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Report No. 12486

Technical Appendices

Laser Fusion Systems Design Study

Final Technical Report

UNIVERSITY OF CALIFORNIA
Lawrence Livermore Laboratory

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Laser Fusion Systems Design Study

Final Technical Report

JUNE 1975

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TABLE OF CONTENTS

<u>Appendices</u>	<u>Title</u>	<u>Page</u>
A	ASSUMED SHIVA CONFIGURATION AS PROVIDED BY LLL	A-1
B	MEASUREMENT OF TYPICAL VIBRATION EFFECTS AT AN INDUSTRIAL FACILITY	B-i
C	FOCUS LENS MOUNT DESIGN CONSIDERATION	C-i
D	AMPEREX DATA ON SILICON TARGET VIDYCONS (SILICON)	D-1
E	DETERMINATION OF SHIVA SYSTEM DIMENSIONS AND GEOMETRIC RELATIONSHIPS PERTINENT TO ALIGNMENT SYSTEM CONSIDERATIONS	E-1
F	CONSIDERATIONS OF SHIVA FOCUSING LENS DESIGNS	F-1
G	MANUFACTURER'S DATA	G-1
H	TRANSMITTANCE CALCULATIONS	H-1
I	OPTICAL PATH DIFFERENCE SENSING	I-1

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Report No. 12486

APPENDIX A

ASSUMED SHIVA CONFIGURATION AS PROVIDED BY LLL

10 K JOULE LASER

"BUSINESS-END" OF SHIVA LASER SYSTEM

CENTRAL PORTION OF SHIVA LASER SYSTEM (one chain only)

"FRONT-END" OF SHIVA LASER SYSTEM

A-5

AAA74-115186-000

⊕

6 DIAMS ON VERTICAL PLANE
PARALLEL TO Z AXIS

AAAT4-115175-00 ©

A-7

8 BEAMS ON 2 INTERSECTING PLANES
STRADDLING Z AXIS

AAA74-115176-00 ©

⊕

6 BEAMS ON VERTICAL PLANE
NORMAL TO Z AXIS

AAA74-115177-00 ©

OFFICIAL USE
JAN 19 1960

SHIVA PRELIMINARY FLOOR PLAN

ELEV. LOOKING TOWARD TARGET

OFFICIAL USE
AAA74-115185-00 ①

40 NINETY-NINETY MIRRORS (15" DIA)
 53 1/4" = 1" 11-19-74

A-13

STAGING FOR MIN. DIVERGENCE ANGLE

AL172-115101-00 00

OFFICIAL

APPENDIX B

MEASUREMENT OF TYPICAL VIBRATIONAL EFFECTS
AT AN INDUSTRIAL FACILITY

1.0 INTRODUCTION

A series of tests to determine the vibration and tilt motions present in the ground at a site in Danbury, Ct., was conducted. The nature and the level of cultural activity at this site is considered to be roughly comparable to Lawrence Livermore Laboratory. The site terrain, a shallow hillside, is less flat than the HELF site. A simple map of the site is shown in Figure 1.

The tests were conducted in the field at a point where a test chamber was to be located within the building.

2.0 PROCEDURE

The vibration data was obtained from Hall-Sears HS-10-1 geophones. The signals from the geophones were conditioned in wide band d.c. amplifiers to levels suitable for recording on magnetic tape. Tape loops were formed and the data recorded at 1-7/8 inches/second. At playback, the tape speed was increased to 60 inches/second, thereby effectively increasing all recorded frequencies by a factor of 32. This technique allowed the frequency spectrum analyzer to analyze frequencies well below its intended minimum. The B&K analyzer which performs this function automatically plots velocity as a function of frequency on a strip chart recorder synchronized with its swept band filter. The data thus obtained is representative of the vibrations present from 0.625 Hz to 625 Hz. Since we are primarily interested in frequencies below 100 Hz, all the data presented here is plotted from 0.625 Hz to 100 Hz.

Figure 1

The tilt data was obtained from two Geonetics Corporation Tiltmeters. The G. C. meter is a capacitance transducer which monitors the movement of the air bubble in a sensitive level vial. This motion is amplified and directly recorded on a strip chart recorder to obtain the degree of tilt encountered. The maximum tilt range obtainable in any plane is ± 15 seconds so the instrument must be reset if "large" tilt excursions occur.

The measurements were made in the following modes:

Vibration - Vertical

- Horizontal; North-South
- Horizontal; East-West

- Tilt
- North-South
 - East-West

The tests were conducted with the intention not only of determining the inherent properties of the ground at the site but also to study the effects of both vehicular and air traffic if possible. An additional test was performed to try to correlate the effect of a water pumping station in the area.

Tapes were run under "noisy" conditions and "quiet" conditions. The "noisy" tests include data recorded with the construction equipment moving and with it idling, with a truck moving North on the adjacent highway, Route 7, and with a large commercial aircraft in the southern sky. The "quiet" tests were run at lunch time and in the evening. The only known disturbances were due to normal vehicular traffic patterns, the water pumps at the pumping station and a portable diesel electric generator.

The tilt data was continuously recorded over a five day period along both North-South and East-West axes. Data is plotted as deviation from reference at initial recording time and does not indicate absolute values.

3.0 RESULTS

Table I is a table of the conditions for which the results are tabulated and plotted in the test results section at the end of this report.

TABLE I

<u>TAPE NO.</u>	<u>CHANNEL NO.</u>	<u>MODE</u>	<u>TIME</u>	<u>CONDITIONS</u>
5	2	Vertical	1715	Portable Generator Off
"	3	Horizontal N-S	1715	All Construction Equipment Off
"	4	Horizontal E-W	1715	No Wind, No Aircraft Normal Car Traffic
6	1	Vertical	0950	Construction Equipment Idling
"	2	Horizontal N-S	0950	
"	3	Horizontal E-W	0950	
"	4	Vertical	1000	Construction Equipment On
"	5	Horizontal N-S	1000	
"	6	Horizontal E-W	1000	
7	1	Vertical	1210	All Construction Equipment Off
"	2	Horizontal N-S	1210	
"	3	Horizontal E-W	1210	Normal Car Traffic
8	1	Vertical	1820	All Construction Equipment Off
"	2	Horizontal N-S	1820	Portable Generator On
"	3	Horizontal E-W	1820	Truck going North on Rt. 7
"	4	Vertical	1824	Large Aircraft Overhead in
"	5	Horizontal N-S	1824	Southern Sky
9	1	Vertical	1835	All Construction Equipment Off
"	2	Horizontal N-S	1835	No Aircraft
"	3	Horizontal E-W	1835	Portable Generator On
9	4	Vertical	1850	Instrumentation Noise
"	5	Horizontal N-S	1850	Level Test
"	6	Horizontal E-W	1850	

4.0 DISCUSSION

The data obtained from the B&K analyzer is transferred to a vibration nomograph to provide a three axis plot of velocity, acceleration, and double amplitude displacement as a function of frequency.

For plots representing "quiet" conditions when local cultural activity is at a minimum, the horizontal modes indicate accelerations approximately one order of magnitude greater than the vertical mode. Both 30 Hz and 60 Hz predominate with 30 Hz appearing as the fundamental and 60 Hz as the 2nd. harmonic. The double amplitude displacements at these frequencies, however, are quite low with the worst cases below 5×10^{-7} inches.

Attempts to record effects of small private aircraft in the area were unsuccessful in that no discernible signals could be recorded both when aircraft were under power and in glide path. The portable generator was turned OFF and ON alternately to determine its effect. No appreciable effect was noticeable.

The duty cycle of the water pumps at the pumping station was timed and data recorded as a function of time in an effort to locate the sources of the 30 and 60 Hz peaks. The tape was analyzed at 60 Hz and did not clearly identify the pump duty cycle.

For plots representing "noisy" conditions, the horizontal modes again indicated greater accelerations than the vertical mode. The 30 Hz fundamental becomes stronger than the 2nd. harmonic and side frequencies around 30 Hz were enhanced when the bulldozers were idling. With the shovel and trucks moving or idling both 30 Hz and 60 Hz are enhanced. The worst case double amplitude displacement is still less than 5×10^{-6} inches. The

movement of a truck going North on the adjacent highway, in an otherwise quiet environment, raised the vertical double amplitude displacement at 30 Hz slightly ($.15 \times 10^{-6}$ in.). The horizontal modes also were slightly affected. The large commercial aircraft in the southern sky increased the horizontal N-S recordings slightly with the double amplitude displacements remaining below 5×10^{-7} inches.

5.0 CONCLUSIONS

The results of the data discussed indicate a generally quiet environment at the site. Even though heavy vehicular and aircraft traffic were discernible with the instrumentation, the effects were negligible in terms of vibration disturbance upon the site. The movement and idling of heavy construction equipment show appreciable effect but again the displacements remained below 10^{-5} inches. The fact that 30 and 60 Hz appear as the predominant resonant modes is somewhat unusual and indicates a very hard strata beneath the site. It was expected from the time of the original measurements that the fundamental resonance present in the building upon completion of construction and the new loads and disturbances of the completed facility will interact with the site to produce new spectra which will remain moderate.

Measurements were made recently (November 1974) on the concrete slab floor in the completed and operating facility. Velocity in the vertical direction was recorded at a representative location and a spectral plot of it is reproduced in Figure 4 at the back of the data package. Both of the contentions of the previous paragraph, that the spectra would be changed and that they would remain moderate, appear to have been proven. The strong 30 Hz component appears still to be present and to dominate, though now shifted downward slightly to

29 Hz. The 60 Hz component has been markedly attenuated. New frequencies are present. The two largest components are a new component at 18 Hz and the component at 29 Hz. Only these two components exceed 10^{-6} inches/second.

The tilt data obtained demonstrated a relatively low tilt along N-S axis (approximately 12 arc seconds). The E-W axis showed a tilt of approximately 12 arc seconds). The E-W axis showed a tilt of approximately 36 arc seconds. Considering the excavation in process along with the earth stockpiling in the West part of the site, the tilts encountered are small. Further, the tilts as measured have a base length of approximately one foot. The effective bases representative of HELF may be one to two orders longer (10-100 ft.) and may afford significant averaging of tilt forces.

6.0 IMPLICATIONS TO HELF

Parallels can be drawn between P-E experiences in alignment and testing of large optical systems and the situations to be anticipated at HELF. In general, it can be said for sites and buildings of the subject sorts, that alignment, functional testing and image forming tests can be performed without serious concern about vibration, seismic and acoustic disturbances beyond concerns which fall under "good practice". The category of testing in which these disturbances do intrude however is high finesse interferometry. Much of P-E's optical testing makes use of multiple pass interferometry to produce interference lines sufficiently fine to allow automatic scanning, centroid determination, and mapping of the element surface or wave surface. It is in this area of testing that extreme isolation is required. It is our opinion that the conditions for successful operation of HELF fall in the alignment and image testing range and not in the high finesse interferometry range.

Some elements of good practice deserve comment. In the testing referred to, it is frequently necessary that it be performed through a vacuum chamber interface. In the case of interferometry, the test article and the interferometer always are hard mounted to a common structure and that common structure is almost always isolated from disturbance sources by an interposed low pass filter. Mass in conjunction with pneumatic isolators is the common configuration. If chamber penetration is required, steel bellows are employed.

For the more common non-interferometric case, carefully squared-up, good fitting hard mounting with high tension in the hold-down fastening is the rule. Careful grouting at mounting feet has been observed to produce discernible differences. Structures free of resonance problems are assumed.

It seems reasonable also to expect that seismic spectra measured on a Connecticut hillside and seismic spectra measured in a California valley would differ in characteristic ways due principally to the relative hardness and proximity to the surface of the crust in Connecticut and to the relatively thicker sand and soil coverage in the California valley site. In spectral terms we would expect to see more high frequency content in the Connecticut seismic spectra and a potential for more large amplitude aperiodic activity at the California site.

FLOOR VERT BENEATH FLAT MIRROR SUPPORT

Figure 4. Velocity Spectrum Measured on Floor of Completed Facility

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Report No. 12486

APPENDIX C

FOCUS LENS MOUNT DESIGN CONSIDERATION

The design considerations for the focus lens mount as set forth by the system requirements are as follows:

- Remote command (stepper motor) and manual control
- 260-mm-diameter clear aperture
- Range of ± 2.0 mm from reference location
- Resolution of smallest step that can be defined $\pm 1.0 \mu\text{m}$
- Position readout
- Lateral translation and tilt of less than $1 \mu\text{m}$ and 2 urad, respectively, over full range
- Linearity error of less than $2 \mu\text{m}$ over full range
- Pressure stability of $\pm 10 \mu\text{m}$ per atmosphere (0 psig to 15 psig)
- Laboratory operating environment, temperature controlled to 20°C $\pm 10^\circ\text{C}$, and minimal vibration disturbances
- All vacuum-exposed parts stainless steel
- Maintain vacuum seal
- Non-distorting uniform edge support of lens
- Non-metallic parts vacuum compatible and not exposed to direct view of target
- Single lens mount (pressure bearing) and blast shield
- Operation in any orientation of gravity
- Use of standard off-the-shelf components
- Simple straightforward low-cost design

With the foregoing considerations in mind, the configuration as shown in Figure C-1 was developed. The focusing lens mount consists of three major subassemblies: the translation assembly, the outer housing assembly, and the drive assembly.

The translation assembly, which contains the focus lens and blast shield optics, also includes a stainless steel flexible bellows which provides the high vacuum seal between the fixed outer housing tube structure (item 1) and the inner translating tube (item 10). The translating tube is constrained radially by low-friction Teflon sleeve bearings (items 4 and 17) and located axially by the flexible bellows (item 13) and the three equally spaced leadscrews (item 18). The focus lens zero reference position is preset by allowing the atmospheric pressure acting on the bellows to partially and always maintain a positive preload on the translating tube which reacts at three points via the leadscrews on the cylindrical pads (item 16). Focus motion is remotely accomplished via three 1.8° step dc motors synchronized together, each of which drives a 4/1 geared 40 pitch leadscrew. The focus position is measured via a 10-turn conductive plastic, infinite resolution potentiometer geared 4/1 to the rear end of each motor drive shaft. This low-cost geared potentiometer arrangement provides a resolution capability of $0.8 \mu\text{m}/\text{step}$ at the focus. Also mounted off the rear end of each motor shaft is a hand wheel (item 27) which is used for manual positioning of the focusing lens.

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DRIVE MECHANISM
FOR SPECTROMETER

SYMBOL		
NO.	DESCRIPTION	UNIT
1	STANDARD	STANDARD

NO.	DESCRIPTION	UNIT
1	STANDARD	STANDARD
2	STANDARD	STANDARD
3	STANDARD	STANDARD
4	STANDARD	STANDARD
5	STANDARD	STANDARD
6	STANDARD	STANDARD
7	STANDARD	STANDARD
8	STANDARD	STANDARD
9	STANDARD	STANDARD
10	STANDARD	STANDARD
11	STANDARD	STANDARD
12	STANDARD	STANDARD
13	STANDARD	STANDARD
14	STANDARD	STANDARD
15	STANDARD	STANDARD
16	STANDARD	STANDARD
17	STANDARD	STANDARD
18	STANDARD	STANDARD
19	STANDARD	STANDARD
20	STANDARD	STANDARD

NO.	DESCRIPTION	UNIT
1	STANDARD	STANDARD
2	STANDARD	STANDARD
3	STANDARD	STANDARD
4	STANDARD	STANDARD
5	STANDARD	STANDARD
6	STANDARD	STANDARD
7	STANDARD	STANDARD
8	STANDARD	STANDARD
9	STANDARD	STANDARD
10	STANDARD	STANDARD
11	STANDARD	STANDARD
12	STANDARD	STANDARD
13	STANDARD	STANDARD
14	STANDARD	STANDARD
15	STANDARD	STANDARD
16	STANDARD	STANDARD
17	STANDARD	STANDARD
18	STANDARD	STANDARD
19	STANDARD	STANDARD
20	STANDARD	STANDARD

Figure C-1. Focus Lens Mount

APPENDIX D

AMPEREX DATA ON SILICON TARGET VIDICONS (SILICON)

INTER-COMPANY COMMUNICATION

PERKIN-ELMER

Date: December 30, 1974

cc: W. Zukowsky
N. Schnog

To: P. Yoder

From: E. Schlesinger

Subj: AMPEREX DATA ON SILICON TARGET VIDICONS (SILICON)

Attached are zerox copies of data recently received from Dr. Ralph S. Levitt. This includes a data package for the type S1200 family and two pages of data for the S1100 type. The S1200 family is standard and features a thinner target to obtain lower spread and therefore better resolution at the expense of reduced response at longer wavelength. In contrast with this type which is in demand, is the thicker target type S1100 available at present only on special order. Figure L1 presents data on the tradeoff between resolution and sensitivity as a function of target thickness and table 1 shows the fall off in silicon absorption coefficient (with wavelength) which accounts for the nearly proportional relationship between target thickness and 1.06μ sensitivity depicted in figure L1. Representative measured results showing sensitivity versus wavelength for tubes with 9.3μ and 18.8μ thick targets is shown in figure L2. It should be noted that the nominal thickness is 15μ for the S1200 and $20-30\mu$ for the S1100. Figure L3 presents similar measured data on one of the S1100 tubes which includes 1) a comparison of Amperex measurement points to those of the customer (EOS/Zerom) and 2) a 1.06μ sensitivity comparison with some other manufacturer's tubes. Figure L4 presents additional data in the form of S1100 and S1200 response to light from a 2850°K source with and without optical filters and, in addition, typical spectral sensitivity and quantum efficiency versus wavelength for the S1100.

Further information can be obtained from Dr. Levitt whose card is duplicated below.

E. R. Schlesinger
E. R. Schlesinger

ERS:em

DR. RALPH S. LEVITT
PRODUCT / MARKET MANAGER - NEW PRODUCTS
ELECTRO-OPTICAL DEVICES DIVISION
Amperex
401 - 782-3900 PROVIDENCE RIKE BLATERSVILLE R. I. 02876
ELECTRONIC CORPORATION A NORTH AMERICAN PHILIPS CO.

D-0532-02

8/16/77

FIGURE 2.1:
CALCULATED AMPLITUDE RESPONSE (400 TVL, OPTICALLY
CORRECTED) AT 1.06μ V.S. SPECTRAL
SENSITIVITY AT 1.06μ FOR SIVICON
WAFERS OF VARIOUS THICKNESS,
(ANTIREFLECTION COATED
FOR 0.8μ).

TABLE I
ABSORPTION COEFFICIENT AND REFLECTIVITY
OF SILICON

<u>Wavelength (nm)</u>	<u>Absorption Coefficient (cm⁻¹)</u>	<u>Reflectivity</u>
400	70,000	0.49
425	35,000	0.43
450	20,000	0.40
475	15,000	0.39
500	10,100	0.38
525	7,000	0.375
550	6,000	0.37
575	5,000	0.36
600	4,500	0.35
625	4,000	0.34
650	3,000	0.33
675	2,500	0.328
700	2,000	0.325
725	1,600	0.322
750	1,500	0.32
775	1,200	0.32
800	1,010	0.32
825	820	0.319
850	700	0.318
875	520	0.316
900	400	0.315
925	320	0.315
950	250	0.315
975	180	0.315
1000	120	0.31
1025	70	0.31
1050	30	0.31
1075	12	0.31
1100	3	0.31

FIGURE L2
SPECTRAL SENSITIVITY OF REPRESENTATIVE
SIVICONTM TUBES

8/16/72

FIG. L4

CHKD. BY. DATE. TYPICAL SPECTRAL SENSITIVITY
QUANTUM EFF. VS. WAVELENGTH JOB NO. 72-06-10-01

	S1100	S1200
S2850	4000 - 4500	3500 - 4000 mW/m
S443	750 - 1000	750 - 1000
S8915	2000 - 2500	1500 - 2000

TYPICAL SPECTRAL SENSITIVITY AND
QUANTUM EFFICIENCY VS WAVELENGTH

Amperex ELECTRONIC CORPORATION / SLATERSVILLE, RHODE ISLAND 02876 / PHONE 401 / 782-3000
ELECTRO-OPTICAL DEVICES DIVISION

Amperex® Electronic Corporation

A NORTH AMERICAN PHILIPS COMPANY

ELECTRO-OPTIC DEVICES DIVISION

P.O. Box 278

Telephone: 401/762-3800

Statersville, R.I. 02876

TWX: 710/382-6332

T.M. Amperex Electronic Corporation

DEVELOPMENT SAMPLE DATA

DESCRIPTION

The Amperex S1200 family are high performance 5/8 inch image diagonal silicon vidicon camera tubes which feature low heater power; separate mesh construction, magnetic focussing and deflection in a one inch diameter envelope. The photosensitive target of the S1200 family is in the form of a mosaic array of silicon diode elements. This target offers the advantages of wide spectral response (including near infrared), high sensitivity, high resolution, low dark current, low lag, low blooming and long life.

The S1200 family can be exposed to direct sunlight without deleterious effects, does not exhibit image burn-in, and is able to withstand 100°C environments. Due to the use of a special resistive sea, the tube is very resistant to internal X-Ray damage with up to 600 volts on the C₄ (mesh) electrode. Life in excess of 10,000 operating hours can be expected with less than a 2 times increase in the 30°C dark current (when operated as specified). The resistive sea also prevents electron charge build-up from occurring at any values of target voltage or illumination level and is very effective in reducing blooming and lag without adversely affecting resolution.

These camera tubes are intended for use in monochrome cameras in high quality industrial, educational, military, security, and surveillance applications. These devices are mechanically interchangeable with any 1 inch vidicons and electrically interchangeable with separate mesh vidicons such as the XO1240, 8551, etc. without major modifications to the camera system. The electron gun employed is the same as used in the high performance, Broadcast Quality XO1070 Plumbicon® series to provide low distortion, low shading, uniform highlight signal handling capabilities, and good corner resolution.

The members of the S1200 family include the S1200, S1201, S1202, S1203 which differ only with regard to picture quality as described in the Spurious Signal Specifications. The S1200 is of the highest quality, the S1203 the lowest, etc.

GENERAL CHARACTERISTICS

MECHANICAL

Focusing Method
Deflection Method
Dimensions and Basing
Mounting Position
Weight
Accessories
Socket
Deflection and Focus Coil Assembly

Magnetic
Magnetic
See Outline Drawing
Any
2.5 oz.
Cinch No. 54A 18088 or Equiv.
Type AT1103, or Equiv.

© T.M. N.V. Philips of The Netherlands

Amperex®

The Amperex S1200 family is the most advanced and successful performance vidicon camera tube ever developed. It is a product of the Philips Research Laboratories in Eindhoven, The Netherlands. It is the result of the most advanced technology in the world. It is the most advanced and successful performance vidicon camera tube ever developed. It is a product of the Philips Research Laboratories in Eindhoven, The Netherlands. It is the result of the most advanced technology in the world.

Amperex®, . . Tomorrow's Thinking in Today's Products®

September, 1972

S1200 FAMILY

GENERAL CHARACTERISTICS (cont'd.)

OPTICAL

Useful Target Diagonal	5/8" Typical (16mm) 5/16" min. - 11/16" max.
Dimensions of Quality Area of Target (4:3)	1/2" x 3/8" (12.8 x 9.6 mm), Typical
Image Orientation	Horizontal Scan Parallel to Plane of Tube Axis and Index Pin
Faceplate, Thickness (Effective)	0.110" $\pm$ 0.01"
Refractive Index	$n = 1.50$
Target Reflectivity	< 1% at 600nm
Sensitivity, 2854°K Tungsten - Light Source - 0.0755 fc	

SPECTRAL REGION	TOTAL	VISIBLE	INFRARED	UNITS
FILTER (FIGURE 3)	NONE	4mm KG3	3mm RG715	-
Luminous Sensitivity - Typ.	4000	1000	2000	$\mu\text{A/lumen}$
Min.	3500	750	1500	$\mu\text{A/lumen}$
Net Signal Current - 0.1 fc	550	150	250	nA

ELECTRICAL

Heater	Indirect AC or DC, series or Parallel Supply
Heater Voltage	6.3 V $\pm$ 5%
Heater Current	95 mA
(When heater is used in series connection, voltage must not exceed 9.5 volts RMS)	
Capacitance, target to all other electrodes	3 to 5 pF
(This capacitance increases when tube is inserted in a coil assembly)	
Gun Cutoff, Grid No. 1 Voltage at $E_{c2} \pm 300$ V	-30 to -100 V
Blanking, Peak to Peak, On Grid No. 1	50 $\pm$ 10 V
On Cathode	25 V
Grid No. 2 Current, at Normal Beam Currents	Max. 1.0 mA

ABSOLUTE MAXIMUM RATINGS

(All Voltages are Referred to the Cathode, Unless Otherwise Stated)

Signal Electrode (Target) Voltage	Max. 50 V
Grid No. 4 (Mesh) Voltage	Max. 600 V
Grid No. 3 (Collector) Voltage	Max. 550 V
Voltage Between Grid No. 3 and Grid No. 4	Max. 350 V
Grid No. 2 (Accelerator) Voltage	Max. 350 V
Grid No. 1 (Control) Voltage, Positive	Max. 0 V
Negative	Max. 125 V
Heater to Cathode Voltage, Positive Peak	Max. 125 V
Negative Peak	Max. 50 V
Impedance Between Heater and Cathode	
at Peak Heater to Cathode Voltage > 10 V	Min. 2k Ω
Ambient and Faceplate Temperature, Storage and Operation	-50 to +100°C
Faceplate Illumination	Max. 10 Million fc (provided max. faceplate temp. is not exceeded)

TYPICAL OPERATING CONDITIONS AND PERFORMANCE

TYPICAL OPERATING CONDITIONS: Raster Size = 1/2" x 3/8", Deflection Assembly = AT1103)

Grid No. 2 Voltage	300 V
Target Voltage	8 V
Faceplate Illumination, 2854°K	0.04 fc
Visible	0.13 fc before 4mm KG3 Filter
Infrared	0.08 fc before 3mm RG715 Filter
Faceplate Temperature	30°C
Blanking Voltage, Peak to Peak, Grid No. 1	50 V, Negative Going
Cathode	50 V, Positive Going
Grid No. 3 Voltage	375 V
Grid No. 4 Voltage	550 V
(For Focus and Deflection Currents Refer to Figs. 5 and 6 Respectively)	
Beam Current, Set Via E_{c1} to Stabilize Signal Current of	500 nA
Ratio is adjusted for Best Shading, Fig. 4	

PERFORMANCE

Signal Current (Less Dark Current)	200 nA, Typ.
Gamma of Transfer Characteristic	1.0
Spectral Response, Max.	750 nm, Typ.
Cutoffs	400 and 1100 nm
Spurious Signal	See Spurious Signal Specifications
Modulation Transfer Characteristic	See Fig. 1

	MIN	TYPICAL	MAX	UNITS
Dark Current (Fig. 2) (30°C)		10	20	nA
Limiting Resolution, at 5% Mod. Depth	600	700		TVL
Modulation Depth, 400 TVL, Optically Corr.	30	40		%
Lag, Delay, 50 ms, (Fig. 2) from 200 nA		10	15	%
Uniformity of Sensitivity		10	20	%
Uniformity of Dark Current		10	20	nA
Blooming, 8 TVL Spot, 100 x Overload (Fig. 7)		32	48	TVL
Signal Handling Capability (at $E_{c1}=0$)	600	1000		nA

GENERAL RECOMMENDATIONS

1. During transport, handling and storage the axis of the Sivicon should be either vertical, with faceplate up, or horizontal; the faceplate should be covered with the hood provided.
2. This series of Sivicon tubes is provided with Kovar pins and therefore requires no more care in handling than vidicon tubes.
3. The signal electrode connection is made by a spring contact, which is part of the focusing coil assembly, and is kept pressed against the signal electrode ring.
4. Electrostatic shielding of the signal electrode is required to avoid interference effects in the picture. Effective shielding is provided by one grounded shield inside the focusing coil at the faceplate end, and one inside the deflecting yoke.
5. The faceplate being of optical quality must at all times be protected against scratches and abrasions. Therefore only the highest quality lens tissue should be used for cleaning.
6. A minimum of 1 minute warm-up time for the heater is to be observed before drawing cathode current.

ENGINEERING CONSIDERATIONS

1. Sivicon tubes do not permit automatic sensitivity control by means of regulation of the signal electrode voltage. If the tube is to be used in cameras originally designed for vidicon tubes, the automatic sensitivity control circuitry should be made inoperative and target voltage set as indicated.
2. The input stages of the video amplifiers coupled to the target lead of the Sivicon should be capable of handling signal currents of $1\mu\text{A}$ or greater, without overloading the amplifiers or distorting the picture.
3. Signal currents are measured using a waveform oscilloscope and an even illumination on the target area. When measuring with an integrating instrument the average signal currents will be smaller.
4. Illumination levels in excess of 10 million foot-candles can be tolerated. This is equivalent to the image of the sun or a high intensity projection lamp being focussed onto the target. CAUTION: Care must be taken that the heat content of the focussed radiation does not cause the temperature of the target to exceed the maximum allowed level.
5. Illumination on the faceplate, E_{fp} in the case of a black/white camera is related to scene illumination, E_{sc} , by the formula:

$$E_{fp} = E_{sc} \frac{R \times T}{4F^2 (m + 1)^2}$$

in which R represents the scene-reflectivity (average of the object under consideration, whichever is relevant), T the lens transmission factor, F the lens aperture, and m the linear magnification from scene to target.

6. Increasing the faceplate illumination over a small area to a value which would otherwise produce a signal current considerably more than can be stabilized at the normal beam current setting, can result in an apparent increase in the diameter of this area (blooming). With a 100 times overload the area may bloom to the value indicated in Fig. 7, the diameter of the area being determined at the 50% signal level, excluding lens halation and camera electronics overload.
7. The target voltage (E_t) is typically in the range between 6 and 12 volts with respect to the cathode. For each tube E_t is individually selected and specified for that tube. This is to achieve an optimum operating point consistent with optimal beam acceptance and to optimize other performance characteristics, such as dark current, blemishes, uniformity and lag. See Fig. 8.
8. At the specified target voltage (6-12 volts), the dark current (at a faceplate temperature of 30°C) will not exceed 50 nA over the life of the tube.
9. All of the performance data is highly dependent upon the deflection assembly used. It is therefore recommended that the AT1103 be used if full performance is to be realized.
10. The optimum Grid No. 3 to Grid No. 4 voltage ratio for an S1200 Family depends on the deflection assembly used. This ratio should be adjusted for minimum beam landing errors, (preferably ≤ 1 Volt). See Fig. 4.
11. The polarity of the focus coil field should be such that north-seeking pole is attracted toward the image end of the coil.
12. When converting from using the development type S10XQ to the S1200 Family it is expected that a slight decrease in deflection sensitivity coupled with a shift in deflection damping may be experienced.
13. At all times $E_{c4} > E_{c3}$ and $E_{c4} \geq E_{c2}$. Permanent damage to the target can occur, otherwise.
14. Electronic zooming is possible with the Sivicon by simultaneously varying the height and width of the scanned raster over a target diagonal of $5/16''$ to $11/16''$ without damage to the target (2.25:1 ratio)

OUTLINE DRAWING

S1200 FAMILY

Figure 1 Sivicon Typical Uncompensated Horizontal Square Wave Response - Optically Corrected

Figure 2 Typical Sivicon Decay Lag Characteristics

Figure 3 Filter Characteristics

Fig. 4 Area of Permissible Operation

Fig. 5 Focus Coil Current vs. Grid No. 3 Voltage

Fig. 6 Deflection Sensitivity vs. Grid No. 4 Voltage

Fig. 7 Blooming Characteristics

SI200 FAMILY

Fig. 8 Parameter Dependence (Typical) on Target Potential

Fig. 9 Temperature Dependence of Dark Current

Fig. 10 Typical Spectral Sensitivity and Quantum Efficiency vs. Wavelength

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SIVICON DEVELOPMENT DATA

S1100 TYPES

INFRARED ENHANCED SILICON VIDICON CAMERA TUBES

(To be read in conjunction with data for Amprex Types S1200)

DESCRIPTION

The Amprex SIVICON[™] S1100 Types of TV camera pickup tubes contain an infrared enhanced photosensitive target in the form of a mosaic array of silicon diode elements. This tube is mechanically and electrically identical to the Amprex SIVICON Types S1200. The silicon diode array of the S1100 Types are physically thicker than that used in the S1200 Types by the amount necessary to yield the achievable 25-50% increase in spectral sensitivity in the 700 to 1000nm wavelength region. This increase in sensitivity is, however, accompanied by a reduction in resolution, especially for the visible wavelengths.

The S1100 Types intended for applications where only nonvisible IR illumination is available or provided. A suitable visible blocking filter such as the Schott RG715 or equivalent should be placed in close proximity to the input faceplate. Further, the camera lens selected should be optimized for use in the near infrared spectral region to minimize resolution or other aberration losses.

The S1100 Types differ among themselves only as to picture quality in the same fashion as the S1200 Types; the S1100/S1101/S1102 Types have the same picture quality and blemish distribution as the S1200/S1201/S1202 Types, respectively.

The S1100 Types are normally available in the standard 1" diameter by 6 1/4" length but are also available on special order in a 5 1/4" length.

September 1, 1972

[™]Amprex Electronic Corporation

(over)

Amprex[®]
TOMORROW'S THINKING IN TODAY'S PRODUCTS[®]

S1100 TYPES
GENERAL CHARACTERISTICS

(See "Quality Levels for Amperex SIVICONtm Camera Tubes - S1200 FAMILY"
and S1200 Family Development Sample Data except as noted below)

OPTICAL

Sensitivity (Typical), $\frac{1}{2} \times \frac{3}{8}$ inch² raster size

CHART A

Light Source ⁽¹⁰⁾	Luminous Sensitivity ($\mu\text{A}/1\text{m}$) ⁽¹¹⁾	Sensitivity (mA/W) ⁽¹²⁾	Net Signal Current with 0.1 fc incident illumination (nA)
Tungsten, 2870 K	4500	92	600
Visible (13)	1200	25	160
Infrared (14)	2500	53	340

CHART B

Wavelength (nm)	Radiant Sensitivity (mA/W)	Quantum Efficiency (%)
550	350	75
750	500	80
950	350	45

Spectral Response:

Limits

500-1100nm.

Max Sensitivity at

800nm, typ.

TYPICAL OPERATING CONDITIONS AND PERFORMANCE, $\frac{1}{2} \times \frac{3}{8}$ inch² raster size.

Operating Conditions:

Ec4/Ec3/Ec2/Et

550/375/300/8 Volts

Faceplate Illumination

(Visible)

0.125 fc

(Infrared)

0.06 fc

Performance:

Signal Current, Highlight (i_{gh}), net

200nA DC

Dark Current, Average (30°C)

15nA DC

Resolution, Central

Limiting

650 TVL

Modulation Depth (Uncompensated Horizontal

Amplitude Response) at 400 TVL, optically corrected.

Illumination (Visible)

20%

(Infrared)

30%

Lag (decay after 50msec, from 200 nA)

10%

Blooming (2% diag. spot, 100X overload)

6%

Uniformity of Sensitivity (shading)

10%

Uniformity of Dark Current

10 nA

Signal Handling Capability

750 nA

APPENDIX E

DETERMINATION OF SHIVA SYSTEM DIMENSIONS AND GEOMETRIC
RELATIONSHIPS PERTINENT TO ALIGNMENT SYSTEM CONSIDERATIONS

LLL drawings of the SHIVA space frame and turning mirror frame forwarded with G. Linford's letter dated 12/6/74 formed a partial basis for Perkin-Elmer's analytical considerations of alignment requirements. Since these drawings did not explicitly define the geometry of the optical system and its dimensions, approximate values for needed parameters were derived from the drawings. This data is summarized in Figures E-1 through E-3 and Tables E-I and E-II.

An approximate analytical model of one arm of SHIVA (see Figure 4-4) was created from the above data and ray traced (paraxially) to determine the beam axis displacement resulting from 10 arc-seconds angular tilt at the apodizer as well as beam growth due to divergence (5 mrad assumed). The aperture requirements of the turning mirrors and of the focusing lens were then computed. Figures E-4 through E-9 show the calculations. It should be noted that SF_2 is here assumed to have two foci and a magnification of +1 whereas all the other filters have one focus and $M = 1$. Whether M_2 is + or - has a small effect upon the results of the calculation since slight translation compensation occurs for $M = +1$.

"SHIVA" MICROES IN ISOMETRIC
28
11-21-74

OFFICIAL USE

Figure E-2

E-3

Figure E-3

TABLE E-1.

ARM NO	DIRECTION ANGLES			DIRECTION COSINES		
	α (X-AXIS)	β (Y-AXIS)	γ (Z-AXIS)	$\cos \alpha$	$\cos \beta$	$\cos \gamma$
1	90°	41.5°	128.5°	0	-0.782608	-0.622515
2	90°	90°	180°	0	0	-1
3	132.6687°	113.0357°	128.5°	-0.677758	-0.391305	-0.622515
4	120°	150°	90°	-0.5	-0.866025	0
5	180°	90°	90°	-1	0	0
6	132.6687°	113.0357°	51.5°	-0.677758	-0.391305	0.622515
7	90°	141.5°	51.5°	0	-0.782608	0.622515
8	47.3313°	113.0357°	51.5°	0.677758	-0.391305	0.622515
9	60°	150°	90°	0.5	-0.866025	0
10	0°	90°	90°	1.0	0	0
11	47.3313°	113.0357°	128.5°	0.677758	-0.391305	-0.622515
12	47.3313°	66.9645°	128.5°	0.677758	0.391301	-0.622515
13	90°	38.5°	128.5°	0	0.782608	-0.622515
14	132.6687°	66.9645°	128.5°	-0.677758	0.391301	-0.622515
15	120°	30°	90°	-0.5	0.866025	0
16	132.6687°	66.9645°	51.5°	-0.677758	0.391301	0.622515
17	90°	38.5°	51.5°	0	0.782608	0.622515
18	47.3313°	66.9645°	51.5°	0.677758	0.391301	0.622515
19	60°	30°	90°	0.5	0.866025	0
20	90°	90°	0°	0	0	1.0

R24 12/31/74

TABLE 2-II. SHIVA TURN MIRRORS BASED ON 11/21/74 DATA

Arm NO	MIRROR #1 COORD.			MIRROR #2 COORD.			DIR. COS. OF CONNECTING AXIS			MIRROR SEPARATION	MIRROR ANGLE TASSEL
	X	Y	Z	X	Y	Z	α	β	γ		
1	16.0	5.6	4.7	0	5.8	4.7	-1.0	0	0	16.00	7.47
2	8.9	1.9	6.9	0	0	6.9	-0.9781	-0.2079	0	9.10	6.90
3	16.0	1.9	11.9	13.0	7.3	11.9	-0.9890	0.5716	0	6.18	19.08
4	8.9	4.1	0	3.8	6.8	0	-0.9829	0.9695	0	5.77	7.78
5	8.9	-1.9	0	8.9	0	0	0	1.0	0	1.90	8.90
6	16.0	4.1	-4.3	4.6	0	-4.3	-0.9925	-0.1219	0	11.49	6.85
7	-16.0	5.8	-9.7	0	5.8	-9.7	1.0	0	0	16.00	17.47
8	-16.0	4.1	-4.3	-4.6	2.7	-4.3	0.9925	-0.1219	0	11.49	6.85
9	-8.9	4.1	0	-3.8	6.8	0	0.9829	0.9695	0	5.77	7.78
10	-8.9	1.9	0	-8.9	0	0	0	-1.0	0	1.90	8.90
11	-16.0	1.9	11.9	-13.0	7.3	11.9	0.9890	0.5716	0	6.18	19.08
12	-16.0	-1.9	11.9	-13.0	-7.3	11.9	0.9890	-0.5716	0	6.18	19.08
13	16.0	-5.8	4.7	0	-5.8	4.7	-1.0	0	0	16.00	7.47
14	16.0	-1.9	11.9	13.0	-7.3	11.9	-0.9890	-0.5716	0	6.18	19.08
15	8.9	-4.1	0	3.8	-6.8	0	-0.9829	-0.9695	0	5.77	7.78
16	16.0	-4.1	-4.3	4.6	-2.7	-4.3	-0.9925	0.1219	0	11.49	6.85
17	-16.0	-5.8	-4.7	0	-5.8	-4.7	1.0	0	0	16.00	7.47
18	-16.0	-4.1	-4.3	-4.6	-2.7	-4.3	0.9925	0.1219	0	11.49	6.85
19	-8.9	-4.1	0	-3.8	-6.8	0	0.9829	-0.9695	0	5.77	7.78
20	-8.9	-1.9	-6.9	0	0	-6.9	0.9781	0.2079	0	9.10	6.90
			11.9+3.63								
			-6.21-1.92								

By 1/10/75

Figure E-4. Optical Schematic of Thin-lens System Ray Traced

RAY NO. 1

Figure E-5

1 ARC
SEC →

Stop

ERECTING TELESCOPE

JUVENILE TELESCOPE $M = -1.0$

Trans:

INVERTING TELESCOPE $m_2 = 1.0$

Tues May 28

$$H_{Tm_1} \text{ for } \pm 10 \text{ SEC} = \pm 1.90 \text{ mm}$$

$$\text{OR } 3.8 \text{ mm}$$

Figure E-6

RAY NO. 3

Figure E-7

[illegible]

From Ray Trace No. 3 $2X = 4.67 \text{ mrad}$, $\phi_{\text{APOD}} = 20 \text{ mm}$

H at Tm #1 = 101.6 mm

ϕ at Tm #1 = 203.2 mm

To convert to 25-mm Apodizer Aperture and 5-mrad divergence:

$$\frac{203.2 - 20.0}{0.00467} = 39,229.12 \text{ mm Effective Distance to Tm}$$

$$\Delta \phi \text{ Tm}_1 = (\text{Eff. Dist.}) (\text{New } 2X) = (39,229.12) (0.005) = 196.146 \text{ mm}$$

$$\Delta \phi = (\text{Tm}_1 \text{ to Tm}_2) (\text{New } 2X) = (4877) (0.005) = 24.385 \text{ mm}$$

$$\Delta \phi = (\text{Tm}_2 \text{ to Lens}) (\text{New } 2X) = (1756) (0.005) = 8.780 \text{ mm}$$

$$\text{New Apodizer Aperture} = 25.000 \text{ mm}$$

$$\text{At Tm}_1 \quad \phi = 196.146 + 25 = 221.1 \sim 222 \text{ mm}$$

$$\text{At Tm}_2 \quad \phi = 221.1 + 24.385 = 245.5 \sim 246 \text{ mm}$$

$$\text{At Lens} \quad \phi = 245.5 + 8.780 = 254.3 \sim 255 \text{ mm}$$

Add for 10-arc-sec beam displacement per ray trace #2 x 10 sec

$$\text{At Tm}_1 \quad \phi = 222 + 4 = 226 \text{ mm}$$

$$\text{At Tm}_2 \quad \phi = 246 + 5 = 251 \text{ mm}$$

$$\text{At Lens} \quad \phi = 255 + 5 = 260 \text{ mm}$$

Figure E-9

APPENDIX F

CONSIDERATIONS OF SHIVA FOCUSING
LENS DESIGNS

The SHIVA focusing lens has been defined by LLL as an $f/2$ component of aperture 26 cm. Specific designs for that lens have not been disclosed by LLL. As part of Perkin-Elmer's analysis of tradeoff of cost versus performance of various portions of the optical system, preliminary designs for five lens configurations having various degrees of complexity have been developed. All but one design use BK7 glass. The aspheric triplet uses a higher index glass to minimize thickness. These designs are represented in Figures F-1 through F-5. The lens design data, the ray traced aberrations (H-Tan V' format) for 0, 1, and 4 milliradian semi-field angles and a drawing of the lens are given as sheets 1 through 3 of each figure. The geometrical blur diameter on axis and at each field angle derived from the aberrational data is given in Table F-I.

The quality of the image may be estimated by comparing this geometrical blur diameter to the diffraction central maximum blur, which is for each lens given by:

$$\text{Diffraction Blur} = (2.44) (1.06 \times 10^{-3}) (2) = 5.2 \text{ mm}$$

It is obvious from the aberrations off-axis that the various designs perform differently for a misaligned beam. The simpler aspheric singlet design is best off-axis.

Designs for all-spherical lenses were also developed but not seriously considered since their aberrations on-axis create blur diameters measured in millimeters instead of micrometers.

While tolerances are indicated for each parameter on the lens drawings, the effect of these tolerances was evaluated only for the aspheric singlet design. In this case, the effect was very insignificant in as much as the final performance is achieved by aspherizing and this corrects for thickness, radius, and centering errors.

Since the lens is to be used in a pressure chamber, calculations of pressure-differential surface deformations were made and the deformed lens system ray traced. Two cases were considered: the aspheric doublet (with pressure differential across second element) and the aspheric singlet plus, pressure window. In the first case, the lens distortion was calculated by NASTRAN as indicated in Figure F-6, sheets 1 through 6. The ray traces of the distorted lens design achieved by fitting best aspherics to the second element curves (see Figure F-7)

HAUL BK7 ASPH SINGLET 10:57:31-----01/29/75
 CYCLE 0 Ref: Pwg 660-3201

WAVELENGTH NO. SURFACE	RADIUS	THICKNESS 0.0	1.06000 1.00000	0.0 1.00000	0.0 1.00000	PHI GL-NAME	1ST-BNDY	2ND-BNDY
1 ASPHER.	0.4879	0.0069	1.40659	1.51086	1.51086	BK 7	0.0	0.0
2 SPHER.	-3.5275	0.9617	1.00000	1.00000	1.00000	AIR	0.0	0.0
3 SPHER.	INF	0.0	1.00000	1.00000	1.00000	AIR	0.0	0.0

TABLE OF ASPHERIC COEFFICIENTS

NO.	E	A(4)	A(6)	A(8)	A(10)
1	1.0000000 00	-5.0933420-01	-1.0750630 00	-1.7935560 00	-4.7506370 00

FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

OBJECT DISTNCE	ENTR.PUP.DIST	FRST.PPAL.PNT	EQV.FCL.LNGTH	SCND.PPAL.PNT	EXT.PUP.DSTNC	IMAGE DISTNCE
INF	0.0	0.004378	0.999984	-0.030266	-0.044667	0.961719
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	TRCK LENGTH	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
INF	0.449944	INF	INF	2.000000	0.503203	0.001745
MAGNIFICATION	SEMIANG.FIELD	BACK VTX.DIST	BARREL LENGTH	FRNT.VTX.DIST	SEMIANG.FIELD	DEMAGNIFICATION
0.0	0.100000	INF	0.066900	1.028619	0.099362	INF
APT.STOP SIZE	APT.STOP DIST	FROM SHFCE.NO	*****	FLD.STOP SIZE	FLD.STOP DIST	FROM SRFCE.NO
0.449994	0.0	1		0.003491	0.961719	2

Figure F-1 (Sheet 1 of 3)

PERKIN-ELMER

Report No. 12486

RAUL
CYCLE 0
COLOR 3

10:57:31-----01/29/75

		M (D refract)		N	E.P.				
1		0.0	0.0	0.0	0.0	0.0	DEL	OPD	
MAY	CLR	Y	Z	Y ¹	Z ¹				
1	3	1.00	0.0	-1.599990-06	0.0	<i>2.000000 (500)</i>	0.0	1.374130-07	
2	3	0.75	0.0	-1.134830-06	0.0	<i>2.000000 (500)</i>	0.0	4.536530-08	
3	3	0.50	0.0	-2.423020-07	0.0	<i>2.000000 (500)</i>	0.0	6.360830-09	
4	3	0.25	0.0	-2.030170-08	0.0	<i>2.000000 (500)</i>	0.0	3.083570-10	
2		M (1mmol)		N	E.P.				
		5.700000-02	0.0	0.0	0.0	0.0	DIST	YS	DEL Y
MAY	CLR	Y	Z	YPR	ZPR				
9	3	0.0	0.0	9.948300-04	0.0		-2.13550-11	-2.00560-07	-2.36360-07
3		M (1mmol)		N	E.P.				
		2.292000-01	0.0	0.0	0.0	0.0	DIST	YS	DEL Y
MAY	CLR	Y	Z	YPR	ZPR				
22	3	0.0	0.0	4.000300-03	0.0		-1.38840-09	-3.24290-06	-3.81600-06
MAY	CLR	Y	Z	Y ¹	Z ¹	DEL	OPD		
18	3	1.00	0.0	5.069200-05	0.0	0.0	-3.617780-06		
19	3	0.75	0.0	2.428760-05	0.0	0.0	-1.123020-06		
20	3	0.50	0.0	7.342010-06	0.0	0.0	-2.062130-07		
21	3	0.25	0.0	6.441090-07	0.0	0.0	5.639290-09		
22	3	0.0	0.0	0.0	0.0	0.0	0.0		
23	3	-0.25	0.0	4.235360-06	0.0	0.0	1.053810-07		
24	3	-0.50	0.0	1.506800-05	0.0	0.0	6.626470-07		
25	3	-0.75	0.0	3.758840-05	0.0	0.0	2.217800-06		
26	3	-1.00	0.0	7.403630-05	0.0	0.0	5.686950-06		
27	3	0.0	1.00	1.870140-05	-5.061470-06	0.0	5.516080-07		
28	3	0.0	0.75	9.931640-06	-3.657800-06	0.0	2.763660-07		
29	3	0.0	0.50	3.479580-06	-1.890340-06	0.0	1.083150-07		
30	3	0.0	0.25	7.979750-07	-8.343200-07	0.0	2.568260-08		

Figure F-1 (Sheet 2 of 3)

Figure F-1 (Sheet 3 of 3)

BK7 ASPH SINGLET
w/ PLANO WINDOW
CYCLE 2 Ref: Dwg 660 - 3204

15:57:27-----01/30/75

WAVELENGTH NO. SURFACE	RADIUS	THICKNESS	1.00000 0.0	0.0 HI-INDEX 1.00000	0.0 LO-INDEX 1.00000	GL-NAME	PHI 1ST.BNDY	8.943830D-12 2ND.BNDY
1 ASPHER.	0.5879	0.0069	1.50669	1.51086	1.51086	BK 7	0.0	0.0
2 SPHER.	-3.5275	0.0385	1.00000	1.00000	1.00000	AIR	0.0	0.0
3 SPHER.	INF	0.0577	1.50669	1.51086	1.51086	BK 7	0.0	0.0
4 SPHER.	INF	0.8849	1.00000	1.00000	1.00000	AIR	0.0	0.0
5 SPHER.	INF	0.0	1.00000	1.00000	1.00000	AIR	0.0	0.0

TABLE OF ASPHERIC COEFFICIENTS

NO.	E	A(4)	A(6)	A(8)	A(10)
1	1.0000000 00	-5.049484D-01	-1.057257D 00	-1.766556D 00	-5.752928D 00

FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

OBJECT DISTNCE	ENTR.PUP.DIST	FRST.PPAL.PNT	ENV.FCL.LNGTH	SCNU.PPAL.PNT	EXT.PUP.DSTNC	IMAGE DISTNCE
INF	0.0	0.004378	0.499988	-0.115064	-0.121483	0.804924
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	TRACK LENGTH	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
INF	0.499994	INF	INF	2.000000	0.503203	0.701745
MAGNIFICATION	SEMIANG.FIELD	BACK VTX.DIST	BARREL LENGTH	FRNT.VTX.DIST	SEMIANG.FIELD	DEYMAGNIFICATION
0.0	0.100000	INF	0.163100	1.048024	0.099362	INF
APT.STOP SIZE	APT.STOP DIST	FROM SRFCE.NO	*****	FLD.STOP SIZE	FLD.STOP DIST	FROM SRFCE.NO
0.499994	0.0	1		0.003491	0.884924	4

Figure F-2 (Sheet 1 of 3)

RAUL
CYCLE 2
COLOR 3

15:57:27-----01/30/7

M				N		E.P.			
RAY	CLR	Y	Z	Y _P	Z _P	DEL	OPD		
1	3	1.00	0.0	-5.132850-07	0.0	0.0	-2.591380-07		
2	3	0.75	0.0	2.058620-06	0.0	0.0	-2.305340-07		
3	3	0.50	0.0	2.072030-06	0.0	0.0	-7.880260-08		
4	3	0.25	0.0	3.861790-07	0.0	0.0	-4.244330-09		
<i>(2.2 μm)</i>									
M				N		E.P.			
RAY	CLR	Y	Z	Y _P	Z _P	DIST	YS	DEL	Y
9	3	0.0	0.0	4.94830-04	0.0	-3.17020-11	-1.97940-07	-2.30770-	
RAY	CLR	Y	Z	Y _P	Z _P	DEL	OPD		
5	3	1.00	0.0	1.432350-05	0.0	0.0	-1.194550-06		
6	3	0.75	0.0	0.268350-06	0.0	0.0	-5.452520-07		
7	3	0.50	0.0	4.143890-06	0.0	0.0	-1.526570-07		
8	3	0.25	0.0	7.614070-07	0.0	0.0	-1.270240-08		
9	3	0.0	0.0	0.0	0.0	0.0	0.0		
10	3	-0.25	0.0	2.044400-07	0.0	0.0	4.923920-04		
11	3	-0.50	0.0	4.367520-07	0.0	0.0	2.202100-08		
12	3	-0.75	0.0	4.821550-06	0.0	0.0	1.452730-07		
13	3	-1.00	0.0	1.427090-05	0.0	0.0	7.855950-07		
14	3	0.0	1.09	3.976270-06	-7.245100-07	0.0	-2.338130-07		
15	3	0.0	0.75	1.344550-06	1.906680-06	0.0	-2.154210-07		
16	3	0.0	0.50	6.490120-07	1.371430-06	0.0	-7.257700-08		
17	3	0.0	0.25	1.570200-07	3.384910-07	0.0	-4.695360-09		
<i>(1.7 μm)</i>									
M				N		E.P.			
RAY	CLR	Y	Z	Y _P	Z _P	DIST	YS	DEL	Y
22	3	0.0	0.0	4.00030-03	0.0	-2.06120-09	-3.20050-06	-3.73140-	
RAY	CLR	Y	Z	Y _P	Z _P	DEL	OPD		
18	3	1.00	0.0	5.355590-05	0.0	0.0	-3.355190-06		
19	3	0.75	0.0	2.295910-05	0.0	0.0	-1.124420-06		
20	3	0.50	0.0	7.750380-06	0.0	0.0	-2.117420-07		
21	3	0.25	0.0	5.869990-07	0.0	0.0	8.566570-09		
22	3	0.0	0.0	0.0	0.0	0.0	0.0		
23	3	-0.25	0.0	3.297330-06	0.0	0.0	9.744320-08		
24	3	-0.50	0.0	1.067110-05	0.0	0.0	4.902650-07		
25	3	-0.75	0.0	2.468210-05	0.0	0.0	1.651130-06		
26	3	-1.00	0.0	6.447460-05	0.0	0.0	4.604580-06		
27	3	0.0	1.00	1.598730-05	-1.930520-06	0.0	1.503550-07		
28	3	0.0	0.75	7.416200-06	-4.317380-07	0.0	-2.336090-09		
29	3	0.0	0.50	2.810390-06	4.454330-07	0.0	2.186030-08		
30	3	0.0	0.25	6.312500-07	-4.172240-07	0.0	1.880110-08		
<i>(2.2 μm)</i>									

Figure F-2 (Sheet 2 of 3)

Figure F-2 (Sheet 3 of 3)

PAUL
CYCLE 0

BK7 ASPH DOUBLET
Ref-Dwg 660-3202

13:53:43-----01/29/75

WAVELENGTH NO. SURFACE	RADIUS	THICKNESS 0.0	1.06000 MU-INDEX 1.00000	0.0 HI-INDEX 1.00000	0.0 LO-INDEX 1.00000	GL.NAME	PHI 1ST.BNDY	0.0 2ND.BNDY
1 ASPHER.	1.3434	0.0462	1.50669	1.51086	1.51086	SK 7	0.0	0.0
2 SPHER.	-21.2423	0.0058	1.00000	1.00000	1.00000	AIR	0.0	0.0
3 SPHER.	0.8262	0.0562	1.50669	1.51086	1.51086	SK 7	0.0	0.0
4 SPHER.	INF	0.9490	1.00000	1.00000	1.00000	AIR	0.0	0.0
5 SPHER.	INF	0.0	1.00000	1.00000	1.00000	AIR	0.0	0.0

NO.	E	A(4)	A(4)	A(8)	A(10)
1	1.0000000	00	-1.7080530-01	-7.0449620-02	0.0

FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

OBJECT DISTNCE	ENTR.PUP.DIST	FST.PPAL.PNT	EQV.FCL.LNGTH	SCND.PPAL.PNT	EXT.PUP.DSTNC	IMAGE DISTNCE
INF	0.0	0.023042	1.000027	-0.050984	-0.074621	0.949043
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	TRACK LENGTH	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
INF	0.500013	INF	INF	2.000000	0.511632	0.001745
MAGNIFICATION	SEMIANG.FIELD	BACK VTX.DIST	BARREL LENGTH	FRNT.VTX.DIST	SEMIANG.FIELD	DEMAGNIFICATION
0.0	0.100000	INF	0.108200	1.057243	0.097691	INF
APT.STOP SIZE	APT.STOP DIST	FROM SRFCE.NO	*****	FLD.STOP SIZE	FLD.STOP DIST	FROM SRFCE.NO
0.500013	0.0	1		0.003491	0.949043	4

Figure F-3 (Sheet 1 of 3)

RAUL
CYCLE 0
COLOR 3

13:53:43-----01/29/75

M				N		E.P.					
RAY	CLR	Y	Z	Y*	Z*	DEL	OPD				
1	3	1.00	0.0	-1.240530-06	0.0	0.0	-5.007680-08				
2	3	0.75	0.0	6.756510-07	0.0	0.0	-3.956720-08				
3	3	0.50	0.0	2.442270-07	0.0	0.0	-8.795560-09				
4	3	0.25	0.0	3.445640-08	0.0	0.0	-5.303970-10				
M				N		E.P.					
RAY	CLR	Y	Z	YPR	ZPR	DIST	YS	DEL	Y		
9	3	0.0	0.0	9.94860-04	0.0	-5.38030-11	-1.49980-07	-2.34310-07			
RAY	CLR	Y	Z	Y*	Z*	DEL	OPD				
5	3	1.00	0.0	4.237260-05	0.0	0.0	-3.546240-06				
6	3	0.75	0.0	2.491440-05	0.0	0.0	-1.515370-06				
7	3	0.50	0.0	1.090890-05	0.0	0.0	-4.431370-07				
8	3	0.25	0.0	2.624200-06	0.0	0.0	-5.323660-08				
9	3	0.0	0.0	0.0	0.0	0.0	0.0				
10	3	-0.25	0.0	2.773080-06	0.0	0.0	5.895230-08				
11	3	-0.50	0.0	1.077450-05	0.0	0.0	-4.525100-07				
12	3	-0.75	0.0	2.423130-05	0.0	0.0	1.496200-06				
13	3	-1.00	0.0	4.574130-05	0.0	0.0	3.551800-06				
14	3	0.0	1.00	1.440170-05	-1.448330-06	0.0	-2.540520-08				
15	3	0.0	0.75	8.040210-06	5.224270-07	0.0	-2.570960-08				
16	3	0.0	0.50	3.595530-06	1.432850-07	0.0	-2.566810-09				
17	3	0.0	0.25	8.963380-07	-1.569570-08	0.0	1.030630-09				
M				N		E.P.					
RAY	CLR	Y	Z	YPR	ZPR	DIST	YS	DEL	Y		
22	3	0.0	0.0	4.00040-03	0.0	-3.50200-09	-3.23340-06	-3.78860-07			
RAY	CLR	Y	Z	Y*	Z*	DEL	OPD				
14	3	1.00	0.0	1.586620-04	0.0	0.0	-1.346590-05				
19	3	0.75	0.0	9.409280-05	0.0	0.0	-5.607980-06				
20	3	0.50	0.0	4.034210-05	0.0	0.0	-1.591490-06				
21	3	0.25	0.0	9.126230-06	0.0	0.0	-1.713190-07				
22	3	0.0	0.0	0.0	0.0	0.0	0.0				
23	3	-0.25	0.0	1.257790-05	0.0	0.0	2.797960-07				
24	3	-0.50	0.0	4.607280-05	0.0	0.0	2.009870-06				
25	3	-0.75	0.0	1.035370-04	0.0	0.0	6.501460-06				
26	3	-1.00	0.0	1.857430-04	0.0	0.0	1.507500-05				
27	3	0.0	1.00	5.790910-05	-4.600530-06	0.0	3.488700-07				
28	3	0.0	0.75	3.255520-05	-1.801980-06	0.0	1.060130-07				
29	3	0.0	0.50	1.445180-05	-1.347900-06	0.0	9.191750-08				
30	3	0.0	0.25	3.612250-06	-7.758120-07	0.0	2.471000-08				

Figure F-3 (Sheet 2 of 3)

Figure F-3 (Sheet 3 of 3)

BK7 Aspheric Triplet
Ref: Dwg 660-3103

10:01:53-----01/13/75

NAME CYCLES 24
WAVELENGTH NO. SURFACE
1 1.000000 0.0 0.0
2 1.000000 1.000000 1.000000
3 1.000000 1.000000 1.000000
4 1.000000 1.000000 1.000000
5 1.000000 1.000000 1.000000
6 1.000000 1.000000 1.000000
7 1.000000 1.000000 1.000000

1 1.000000 0.0 0.0
2 1.000000 1.000000 1.000000
3 1.000000 1.000000 1.000000
4 1.000000 1.000000 1.000000
5 1.000000 1.000000 1.000000
6 1.000000 1.000000 1.000000
7 1.000000 1.000000 1.000000

Table of Aspheric Coefficients
1.000000 0.0 0.0
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000

Table of Aspheric Coefficients
1.000000 0.0 0.0
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000
1.000000 1.000000 1.000000

Figure F-4 (Sheet 1 of 3)

CYCLE 24
 JUL 04 3

10:01:53-----01/13/75

	SPM.	COMA	AST.	WST.	PET.	LDN.CNR.	LAT.CNR.
140	1.2000-05	-1.0125-03	-0.0000-00	-2.0000-00	-2.0000-05	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0		
160	1.0000-07	-0.0000-00	-0.0000-00	-7.0000-10	1.0000-08		
	-2.0000-05	-3.0000-00					
	-1.0000-05	-0.0000-00					
	-1.0000-07	1.0000-00					
170	-0.0000-05	-2.0000-00	TEL.COMA				
180	-1.0000-05	-0.0000-07	SEL.COMA				

POP.DISC. (3)

0.0

FIELD

1.0000-00

PUP.SPM.

1.0000-00

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure F-4 (Sheet 2 of 3)

Figure F-4 (Sheet 3 of 3)

WAVELENGTH
CYCLE

BK7 "ALL PLUS" TRIPLET
Ref: 139 660 - 3200

10:05:14

01/21/75

WAVELENGTH NO. SURFACE	RADIUS	THICKNESS 0.0	1.00000 MU-INDEX	0.0 HI-INDEX	0.0 LO-INDEX	GL.CODE	PHI 1ST.BNDY	0.0 2ND.BNDY
1 SPHER.	2.1475	0.0577	1.51086	1.51086	1.51086 BK 7		0.50	0.0
2 SPHER.	-7.8417	0.0770	1.00000	1.00000	1.00000 AIR		0.50	0.0
3 SPHER.	1.1042	0.0577	1.51086	1.51086	1.51086 BK 7		0.48	0.0
4 SPHER.	2.2313	0.0770	1.00000	1.00000	1.00000 AIR		0.47	0.0
5 SPHER.	0.4168	0.1000	1.51086	1.51086	1.51086 BK 7		0.44	0.0
6 SPHER.	81.5754	0.7904	1.00000	1.00000	1.00000 AIR		0.40	0.0
7 SPHER.	INF	0.0	1.00000	1.00000	1.00000 AIR		0.01	0.0

TABLE OF ASPHERIC COEFFICIENTS

NO. 1 1.00000000 00 -1.1790420-01 -2.0429590-02 0.0 0.0

FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

OBJECT DISTANCE	ENTR.PUP.DIST	FOST.PPPL.PNT	EOV.FLL.LENGTH	SCMD.PPPL.PNT	EXT.PUP.DSTNC	IMAGE DISTANCE
INF	0.0	0.104547	1.002238	-0.211818	-0.387650	0.790420
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	TRACK LENGTH	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
INF	0.001117	INF	INF	2.000000	0.589035	0.001749
MAGNIFICATION	SEMIANG.FIELD	BACK VTX.DIST	BARREL LENGTH	FRONT.VTX.DIST	SEMIANG.FIELD	DEMAGNIFICATION
0.0	0.100000	INF	0.442400	1.232820	0.085075	INF
APT.STOP SIZE	APT.STOP DIST	FROM SURFCE.NO	*****	FLO.STOP SIZE	FLO.STOP DIST	FROM SURFCE.NO
0.001117	0.0	1		0.003499	0.790420	6

Figure F-5 (Sheet 1 of 3)

Q400
CYCLE

15:05:17

01/21/75

	SPM	CUM	AST	UTST	RETZ	LDN,CHN	LAT,CH
3-7	-3.6450-07	1.2700-05	-3.6430-07	-1.6670-07	-2.6700-07	0.0	0.0
3-7	0.0	0.0	0.0	0.0	0.0		
5-7	-3.1421-04	7.5400-07	-4.0000-13	-4.2410-13	0.1400-13		
	-5.3030-04	4.4000-07					
	-1.3030-15	1.0400-10					
	-2.5040-03	3.0640-11					
7-7	-5.9130-03	5.3000-10	T.EL.COM				
5-7	-1.7000-04	1.7000-10	S.EL.COM				
	PUP,DISP.(3)		FIELD	PUP,SPM			
	1.0		1.0000-01	2.3040-10			
	(pmnub)						
	1	0.0	N	0.0	0.0		
DAY CL	Y	Z	Y*	Z*	DEL	OPD	
1 3	1.00	0.0	-3.0000-05	0.0	Blue = 0.0	1.019980-07	
2 3	0.75	0.0	-4.0000-07	0.0	0.0	1.477180-06	
3 3	0.50	0.0	-5.0000-05	0.0	0.0	1.703300-09	
4 3	0.25	0.0	-5.0000-07	0.0	0.0	8.990470-11	
	(pmnub)						
	2	0.7290-05	N	0.0	0.0		
DAY CL	Y	Z	Y*	Z*	DEL	OPD	
4 3	0.0	0.0	1.0000-03	0.0	0.0	-2.7000-10	
5 3	1.00	0.0	3.0000-05	0.0	0.0	-3.258010-06	
6 3	0.75	0.0	2.877700-05	0.0	0.0	-1.400030-06	
7 3	0.50	0.0	1.010000-05	0.0	0.0	-4.187130-07	
8 3	0.25	0.0	2.000000-05	0.0	0.0	-5.121000-08	
9 3	0.0	0.0	0.0	0.0	0.0	0.0	
10 3	0.0	0.0	2.700000-05	0.0	0.0	5.712100-08	
11 3	0.0	0.0	1.000000-05	0.0	0.0	4.444580-07	
12 3	0.0	0.0	2.000000-05	0.0	0.0	1.889900-06	
13 3	1.00	0.0	4.000000-05	0.0	0.0	3.551000-06	
14 3	0.0	1.00	1.000000-05	0.0	0.0	1.243010-07	
15 3	0.0	0.75	1.700000-06	0.0	0.0	2.741070-08	
16 3	0.0	0.50	3.400000-05	0.0	0.0	7.346020-09	
17 3	0.0	0.25	5.000000-07	0.0	0.0	1.504240-09	
	(pmnub)						
	2	2.000000-01	N	0.0	0.0		
DAY CL	Y	Z	Y*	Z*	DEL	OPD	
4 3	0.0	0.0	4.000000-03	0.0	0.0	-1.7000-08	
5 3	1.00	0.0	1.000000-04	0.0	0.0	-1.279080-05	
6 3	0.75	0.0	0.000000-05	0.0	0.0	-5.371100-06	
7 3	0.50	0.0	3.000000-05	0.0	0.0	-1.542500-06	
8 3	0.25	0.0	4.000000-06	0.0	0.0	-1.700000-07	
9 3	0.0	0.0	0.0	0.0	0.0	0.0	
10 3	0.0	0.0	1.000000-05	0.0	0.0	2.625750-07	
11 3	0.0	0.0	4.000000-05	0.0	0.0	1.911100-06	
12 3	0.0	0.0	4.000000-05	0.0	0.0	6.210040-06	
13 3	1.00	0.0	1.700000-04	0.0	0.0	1.443440-05	
14 3	0.0	1.00	5.000000-05	0.0	0.0	4.594000-07	
15 3	0.0	0.75	5.110000-05	0.0	0.0	2.169850-07	
16 3	0.0	0.50	1.000000-05	0.0	0.0	9.194530-08	
17 3	0.0	0.25	1.000000-05	0.0	0.0	2.210000-08	

Figure F-5 (Sheet 2 of 3)

TABLE F-1

GEOMETRICAL BLUR DIAMETER DERIVED FROM RAY TRACE
RESULTS FOR EACH LENS DESIGN

Figure Number	Drawing 660-	Description	Blur Diameter (μ m)		
			at 0 mrad	at 1 mrad	at 4 mrad
-1	3201	Aspheric Singlet	1.7	20	82
-2	3204	Aspheric Singlet with window	2.2	17	72
-3	3202	Aspheric Doublet	1.3	58	198
-4	3203	Aspheric Triplet	15.6	not traced	not traced
-5	3200	Aspheric Triplet (positive elements)	3.2	47	184

LASER FUSION STUDY, SECOND LENS OF ASPHERICAL DOUBLET, 600-3202
ANALYTIC PRESSURE IN FLAT CURVED SURFACE AND SIDE SURFACE
ALL ANGLES DEFINED THROUGH THE FLAT SURFACE DOTTED DASHES

JANUARY 28, 1979 NASTRAN 11/15/74

PAGE 3

GRID POINT NO.	TYPE	R ₀ IN IN	DISPLACEMENT VECTOR			
			T2	R1	R2	R3
1	G	0.0	0.0	0.0	0.0	0.0
2	G	-1.712695E-04	0.0	-1.055310E-02	0.0	0.0
3	G	-3.411672E-04	0.0	-1.901403E-02	0.0	0.0
4	G	-5.063644E-04	0.0	-1.023718E-02	0.0	0.0
5	G	-6.341800E-04	0.0	-9.314591E-03	0.0	0.0
6	G	-7.402533E-04	0.0	-8.661034E-03	0.0	0.0
7	G	-8.282233E-04	0.0	-8.257950E-03	0.0	0.0
8	G	-1.023842E-03	0.0	-8.237581E-03	0.0	0.0
9	G	-1.168103E-03	0.0	-7.554773E-03	0.0	0.0
10	G	-1.237670E-03	0.0	-6.887370E-03	0.0	0.0
11	G	-1.241172E-03	0.0	-5.962318E-03	0.0	0.0
12	G	-1.211401E-03	0.0	-5.316418E-03	0.0	0.0
13	G	-1.157140E-03	0.0	-4.730626E-03	0.0	0.0
14	G	-1.152222E-03	0.0	-4.230626E-03	0.0	0.0
15	G	-1.017937E-03	0.0	-3.730626E-03	0.0	0.0
16	G	-7.019410E-04	0.0	-3.187406E-03	0.0	0.0
17	G	-6.125207E-04	0.0	-2.637406E-03	0.0	0.0
18	G	-4.364324E-04	0.0	-1.063731E-02	0.0	0.0
19	G	-3.478943E-04	0.0	-1.722959E-02	0.0	0.0
20	G	-2.946030E-04	0.0	-1.517724E-02	0.0	0.0
21	G	-2.427953E-04	0.0	-1.039391E-02	0.0	0.0
22	G	-1.645403E-04	0.0	-9.723702E-03	0.0	0.0
23	G	-6.331292E-04	0.0	-9.321732E-03	0.0	0.0
24	G	-6.331292E-04	0.0	-8.927201E-03	0.0	0.0
25	G	-6.331292E-04	0.0	-7.625291E-03	0.0	0.0
26	G	-6.331292E-04	0.0	-6.466151E-03	0.0	0.0
27	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
28	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
29	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
30	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
31	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
32	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
33	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
34	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
35	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
36	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
37	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
38	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
39	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
40	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
41	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
42	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
43	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
44	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
45	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
46	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
47	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
48	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
49	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
50	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
51	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
52	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
53	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
54	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
55	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
56	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
57	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
58	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
59	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
60	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
61	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
62	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
63	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
64	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
65	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
66	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
67	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
68	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
69	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
70	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
71	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
72	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
73	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
74	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
75	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
76	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
77	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
78	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
79	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
80	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
81	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
82	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
83	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
84	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
85	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
86	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
87	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
88	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
89	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
90	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
91	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
92	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
93	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
94	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
95	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
96	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
97	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
98	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
99	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0
100	G	-7.245127E-04	0.0	-5.933371E-03	0.0	0.0

Figure F-6 (Sheet 2 of 6)

LASER FUSION STUDY, SECOND LENS OF ASPHERICAL DRUGLET, 660-3202
ATMOSPHERIC PRESSURE ON FRONT CURVED SURFACE AND SIDE SURFACE

JANUARY 28, 1975 NASTRAN 11/15/74 PAGE 4

ALL AROUND UNIFORM SUPPORT ON FLAT SURFACE OUTER BOUNDARY

GRID POINT	IN- TYPE	DISPLACEMENT VECTOR			R1	R2	R3
		Radial in	12	Angle in			
67	G	3.741441E-04	0.0	-0.334501E-03	0.0	0.0	0.0
68	G	4.563389E-04	0.0	-0.845411E-03	0.0	0.0	0.0
69	G	5.154102E-04	0.0	-0.271877E-03	0.0	0.0	0.0
70	G	5.714176E-04	0.0	-7.610594E-03	0.0	0.0	0.0
71	G	6.777017E-04	0.0	-6.925702E-03	0.0	0.0	0.0
72	G	6.684046E-04	0.0	-6.001132E-03	0.0	0.0	0.0
73	G	7.003127E-04	0.0	-5.042514E-03	0.0	0.0	0.0
74	G	7.340303E-04	0.0	-3.977071E-03	0.0	0.0	0.0
75	G	3.917431E-04	0.0	-2.803227E-03	0.0	0.0	0.0
76	G	7.631553E-04	0.0	-1.510267E-03	0.0	0.0	0.0
77	G	7.417053E-04	0.0	-1.671707E-04	0.0	0.0	0.0
78	G	0.0	0.0	-1.057471E-02	0.0	0.0	0.0
82	G	1.345971E-04	0.0	-1.094217E-02	0.0	0.0	0.0
83	G	2.132254E-04	0.0	-1.037443E-02	0.0	0.0	0.0
84	G	4.107954E-04	0.0	-1.027415E-02	0.0	0.0	0.0
85	G	5.449248E-04	0.0	-1.032900E-02	0.0	0.0	0.0
86	G	6.216915E-04	0.0	-9.693543E-03	0.0	0.0	0.0
87	G	6.216931E-04	0.0	-9.214537E-03	0.0	0.0	0.0
88	G	5.664704E-04	0.0	-8.779252E-03	0.0	0.0	0.0
89	G	1.113553E-03	0.0	-8.221161E-03	0.0	0.0	0.0
90	G	1.754259E-03	0.0	-7.559953E-03	0.0	0.0	0.0
91	G	1.595768E-03	0.0	-6.850622E-03	0.0	0.0	0.0
92	G	1.596635E-03	0.0	-5.951676E-03	0.0	0.0	0.0
93	G	1.571346E-03	0.0	-4.995930E-03	0.0	0.0	0.0
94	G	1.765103E-03	0.0	-3.936074E-03	0.0	0.0	0.0
95	G	1.905425E-03	0.0	-2.770047E-03	0.0	0.0	0.0
96	G	1.973736E-03	0.0	-1.671910E-03	0.0	0.0	0.0
97	G	2.045151E-03	0.0	0.0	0.0	0.0	0.0

Surface
R4

Figure F-6 (Sheet 3 of 6)

LASER POSITION STUDY, SECOND LENS OF ASPHERICAL PROBLEM, 600-3202
 ATMOSPHERIC PRESSURE OF PRISM SURFACE AND SIZE SURFACE
 ALL AROUND UNIFORM SUPPORT ON FLAT SURFACE OUTER BOUNDARY

RELENT LOC	STRESSES IN S T P E S S E S I N	Y R I A X A	E L E M E N T S	MAX	DETERMEDAL
1	1.466444E 02	1.501800E 02	1.501800E 02	1.501800E 02	1.501800E 02
2	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
3	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
4	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
5	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
6	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
7	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
8	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
9	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
10	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
11	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
12	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
13	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
14	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
15	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
16	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
17	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
18	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
19	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
20	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
21	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
22	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
23	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
24	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
25	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
26	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
27	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
28	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
29	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
30	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
31	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
32	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
33	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
34	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
35	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
36	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
37	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
38	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
39	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
40	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
41	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
42	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
43	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
44	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
45	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
46	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
47	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
48	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
49	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02
50	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02	1.187250E 02

Figure F-6 (Sheet 4 of 6)

ALL 360/40 UNIFORM SUPPORT BY FLAT SURFACE OUTER BOUNDARY

STRESSES IN TRIAXIAL ELEMENTS										
ELEMENT ID	LOC	STRESSES IN MATERIAL COORD SYSTEM				MAX		MAX		OCTAHEDRAL
		RADIAL	AXIAL	HOUSING	AXIAL	SHEAR	PRINCIPAL	SHEAR		
16	3	-4.419330E 01	-2.348630E 01	-3.722650E 00	1.461426E 01	-4.804553E 01	2.467880E 01	2.915396E 01		
16	5	-8.609372E 01	-3.503703E 01	-1.063672E 01	2.510913E 01	-7.809132E 01	3.183435E 01	3.119193E 01		
21	C	9.541470E 01	5.367750E 01	2.500000E 01	8.561336E 02	5.362250E 01	2.708634E 01	2.603412E 01		
21	1	-1.709430E 02	-1.408201E 02	4.164675E 02	1.407100E 01	-1.947704E 00	1.051591E 00	9.016361E 01		
21	3	1.717470E 02	1.717470E 02	4.175530E 01	-1.523430E 01	1.717470E 02	8.575312E 01	8.214495E 01		
21	5	-3.737331E 03	-1.047031E 00	2.226503E 01	2.734375E 01	-3.725946E 00	1.981770E 00	1.738530E 00		
22	C	5.147194E 01	5.438370E 01	-1.953120E 01	6.362173E 01	5.438370E 01	2.252791E 01	2.552791E 01		
22	1	-3.751711E 00	-3.109375E 00	1.406750E 01	1.156325E 00	-4.166022E 00	2.376270E 00	2.036575E 00		
22	3	1.721125E 02	1.721125E 02	-3.041077E 02	-0.062530E 01	1.721125E 02	8.644308E 01	8.160927E 01		
22	5	-7.774231E 00	-5.307190E 00	-3.229165E 01	1.444513E 00	-0.064131E 00	3.793031E 00	3.314475E 00		
23	C	5.132711E 01	5.370106E 01	1.136760E 02	1.071701E 01	5.370106E 01	2.668560E 01	2.464321E 01		
23	1	-1.557741E 00	-2.742105E 00	-2.195111E 01	1.556432E 00	-1.557741E 00	3.723119E 00	1.264470E 00		
23	3	1.751940E 02	1.727072E 02	9.043430E 01	-1.367656E 00	1.751940E 02	8.759160E 01	8.292625E 01		
23	5	-1.557741E 00	-4.097640E 00	-2.560030E 01	3.136719E 00	-1.611710E 01	0.016129E 00	4.561243E 00		
24	C	4.473730E 01	4.473730E 01	-1.111701E 00	3.071195E 00	4.473730E 01	2.635902E 01	2.468303E 01		
24	1	-1.542255E 01	-9.076710E 00	-7.031250E 01	4.712790E 00	-1.666111E 01	3.775902E 00	7.180040E 00		
24	3	1.741810E 02	1.750201E 02	4.553710E 01	-2.007913E 01	1.750201E 02	8.720870E 01	8.197032E 01		
24	5	-2.732744E 01	-1.501540E 01	-2.364777E 02	6.452125E 00	-2.001494E 01	1.391827E 01	1.336515E 01		
25	C	3.624533E 01	4.537670E 01	-1.103550E 00	5.262372E 00	4.537670E 01	2.416787E 01	2.094293E 01		
25	1	-2.715134E 01	-1.502736E 01	-2.300719E 03	6.435544E 00	-2.006018E 01	1.375533E 01	1.137659E 01		
25	3	1.759570E 02	1.759570E 02	2.261719E 02	-2.759570E 00	1.759570E 02	8.917040E 01	8.320790E 01		
25	5	-4.771470E 01	-2.150704E 01	-3.244541E 00	1.214713E 01	-4.771470E 01	2.375810E 01	1.940263E 01		
26	C	1.751470E 01	3.636011E 01	4.622450E 01	1.771795E 01	3.636011E 01	2.359145E 01	1.971112E 01		
26	1	-4.511134E 01	-2.417113E 01	-4.559345E 00	1.751720E 01	-5.023490E 01	2.544446E 01	2.070730E 01		
26	3	1.603470E 02	1.727964E 02	3.485477E 01	-0.436240E 01	1.727964E 02	9.620575E 01	1.064010E 01		
26	5	-4.521711E 01	-3.527171E 01	-8.700766E 00	2.351430E 01	-7.624420E 01	3.795427E 01	3.102220E 01		
27	C	-3.433171E 01	3.275121E 00	-8.115677E 00	2.622757E 01	-5.213951E 01	3.104057E 01	2.783555E 01		
27	1	-4.537771E 01	-3.433171E 01	-1.291430E 01	2.500150E 01	-7.819143E 01	3.901544E 01	3.111430E 01		
27	3	1.131367E 02	1.509035E 02	1.699360E 01	4.527344E 00	1.699360E 01	7.506851E 01	6.607970E 01		
27	5	-1.627194E 00	-1.162119E 02	-2.662450E 01	5.455157E 00	-1.627194E 00	8.721206E 01	7.132710E 01		
28	C	-3.453430E 01	-4.506165E 01	-2.130745E 01	3.068350E 01	-6.767710E 01	3.770293E 01	1.202063E 01		
28	1	-1.131367E 02	-1.070142E 02	-1.941727E 02	5.441731E 01	-1.941727E 02	7.732561E 01	6.626751E 01		
28	3	1.711370E 02	1.551392E 02	1.177605E 00	2.447107E 01	1.551392E 02	7.032344E 01	6.643790E 01		
28	5	-4.537771E 01	-4.506165E 01	-4.219307E 02	3.139724E 01	-7.734570E 01	3.157995E 01	2.547155E 01		
31	C	1.136730E 02	1.136730E 02	1.210930E 01	1.136730E 01	1.136730E 02	5.617275E 01	5.351131E 01		
31	1	-1.711370E 02	-3.068350E 01	1.711370E 01	2.461750E 01	-1.711370E 02	1.956010E 01	1.711370E 01		
31	3	1.722770E 02	1.722770E 02	3.159313E 01	-2.595455E 01	1.722770E 02	8.577921E 01	8.050762E 01		
31	5	1.722770E 02	1.722770E 02	-1.019525E 01	4.712525E 01	1.722770E 02	6.638233E 01	6.114462E 01		
32	C	1.137730E 02	1.137730E 02	-1.009652E 01	-4.115360E 02	1.137730E 02	5.629213E 01	5.354421E 01		
32	1	-3.556222E 01	-3.556222E 01	3.323113E 01	6.923410E 01	-5.717043E 00	2.733705E 00	2.269773E 00		
32	3	1.711370E 02	1.224415E 02	8.591750E 02	-4.017525E 01	1.711370E 02	8.664351E 01	8.151826E 01		
32	5	1.711370E 02	1.711370E 02	3.068350E 01	-3.661357E 01	1.711370E 02	6.677611E 01	5.164522E 01		
33	C	1.137730E 02	1.137730E 02	5.070125E 02	6.762675E 02	1.137730E 02	5.651675E 01	5.112305E 01		
33	1	-1.545590E 01	-0.551700E 00	1.531551E 01	2.571425E 00	-1.545590E 01	1.159030E 01	6.306303E 00		
33	3	1.711370E 02	1.711370E 02	3.120000E 01	-1.107154E 00	1.711370E 02	8.755271E 01	8.211347E 01		
33	5	1.711370E 02	1.711370E 02	-2.734375E 01	-1.137015E 00	1.711370E 02	8.021964E 01	6.278326E 01		
34	C	1.137730E 02	1.137730E 02	-3.994570E 01	3.994570E 01	1.137730E 02	5.655934E 01	5.311279E 01		
34	1	-2.232450E 01	-1.221370E 01	-1.375000E 00	3.109375E 00	-2.074421E 01	9.434662E 00	8.116536E 00		
34	3	1.751470E 02	1.751470E 02	3.251750E 01	-1.201250E 00	1.751470E 02	6.935412E 01	6.316895E 01		
34	5	1.751470E 02	1.751470E 02	5.741250E 01	-6.245117E 01	1.751470E 02	8.870140E 01	8.315695E 01		

Figure F-6 (Sheet 5 of 6)

ALL AROUND UNIFORM SUPPORT ON FLAT SURFACE OUTER BOUNDARY

ELEMENT ID	LOC	STRESSES IN MATERIAL COORD. SYSTEM						MAX			OCTAHEDRAL
		RADIAL	AXIAL	THETA	AXIAL	THETA	AXIAL	PRINCIPAL	SHEAR	PRINCIPAL	
35	C	1.044517E 02	1.094255E 02	-5.703125E -01	2.344238E 00	1.094255E 02	5.527406E 01	5.088316E 01			
35	I	-6.471214E 01	-2.321633E 01	-2.439453E 03	1.170516E 01	-4.802872E 01	2.431770E 01	1.9880674E 01			
35	B	1.911287E 02	1.767070E 02	1.001000E 00	-2.630184E 00	1.011475E 02	9.010307E 01	8.391943E 01			
35	S	1.772144E 02	1.763434E 02	-2.500000E -01	-2.120117E 00	1.772441E 02	8.375969E 01	8.347293E 01			
36	C	9.437411E 01	1.075710E 02	-1.433200E 00	4.715234E 00	1.073710E 02	5.452280E 01	4.944411E 01			
36	I	-5.276400E 01	-2.527344E 01	-4.433491E 03	1.105469E 01	-5.005300E 01	2.753752E 01	2.245747E 01			
36	B	1.804754E 02	1.773271E 02	7.187500E 00	-2.115737E 00	1.809629E 02	9.013069E 01	9.417266E 01			
36	S	1.874218E 02	1.742483E 02	3.984375E -01	1.509521E 00	1.742483E 02	8.693172E 01	9.051373E 01			
37	C	7.735747E 01	9.995174E 01	-1.953747E 03	9.337491E 00	9.995174E 01	5.152029E 01	4.436513E 01			
37	I	-7.375765E 01	-3.549493E 01	-9.103544E 03	2.610406E 01	-8.035720E 01	4.040106E 01	1.334141E 01			
37	B	1.574531E 02	1.744531E 02	2.054588E 00	5.102539E -02	1.744531E 02	8.620039E 01	7.962923E 01			
37	S	1.340714E 02	1.652466E 02	2.296479E 00	2.547607E 00	1.652466E 02	8.149872E 01	7.131242E 01			
38	C	2.339454E 01	6.774101E 01	-5.363176E 01	3.198120E 01	6.774101E 01	6.664551E 01	5.636412E 01			
38	I	-1.121945E 02	-5.337327E 01	-5.022290E 01	5.110115E 01	-1.427599E 02	6.155013E 01	5.095390E 01			
38	B	1.265114E 02	1.807153E 02	8.824429E 01	-1.655762E 01	1.807153E 02	4.931866E 01	4.027307E 01			
38	S	4.798034E 01	9.749130E 01	-1.958181E 02	5.921758E 01	-2.093099E 02	1.534408E 02	1.373474E 02

○ Element ID;
Elastic elements are 3-D,
Linear Strain, Axisymmetric
elements (TRIA6 in Nastran)

Figure F-6 (Sheet 6 of 6)

HAUL
CYCLE 0

13:20:55-----02/04

COLOR 3

1	RAY	CLR	M		N		E.D.		DEL	UPD
			0.0	Y	0.0	Z	0.0	Z		
1	3	1.00	0.0	7.307271E-05	0.0	0.0	0.0	-4.200041E-05		
2	3	0.75	0.0	5.976041E-05	0.0	0.0	0.0	-4.448560E-05		
3	3	0.50	0.0	3.271401E-05	0.0	0.0	0.0	-2.300560E-05		
4	3	0.25	0.0	1.474061E-05	0.0	0.0	0.0	-3.702450E-07		

$$I(\mu\text{m}) = (e)(7.3 \times 10^{-5} \text{ W}) = 26 \mu\text{m}$$

Figure F-7 (Sheet 2 of 2)

indicated that the $1.3\mu\text{m}$ geometrical blur for the on-axis image degrades to about $26\mu\text{m}$ with the pressure applied. The back focal length (BFL) of the lens changed by $120\mu\text{m}$ when the pressure was applied. This indicates that focusing must be done at operational pressure if that lens design is used. The singlet plus distorted window* design (see Figure F-8) did not degrade performance-wise and the BFL of that design did not change appreciably. The application of pressure across an element with optical power is not recommended.

In order to determine the effects of decentering of the collimated beam input to the focusing lens, the aspheric singlet design was analyzed with 0.5-mm and 1.0-mm displacements. The image quality was unchanged by these beam translations. It was estimated that translation of several millimeters could be tolerated before the performance of the f/2 lens degrades significantly.

* Window distortions were calculated from standard equations for an edge supported round plate.

10:08:11-----01/30/75

WAVELENGTH NO. SURFACE	RADIUS	TRANSMISS 0.0	1.00000 MO-1. JEX 1.00000	0.0 HI-INDEX 1.00000	0.0 LO-INDEX 1.00000	PLI BL-NAME	8.943830D-12 1ST-BNDY 2ND-BNDY
1 ASPHER.	0.54179	0.0064	1.50664	1.51086	1.51086 BK 7	0.0	0.0
2 SPHER.	0.54275	0.0305	1.00000	1.00000	1.00000 AIR	0.0	0.0
3 ASPHER.	003.0106	0.0577	1.50664	1.51086	1.51086 BK 7	0.0	0.0
4 ASPHER.	003.0106	0.4849	1.00000	1.00000	1.00000 AIR	0.0	0.0
5 SPHER.	INF	0.0	1.00000	1.00000	1.00000 AIR	0.0	0.0

F-27

NO.	E	A(4)	A(6)	A(8)	A(10)
1	1.0000000 00	-5.044444(-01)	-1.057257(-01)	-1.766550(-01)	-5.752428(-01)
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0

1

OBJECT USAGE	ENTR.PUP.DIST	FHST.PPPL.PNT	EDV.FCL.LGTH	SCND.PPPL.PNT	EXT.PUP.DSTNG	IMAGE DISTNG
INF	0.0	0.013308	0.999900	0.115081	-0.121474	0.880885
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.PPPL.FND	THACK LENGTH	USE.SPCE.FND	EXT.PUP.SIZE	IMAGE HEIGHT
INF	0.004943	INF	INF	2.003001	0.903102	0.001745
MAGNIFICATION	SEMIANG.FIELD	BACK.VIA.DIST	BARREL LENGTH	FHNT.VTX.DIST	SEMIANG FIELD	DEMAGNIFICATION
0.0	0.100000	INF	0.163100	1.047985	0.059304	INF
APT.STOP SIZE	APT.STOP DIST	FROM SRCE.NO	*****	FLD.STOP SIZE	FLU.STOP DIST	FROM SRCE.NO
0.499903	0.0	1		0.003491	0.880885	4

Figure F-8 (Sheet 1 of 2)

RAUL
CYCLE 2
COLOR 3

16:08:11-----01/30/

M				N		E.P.			
RAY	CLR	Y	Z	Y*	Z*	DEL	OP		
1	3	1.00	0.0	-1.568450-06	0.0	0.0	-1.956220-07		
2	3	0.75	0.0	1.630150-06	0.0	0.0	-2.108460-07		
3	3	0.50	0.0	1.948420-06	0.0	0.0	-7.497240-08		
4	3	0.25	0.0	3.709700-07	0.0	0.0	-6.007190-09		

(X100)(X100)=1.72

M				N		F.P.			
RAY	CLR	Y	Z	YPR	ZPR	DIST	YS	DEL	Y
9	3	0.0	0.0	9.94800-04	0.0	-3.16760-11	-1.97940-07	-2.30780-	

RAY	CLR	Y	Z	Y*	Z*	DEL	OPD
5	3	1.00	0.0	1.327630-05	0.0	0.0	-1.131700-06
6	3	0.75	0.0	7.644710-06	0.0	0.0	-5.258580-07
7	3	0.50	0.0	4.022440-06	0.0	0.0	-1.489160-07
8	3	0.25	0.0	7.467430-07	0.0	0.0	-1.247660-08
9	3	0.0	0.0	0.0	0.0	0.0	0.0
10	3	-0.25	0.0	2.201990-07	0.0	0.0	7.172510-09
11	3	-0.50	0.0	5.625440-07	0.0	0.0	2.594120-08
12	3	-0.75	0.0	5.254660-06	0.0	0.0	1.652560-07
13	3	-1.00	0.0	1.733490-05	0.0	0.0	8.497850-07
14	3	0.0	1.00	3.979170-06	-1.760190-06	0.0	-1.702960-07
15	3	0.0	0.75	1.846190-06	1.476130-06	0.0	-1.967330-07
16	3	0.0	0.50	6.397430-07	1.847620-06	0.0	-6.874670-08
17	3	0.0	0.25	1.572030-07	3.212620-07	0.0	-4.458210-09

(X100)(X100)=5.150
=1.84

M				N		E.P.			
RAY	CLR	Y	Z	YPR	ZPR	DIST	YS	DEL	Y
22	3	0.0	0.0	4.00020-03	0.0	-2.05450-09	-3.20060-06	-3.73150-	

RAY	CLR	Y	Z	Y*	Z*	DEL	OPD
18	3	1.00	0.0	5.253690-05	0.0	0.0	-3.294360-06
19	3	0.75	0.0	2.254490-05	0.0	0.0	-1.105900-06
20	3	0.50	0.0	7.535440-06	0.0	0.0	-2.083180-07
21	3	0.25	0.0	5.739540-07	0.0	0.0	8.759120-09
22	3	0.0	0.0	0.0	0.0	0.0	0.0
23	3	-0.25	0.0	3.314780-06	0.0	0.0	8.772730-08
24	3	-0.50	0.0	1.700360-05	0.0	0.0	4.944610-07
25	3	-0.75	0.0	3.013010-05	0.0	0.0	1.672010-06
26	3	-1.00	0.0	7.056420-05	0.0	0.0	4.670820-06
27	3	0.0	1.00	1.599400-05	-4.486110-06	0.0	2.138740-07
28	3	0.0	0.75	7.422400-06	-8.602200-07	0.0	1.735300-06
29	3	0.0	0.50	2.413330-06	3.216100-07	0.0	2.569090-08
30	3	0.0	0.25	6.320260-07	-4.324360-07	0.0	1.903840-08

(X100)(X100)=7.72

Figure F-8 (Sheet 2 of 2)

PERKIN-ELMER

Report No. 12486

APPENDIX G

MANUFACTURER'S DATA

1101 Bristol Road,
Mountainside,
New Jersey, 07092
Tel: (201) 233-7200
Telex: 138275

Integrated Photomatrix Incorporated

April 17, 1975

Mr. Walter Zukowsky
Perkin Elmer Corp.
50 Danbury Road
Wilton, Connecticut 06897

Dear Mr. Zukowsky,

Thank you for your inquiry regarding our IPL 30 photodiodes. We have obtained the following answers to your technical questions.

The quantum efficiency at 1.06 microns is 30% of the maximum which occurs at 0.86 microns. A plot of the spectral response is attached.

In order to achieve 1 nsecond response, an input amplifier of very low impedance is necessary. The limiting rise time is the capacitance of the detector times the forward resistance of the structure. This latter component includes the amplifier input. Maximum safe current will be a few 100 mA. Linearity will be no problem. All silicon detectors are fundamentally linear. This has been evaluated over 12 orders of magnitude! When a light spot crosses an apparent dead space there is no zero point, only a null. This is because the geometrically defined detector has a collection area up to 30 to 50 microns outside its perimeter.

We are unable to supply similar photodiodes with larger quadrants at this time.

Please contact us if you have further questions.

Very truly yours,

Dick Richards
Technical Sales

1161 Forest Road,
Haddonfield,
New Jersey, 07942
Tel. (201) 235-7200
Telex: 198725

Integrated Photomatrix Incorporated

Now 50% more area per chip
Pusher capability - 1 msec
10.6" diameter - up to 30% more value

No. PX 124 January 1971

SI PHOTODIODES IPL 30/31/32

A family of silicon planar photodiodes designed to cover a multitude of applications. All feature low noise and leakage properties together with high quantum efficiency.
IPL 30 - a four quadrant diode for very accurate position sensing.
IPL 31 - an annular configuration of two diodes with a sharp transfer characteristic for accurate edge-sensing.
IPL 32 - a single photodiode for all linear applications.

IPL 30 - Technical Data

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Responsivity	2070°K Tungsten Peak (0.85 μ)		75 260		μ A/mW μ A/mW
Displacement * Responsivity	Per quadrant, for a centred spot moving parallel to a dividing line, in terms of total power in spot. SPOT DIA: 0.5mm 0.1mm		0.1 2.5 0.5 12.5		μ A/mW/ μ μ A/mW/.001" μ A/mW/ μ μ A/mW/.001"
Positional Variation of Responsivity *				±3	%
Quadrant Mismatching				±3	%
Noise Equivalent Displacement *	Spot dia. 0.1mm Spot power 0.12mW		0.82		μ
Dark Current	Per Quadrant -1V Bias -20V Bias		< 30 1	2	pA nA
Capacitance	Per Quadrant -5V Bias -20V Bias		15 10		pF pF
Rise Time	Zero Bias, 470 Ω Load		30		nS
Reversed Breakdown Voltage		-80			V
Operating Temperature Range		-55		+85	°C
Temp. Coefficient of Responsivity			-0.3		%/°C

* IPL 30 only

IPL 31 where different from above

Dark Current	-1V Bias -20V Bias		< 50 0.4	2	pA nA
Capacitance	Per Diode -5V Bias -20V Bias		27 17		pF pF
Rise Time	Zero Bias, 470 Ω Load		50		nS

IPL 32 where different from above

Dark Current	-1V Bias -20V Bias		< 10 0.5	2	pA nA
Capacitance	-5V Bias -20V Bias		33 20		pF pF
Rise Time	Zero Bias, 470 Ω Load		60		nS

Integrated Photomatrix Limited reserves the right to make changes at any time in order to improve the design and specification of their products

SPECIFICATIONS

PARAMETER	OPERATING CONDITIONS	TYPE 7226			TYPE 7258			TYPE 7221-Q			UNITS
		min	typical	max	min	typical	max	min	typical	max	
Active area		5.1			20.0			73.0	quad		mm ²
Package style		TO-9			TO-8			WIDE ANGLE			See mechanical
Operating voltage			180.0	250.0		180.0	250.0		180.0	250.0	Volts
Breakdown voltage	100µA leakage, 25°C	300.0	500.0		300.0	500.0		300.0	500.0		Volts
Dark current	180 volts, 25°C		15.0	60.0		50.0	100.0		100.0	500.0	Nanoamps
Channel impedance	180 volts, 25°C	1.0	5.0		1.0	3.0		1.0	3.0		Megohms
Spectral sensitivity	180 volts, 25°C, 1.08µm	0.43	0.51		0.43	0.51		0.43	0.51		Amps/Watt
Quantum efficiency	180 volts, 25°C, 1.08µm	50.0	60.0		50.0	60.0		50.0	60.0		%
Spectral range		0.35		1.13	0.35		1.13	0.35		1.13	µm
Rise time	180V, 25°C 10% to 90% (Rise) 90% to 10% (Fall)		8.0	10.0		8.0	10.0		10.0	15.0	Nanoseconds
Fall time			10.0	15.0		10.0	15.0		15.0	20.0	Nanoseconds
N.E.P. 20µA	180 volts, 25°C (1.06, 10 ³ , 1)		1.5x10 ¹³			2.9x10 ¹³			3.4x10 ¹³		Watts/Hz ^{1/2}
Capacitance	180 volts, 25°C		3.0	5.0		12.0	20.0		18.0	30.0	Picofarads
Linearity over 5 decades	180 volts, 25°C		5.0			5.0			5.0		%
Anode common with cath			YES			YES			NO		

NOTE: These photodiodes consist of an N⁺ type diffusion into high resistivity P type silicon.

OPERATING CIRCUIT

- A = ACTIVE AREA
- G = GUARD RING
- R_L = LOAD RESISTOR
- I₀ = GUARD RING PHOTOCURRENT NORMALLY BY-PASSED THROUGH POWER SUPPLY
- C_G = GUARD RING DEPLETION LAYER CAPACITANCE
- R_G = GUARD RING JUNCTION RESISTANCE

EQUIVALENT CIRCUIT

- C_G = GUARD RING TO ACTIVE CHANNEL CAPACITANCE
- R_G = GUARD RING TO ACTIVE CHANNEL IMPEDANCE
- R_D = DYNAMIC SHUNT RESISTANCE
- C_D = DEPLETION LAYER CAPACITANCE
- I_s = SIGNAL CURRENT
- R_s = SERIES RESISTANCE (UNDEPLETED BULK SILICON PLUS CONTACT RESISTANCE)
- C_L = LOAD CAPACITANCE

DATA SHEET NO. 1013

HOW TO ORDER

Specify quantity and type number as shown on above table.

UPON REQUEST:

- (1) APPLICATION NOTES
- (2) DATA SHEETS OR CATALOG HANDBOOKS DESCRIBING OTHER CONFIGURATIONS AND DETECTOR TYPES SUCH AS LEAD SULFIDE, LEAD SELENIDE, AND INDIUM ANTIMONIDE
- (3) DESIGNER'S GUIDE AND CATALOG, OPTICAL FILMS

PRICES AND SPECIFICATIONS SUBJECT TO
CHANGE WITHOUT NOTICE

general photonics corporation

March 5, 1975

AIR MAIL - SPECIAL DELIVERY

John Cunniff
Perkin Elmer Corp.
100 Wooster Heights Road
Danbury, Connecticut 06810

Dear Mr. Cunniff:

Thank you for your inquiry regarding General Photonics Corporation VAG-TWO lasers.

Probably the most frequent usage of our lasers is in the alignment of large glass laser systems, however, relatively little data is relayed back to us regarding information such as you requested.

Parameter on which we do have some measurements is the very short term (10 Hertz and higher) beam wander which is typically less than 10% of the beam divergence. This wander is typically due to thermal effects within the laser rod and would not appear on a meter output. Expected value for beam wander as you describe it would be less than 5% and possibly as low as 1 or 2% of the beam divergence.

Incidntally, the absolute angle beam wander can be reduced by the use of a beam expander since the wander is usually a percentage of beam divergence. A 6x beam expander such as our Model 102 will reduce the beam divergence of the Model TWO-12A from 3 milliradians to about 0.5 milliradians. Five percent of the expanded beam divergence is then 25 microradians instead of the 150 microradians of the unexpanded beam.

Please note the Model TWO-15 has a lower initial beam divergence, provides lamp accessibility without disturbing optical alignment, and the output can be continuously varied via the DC power supply provided.

Typical delivery of the Model TWO-12A is about 30 days, and the Model TWO-15 is 60 days.

John Cunniff

-2-

March 5, 1975

If you have any further questions please do not hesitate to contact me or our representatives in your area. They are:

Cook & Weil, Inc.
518 Madison Drive
E. Windsor Twp., NJ 08520
(609) 448-7409

We look forward to hearing from you soon.

Sincerely yours,

GENERAL PHOTONICS CORPORATION

D. B. Osborn
Vice President
Research/Engineering

DBO:rs
Encls.

Model TWO-15

VERSATILE Nd:YAG LASER

The Model TWO-15 is a versatile, CW, Nd:YAG Laser using advanced techniques for high performance. A special resonator design permits all of the output power to be delivered in a single transverse mode.

A symmetrical laser head; easily replaceable, low-cost pump-lamps; and stable, reliable operation make the TWO-15 an ideal laser for industrial, scientific or OEM use.

Some common applications include: material removal, communications, optical displays, holography, alignment, ranging, illumination, recording, spectroscopy, thermal studies, component testing and multiple wavelength interactions.

Many accessories are available for use with the Model TWO-15 including Q-switches; frequency doublers; beam expanders, automatic amplitude control; polarizers and closed-loop coolers.

Features

- * High Single-Mode Efficiency
- * Symmetrical, Easy-Access Laser Head
- * Full Range of Accessories Available
- * Externally Accessable Mirror Adjustments
- * Low-Cost, Long-Life Pump Lamps
- * Lamp Changing Without Breaking Water Seals
- * Thermally Compensated Resonator Structure
- * Intracavity Space at Both Ends

Specifications

Output Wavelength:	1.064 micrometers ⁽¹⁾
Power Output, TEM ₀₀ :	2 watts, CW
Beam Diameter:	2 millimeters
Beam Divergence:	2 milliradians
Stability:	
Short Term:	3% RMS ⁽²⁾
Long Term:	5% RMS
Polarization:	Unpolarized ⁽³⁾
Intracavity Space:	10 centimeters, front 10 centimeters, back
Pump Lamps:	tungsten-halogen
Dimensions:	
Optical Head:	16 cm W x 19 cm H x 60 cm D
Power Supply:	49 cm W x 49 cm H x 60 cm D
Weight:	
Optical Head:	10 kilograms (22 pounds)
Power Supply:	65 kilograms (145 pounds)
Electrical Input:	208 volts; 3Ø; 50/60 Hertz, 2.7 kilowatts
Cooling:	Clean water at 7.5 liters/minute, (2 GPM) Water temperature 15° to 35°C
Price:	\$7,500 ⁽⁴⁾ FOB Santa Clara, California

- NOTES: (1) 1.34 micrometer option available
(2) improved stability ($\pm 1\%$ RMS) available
with Automatic Amplitude Control (AAC)
(3) optional polarizer available
(4) price slightly higher outside of continental USA

DATA SHEET

BEAM EXPANDERS MODELS 100/101/102

BEAM EXPANDERS, MODELS 100/101/102

MODEL 101

MODEL 102

The Models 101 and 102 are general purpose Beam Expanders designed for use at 1.06 micrometers.

The versatile Beam Expanders may be used to enlarge or reduce the size of a laser beam; increase or decrease beam divergence; position; or, focus a collimated input beam at a distant target.

High quality, anti-reflective coated optics are used to optimally shape a laser beam wavefront at 1.06 micrometers.

Both Beam Expanders use afocal optical designs and may be used with continuously pumped, pulsed or Q-switched lasers or other 1.06 micrometer optical instruments and systems.

Some typical systems applications for the Beam Expanders include: optical communications; alignment; illumination; optical radar; intrusion alarms; material studies and general purpose laboratory experimentation.

Each Beam Expander consists of a diverging lens assembly, an objective lens assembly and adjustable retaining ring.

FEATURES

Multipurpose operation — may be used as a beam expander, collimator or focusing lens.

Antireflective coated optics to optimally shape a laser wavefront at 1.06 micrometers.

Translation mechanism permits precise positioning of the output beam.

Focusing range at infinity to plus and minus three meters.

Pulsed, Q-switched or CW lasers may be used.

Up to 50 watts average power may be transmitted.

Threaded mount for easy attachment to YAG-TWO™ lasers or other 1.06 micrometer lasers.

Lockable focusing ring prevents defocusing and assures repeatable operation.

3004 Lawrence Expressway, Santa Clara, California 95051 (408) 736-7114

MULTI-PURPOSE BEAM EXPANDERS

AS A BEAM EXPANDER

AS A COLLIMATOR

AS A FOCUSING LENS

MODEL 100 BEAM EXPANDER KIT

The Model 100 Beam Expander Kit contains the necessary optics for 3x and 6x beam expansion.

Included in the Model 100 Beam Expansion Kit is a common diverging lens assembly, a 3x objective lens assembly, a 6x objective lens assembly, a common adjustable retaining ring and a protective storage/carrying case.

In either the 3x or 6x configuration the Beam Expander is the same as the Model 101 or Model 102 respectively.

Price of the Model 100 Beam Expander Kit is \$990.*

SPECIFICATIONS

	Model 101	Model 102		Model 101	Model 102
Beam Expansion Ratio:	3 to 1	6 to 1	Optical Coating:	1.05 micrometers A/R	
Input Aperture:	7 mm	6 mm	Optical Transmission:	>90%	>90%
Output Aperture:	21 mm	36 mm	Beam Positionable:	± 10 milliradians—orthogonal	
Effective f/number:	3.6	4.2	Size: diameter x length, mm (inches)	51x80 (2x3.2)	51x156 (2x6.1)
Focusing Range:	infinity to ± 3 meters		Weight: grams (pounds)	250 (.55)	350 (.77)
Maximum Average Power:	50 watts	50 watts	Mounting:	standard C mount (1"-32) male thread	
Peak Power Density:	10 ⁴ w/cm ²	10 ⁴ w/cm ²	Price*	\$590	\$690
Optical System:	refractive — afocal optimized for 1.05 micrometers				

* All prices are FOB factory. Slightly higher outside of continental USA.

general photonics corporation 3004 Lawrence Expressway, Santa Clara, California 95051 (408) 736-7114

LOW COST FET-INPUT OP AMP

AD503

PIN CONFIGURATION

Top View

This circuit has excellent dynamic performance, with a typical slew rate of 6V/μsec, and is supplied in the TO-99 package for operation from 0 to +70°C and -55°C to +125°C.

GENERAL DESCRIPTION

The AD503 IC FET-input op amp provides medium to high performance at low cost for all general purpose applications where the measurement of low-level currents, or small voltages from high impedance sources is a primary requirement. Despite low cost, this model offers such benefits as bias current (maximum for either input) and offset voltage specified under fully warmed-up conditions, minimum gain guaranteed with the offset voltage both nulled and unnulled, and minimal variation in offset voltage drift with nulling. The AD503 series provides higher accuracy with maximum bias currents below 10pA, maximum offset voltage of less than 20mV, maximum offset voltage drift below 25μV/°C and minimum CMRR above 80dB.

ELECTRICAL SPECIFICATIONS (Typical at +25°C and ±15VDC, unless otherwise noted)

PARAMETER	AD503J	AD503K	AD503S
Open Loop Gain (Note 1)			
$V_{OUT} = \pm 10V$, $R_L \geq 2k\Omega$	20,000 min	50,000 min	50,000 min
$T_A = \text{min to max}$	15,000 min	40,000 min	25,000 min
Output Characteristics			
Voltage @ $R_L = 2k\Omega$, $T_A = \text{min to max}$	$\pm 10V$ min	*	*
@ $R_L = 10k\Omega$, $T_A = \text{min to max}$	$\pm 12V$ min	*	*
Load Capacitance	750pF	*	*
Short Circuit Current	25mA	*	*
Frequency Response			
Unity Gain, Small Signal	1.0MHz	*	*
Full Power Response	100kHz	*	*
Slew Rate, Unity Gain	3.0V/μsec min	*	*
Settling Time, Unity Gain (to 0.1%)	10μsec	*	*
Input Offset Voltage (Note 2)			
$T_A = \text{min to max}$	50mV max	20mV max	20mV max
vs Supply, $T_A = \text{min to max}$	75μV/°C max	25μV/°C max	50μV/°C max
vs Supply, $T_A = \text{min to max}$	400μV/V max	200μV/V max	200μV/V max
Input Bias Current			
Either Input (Note 3)	15pA max	10pA max	10pA max
Input Impedance			
Differential	$10^{11} \Omega / 12pF$	*	*
Common Mode	$10^{12} \Omega / 12pF$	*	*
Input Noise			
Voltage, 0.1Hz to 10Hz	15μV (p-p)	*	*
5Hz to 50kHz	5.0μV (rms)	*	*
(= 1kHz (spot noise))	10.0nV/√Hz	*	*
Input Voltage Range			
Differential	±3.0V	*	*
Common Mode, $T_A = \text{min to max}$	$\pm 10V$ min	*	*
Common Mode Rejection, $V_{in} = \pm 10V$	70dB min	80dB min	80dB min
Power Supply			
Rated Performance	±15V	*	*
Operating	±(5 to 18)V	*	±(5 to 22)V
Quiescent Current	7mA max	*	*
Temperature			
Operating, Rated Performance	0 to +70°C	*	-55°C to +125°C
Storage	-65°C to +150°C	*	*
Price			
(1-24)	\$16.80	\$23.00	\$29.00
(25-99)	\$14.00	\$18.80	\$23.50
(100-999)	\$11.40	\$16.00	\$20.00

1.0078.

1. Open Loop gain is specified with V_{IN} both nulled and unnulled.

2. Input offset spec is guaranteed after 5 minutes of operation at $T_A = +25^\circ C$.

3. Bias current spec is guaranteed after 5 minutes of operation at $T_A = +25^\circ C$. For higher temperatures, the current doubles every +10°C.

* Same as for AD503J.

LINEAR IC's 187

C & D SERIES

These motors are designed for use in applications requiring high accuracy and low noise. They are available in two sizes, 1/2" and 1" diameter, and are available in two mounting styles, flange and foot. They are available in two types, C and D, which differ in their internal wiring and in their mounting style.

Series D are similar to Series C except for short turnoff, shaft eccentricity and perpendicularity of mounting face to shaft. Stepping accuracy of both C and D types is $\pm 3\%$ maximum.

Speed torque characteristics of stepping motors

are dependent on the type of driver and the load. In applications where data presented in this section are obtained with motor of excitation shown in Table 1 (dual phase, unipolar) and open loop. Drive Model 6662 is utilized for start-stop curve, and Model 6661 for running curve. Source voltage of 28VDC and appropriate resistors (see Fig 3 to 13) are used to maintain the rated current. With buffered drivers, speed of 10,000 pulse per second is achievable.

TABLE 2 ELECTRICAL CHARACTERISTICS

MODEL ** NUMBER	ACCURACY	RES. μ	RATED VOLTAGE*	CURRENT PER PHASE	INDUCTANCE PER PHASE	TIME FOR SINGLE STEP	HOLDING TORQUE	MAXIMUM RUNNING TORQUE	DETENT TORQUE	MAXIMUM THRUST LOAD	MAXIMUM OVERTWING LOAD	ROTOR INERTIA	WEIGHT	LENGTH	SIZE
23D 6102 23C 6102	3%	5.1	5.1	1.0	10 G	2.5	53	35	5	25	15	87	20	2.0	23
23D 6108 23C 6108	3%	0.33	1.3	1.9	0.63	2.0	53	35	5	25	15	87	20	2.0	
23D 6204 23C 6204	3%	2.6	4.3	1.8	5.7	2.8	100	65	8	25	15	234	32	3.25	
23D 6209 23C 6209	3%	0.37	1.7	4.7	0.8	2.2	100	65	8	25	15	234	32	3.25	
23D 6306 23C 6306	3%	1.16	3.4	2.9	2.9	2.6	150	100	10	25	15	320	44	4.0	
23D 6309 23C 6309	3%	0.48	2.2	4.6	1.2	4	150	100	10	25	15	320	44	4.0	
34D 9106 34C 9106	3%	0.95	2.9	3.0	3.8	3.9	150	110	5	50	25	643	52	2.45	
34D 9109 34C 9109	3%	0.39	1.8	4.8	1.5	3.1	150	110	5	50	25	643	52	2.45	
34D 9209 34C 9209	3%	0.55	2.5	4.6	2.5	3.9	300	200	10	50	25	1200	88	3.7	34
34D 9311 34C 9311	3%	0.52	2.8	5.5	2.9	4.1	450	300	15	50	25	1850	124	5.31	
34D 9314 34C 9314	3%	0.31	2.2	7.0	1.68	3.4	450	300	15	50	25	1850	124	5.31	
UNIT	PER- CENT	OHMS	VDC	AMP	MILLI- HENRY	MILLI- SEC.	OZ-IN	OZ-IN	OZ-IN	LBS	LBS	GM- CM ²	OZ	INCH	

*Source Voltage = 28 VDC

** Use suffix A for single shaft
and C for double ended shaft. (e.g. 23C-6108C)

DYNAMIC CHARACTERISTICS

Source Voltage: 28 VDC

Mode: Dual Phase

FIG 3 23D-6102

FIG 4 23D-6108

FIG 5 23D-6204

FIG 6 23D-6209

FIG 7 23D-6306

FIG 8 23D-6309

FIG 9 34D-9106

FIG 10 34D-9109

FIG 11 34D-9209

FIG 12 34D-9311

FIG 13 34D-9314

FIGURE 1
SCHEMATIC

TABLE 1
SWITCHING SEQUENCE
FOR DUAL PHASE EXCITATION

STEP	RED	GREEN	RD-WT	GRN-WT	SK & WT
1	—	—	0	0	+
2	0	—	—	0	+
3	0	0	—	—	+
4	—	0	0	—	+

TABLE 2

GENERAL CHARACTERISTICS

Operating Temperature: -55°C to $+125^{\circ}\text{C}$
 Insulation Resistance: 1000 Megohms
 Min. with 500 VDC
 End Play: .005 Inch Max with 16 Oz Load
 Radial Play: .001 Inch Max with 16 Oz Load
 Shaft Runout:
 C Series, .001 Max
 D Series, .002 Max
 Shaft Concentricity with $\pm$ Dia:
 C Series, .001 TIR
 D Series, .003 TIR
 Perpendicularity of Surface $\perp$ with Shaft:
 C Series, .001 TIR
 D Series, .003 TIR

FIGURE 2
SIZE 23

FIGURE 3
SIZE 34

* USE SUFFIX "A" FOR SINGLE SHAFT AND "C" FOR DOUBLE SHAFT (e.g. 23C-6108C)

COMPUTER DEVICES OF CALIFORNIA
 11901 Burke St., Santa Fe Springs, Calif. 90670
 (213) 694-2595 • TELEX: 65-7478

RAPID SYN

DRIVERS

M4 SERIES

M6 SERIES

DESCRIPTION:

Rapid-Syn Drivers are solid state pulse-to-step converters capable of providing bi-directional operation of the stepping motor.

All Rapid-Syn Drivers listed, except Model M2301F, are designed to drive 3 Phase and 4 Phase motors regardless of type or step angle of the motor. Model

M2301F is a bi-polar driver designed for 4 Phase PM motors.

All models require 2.4 to 30 volts positive going pulse with a minimum pulse width of 20 micro-seconds (TTL comparable). For rated input voltage and maximum current rating of various models, refer to table.

GENERAL SPECIFICATIONS:

Operating Temperature Range: 0°C to 60°C

Input Impedance: 3KΩ Minimum

Switching Capability: 10K PPS Minimum

Model No.	Rated Current Amp / Phase Max.	Rated Voltage VDC	Excitation Mode	Connection Diagram	Type
M61	6	10 to 40	Single Phase	Fig. 1, 2, 3	Unipolar
M62	6	10 to 40	Dual Phase	Fig. 1, 2, 3	Unipolar
M68	6	10 to 40	Single, Dual	Fig. 1, 2, 3	Unipolar
M43010	3	22 to 34	Single Phase	Fig. 1, 2, 3	Unipolar
M43028	3	22 to 34	Dual Phase	Fig. 1, 2, 3	Unipolar
M83010	3	22 to 34	Single, Dual	Fig. 1, 2, 3	Unipolar
M2301F	3	22 to 34	Two Phase	Fig. 4	Bipolar

FIG. 1

FIG. 2

FIG. 3

FIG. 4

Computer
Devices

COMPUTER DEVICES OF CALIFORNIA
11901 Burke St., Santa Fe Springs, CA 90670
(213) 698-2595 723-6593

STEPPED MOTORS

Clifton offers a wide variety of permanent magnet or variable reluctance stepper motors in sizes 8 through 15.

Clifton also designs and manufactures the logic and pulse source modules for stepper motors. The convenience of stepper motors where signals are presented as pulse trains rather than analog voltages is making them more and more popular with servo designers.

Critlon stopper motors, like our servo motors, have distinct advantages of construction and high temperature resistance as standard units over competitive types. Materials in Critlon stoppers can withstand 200°C. Improved insulation makes current leakage as a variation with temperature the lowest in the industry. In addition, Critlon motors incorporate several extra features as: welded leads, flanged bearings, and the use of materials and design with high thermal conductivity for improved heat dissipation.

STEPPER MOTOR ELECTRICAL CHARACTERISTICS

CATALOG NO.	DIAMETER (IN)	LENGTH (FROM M.T.) IN	INDIC. ANGLES	TYPE	INERTIA	M.T. RESPONSE RATE PULSES/SEC	M.T. ALLOW RATE PULSES/SEC	HOLDING TORQUE OZ-INCHES	DEVIANT OF IN ZERO INPUT	WEIGHT (OZ)	D.C. RESISTANCE (OHMS)
MSA-11-AS-1	0.750	1.112	90° ± 3°	PM2G	0.45	250	300	0.75	0.13	1.7	300
MSA-11-AS-2	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-3	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-4	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-5	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-6	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-7	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-8	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-9	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-10	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-11	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-12	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-13	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-14	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-15	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-16	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-17	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-18	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-19	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-20	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-21	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-22	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-23	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-24	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-25	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-26	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-27	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-28	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-29	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300
MSA-11-AS-30	0.750	0.720	90° ± 3°	PM2G	0.19	175	200	0.15	0.05	1.15	300

20 replications measured and used. 30 replications measured and used to enter slip on a load curve.

STEPPER MOTOR CIRCUITRY

MOTOR STARTS

Motor	Type	Size	Speed	Start	Stop	Time	Time
MSA-11-AS-1	PM2G	0.750	175	100	100	100	100
MSA-11-AS-2	PM2G	0.750	175	100	100	100	100
MSA-11-AS-3	PM2G	0.750	175	100	100	100	100
MSA-11-AS-4	PM2G	0.750	175	100	100	100	100
MSA-11-AS-5	PM2G	0.750	175	100	100	100	100
MSA-11-AS-6	PM2G	0.750	175	100	100	100	100
MSA-11-AS-7	PM2G	0.750	175	100	100	100	100
MSA-11-AS-8	PM2G	0.750	175	100	100	100	100
MSA-11-AS-9	PM2G	0.750	175	100	100	100	100
MSA-11-AS-10	PM2G	0.750	175	100	100	100	100
MSA-11-AS-11	PM2G	0.750	175	100	100	100	100
MSA-11-AS-12	PM2G	0.750	175	100	100	100	100
MSA-11-AS-13	PM2G	0.750	175	100	100	100	100
MSA-11-AS-14	PM2G	0.750	175	100	100	100	100
MSA-11-AS-15	PM2G	0.750	175	100	100	100	100
MSA-11-AS-16	PM2G	0.750	175	100	100	100	100
MSA-11-AS-17	PM2G	0.750	175	100	100	100	100
MSA-11-AS-18	PM2G	0.750	175	100	100	100	100
MSA-11-AS-19	PM2G	0.750	175	100	100	100	100
MSA-11-AS-20	PM2G	0.750	175	100	100	100	100
MSA-11-AS-21	PM2G	0.750	175	100	100	100	100
MSA-11-AS-22	PM2G	0.750	175	100	100	100	100
MSA-11-AS-23	PM2G	0.750	175	100	100	100	100
MSA-11-AS-24	PM2G	0.750	175	100	100	100	100
MSA-11-AS-25	PM2G	0.750	175	100	100	100	100
MSA-11-AS-26	PM2G	0.750	175	100	100	100	100
MSA-11-AS-27	PM2G	0.750	175	100	100	100	100
MSA-11-AS-28	PM2G	0.750	175	100	100	100	100
MSA-11-AS-29	PM2G	0.750	175	100	100	100	100
MSA-11-AS-30	PM2G	0.750	175	100	100	100	100

20 replications measured and used. 30 replications measured and used to enter slip on a load curve.

STEPPER CONTROLLERS

529-1 SPECIFICATIONS

Output Patterns: Modes 1, 2 or 3

Signal Voltage: 5.0 volts peak minimum
Input Impedance: 5k minimum
Bi-directional: CW and CCW inputs
Maximum Pulse Rate: 1000 pulses/sec. minimum

TYPICAL WIRING CONFIGURATION

Output Patterns: Modes 1, 2, and 3
Load: 500ma maximum
Supply Current: 50ma + motor current
Supply Voltage: 28VDC $\pm 10\%$

MOTOR CONNECTION PATTERNS

Since a controller output is a current sink when the output is 0 and a current source when the output is 1, various modes of motor operation can be obtained. The connections and the advantages of each are shown below:

Motor Connections	Center	Blue	Green	Red	White	Black
Winding 1	1	4	2	3	5	6
Winding 2	1	4	2	3	5	6
Mode 1	1	4	2	3	5	6

TYPICAL OUTPUT SEQUENCE

Input Pulses	Potential of Output Terminals
1	1 0 1 0
2	1 0 1 0
3	1 0 1 0
4	1 0 1 0

1 = Switch Under +5VDC
0 = Switch Under -5VDC

Model 529-1 529-2 529-3

OUTLINE DRAWING

529-2 / 529-3 SPECIFICATIONS

Output Patterns: 529-2 Mode 13, 529-3 Mode 03.

Bi-directional: CW and CCW inputs by direct control voltage
Direction Control Voltage: 5VDC (0.5VDC applied to Pin 1)
Input Impedance of Direction Control: 5k minimum
Output Patterns: 529-2 Mode 13, 529-3 Mode 03
Maximum Pulse Rate: 1000 pulses/sec. minimum
Signal Voltage: 5.0 volts peak minimum
Supply Current: 100ma + motor current
Input Impedance: 5k minimum

TYPICAL WIRING CONFIGURATION

TYPICAL OUTPUT SEQUENCE

Input Pulses	Potential of Output Terminals
1	1 0 1 0
2	1 0 1 0
3	1 0 1 0
4	1 0 1 0

1 = Switch Under +5VDC
0 = Switch Under -5VDC

TYPICAL OUTPUT SEQUENCE

Input Pulses	Potential of Output Terminals
1	1 0 1 0
2	1 0 1 0
3	1 0 1 0
4	1 0 1 0

1 = Switch Under +5VDC
0 = Switch Under -5VDC

- Two and Four Phase Motors
- Mode 0: One half of one of the two center tapped windings excited.
Torque: 70% rated, Figure of merit - 1.4.
- Mode 1: One half of each of two center-tapped windings excited.
Torque: 1Med, Figure of merit - 1.
- Mode 2: Each winding excited one at a time and in alternate directions.
Torque: 70% rated, Figure of merit - 2.37
- Mode 3: Both windings excited all the time in alternate directions.
Torque: rated, Figure of merit - 2.0.

Three Phase Motors

- Mode 03: One winding excited at a time
- Mode 13: Two windings excited at a time

556-3 SPECIFICATIONS

Output Pattern: Mode 1.

Signal Voltage: Positive Pulses - 0 to 5VDC
Input Impedance: 5k minimum
Pulse Rate: 1000 pulses/sec. maximum
Maximum Pulse Rate: up to 1000 FPS

TYPICAL WIRING CONFIGURATION

TYPICAL OUTPUT SEQUENCE

Input Pulses	Potential of Output Terminals
1	1 0 1 0
2	1 0 1 0
3	1 0 1 0
4	1 0 1 0

1 = Switch Under +5VDC
0 = Switch Under -5VDC

Model 556-3

OUTLINE DRAWING

THE EMPCO SMOOTH TOUGH and SILENT SHUTTER

A "behind the lens"
auto-electromagnetic
photographic shutter.
that completely eliminates
annoying vibration and hum.

This EMPCO Shutter (Type RS) was designed specifically for the graphic arts, process cameras, enlargers and projection machines. With total insulation, simple construction and minimal moving parts, its rugged but precise electromagnetic action noiselessly opens and closes at approximately 1/25 second under the continuous hard use it was designed for. Far superior to delicate "between the lens" shutters, it has been time tested—with thousands in use in plants worldwide.

- Positive action square design, hole in center
- Light weight, firm gauge aluminum construction
- Heavy duty, brass bushings
- Non-chipping, anodized, black matte finish
- Standard wings are M-N type 2, rigid, black matte, opaque material
- Available normally closed
- Normally used in vertical position (horizontal position available on request)
- Complete with attached power rectifier unit, 10' cable and connectors, 55, 125V 25-60 cycle.
- DC operation available, 110V standard (specify voltage requirements). Very small case.

**ELECTRONIC
MECHANICAL
PRODUCTS CO.**

STANDARD SHUTTER SIZES

APERTURE OPENING	OVERALL FRAME SIZE
2" (Type S only)	4 1/4" x 4 1/4"
2 1/2"	5" x 5 1/4"
3"	6" x 6 1/4"
3 1/2"	6 3/4" x 7"
3 3/4" Special	7 1/4" x 8"
4"	7 3/4" x 8"
4 1/2"	8 1/4" x 8 1/2"
5"	8 3/4" x 9"

Prices of larger sizes up to 10" aperture opening on request.
All Prices FOB Atlantic City, N. J.

929-935 ATLANTIC AVE., ATLANTIC CITY, N.J. 08404 • (609) 344-8557

PERKIN-ELMER

Report No. 12486

APPENDIX H

TRANSMITTANCE CALCULATIONS

APPENDIX H

TRANSMITTANCE CALCULATIONS

The transmittance of the auxiliary laser to various points of sensing in the alignment system are computed. Polarization losses upon transmission through unactivated elements (Faraday rotators, etc.) are far greater than absorption losses and are listed in Table H-I, below, for the case of coalignment sensing as shown in Figure H-1.

TABLE H-1. TRANSMITTANCE FROM A/O TO COALIGNMENT SENSOR

<u>Element</u>	<u>T(%)</u>	<u>Loss (dB)</u>
Polarizer No. 1	98.5	0.06
Pockel's Cell	98.0	0.05
Rod Amplifier	100.0	0
Spatial Filter	70.0	1.55
Beamsplitter No. 1	50.0	3.00
Beamsplitter No. 2	50.0	3.00
Faraday Rotator	98.0	0.09
Rod Amplifier	100.0	0
Polarizer No. 2	50.0	3.00
	8.3%	10.79 dB

The transmittance from the auxiliary oscillator to the surrogate target is given in Table H-II.

Figure H-1. Co-alignment Sensor Optical Path Used in Calculating Transmittance Losses

TABLE H-II. TRANSMITTANCE FROM A/O TO SURROGATE TARGET

<u>Element</u>	<u>T(%)</u>	<u>Loss (dB)</u>
Polarizer #1	98.5	0.06
Pockel's Cell	98.0	0.09
Rod Amplifier	100.0	0
Spatial Filter	70.0	1.55
Beamsplitter #1	50.0	3.0
Beamsplitter #2	50.0	3.0
Polarizer #2	50.0	3.0
Beamsplitter #3	40.0	3.98
Beamsplitter #4	50.0	3.0
Apodizing Aperture	10.0	10.0
Polarizer #3	100.0	0
Polarizer #4	50.0	3.0
Polarizer #5	50.0	3.0
α Amplifier	50.0	3.0
β Polarizer	100.0	0
β Amplifier #1	50.0	3.0
β Polarizer	100.0	0
β Amplifier #2	100.0	0
Spatial Filter	75.0	1.25
γ Polarizer	100.0	0
γ Amplifier #1	50.0	3.0
γ Polarizer	100.0	0
γ Amplifier #2	100.0	0
$\gamma +$ Polarizer	<u>95.0</u>	<u>0.22</u>
	0.00376 (%)	44.15 dB Loss

The additional loss to the opposing sensor off the γ^+ polarizer is only 0.06 dB above the 44.15 dB calculated above.

If centering alignment using the γ^+ polarizer and a reference flat mirror are considered, there is an additional loss of 13 dB to the sensor to give a total loss of 57 dB (auxiliary laser to sensor on near side of chamber).

Auxiliary laser optics losses are given in Table H-III.

TABLE H-III. AUXILIARY LASER OPTICS LOSSES

<u>Element</u>	<u>T(%)</u>	<u>Losses (dB)</u>
Beam Expander	90	0.45
Fold Mirror	95	0.2
Phase Plates (2 plates, 4 surfaces)		
2% per Surface	92	0.35
2 Axis Servo Mirror	95	0.2
Fold Mirror	95	0.2
Retro		
Air/Glass (2 surfaces)	96	0.2
Mirror (3 reflectors)	86	0.65
Absorption Losses	$\approx$ <u>90</u>	<u>0.45</u>
	53	2.70
Sensor Losses		
3 Elements	89	0.45
(6 Air/Glass surfaces 2% per surface)		
Prism	<u>99</u>	<u>0.05</u>
	88	0.50

APPENDIX I

OPTICAL PATH DIFFERENCE SENSING

THE PERKIN-ELMER CORPORATION

OPTICAL GROUP

TECHNICAL MEMORANDUM

Register No.: RC-107

Key Words: equal path interferometry,
coherence length sensing,
diffuse reflection,
laser fusion

Author: Robert Crane

Department: Optical Systems

Date: May 14, 1975

Title: Optical Path Difference Sensing

Optical Path Difference Sensing

1. Requirement

In the Livermore laser fusion experiment there is a need to equalize optical path lengths of the multiple amplifier channels to insure simultaneous arrival at the pellet of pulses from each channel. There is therefore a requirement for a sensor to measure optical path differences (OPD) between channels with a precision of a few millimeters. It is preferred that a scheme be found which requires no additional optical elements in the beam paths being measured, and that an existing source be used.

2. Approach

The suggested measurement concept senses the OPD between two channels at a time using equal-path interferometry with a quasi-coherent source. Source coherence is selected so that interference takes place only when the OPD is less than the source coherence length, which can be on the order of a millimeter. A detector then senses interference fringe contrast, where maximum contrast corresponds to minimum OPD. An ac system is suggested to avoid ambiguity between fringe contrast and dc drift of either the source or the detector.

Others have suggested that the existing 2 watt cw laser can be used as a source with the appropriate coherence length obtained by PM modulation (1). This memo is primarily concerned with the detection portion of the measurement.

Several detection arrangements have been suggested, including the use of:

- a) diffracted energy from a very small pellet
- b) reflected energy from a specular pellet
- c) scattered energy from a diffuse pellet

(1) J. L. Kreuzer

The use of a diffuse pellet allows the detector to be placed at an unused input window of the fusion chamber so no elements need to be inserted in the active channels. It also results in at least 20 db greater signal level at the detector. Detection of interference between diffusely reflected light has limitations which will be described subsequently.

3. Previous Experience

The detection of fringe contrast for OPD control is not a new idea. It was used several years ago in the first Active Optics experiment to automatically align the relative displacement of mirror segments to a few microinches. A white light source and Koesters prism equal-path interferometer were used. The concept is described by figure 1. Because of the very small OPD to be measured, the coherence length of the source x detector combination was made very short. Figures 2 & 3 shown several interferograms for different type sources. Interferogram A in figure 3 was used in the experiment.

Results of the Active Optics axial alignment tests are shown in figure 4. Short term precision was within 5 microinches. Long term accuracy was not measurable because of thermal drift in the monitoring instrument. However, the 20-inch segmented mirror assembly always produced a diffraction limited point source image.

Previous experience with interferometry via diffusely reflected light is limited to special cases such as the:

- a) holograph
- b) scatter-plate interferometer
- c) speckle-detection for velocity sensing

Therefore, an experiment was performed to demonstrate interference under conditions simulating the laser fusion optical arrangement.

4. Experimental Data

The purpose of this experiment was to demonstrate:

- a) the availability of high contrast interference fringes using diffusely reflected light
- b) the limitations of this approach.

Time and available apparatus limited the experiment to the use of a laser source only.

Two optical arrangements were tried. (see figures 5 and 8) The arrangement of figure 5 was used to demonstrate static fringe characteristics. Polaroid pictures of the fringe patterns are given in figures 6 and 7. Figure 6 shows the speckle pattern for two different adjustments of the OPD control. The first limitations of this concept is shown by these pictures:

- a) for good fringe contrast the detector must be small compared to the speckle pattern
- b) it will be necessary to adjust detector position to avoid areas of very high frequency in the speckle pattern.

Figure 7 shows the effect of beam misalignment. If the two beams strike the pellet at different positions there will be a line fringe pattern at the detector plane with a spatial frequency of:

$$k = \frac{s}{\lambda r}$$

where: s = image separation between images
from the two beams

λ = wavelength

r = distance from pellet to detector

The pictures in figure 7 were obtained by an axial displacement of the diffuse surface which caused the speckle spatial frequency to increase plus a fringe pattern due to a finite value of "s".

Dynamic fringe contrast measurements were made with the optical arrangement of figure 8. In this case the OPD was varied continuously by a triangular wave oscillator driving a rotating window. Figure 9 shows the fringe contrast obtained after optimizing the iris position. This was done by translating the reflector instead of the iris. The bottom trace of each recording shows the OPD drive. The top trace of figure 10 shows the effect of OPD drift. The bottom recording in this figure was obtained by rotating the average angle of the OPD wobble window to 45 degrees, thus generating an OPD wobble of many wavelengths.

5. Conclusion

The results of this experiment indicate that optical path differences can be sensed by detecting fringe contrast resulting from reflections from a diffuse pellet if certain precautions are taken. These include:

- a) use a detector size smaller than the speckle pattern
- b) provide for detector position adjustment
- c) use dynamic OPD wobble of more than one wavelength

Figure 11 shows how this sensor technique might be incorporated into the laser fusion optical system.

Figure 1. Optical Arrangement of the Ambiguity Sensor Used in the Active Optics Experiment to Adjust Segment Axial OPD Within One Wavelength

Source = Sunlight, Detector = PbS

Source = Tungsten Arc, Detector = Si

Source = HeNe Laser

Figure 2. Interferograms Obtained with Different Light Sources and Detectors

Relative
Scale

Zero Path Difference

Mirror Separation (No Scale)

A. Source: Tungsten Arc

Detector: Silicon Photo Diode 1N2175

Relative
Scale

Zero Path Difference

Mirror Separation (No Scale)

B. Source: Tungsten Arc

Detector: Lead Sulphide Photoconductor

Figure 3. These are Recordings of Relative Light Intensity vs. Separation of Two Flat Mirrors in a Kesters' Prism Interferometer.

Showing the relative positions at which slew of one segment relative to second was stopped by signal from white light interferometer. Long term drift was due to thermal drift in mount.

Figure 4. White Light Interferometer Performance

Figure 5. Optical Arrangement for Static Fringe Contrast Measurement

Figure 6. Speckle Pattern From Arrangement of Figure 5 for Two Different Adjustments of the OPD Adjust

Small Displacement
From Focal Plane

Large Displacement
From Focal Plane

Figure 7. Speckle Pattern with a Finite Value of Image Separation,
Obtained by Axial Displacement of Diffuse Surface

Figure 8. Optical Arrangement for Dynamic Fringe Contrast Measurement

Figure 9. Interferograms From Optical Arrangement of Figure 8

DETECTOR OUTPUT
SHOWING EFFECT OF
OPD DRIFT

↑
OPD
DRIVE

DETECTOR OUTPUT
WITH LARGE OPD
WOBBLE

↑
DRIVE

Figure 10. Interferograms From Optical Arrangement of Figure 8

Figure 11. OPD Sensor Concept