Section 1
LASER SYSTEM REPORT

1.A GDL Facility Report

During the third quarter of FY 81, GDL continued operations as a 0.35 μm irradiation facility

A total of 690 shots were delivered by the facility in the April 1 to June 30, 1981 period. The shot distribution was as follows:

3ω target experiments	53 Shots
x-ray program	60
damage test facility	560
alignment	17
	total 690 Shots

The results of the 3ω interaction experiments continued to support previous expectations of improved overall coupling efficiency with 0.35 μm compared to 1 μm radiation. In the last series of experiments ablation pressure, mass ablation rate and preliminary preheat measurements have been conducted. The ablation pressure was found to increase nearly linearly with irradiance and was 70 Mbar at 10^{15} W/cm^2. Preheat as evidenced by Kα x-ray line emission is significantly lower than in 1.05 μm irradiation. Measurements have also been made of the threshold, gain and saturation of the stimulated Raman scattering instability that we discussed elsewhere in this report.

During this quarter a significant amount of work was conducted on the damage testing facility. Promising index matching liquids for 0.35 μm operations were identified and tested successfully. In addition a variety of anti-reflection and high reflectance coatings for 0.35 μm operation were tested. Some of these coatings performed well enough to be considered for use in the planned conversion of OMEGA to an ultraviolet irradiation facility.

1.B Laser Damage Testing of Optical Coatings at 351 nm

As the laser fusion community begins to frequency convert their Nd:glass lasers to shorter wavelengths, the importance of the performance of optical coatings at these wavelengths becomes of great interest. Of particular interest at LLE is the performance of these coatings at the tripled frequency of Nd:glass, 351 nm. The level at which the optical coatings can transport the UV beam will have a major impact on the size, cost and energy on target in any UV upgrade of OMEGA.

Over the last several years a major effort has gone into measuring and attempting to improve the damage thresholds of optical coatings at 1.06 μm[1]. There has been very little done at shorter wavelengths[2,3]. What has been done has shown that damage thresholds are considerably lower than those at 1.06 μm. State-of-the-art coatings for 1.06 μm have damage thresholds for 1 ns pulses of 6 to 10 J/cm^2 for high reflectors (HR) and 4 to 7 J/cm^2 for anti-reflectors (AR).[1] Our measured damage thresholds for 351 nm light in 400 psec pulses have been found to be 0.5 to 2.5 J/cm^2 for HR coatings and 2.5 J/cm^2 for an AR coating.

A diagram of the apparatus used to measure the damage thresholds is shown in Fig. 1. Damage testing is done by irradiating a given sample and characterizing the incident light pulses' energy, spatial intensity distribution and pulse width. These parameters change from shot to shot, so it is imperative that they be accurately determined. After irradiating the sample one must decide which laser pulses actually caused damage.

The LLE UV damage tester uses the output of the Glass Development Laser (GDL) after the 40 mm rod amplifier. Firing through the 40 mm amplifier gives typically an output of 1.6 J of 1.06 μ light and the laser system can be fired every 10 minutes. This output is directed to a set of KDP crystals operated in a similar manner to Seka, et al.[4] to produce 351 nm light. The efficiency of conversion is 60%. The residual 1.06 μm and 0.53 μm light from the tripling process is removed by a dichroic mirror and the 0.35 μm light is then focused down onto the coating sample. A half wave plate and a set of two dielectric polarizers are used to throttle the amount of energy that is delivered onto the sample. This keeps the loading on the KDP crystals the same for all intensities on the sample and as a result, keeps the beam profile and pulse width relatively constant during the tests. The beam is 5 mm in diameter when it strikes the sample.

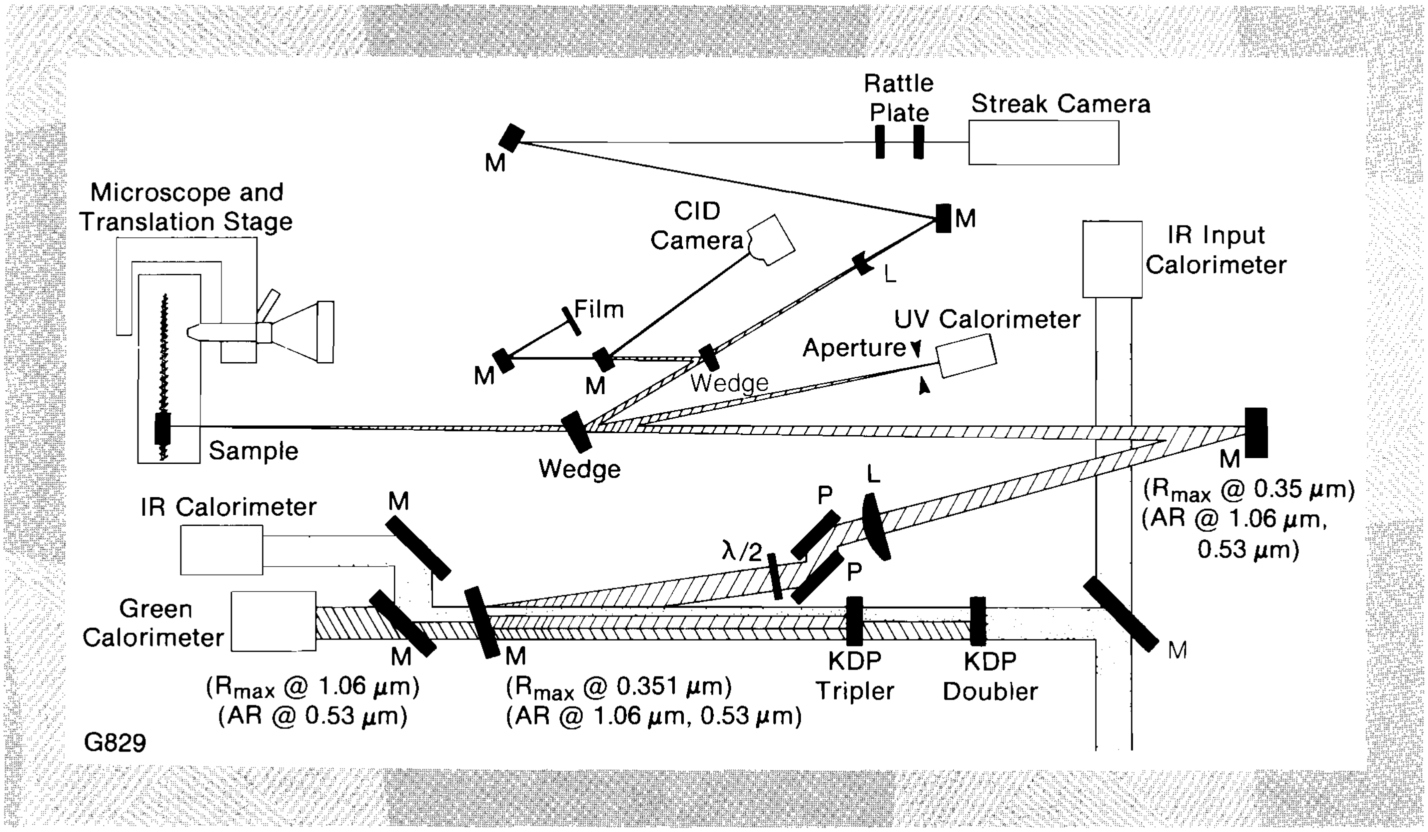

Fig. 1
0.35 μm damage tester.

An uncoated wedge picks off a portion of the beam and directs it to a set of diagnostics to measure the energy, pulse width and intensity profile of the beam for each shot. The intensity profile is recorded both on film and a solid state TV camera. The TV image is recorded in a mini-computer with the aid of a high speed video digitizer. Figure 2 shows a block diagram of data collection system. The maximum energy density is determined from this spatial distribution and the total energy on the sample. This analysis takes approximately 8 minutes. The determination of damage is done by taking photo-micrographs of the portion of the sample that is irradiated, both before and after the shot.

Approximately 30 samples have been tested to date. The average results of these tests are summarized in Figs. 3 and 4. All but those noted of these samples were produced by University of Rochester coating shop. The preliminary results indicate that for 400 psec pulses damage thresholds for dielectric coatings with 351 μm light run from 0.5 to 3 J/cm^2. It is also interesting that AR coatings have a slightly higher threshold than the HR coatings. This is just the opposite of the results found for coatings at 1.06 μm. This probably indicates that we are seeing a bulk coating materials effect rather that usual interface problem.

The highest damage threshold that we have measured has been on AR treatment to BK-10 glass developed by Schott Glass. In this process, known as the "Schroeder Process," the surface of the glass is etched to a quarter wave depth by an acid, leaving the

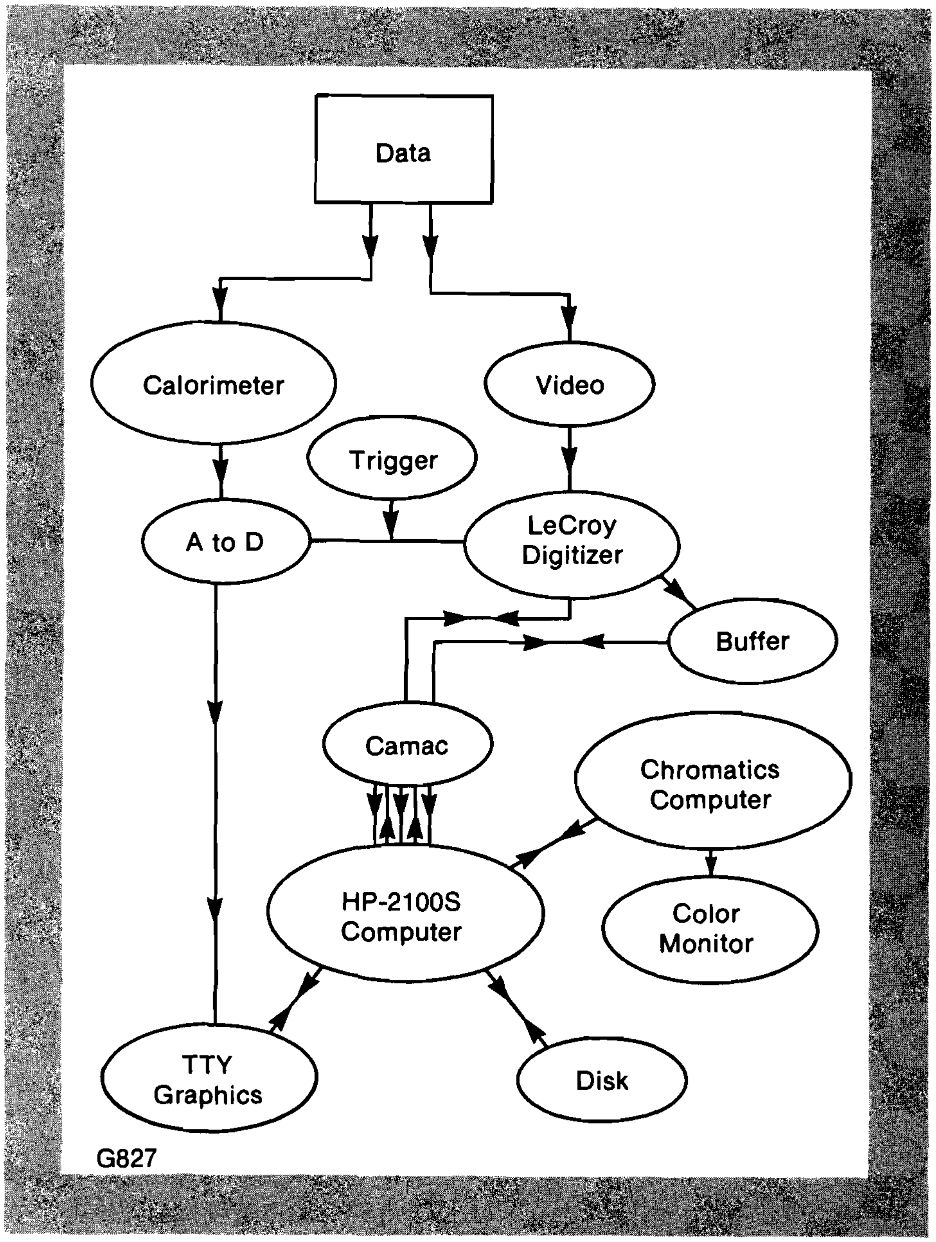

Fig. 2
Image analysis hardware.

surface with a reflectivity less than 0.5%. Previous surface treatments[5] to produce AR properties have not been very durable and could not be cleaned. The Schroeder process is cleanable and appears fairly durable. This, plus a damage threshold of 9 J/cm² makes this coating look very promising for future UV systems.

This initial set of data gives the laser designers a good idea of the state-of-the-art of UV coatings. In the next several months a series of tests on additional coatings will be performed as the coatings engineers begin to vary materials and deposition parameters in an attempt to improve damage thresholds at 351 nm.

Materials	*Threshold (J/cm^2) ±0.2 J/cm^2*
• Y_2O_3 (AR @ 0.35 μm)	2.5 [4 samples]
• Schott Schroeder Process	9.0 [2 samples]

G823

Fig. 3
Damage thresholds of AR coatings.

	Material	*Threshold (J/cm^2) ±0.2 J/cm^2*
•	Ta_2O_5 (HR @ 45°)	1.8 [8 samples]
•	Ta_2O_5 (HR @ 0°, AR for 1.06 μ, 0.53 μ)	1.7 [1 sample]
•	HfO_2* (HR @ 0°)	0.75 [1 sample]
•	ZrO_2*	1.8 [1 sample]
•	Ta_2O_5* (HR @ 0°)	1.7 [1 sample]

*supplied by D. Milam, LLNL
G824

Fig. 4
Damage thresholds of HR coatings.

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2. T. F. Douton and W. L. Smith, *1979 Symposium on Materials for High Power Lasers, NBS Special Publication* **568** (1979).
3. B. E. Newman and D. H. Gill, *1978 Symposium on Materials for High Power Lasers, NBS Special Publication* **541** (1978).
4. W. Seka, S. D. Jacobs, J. E. Rizzo, R. Boni, and S. Craxton, *Opt. Comm.* **34,** 469 (1980).
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1.C Beam Uniformity Measurements on the OMEGA Laser

The OMEGA laser facility utilizes 24 beams to uniformly illuminate a spherical target. To achieve uniform compression theoretical predictions indicate that the uniformity of the intensity in each beam must be within 5-10%.[1] Measurements have been made of the intensity distribution, phase profile and far field intensity distribution of a single beam of the laser system. We have used a computer code (Beamprop) to simulate the intensity patterns on target using the amplitude and phase measurements on the beam at the input to the OMEGA focus lens. Using this code, we have investigated the effects of spherical aberration upon the intensity at the target plane.

Measurements of the OMEGA beam have been made at long pulse (600 psec) and short pulse (100 psec). Beam diagnostic packages were modified to take pictures of the phase profile of the beam and the equivalent target plane intensity both at the end of the laser and at the plane of the OMEGA focus lens, a propagation distance of approximately 20 meters.[2] These data support the initial conclusion[1] that this propagation distance does not affect the laser intensity on target.

The phase profile was measured using a double frequency lateral shear interferometer. Figure 5 shows two orthogonal shear photos of a single shot. Fringes which show departure from a straight line indicate aberration, and these shear patterns show the laser beam phase departs from a perfect plane wave front. The wave front aberrations are not rotationally symmetric, but a single average between the horizontal and the vertical cross sections indicate that there is need for spherical correction of the wave front. The shear pattern photographs were evaluated by measuring the fringe locations on a diagonal along the shear direction. These positions and their corresponding order numbers

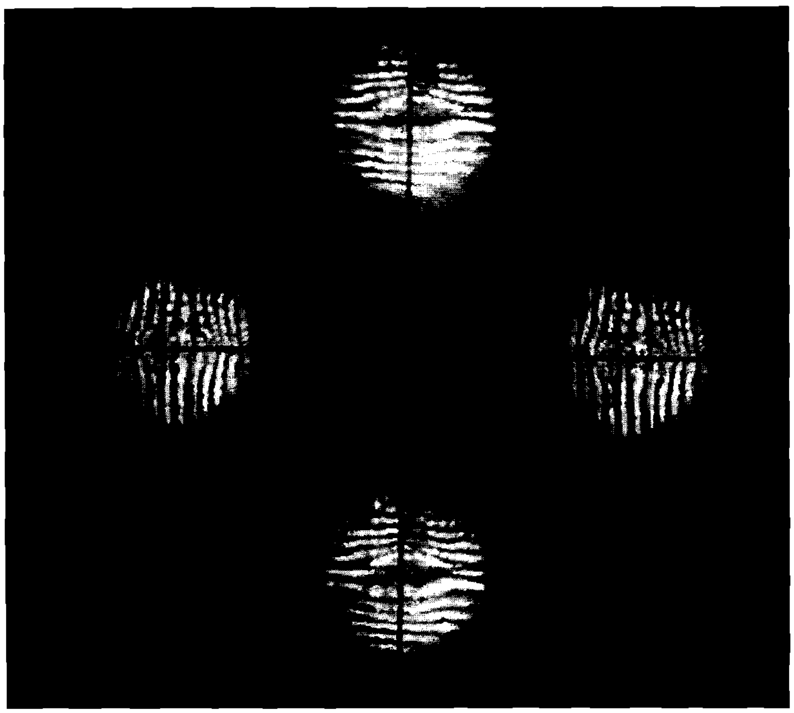

Fig. 5
Shot #5594 (beam power 340 GW, 100 psec pulse.)

were then inserted into a program that computed the wave front aberration polynomial assuming the data represented a rotationally symmetrical wave front. The same procedure was then repeated for the orthogonal shear. In this way, two cross sections of the wave front were found. Table 1 lists some of the resulting computed wave fronts for 100 psec pulses.

SHOT #	POWER	HORIZONTAL SCAN				VERTICAL SCAN			
		OPD2	OPD4	OPD6	OPD8	OPD2	OPD4	OPD6	OPD8
5596	316 GW	-3.37	-24.71	26.32	-9.21	-8.41	-8.46	5.56	-0.115
5595	240 GW	-8.06	-8.21	2.98	1.75	-6.19	-29.84	47.20	-22.80
5593	347 GW	-3.25	-31.26	44.70	-22.80	-4.65	-13.90	3.85	5.530
5591	260 GW	-7.72	-11.11	10.86	-3.80	-9.376	-4.91	-4.32	7.020

Table 1
The wave front coefficients as measured from the shearing photographs and fitted to an even eighth order polynomial.

Near field data was obtained by propagating the beam undisturbed onto a piece of film. These measurements were also made at the end of the laser and in the target bay to show any effects due to long path propagation. A typical photo is shown in Fig. 6.

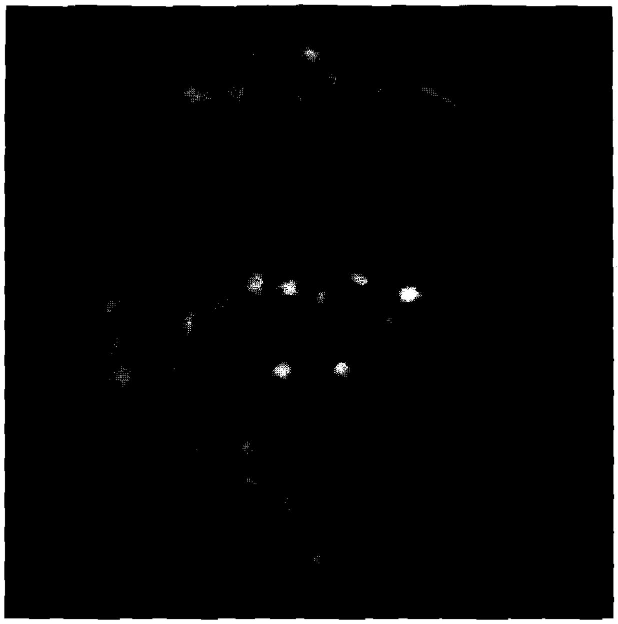

Fig. 6
"Near field" photograph of laser beam at input to OMEGA focus lens (short pulse): shot #5596.

The far field image photographs were measured on a microdensitometer and the data was processed in an image analysis program. Figure 7 shows a radially averaged plot of intensity from a 100 psec pulse at 1400 μm from best focus of the OMEGA lens. This 1400 μm corresponds to a focus shift of six target radii from best focus for a 400 μm diameter target. This focal shift has been predicted to give optimum uniformity on target.[1] Additional analysis of these photographic data is ongoing.

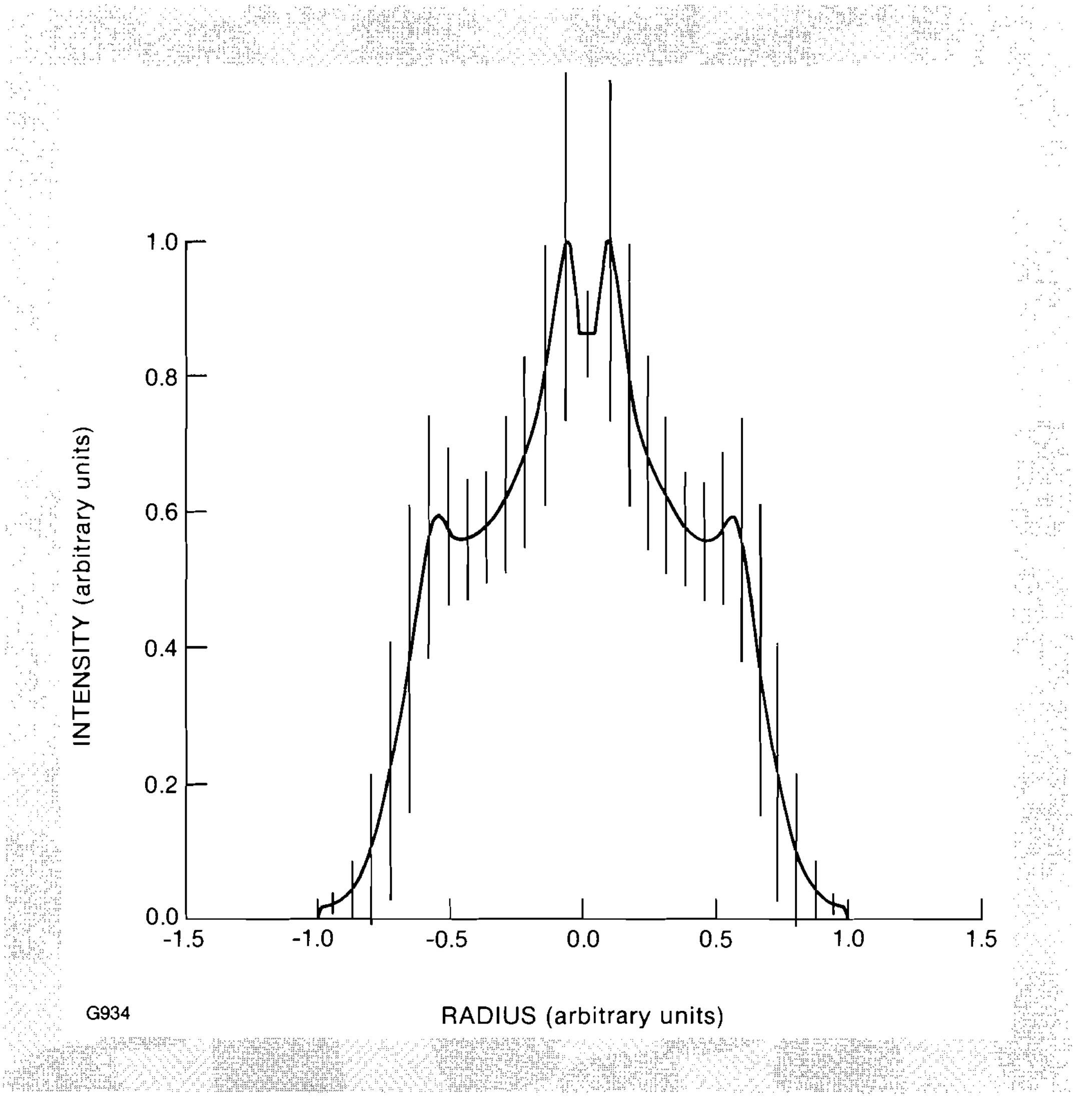

Fig. 7
Beam intensity 1400 μ from best focus (radial average): shot #5596.

Beamprop is a Fast Fourier Transform diffraction code for the propagation of wave fronts through a homogeneous medium. With this program, it is possible to start with a spherical wave front and propagate it through a lens to an out of focus image plane which corresponds to the surface tangent to the target. It provides the intensity distribution of the image in that plane.

The program will accept phase profiles of an eighth order polynomial of spherical aberration assuming radial symmetry. Using this program the measured values of beam phase aberration can be inserted to compute the intensity distributions in the out of focus image plane. Figure 8 shows the distribution of intensity across the aperture of the focusing lens that was used to calculate the following far field intensity patterns. The focus lens was run at f/3.5 with a 60 cm focal length. Figure 9 is a plot of the far field pattern simulation 1400 μm from best focus when the wave front has zero aberration. Figure 10 shows the computed intensity distribution with phase aberration. The coefficients of the spherical aberration polynomial are shown on the figure. The

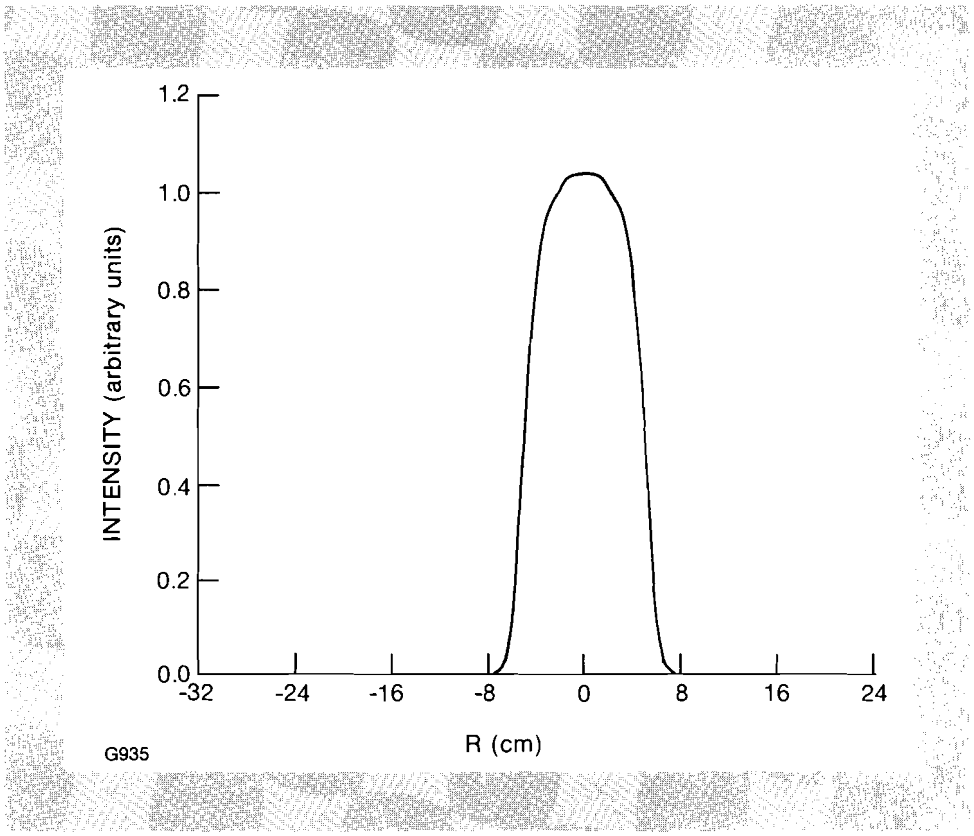

Fig. 8
Beam intensity distribution into OMEGA f/3.4 lens (simulation).

intensity is peaked in the center in a fashion comparable to the real data of Fig. 8.

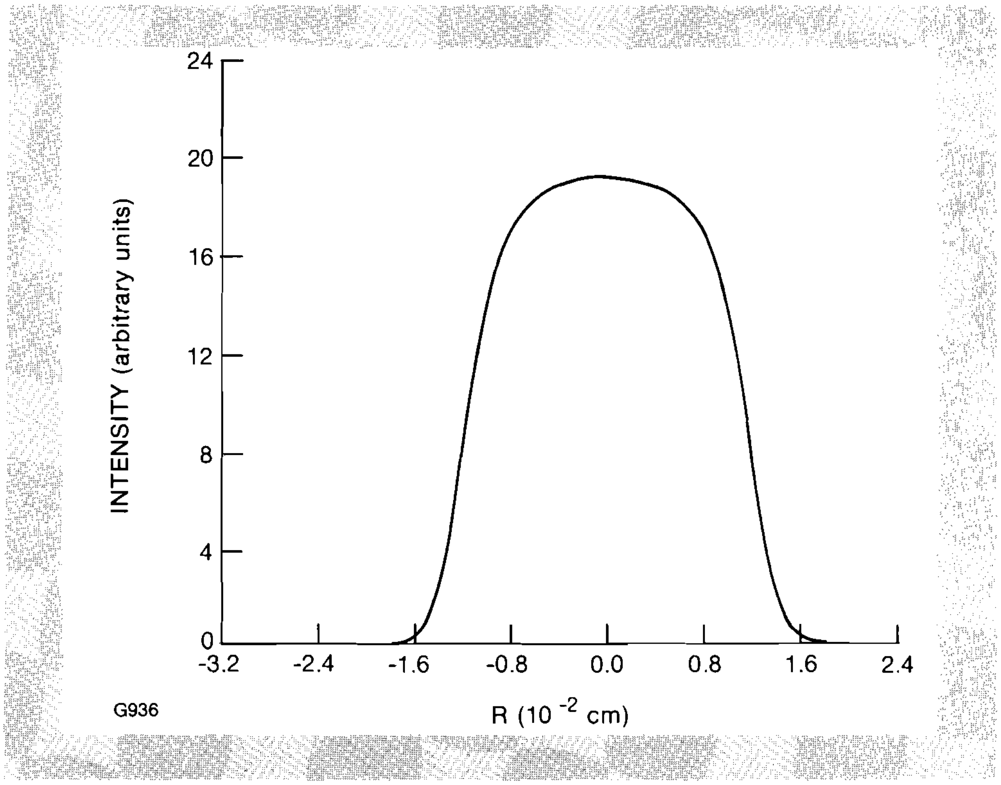

Fig. 9
Intensity pattern 1400 μ from best focus, no beam aberrations (simulation).

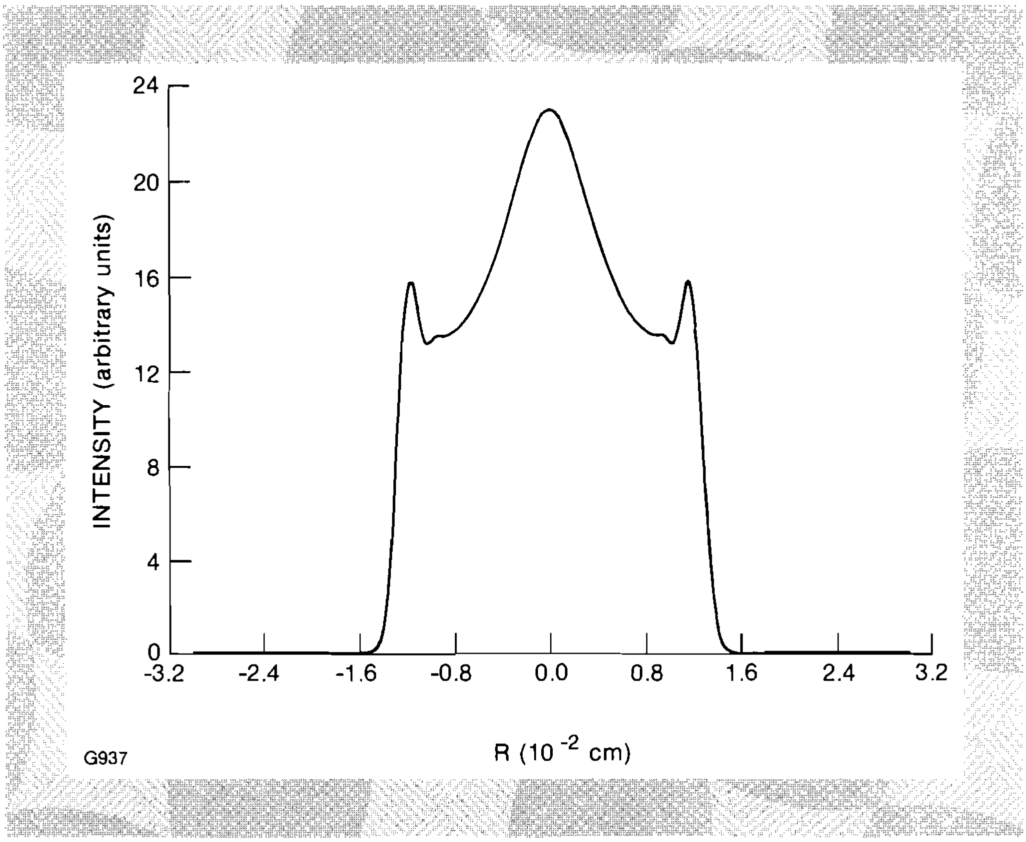

Fig. 10
Beam intensity 1400 μ from best focus (simulation). Beam aberrations:
− 13.6 waves third order
+ 28.3 waves fifth order
− 15.0 waves seventh order
+ 1.3 waves focus

Two runs have been made using Beamprop to show the effects of pure positive and negative third order spherical aberration. These were run in order to illustrate a possible method of significantly modifying the intensity profile on target by the use of phase correction plates. The results are shown in Figs. 11 and 12. Positive third order optical path difference (OPD) (a leading wave front at the edge of the aperture) causes an inverse quadratic type of intensity distribution, as seen in Fig. 11, and negative OPD (a lagging wave front at the edge of the aperture) causes spreading of the image at the edge and a concentration in the center of the image, as seen in Fig. 12.

The performance of OMEGA at longer pulse length (~ 1 nsec) will be measured in the future. The correction of system phase aberration with fixed corrector plates or deformable mirrors will be evaluated. In addition, off line component testing will be utilized to understand the source of the phase aberrations.

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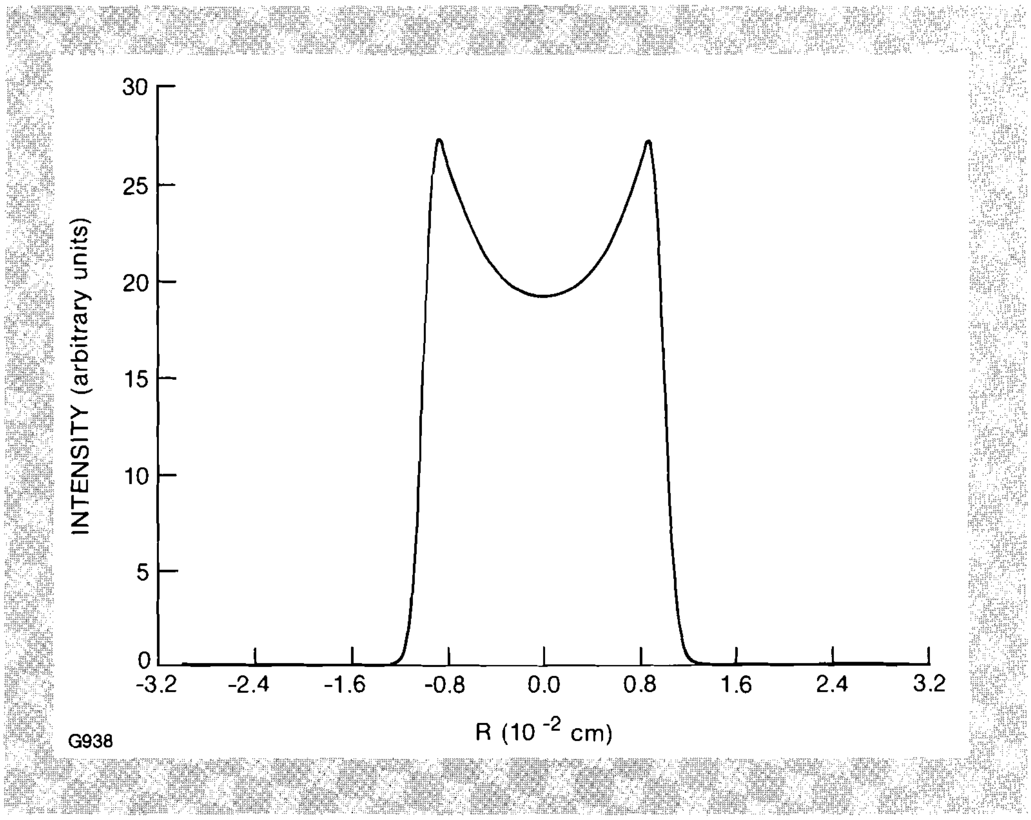

Fig. 11
Intensity pattern 1400 μ from best focus (simulation). Beam aberrations:
+ 3 waves third order

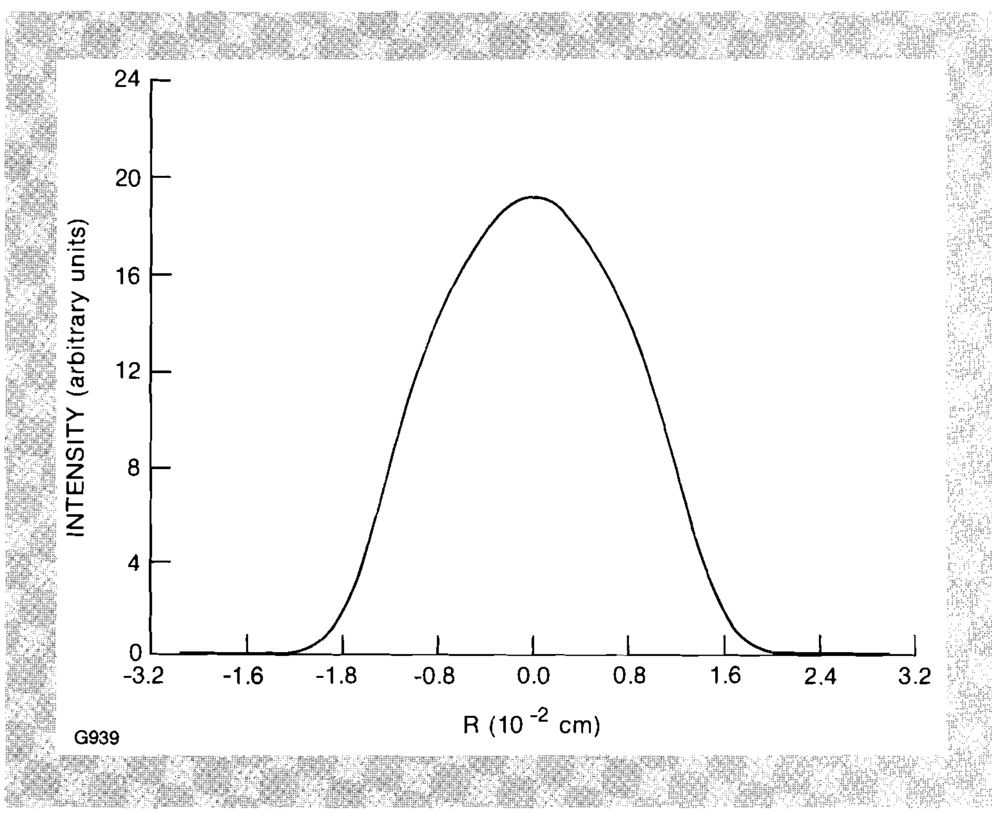

Fig. 12
Intensity pattern 1400 μ from best focus (simulation). Beam aberrations:
– 3 waves third order.