March 2004 Progress Report on the Laboratory for Laser Energetics
Inertial Confinement Fusion Program Activities

OMEGA EP Front End: The OMEGA EP baseline design requires a front-end laser system that produces at least 250-mJ chirped pulses at a 5-Hz repetition rate with 8 nm of bandwidth centered at 1053 nm. Optical parametric chirped-pulse amplification[1] (OPCPA) can meet this need and is an area of active research and development at LLE.[2,3] The energy requirement poses a significant challenge; it is nearly an order of magnitude larger than any other OPCPA high-repetition-rate system reported in the literature. The research and development effort is twofold. First, a two-stage OPCPA design is being optimized to maximize the pump-to-signal conversion efficiency and thereby reduce the pump-laser energy requirements. Secondly, a laser that fulfills the challenging requirements for the OPCPA pump laser for OMEGA EP is being developed.

A nearly collinear two-stage OPCPA design employs lithium triborate (LBO) crystals to minimize the sensitivity of the conversion efficiency to the pump-laser wavefront quality.[2] The first stage of the OPCPA is pumped by 200 mJ of energy and produces 42 mJ of signal energy. After this stage, the idler beam, as well as the rest of the pump laser, is discarded and the signal beam is imaged to the power amplifier. The power-amplifier stage uses up to 800 mJ of pump energy, and the signal output energy exceeds the 250-mJ requirement.

A high-energy pump laser with carefully controlled spatial and temporal profiles is critical to realizing highly efficient OPCPA.[1] The OPCPA pump laser employs OMEGA front-end technology, including a single-longitudinal-mode oscillator, temporal pulse shaping, a regenerative amplifier, and spatial beam shaping. The large-aperture-ring amplifier design employed in OMEGA has been adapted by replacing the 40-mm Nd-doped phosphate glass laser rod with two 1-in. Nd:YLF crystal laser rods in a crystal large-aperture ring amplifier (CLARA).

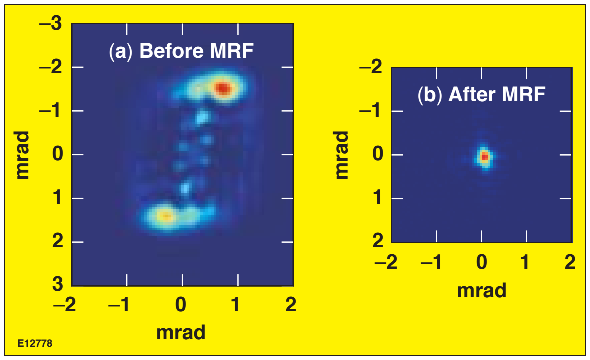

Figure 1. The OPCPA pump-laser far-field spatial distribution reflects the wavefront quality of the CLARA laser. (a) The relatively poor wavefront quality of the CLARA laser rods before MRF correction results in a large divergence that causes poor phase matching in the OPCPA process. (b) After MRF correction, the CLARA rods produce a nearly diffraction limited quality beam that is well suited for pumping an OPCPA system.

The transmitted wavefront quality of commercially available, large-aperture rods is not sufficient for pumping an OPCPA system because the resulting beam divergence [see Fig. 1(a)] poorly phase matches in the OPCPA process. Surface figure corrections were polished on one face of each CLARA rod using magnetorheological finishing (MRF)[4] to compensate the bulk inhomogeneities that cause the transmitted wavefront errors. Correcting these errors increases the usable aperture of the Nd:YLF laser rods, which consequently increases the energy extraction. The improved CLARA wavefront quality after MRF correction is shown in Fig. 1(b); a nearly diffraction limited laser far-field spatial distribution is achieved.

Using the MRF-corrected CLARA rods, the 250-mJ OMEGA EP energy requirement was experimentally demonstrated, as shown in Fig. 2.

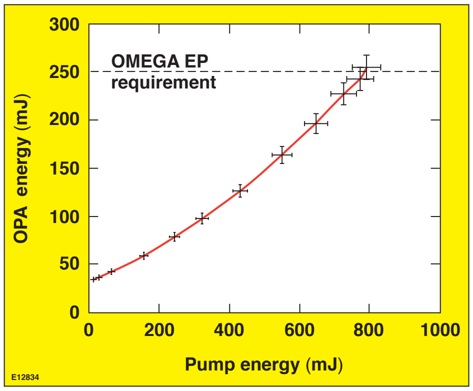

Figure 2. The OPCPA power amplifier's output energy performance versus pump energy input is plotted. The error bars represent the uncertainty in the energy measurements.

OMEGA Operations Summary: During March, a total of 148 target shots were taken on OMEGA. The principal users were LLNL (39 shots); LANL (13 shots); LLE (69 shots); SNL (13 shots); NRL (13 shots); and NLUF (1 shot). Planned maintenance was carried out during the last full week of the month.

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1. I. N. Ross *et al.*, Opt. Commun. **144**, 125 (1997).
2. L. J. Waxer *et al.*, Opt. Lett. **28**, 1245 (2003).
3. M. J. Guardalben *et al.*, Opt. Express **11**, 2511 (2003).
4. S. D. Jacobs *et al.*, in *Finishing of Advanced Ceramics and Glasses*, edited by R. Sabia, V. A. Greenhut, and C. G. Pantano, Ceramic Transactions, Vol. 102 (The American Ceramic Society, Westerville, OH, 1999), pp. 185–199.

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