Section 1
LASER SYSTEM REPORT

1.A GDL Facility Report

The glass development laser (GDL) was shut down for a substantial portion of the fourth quarter of this fiscal year after a series of shots for damage testing, liquid-crystal polarizer evaluation, x-ray studies, and user experiments in early July. This shutdown was planned in order to carry out changes necessary to implement the active mirror booster and to improve the layout for beamline alignment. During this period, operations personnel also upgraded the target area by installing a new focus lens on the target chamber and rerouting the beam paths in order to facilitate alignment. With the implementation of active mirrors on GDL, the system will incorporate for the first time a monolithic OMEGA-style conversion cell and the multi-wavelength energy-sensing system. GDL is scheduled for complete reactivation during the month of October.

A summary of GDL operations this quarter follows:

Interaction Shots	9
NLUF Shots (UCLA/Yale)	34
Damage-Testing Shots	96
Alignment, Test Shots	8
Liquid-Crystal Test Shots	28
TOTAL	175

A summary of GDL operations for FY84 follows:

Interaction Shots	246
X-Ray Shots	147
Damage-Testing Shots	947
Alignment, Test Shots	196
TOTAL	1536

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy Office of Inertial Fusion under contract number DE-AC08-80DP40124 and by the Laser Fusion Feasibility Project at the Laboratory for Laser Energetics which has the following sponsors: Empire State Electric Energy Research Corporation, General Electric Company, New York State Energy Research and Development Authority, Northeast Utilities Service Company, Ontario Hydro, Southern California Edison Company, The Standard Oil Company, and University of Rochester. Such support does not imply endorsement of the content by any of the above parties.

1.B OMEGA Facility Report

OMEGA operations during this quarter consisted of two brief experimental campaigns in July and then a temporary suspension of target experiments in order to complete the conversion of the next six OMEGA beams from the infrared (IR) to the ultraviolet (UV).

In early July, we spent a week converting the focusing geometry of OMEGA from circular to linear, to provide line focus on cylindrical targets with four of the six UV beams. We then carried out a set of target experiments, investigating cylindrical plasmas produced with the line-focused beams. The results were interesting, and we anticipate more of these experiments in the future.

In mid-July the operations group reconverted to circular focus geometry for a brief series of experiments. In the remaining single week, shots were taken to support a user experiment from the University of Hawaii, to conduct some LLE implosion studies, and to carry out additional high-Z plasma-dynamics experiments in collaboration with Los Alamos National Laboratory. A total of 40 shots were taken during the week of 16 July. After this series, the system was shut down for conversion. In the remainder of the quarter we converted the six-beam "A" group of OMEGA's 24 beams to the UV. In August the structures were put in place and the major assemblies installed in the system. In September the conversion optics arrived from the vendors for local testing and installation. Beamline alignment was completed in September, and we began to tune the assembled conversion cells. At present we plan to fire 12 UV beams on target by 22 October.

Other activities during this quarter included the work on the x-ray probe beam project, and the active-mode-locked, Q-switched oscillator project scheduled for late fall implementation in both OMEGA and GDL.

A summary of OMEGA operations this quarter follows:

Target Shots	50
Beamline Test Shots	0
Driver Test Shots	17
Software Test Shots	13
TOTAL	80

A summary of OMEGA operations for FY84 follows:

Target Shots	618
Beamline Test Shots	221
Driver Test Shots	292
Software Test Shots	207
TOTAL	1338

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1.C A New Front-End Design for OMEGA

We have recently completed the design of a new front end for the OMEGA laser system and are now constructing a full-scale prototype. The purpose of this project is to implement fully active mode-locked and Q-switched (AMQ) oscillators[1] in OMEGA and to improve control of the beam profile. The new front end is commonly referred to as the predriver, because it is a subsystem to replace all the present components between the oscillator and the first driver-line amplifier. Three important design requirements for the predriver are high-contrast pulse switchout, pulse amplification, and readily adjustable beam profile.

The optical design is based on both measurements and computations. Over the past five years we have made many measurements of the oscillator output profile and the beamline output profile and energy, and have compared the measurements with optical ray-trace code predictions in order to calibrate the code. Agreement of the measurements and *RAINBOW* code predictions has improved steadily and is now extremely close as shown in Fig. 20.1. As a result, we are confident that we can characterize the AMQ oscillator output experimentally and use these data as input to *RAINBOW* for predriver design evaluation.

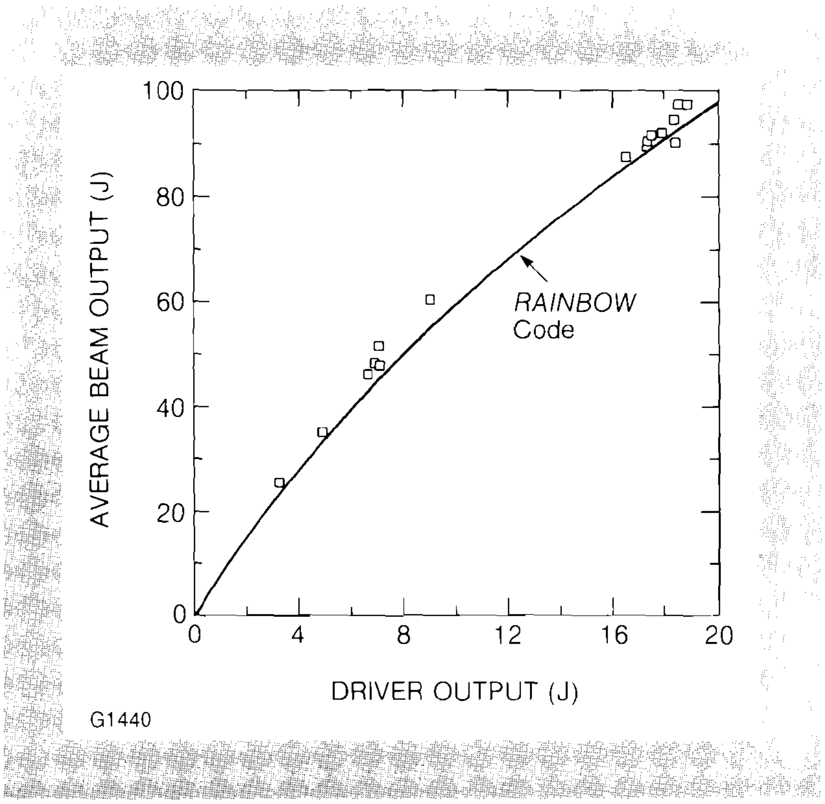

Fig. 20.1
Comparison of the predicted and observed OMEGA beamline output characteristics for 1.0-ns FWHM pulse duration.

The prototype under construction will be used to debug the pre-driver configuration and to identify and eliminate reliability problems. Experience with the prototype will also be helpful in developing new operation and maintenance procedures.

Motivation for New Design

The active/passive mode-locked, Q-switched OMEGA oscillators are reliable, high-energy output devices (1 mJ per pulse at 1 ns). However, it is inconvenient to change the pulse duration of an active/passive oscillator and virtually impossible to synchronize two of them. That is why we decided to convert to fully active oscillators.

Previous AMQ oscillators have been operated successfully with both YAG and YLF as lasing media. The lasing wavelength of YAG, at 1.064 μm, is too far from OMEGA's phosphate-glass wavelength of 1.054 μm, but YLF (1.053 μm) is well matched. Unfortunately, the optical quality of YLF was limited by existing materials technology, so we chose to use Q-100 phosphate glass[2] as the oscillator lasing medium. With Q-100 as the active medium, the oscillator output is optically clean, but the measured single-pulse energy is only 25-50 μJ. This is less than one-tenth the output of active/passive oscillators at 1 ns and requires a compensating gain of 20 - 40.

In the existing driver line, there is no reserve gain. A 1-ns oscillator pulse of 1-mJ energy is amplified to a maximum driver output of 20 J. At this driver output level, OMEGA attains a total 24-beam output of slightly more than 3 kJ. Although that output level is consistent with damage limits on present optical coatings, new damage-resistant coatings are now available. If a few key elements were recoated, then the system could be operated safely at an output of 4 kJ, but only if the driver output could be increased to more than 30 J.

These two factors — lower oscillator output and greater required driver output — establish the predriver gain specification. Including some reserve, the predriver gain should be 30-50.

Increasing emphasis on target illumination uniformity and the installation of frequency-tripling crystals at the beamline outputs make it necessary to control the beams' phase and amplitude distributions very closely. Preferably, control is carried out early in the chain, as near as possible to the oscillator output. With the present front-end configuration shown in Fig. 20.2, this is a tedious process. The adjustable parameters are the focal length and location of the single collimating lens and the diameters of the hard aperture and the pinhole in the air spatial filter (ASF).

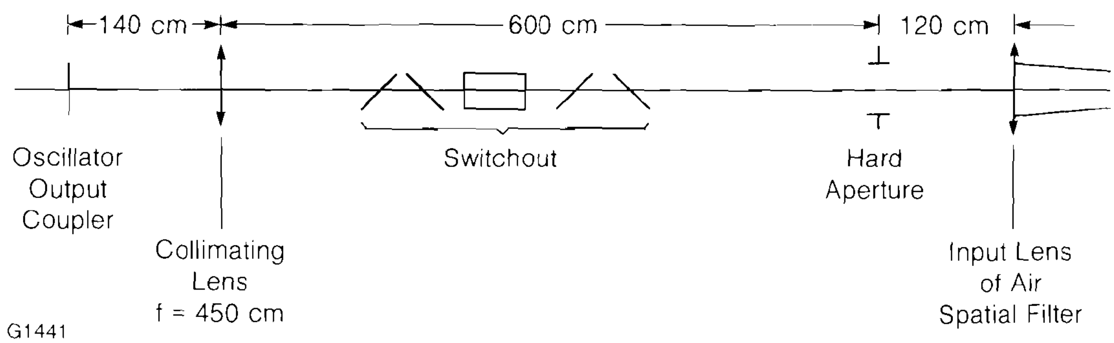

Fig. 20.2
Schematic diagram of the optical arrangement of the present OMEGA front end.

Changes made to the oscillator configuration itself usually require that all four of these parameters be adjusted. The adjustments are interactive, and their effects take some time to confirm quantitatively. One or more driver amplifiers have to be fired to obtain beam photographs, and then the photographs have to be processed and analyzed.

Another requirement for the new predriver, therefore, is that simple and effective adjustments be provided for beam phase, intensity profile, and fill factor.

Contrast between the pulse and baseline noise is excellent in the existing configuration. Three carefully timed Pockels cell/polarizer assemblies are fired by a low-jitter, laser-triggered silicon switch to provide a contrast ratio of $> 10^9$. This contrast should be maintained in the new predriver.

Basic Staging

The basic staging of the new OMEGA predriver is shown in Fig. 20.3. The major changes from the old configuration are the addition of a new preamplifier, the insertion of two new relays, and the addition of a zoom-lens assembly at the output of the ASF.

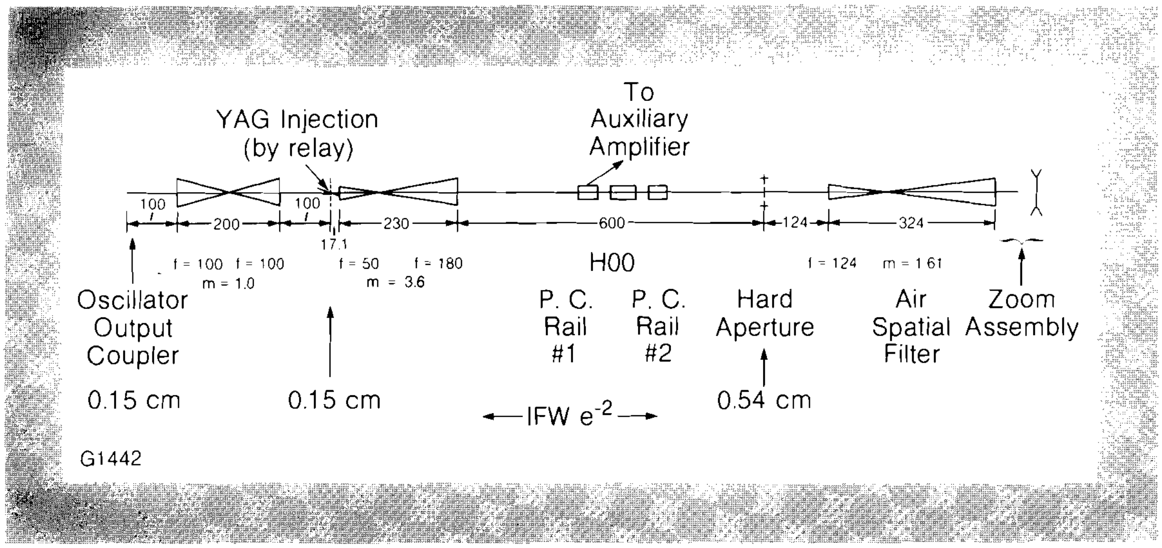

Fig. 20.3
Schematic diagram of the optical arrangement of the new front end for OMEGA.

For the new preamplifier, we chose a 16-mm-diameter head. This head is identical with the first head in the current OMEGA driver line and has a net small-signal gain (center line) of 100. This is three times the additional gain needed at 1 ns. The e^{-2} full-width intensity of the beam in the rod is approximately 4.4 mm; at this diameter, the beam will not be reshaped appreciably by the radial gain variation in the amplifier. Maximum repetition rate of this head is one shot per minute.

The output-coupling mirror of the AMQ oscillator has been fixed as a flat reflector. For oscillator pinholes that are not too small,[3] this assures a Gaussian-beam waist there. This flat phase front is then relayed to the hard aperture plane. We chose to do this with two separate relays, rather than a single relay. This option allows ample space for a mirror pair for oscillator pointing and a kinematic mirror, if desired, for rapid changeover to a second AMQ oscillator. In addition, a real image of the oscillator output coupler is formed at a convenient location for alignment laser injection and near-field diagnostic photography. The image plane of the first relay is located inside the front focal plane of the magnifying relay and the output image of the magnifier is 6 m from the output lens. The switchout is located at this magnified image point. Since the entire region up to the hard aperture is governed by Gaussian-beam propagation, there are no pinholes in either of the first two relays.

Finally, with this relayed system, future oscillators may replace the AMQ oscillators in a straightforward manner. All that is required is that they have flat output mirrors. A minor change in the spot size is accommodated by adjusting the zoom lens; a greater change, by altering the magnification of the second relay. A Gaussian profile is not required at the output coupler, but a flat phase front is desirable.

Control of the Beam Profile

Compensation for the substantial radial-gain variation in OMEGA requires close control of the transverse beam profile. Figure 20.4 is a plot of the calculated small-signal gain relative to the center-line gain of the entire system normalized to the clear aperture of the final amplifier (note that the gain scale is logarithmic). In order to find the input profile that maximizes the fill factor of the final amplifier, it is necessary to use the ray-trace code, *RAINBOW*. *RAINBOW* uses measured radial gains for each amplifier in the chain and radial birefringent losses in a Frantz-Nodvik model to predict OMEGA's output. *RAINBOW* is applied to the relayed portion of the system beginning with the output of the zoom-lens assembly.

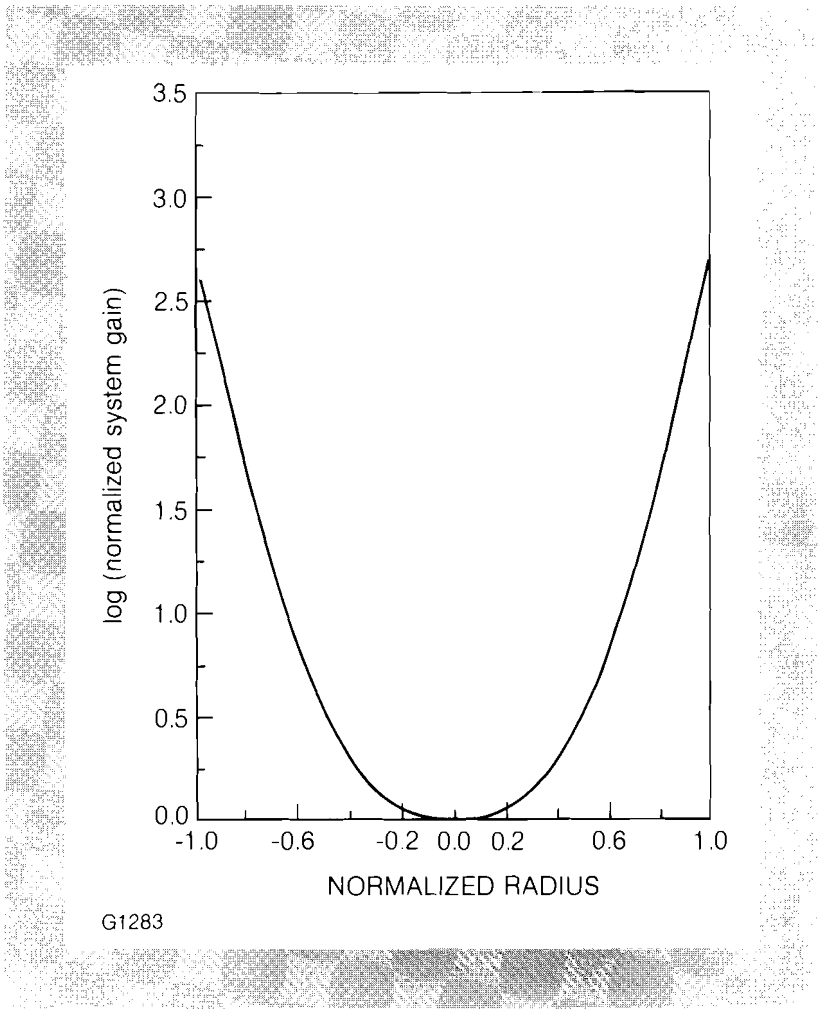

Fig. 20.4
Small-signal gain profile for the entire OMEGA amplifier chain, normalized with respect to centerline gain and clear aperture of the final amplifier.

We know from simulations and from experience that the starting intensity profile is required to have a value of zero at and beyond some finite radius and that it be smoothly convex inside. The shape should be approximately quadratic. A straightforward method for generating such a profile is to clip a Gaussian-profile beam on a hard aperture, propagate the beam through a spatial filter, and clip it again at its diffraction minimum with a second aperture. A simple diffraction code was written to model this process. The output of this code was used to initiate *RAINBOW*.

Three independent parameters are available for beam-profile adjustment. The first is the ratio of Gaussian-beam radius ω_0 to hard-aperture radius A. The second is the cutoff frequency of the ASF, and the last is the zoom-lens magnification. If the ratio ω_0/A is infinite, an

Airy pattern is produced at the ASF pinhole. One finds that the pattern there is still very similar to an Airy pattern for ω_0/A ratios as low as 0.6. This corresponds to clipping the profile at an intensity level equal to 0.004 times the on-axis intensity.

Figure 20.5 shows the change of beam profile in the ASF image plane with ASF pinhole size for infinite ω_0/A. When the radius of the pinhole is equal to the radius of the first Airy zero, the ASF image amplitude profile coincides with curve A of Fig. 20.5. If the radius of the pinhole is extended to equal the radius of the second Airy zero, the image amplitude profile peaks at a nonzero radius and passes through zero closer to the axis (curve B). This happens because the light between the first and second zeros of the Airy pattern is of opposite phase from the light in the central disk and subtracts from the central image amplitude. How much is subtracted depends upon the ASF pinhole diameter. By adjusting the pinhole diameter, the amplitude distribution may be varied continuously between the two profiles drawn in Fig. 20.5.

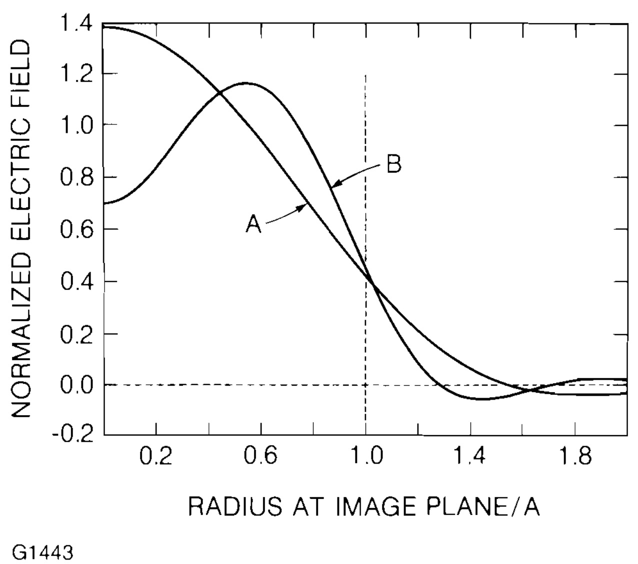

Fig. 20.5
Amplitude of the electric field in the image plane of the air spatial filter:
Curve A: for air-spatial-filter pinhole radius = first Airy zero radius.
Curve B: for air-spatial-filter pinhole radius = second Airy zero radius.

Qualitatively, the result is the same for finite ω_0/A ratios. The principle effect of changing ω_0/A is to change the amount of light in the second Airy ring which slightly alters the range of available amplitude profile shapes.

To avoid propagating the additional rings that appear in the image plane outside the first zero, the rings are clipped by a "scraper" aperture after the ASF. This effectively eliminates the peripheral ring structure from the beam profile. Any rings produced by subsequent spatial filtering have a calculated intensity less than 10^{-5} times the peak intensity.

Modeling the beam propagation has led to a suggested procedure for adjusting the beam profile. First, the ratio ω_0/A is set for an acceptable range of image modulation. Precision is not critical; a ratio of 0.9–1.0 is a reasonable choice. Next, the ASF pinhole size is chosen to produce an appropriate driver input profile. Finally, the zoom-lens magnification and scraper aperture are set. The most difficult case to handle is long-pulse operation because of gain saturation. The predicted output of OMEGA at 1 ns for intermediate drive is shown in Fig. 20.6. For this worst case the system can operate over a range of profiles from nearly flat to reverse quadratic.

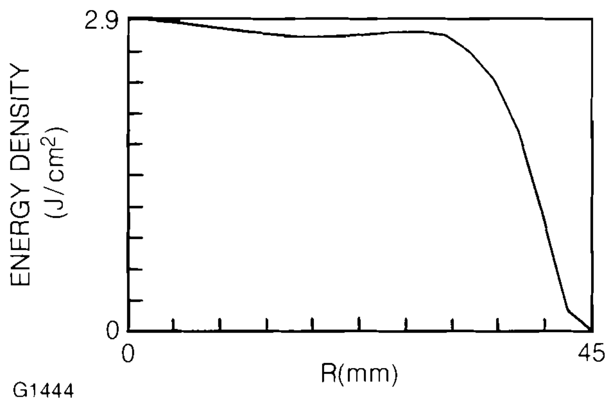

Fig. 20.6
Predicted OMEGA output profile for intermediate drive.

Schedule

When the front-end prototype is completed, measurements of its beam profile will be compared to the profile of the current driver-line input and to the profile expected on the basis of modeling. Energy output and the contrast and transmission of the pulse switchout will also be characterized. Installation on OMEGA is scheduled to begin in December.

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1. G. Albrecht, M. Gruneisen, and D. Smith, Technical Digest of the Conference on Lasers and Electro-Optics (Optical Society of America, Washington, D.C., 1983), Paper TuM10. Submitted to *IEEE J. Quantum Electron.*

2. Product of Kigre, Inc., Toledo, OH.

3. H. P. Kortz and H. Weber, *Appl. Opt.* **20**, 1936 (1981).