. G. I. Kerley, "Theoretical Equation of State for Deuterium," Los Alamos National Laboratory, Report LA-4776 (1972).
2. D. Saumon and G. Chabrier, "Fluid Hydrogen at High Density: Pressure Dissociation," Phys. Rev. A **44**, 5122 (1991).
3. L. B. Da Silva *et al.*, "Absolute Equation of State Measurements on Shocked Liquid Deuterium up to 200 GPa (2 Mbar)," Phys. Rev. Lett. **78**, 483 (1997).

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