Section 1
LASER SYSTEMS REPORT

1.A OMEGA Laser System

The principle activity on the OMEGA laser system during the past quarter was the 24 beam system performance test completed in January and described in a special report below. The ZETA beamlines (6 of the 24 OMEGA beamlines) were consequently not available for ZETA target experiments during this period. In February, work commenced on reactivating the ZETA system for experiments during the next quarter.

In the OMEGA target area, Figure 1, the secondary personnel platform was installed and final painting of the main structure was completed. The OMEGA target chamber, 1.6 m in diameter with 138 ports, was placed on the support structure, Figure 2, for initial testing. As a result of this testing, some additional work has been required to insure that the port axes are pointed to the chamber center to within the required tolerances.

1.B OMEGA Laser System Performance Test

The OMEGA 24 beam Neodymium phosphate glass laser system ($\lambda = 1.054\mu m$) at LLE has been tested for overall performance, as specified by the Department of Energy contract EY-76-C-02-2812.* The test program was successfully concluded on January 18, 1980.

The OMEGA system test was designed to insure that the system met its laser energy and power requirements while maintaining high repetition rate and adequate beam quality for target experiments. The principle objectives and results from this performance test are given in Table 1. The system minimum requirements have been exceeded by a considerable margin while maintaining a high repetition rate. Further improvements in peak power and energy are anticipated.

	MINIMUM DOE REQUIREMENTS	DESIGN GOAL	OMEGA OUTPUT (1/80)
Peak Power (short pulse)	7.5 TW (50 psec)	12-14 TW (50 psec)	12.2 TW (53 psec)
Energy (long pulse)	1.2 kJ (300 psec)	2.5 kJ (300 psec)	1.76 kJ (273 psec)

Table 1 The principal objectives and results from the OMEGA laser system performance test.

Before continuing with details of the DOE test series, the major characteristics of the OMEGA laser system will be reviewed. OMEGA was designed to be a high power, high energy system with an unusually high repetition rate of one shot per 30 minutes. The following features were incorporated into the system in order to reach the design goals and to hold down costs.

1. Phosphate glass rods which produce a higher specific power output than other solid state lasing materials, while maintaining rapid cool down characteristics.
2. Beam propagation with circularly polarized light to reduce the nonlinear index of refraction of the laser glass and therefore reduce high power beam breakup.

Figure 2 Placement of OMEGA target chamber on its support structure.

*The OMEGA laser system construction began under the DOE contract EY-76-C-02-2812. On January 7, 1980 the contract number was changed to DE-AC02-76DP-40051.

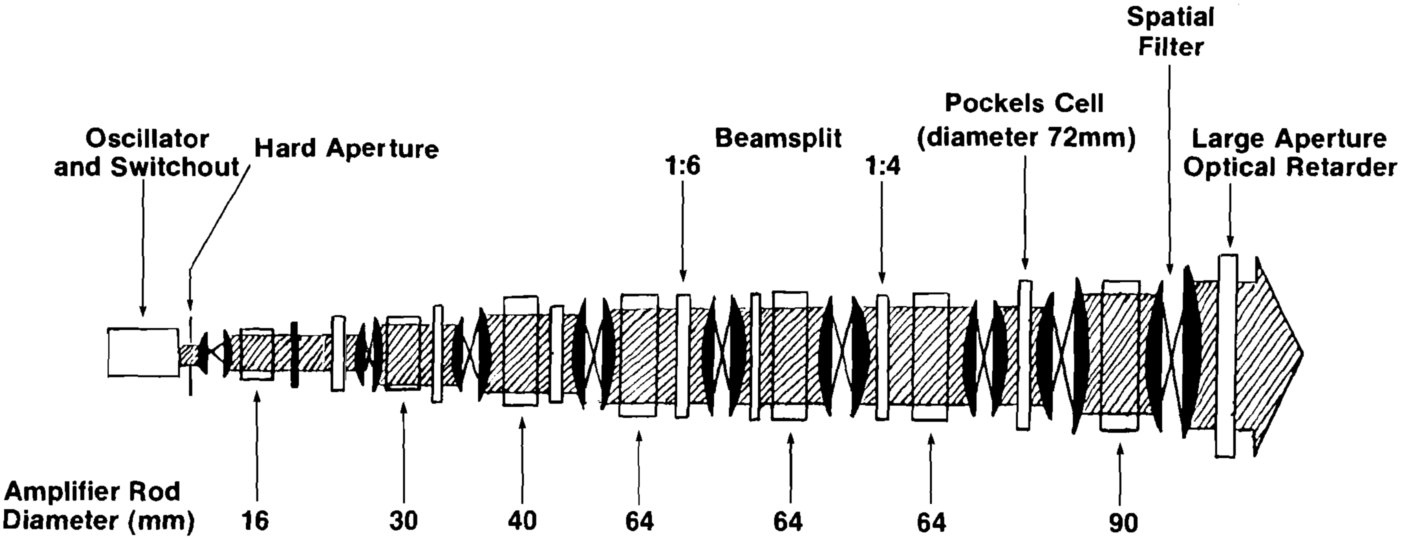

Figure 3 Staging diagram for OMEGA beamline.

3. Amplifier rods and flashlamp units of modular design which simplifies component replacement and minimizes the number of spare parts stored.
4. Full computer control of the laser charging system (power conditioning) to provide efficient operation.

A staging diagram for an OMEGA beamline is shown in Figure 3. The major elements are as follows:

1. An actively-passively mode-locked oscillator capable of producing pulse trains with a single pulse duration between 50 and 500 psec.
2. A Pockels cell switch-out system employing fast optically triggered switching (see 3.A) to select one pulse from the mode-locked train and send it into the amplifier chain. This eliminates all prepulse suppression dye cells which are commonly used in laser systems.
3. Hard aperture input to the amplifier chains, i.e., a Gaussian beam profile truncated near the 1% level. This eliminates damage sensitive soft apertures.
4. Spatial filter relaying of the image of the hard aperture throughout the laser system. This technique preserves beam quality by reducing small scale ripple growth and Fresnel ring formation.
5. Seven stages of amplification with high repetition rate rod amplifiers 16 to 90 mm in diameter with an overall gain in excess of 3×10^9.
6. Beam splitting 1 to 6 then 1 to 4 to reach the total of 24 beams.
7. A large aperture Pockels cell to reduce Amplified Spontaneous Emission (ASE) to a value below the design limit.
8. Large aperture optical retarder (a polarizer and wave plate) to prevent the backreflected beam from the target from re-entering the laser system. The large aperture Pockels cell acts as a back-up system for this function also.

In order to certify the OMEGA system repetition rate requirement, the performance test consisted of two shot volleys, where a volley is a series of five consecutive shots with all 24 beams firing simultaneously and with a time interval between shots of 30 minutes or less. The first volley tested high energy output of the system with long pulses (264 ± 15 psec FWHM), while the second volley tested high power output with short pulses (55 ± 5 psec FWHM). The elapsed time between shots for these volleys is collected in Table 2, which demonstrates a repetition rate in excess of one shot per 30 minutes.

Figures 4 and 5 show, respectively, the OMEGA system energy output on the long pulse series and power output on the short pulse series. The beam balance was being adjusted during these tests. For the series of long pulses, the standard deviation of beam energies about the mean was ± 18%; this was reduced to ± 11% for the short pulse series. Experience with the 6 beam ZETA system suggests that a beam balance of ± 7% (standard deviation) is a realistic expectation for OMEGA.

The temporal and spatial beam quality exceeded DOE specifications. The full angle beam divergence averaged 153 μrad for the high energy shots and 160 μrad for the

Table 2 OMEGA twenty-four beam performance test firing rate data.

SHOT NUMBER	ELASPED TIME FROM PREVIOUS SHOT (MIN.)
3606	*Start*
3607	*27*
3608	*28*
3609	*29*
3610	*27*
3641	*Start*
3642	*28*
3643	*28*
3644	*28*
3645	*27*

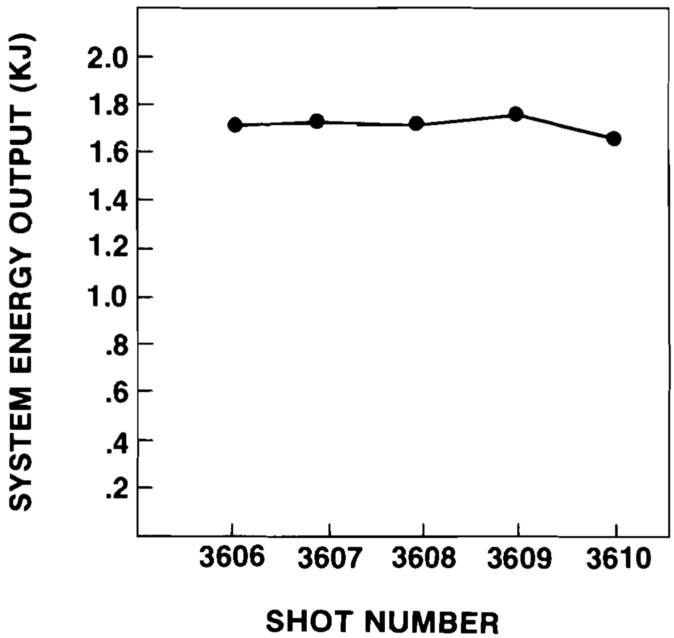

Figure 4 OMEGA energy output on long pulse series (264 ± 15 psec FWHM).

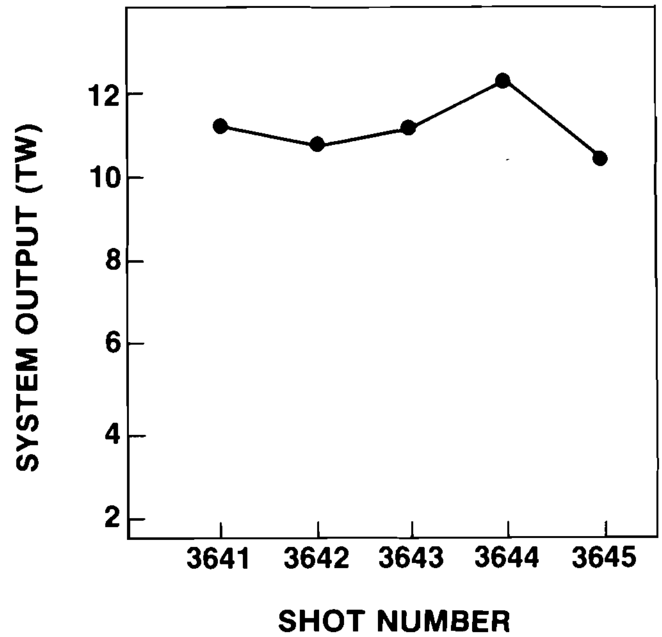

Figure 5 OMEGA power output on short pulse series (55 ± 5 psec FWHM).

high power shots. The DOE requirement was < 400 μrad. These results translate into equivalent focal spot diameters (90% energy diameter) for OMEGA focusing lenses (f/3) of 92 μm for high energy shots and 96 μm for high power shots. Therefore, the energy and power parameters measured on this test are certainly focusable onto fusion targets. The minimum target diameter presently contemplated for OMEGA is 110 μm.

Output near field beam profiles for a representative high energy and high power shot from this test series are shown in Figures 6 and 7, respectively. The characteristic "worm" pattern of high power lasers due to small scale ripple growth is evident. The degree of ripple growth is indicated by the magnitude of the fluctuations about the radially averaged profile. The present results are considered good. The residual ring structure in the radial averaged profile is due to passage of the beam through the initial hard aperture and subsequent spatial filter pinholes, and is predicted by our Fresnel diffraction code.

The high energy, long pulse shot (Figure 6) exhibits a radially averaged profile with about a factor of three intensity variation from the center to the edge of the beam. To obtain the desired uniform radial profile, the spatial profile of the pulse entering the amplifier chain must be shaped so that when convolved with all the gain profiles of the amplifiers, the pulse emerges from the final amplifier with a uniform spatial profile. This can be quantified by the fill factor, which is a measure of the efficiency of energy extraction from the final amplifier and has a theoretical limit of 1.0. During the DOE test the fill factor was 0.60-0.65. Computer simulations indicate that a more uniform output spatial profile corresponding to a fill factor of 0.80 should be attainable on OMEGA. This would be especially important for long pulses where the energy output is limited by coating damage. Since the peak intensity must be maintained below the coating damage threshold, a more uniform radial beam profile (higher fill factor) will permit higher energy output. Higher peak power output would also result in short pulses. Steps are presently being taken to improve the fill factor on the OMEGA beams.

Another measure of beam quality is provided by temporal characteristics of the pulse. Streak camera measurements were taken before and after the main amplification stages (in Figure 3, at the 1 to 6 beam split, and after the last spatial filter) and show smooth, near Gaussian temporal shapes exhibiting no beam breakup. For high power shots, most susceptible to beam breakup, the pulse widths agree to within 6%, an indication of good temporal beam quality.

Finally, the pulses in this test had exceedingly high contrast (main pulse energy/prepulse energy) due to the fast optically triggered switchout system. The prepulse energy per beam (excluding ASE) was less than the detection threshold of ~ 0.1 μJ. This corresponds to a measured contrast of greater than 7×10^8 up to 1 nsec before the pulse (-20 nsec $< t < -1$ nsec). The contrast in the 1 nsec preceding the pulse is expected to be excellent (see 3.A). The maximum prepulse allowed by DOE specifications was 4 μJ per beam. Laser energy reaching the target at very early times (-100 μsec $< t < -20$ nsec) arises from Amplified Spontaneous Emission (ASE). This was measured to be 2 μJ/beam, well below expected target damage levels, even for cryogenic targets. The total pre-energy (pre-pulse plus ASE) of 48 μJ for all 24 beams was within the DOE requirements of < 100 μJ.

1.C Glass Development Laser (GDL)

During the period December 1, 1979 through February 29, 1980, a total of 374 shots were taken on GDL for a variety of experiments.

1. INTERACTION EXPERIMENTS: 157 shots were taken to support studies of fast ion production, suprathermal electron generation, and Brillouin backscatter and sidescatter.
2. SHORT WAVELENGTH CONVERSION PROGRAM: 137 shots were utilized in frequency doubling and tripling experiments with type II KDP crystals.
3. OMEGA BOOSTER PROGRAM: 74 shots were taken for experiments with a 17 cm diameter double pass active mirror. The beam diameter employed was 15 cm.
4. X-RAY GROUP: 6 shots were taken for crystal spectrometer diagnostic development.

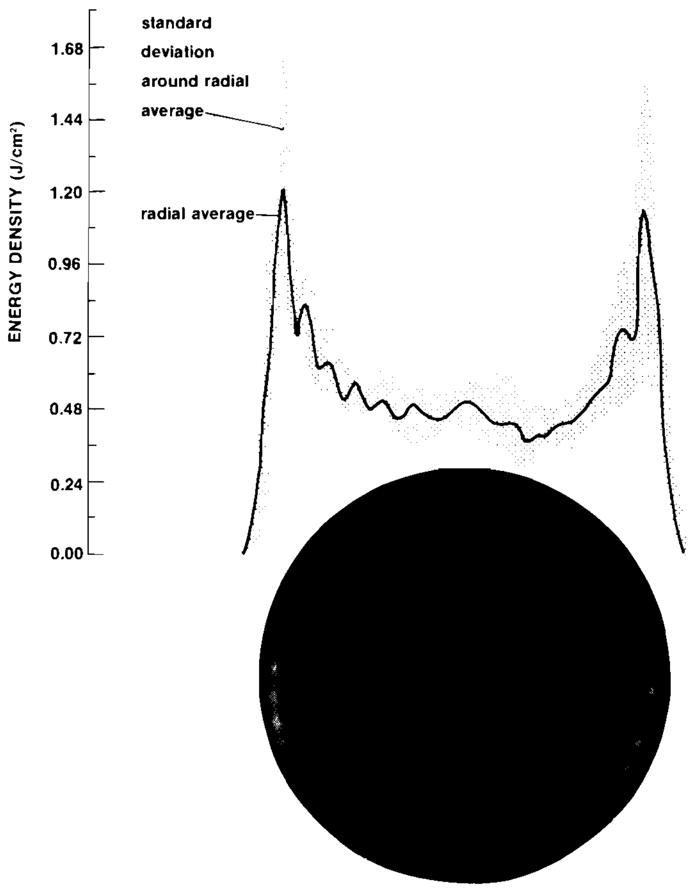

Figure 6 Near field beam profile for high energy, long pulse shot on OMEGA (shot 3606).

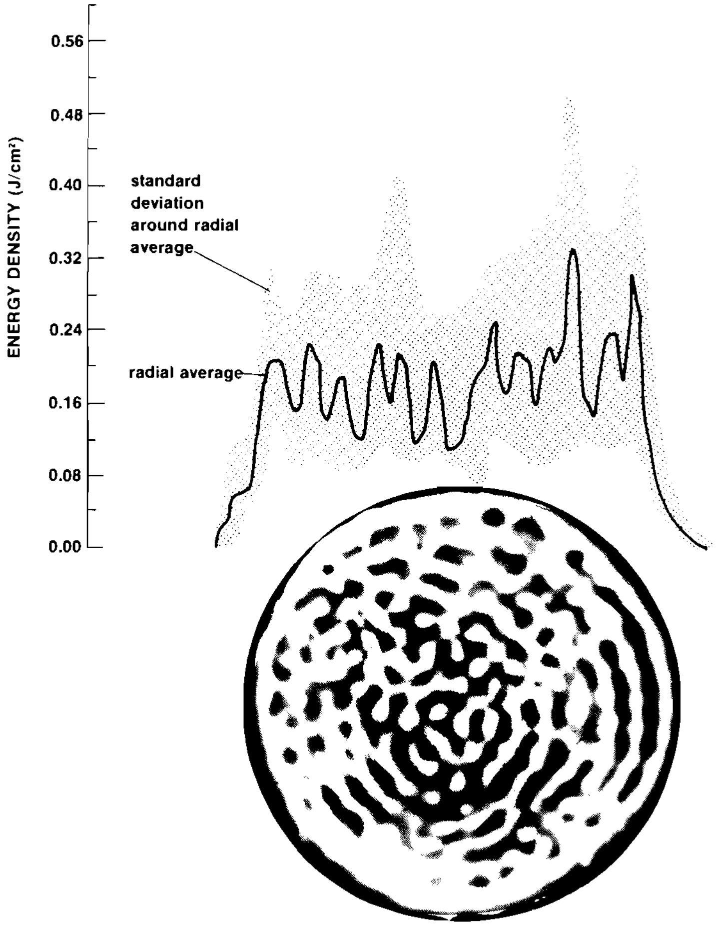

Figure 7 Near field beam profile for high power, short pulse shot on OMEGA (shot 3645).