

ETM02

LIGO-T990141-00-D

BLANK

T970016
ETM 02

LIGO DETECTOR OPTICS
Incoming Inspection Check-off Sheet
Core Optics Blank Material

Page 1 of 1

The purpose of this sheet is to verify material physical dimensions, perform visual inspection, and to facilitate material traceability of LIGO Detector optics. This sheet is to be included in the LIGO Quality Assurance traceability file. Complete a check-off sheet for each optic blank received and inspected.

LIGO Contract No.: PP 207573 Glass Mfg./Order No: Corning / QD 10624801
Core optic Material: (BS ETM ITM ETM RM) Glass Mfg. Part No.: F 855306 FE 08
LIGO Drawing No.: D960794-A-D Manufacturer's Boule No.: 24622D
Optical Glass Spec. MIL-G-174-B Date Received at Caltech: 1-14-97

- Verify glass manufacturer's Certification against LIGO Component Specification No.. E960097-A-D
- Attach a copy of the glass manufacturer's Certification to check-off sheet.
- Attach the glass manufacturer's optical phase maps supplied by vendor per above Component Specifications.
- Visually inspect for shipping container damage. If applicable, describe damage on attached sheet and notify the Cognizant Engineer. Date Notified: NA
- Visually inspect the blanks for damage, for chips on surfaces and edges, or for other defects. If applicable, describe damage/defects on attached sheet and notify Cognizant Engineer. Date Notified: NA
- Verify core optic blank physical dimensions per applicable LIGO drawing.
 - Inspection of material diameter. Diameter 10.110" 256.84 mm
 - Inspection of material thickness. Thickness 4.2860" 108.89 mm
 - Inspection of chamfer.
- Verify that the Registration Mark is present as required by LIGO Component Specification.
- Verify receipt of 25mm X 25mm cylinder Witness Sample(s) required by the LIGO Component Specification and visually inspect for damage. If applicable, describe damage on attached sheet and notify the Cognizant Engineer. Date Notified: NA
- Sign and date original packing slip (shipper) and distribute per paragraph 3.P.

Inspect By: Date Inspected: 1-14-97

Reviewed and/or accepted by:

Cognizant Engineer: Date: 2-25-97

LIGO QA Officer or Designee: _____ Date: _____

LIGO DETECTOR OPTICS
Incoming Inspection Check-off Sheet

Core Optics Blank Material

COMMENTS/DISCREPANCIES: (Disposition damage/discrepancies per LIGO Quality Assurance Plan (LIGO M960076-00-P) paragraphs 5.12 and 5.12.1.) _____

SKETCHES:

DISPOSITIONS: _____

CORNING INCORPORATED
CORNING
CORNING, NEW YORK

SHIPPING ORDER

PACKING LIST

ORD. DATE [PP207573] 08/20/96
 CALIFORNIA INSTITUTE OF TECHNOLOGY
 ACCOUNTS PAYABLE M/S 201-6
 1200 E CALIF BLVD
 PASADENA, CA 91125
 SAME AS "SOLD TO" UNLESS OTHERWISE SPECIFIED
 CALIFORNIA INSTITUTE OF TECHNOLOGY
 ATTN: MR. LOWELL JONES
 291 S HOLLISTON
 PASADENA, CA 91106

DISCOUNT FACTOR []
 DATE ENTERED [08/28/96]
 CANTON, NY
 JPI FOB ORIG PPD FRT INVOICED

CNG ORD NO. [00106248]
 13717
 04 056 04
 13717
 04 056 02
 DESIRED SHIP DATE [11/23/96]
 WE EXPECT TO SHIP [11/25/96]

DATE SHIPPED		INVOICE NUMBER	
DATE SHIPPED		ROUTING <u>520124</u>	
CAR INITIAL AND NUMBER		BEST WAY <u>UPS Recd</u>	
THIS SHIPMENT		PREPAID	COLLECT
PARTIAL	COMPLETE	X	
DATE ISSUED	DATE TO SHIP		
11/2/97	11/3/97		

QTY	WHSE. LOC. - PRODUCT CODE	DESCRIPTION	QUANTITY	
			UNITS	CASES
01	855306 7980 0000	DISC, F S.O A. 10.079"D X 4.252"T, BLANK TOLERANCES: +.040"/-.000" BOTH DIMS FOLDING MIRROR, END TEST MASSES CLEAR APERTURE = 9.252" PRICE INCLUDES 13 WITNESS SAMPLES SAMPLE DIMENSIONS: .984" X .984" CYLINDRICAL WITNESS SAMPLES FROM NEARBY PORTION OF BOULE * BLANKS & CORRESPONDING WITNESS SAMPLES SHALL BE SERIALIZED AS FEXX, WHERE XX INCREMENTS STARTING AT 01. ** SPEC #: LIGO-E960097-A-D DWG#: LIGO-D960794	2	3 FC BW
03	255308 7980 0000	DISC, F S.OA, WITNESS SAMPLE, .984" X .984" CYLINDRICAL YOUR PRODUCT IDENT ->> WITNESS SAMPLES WITNESS SAMPLES FOR ITEMS 1 PRICE IS INCLUDED IN ITEM 001	2	3 FC BW

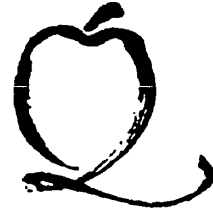
Rec'd 2 cartons
[Signature] 1-14-97
 FE 08

ROUTING

CORNING

334 County Route 16
Canton, New York 13617-9703

Canton Plant . . .



...WHERE QUALITY MIRRORS PRIDE

CERTIFICATE OF COMPLIANCE

Customer: <u>California Institute of Technology</u>	Item: <u>001</u>
Customer Order No.: <u>PP207573</u>	Glass: <u>7980 Grade 0A</u>
Corning Order No.: <u>QD106248</u>	Quantity Shipped: <u>2</u>
Code No.: <u>855306</u>	Date Shipped: <u>1/13/97</u>

Registration Mark for & Serial # per LIGO
 Drawing # D960794-A-D
 Birefringence ≤ 1 nm/cm central 80 mm
 ≤ 5 nm/cm central 200 mm
 Striae per MIL-G-174 Section 4.46 method 1 or 2.

This is to certify that the above material shipped against your order is in conformance with all applicable requirements, specifications, and drawings.

Signed: Brian C. Bush
Brian C. Bush

Title: Quality Assurance Section Leader

Date: 1/13/97

FE Ø7
FE Ø8

DEVIATION APPROVAL FORM

Customer Name: California INST. TECHNOLOGY

Customer P.O. Number: PP 207573

Corning Order Number: QD106 34801

Corning Part Number: F 855306

Drawing Number: E960097-A-D - LIGO - D960794

Boule Number: _____

Quantity Affected: 11 (FE01 Thru FE 11)

Deviation Description: SBT PLCS to be used in lieu of individual pieces of each piece
(attach backup information as deemed necessary)

Cari Lynn Billingsley
Customer Contact (print)

OK
JTB
2/24/97

Randy W. Beard
Authorizing Signature

12/12/96
Date

Send copy with shipment? Y N
(circle Yes or No)

Billing Status

Bill Now

Bill in 30 Days

Other _____

Deviation Number: _____
(sequential number) (year)

cc: Shipping Clerk
Customer Service

FE 08

DATA SHEET - CAL TECH LIGO MIRROR BLANKS

Cal Tech Purchase Order Number:

PP207573

Cal Tech Drawing Number:

LIGO-D960794

Attribute	Specification #	Requirement	Actual	Stamp	
Diameter	Per LIGO - D960097-A-D	10.079", -0.0"/+0.4"	10.104 / 10.104		QA
Thickness	Per LIGO - D960097-A-D	4.252", - 0.0" / + 0.4"	4.2865 / 4.2865 / 4.2865 / 4.2865		QA
Registration Mark	Per LIGO - D960794	Top center of optic	See Attached Cert.		M
Serial & Boule #	Per LIGO -D960794	Boule and Serial No.	24622D-FE08		M
Material	Fused Silica 7980		See Attached Cert.		M
Witness Sample Map			See Attached Map		M
Defects		< 0.5 mm	See Attached Map		QA
Inclusions		< 0.1 mm; < 0.03 mm ² /100cm ² ; < 0.06 mm disregard	See Attached Map		QA
Homogeneity - central		Peak To Valley < 1.0 x 10E-6	1.93 x 10E-7		M
Homogeneity - outside		Peak To Valley < 2.5 x 10E-6	1.51 x 10E-7		M
Interferograms		To be provided	Attached		M
Birefringence	MIL G-174 Section 4.4.5	< 1nm/cm (central 3.150") < 5 nm/cm (central 7.874")	See Attached Cert.		QA
Striae	MIL G-174 Section 4.4.6, Method 1 or 2	Grade <u>A</u>	Inspection Report		M
Absorption		< 20 ppm / cm @ λ = 1.06 μm	See attached Cert.		M

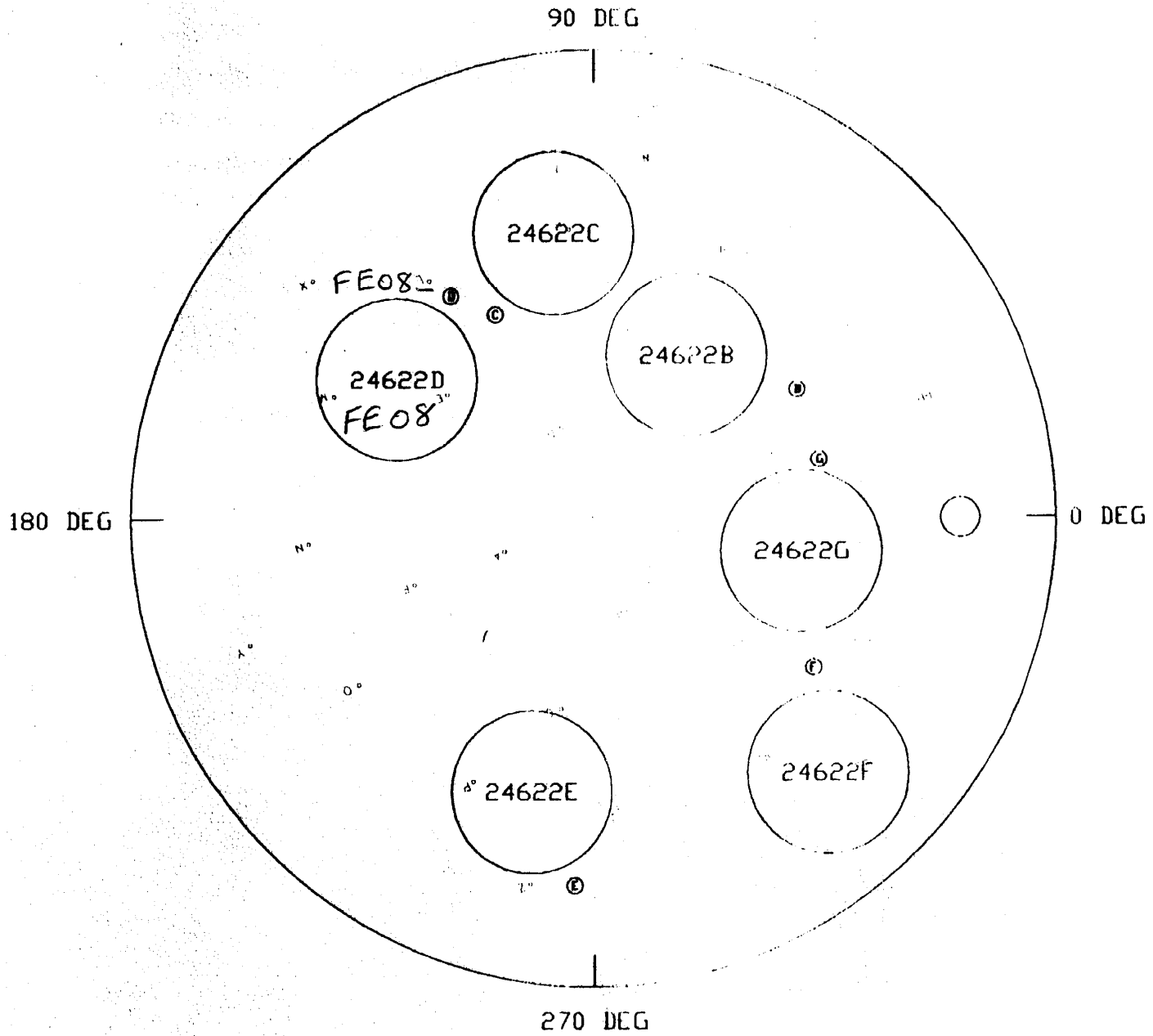
Comments:

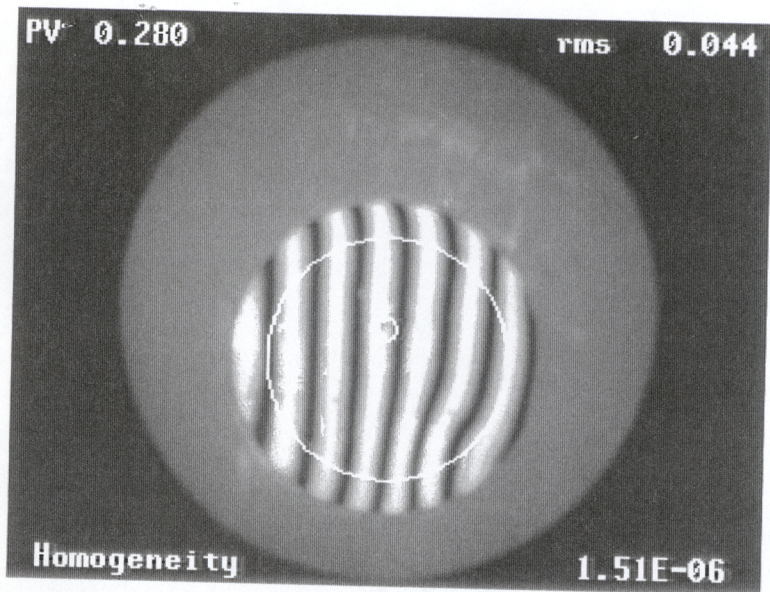
Inspected by:

Gail Andrews

Date: 1-10-97

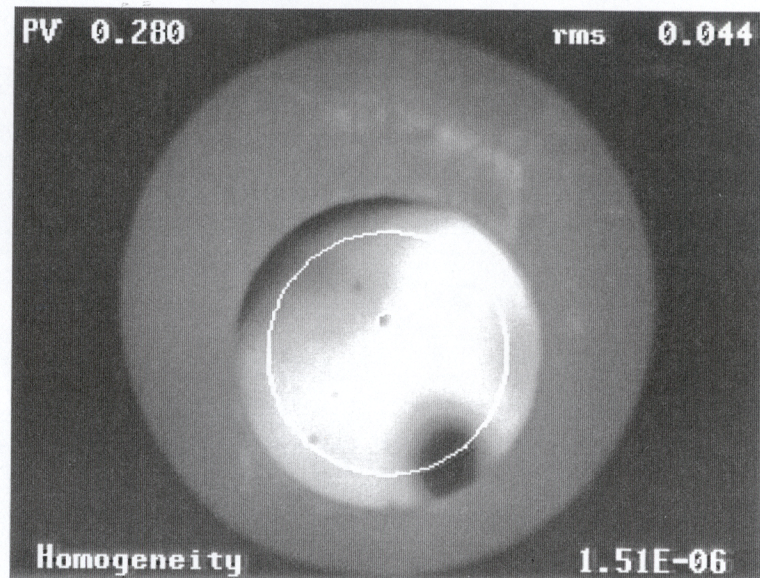
24622D
FE08





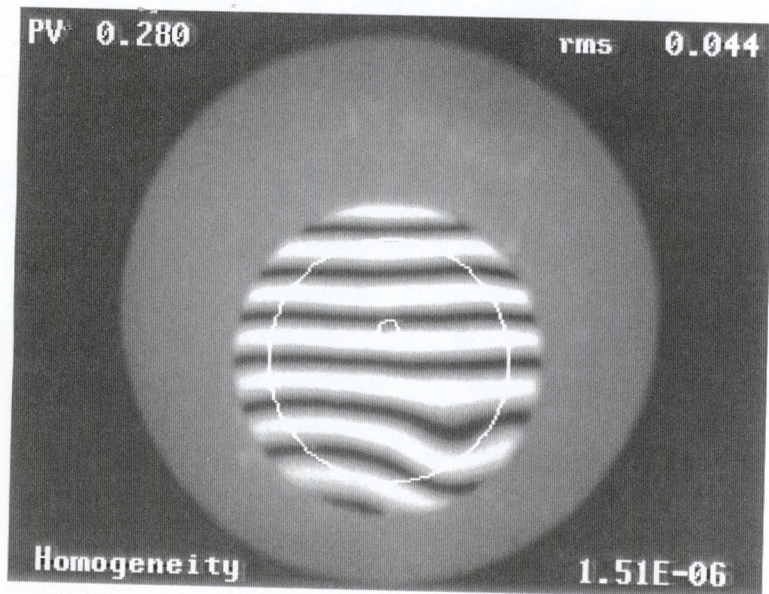
24622D

SN-FE08



24622

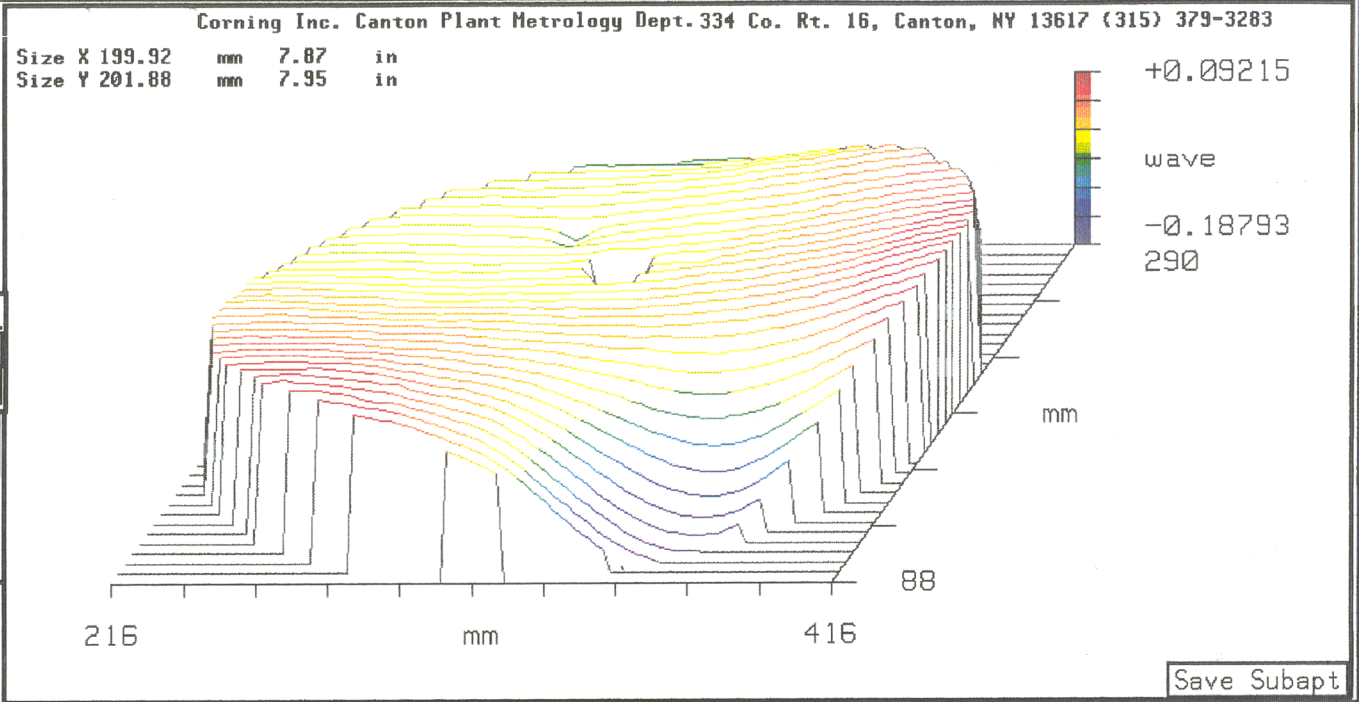
SN-FE08



24622D

FE08

Lg Aperture
 PV 0.280 wave
 rms 0.044 wave
 Power 0.000 wave
 Homogeneity 1.51E-06
 Points 8171
 AstMag (Z) 0.170 wave



zygo Spike
 Remove Spikes: Off (xRMS): 3.00
 Data Fill: Off Data Fill Max: 25

Removed:
 PST TLT PWR
 PST TLT PWR AST CMA SA3
 Zern Terms: 36

Zernike Coefficients from 8170 data points
 Order: 10th Terms: 36 rms: 0.005

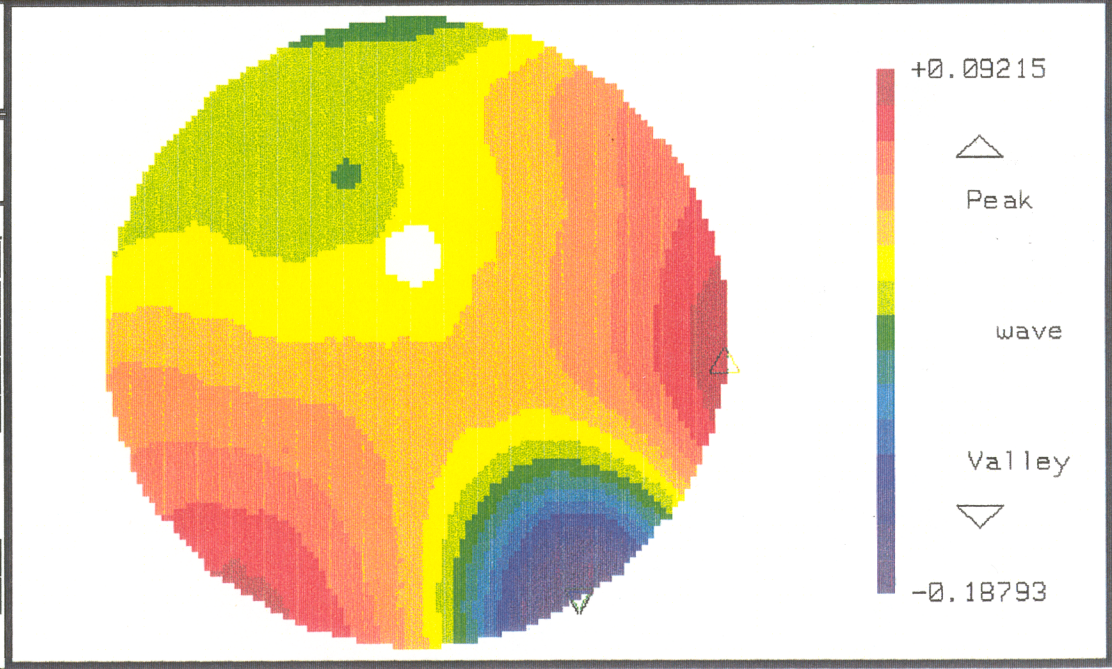
0.000	-0.001	-0.001	0.000						
0.040	0.075	-0.002	0.011	-0.001					
0.061	0.006	0.001	-0.008	0.006	-0.012	0.000			
0.021	-0.031	-0.009	0.001	-0.001	-0.005	0.001	0.000	0.000	
-0.007	-0.031	-0.009	0.008	-0.003	-0.001	-0.001	0.000	-0.002	

Measure Mask Data Save Data **DBSAVE**
 Analyze Calibrate Load Data

zygo File Data

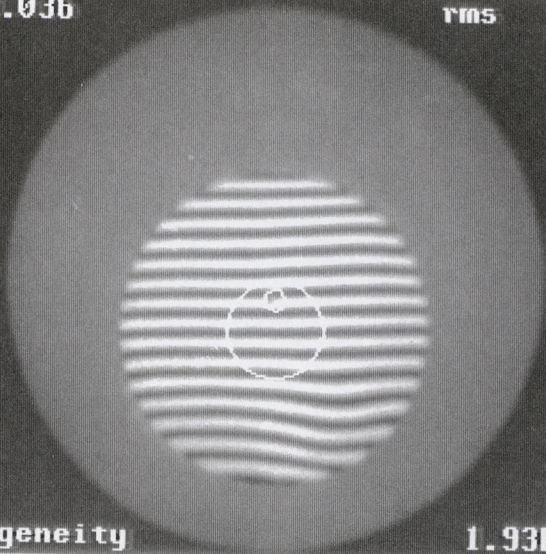
Subtract Sys Err: On Min Mod (%): 1
 Sys Err File: r121396.8a2 Phase Res: High
 Part Thickness: 4.61 in Scale: 0.500
 Boule #: 24622 AGC: Off
 Suffix: D Light Level: 110

CAL TECH *3N-FE08* Comment:
 Data File: 24622D1.ct Phase Avgs: 6
 Camera Res: 1.9500 mm Intens Avgs: 6
 Time: Sat Jan 04 23:37:00 1997



PV 0.036

rms 0.006



Homogeneity

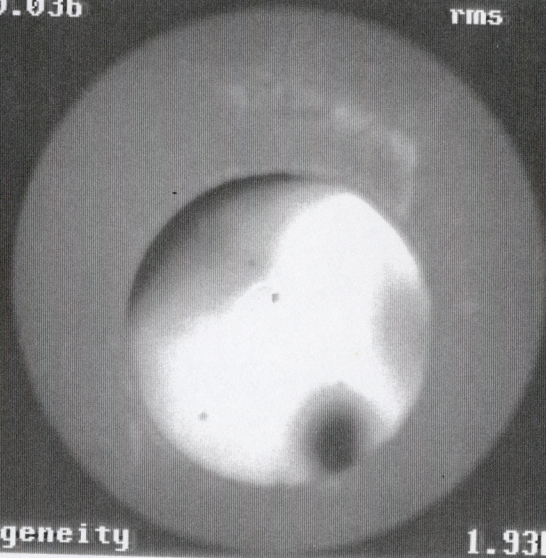
1.93E-07

24622D

SN-FE08

PV 0.036

rms 0.006



Homogeneity

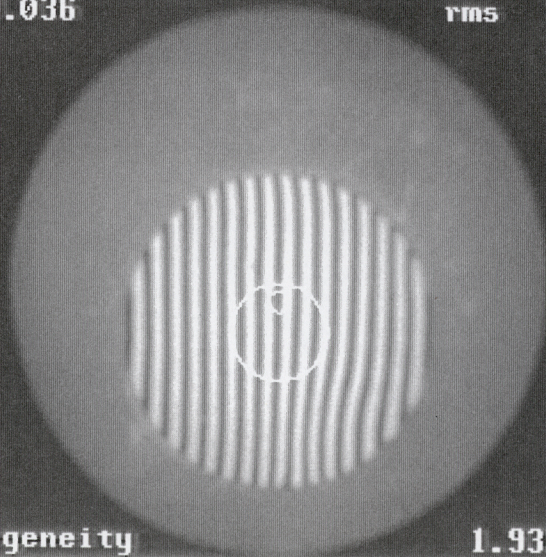
1.93E-07

24622D

SN FE08

PV 0.036

rms 0.006



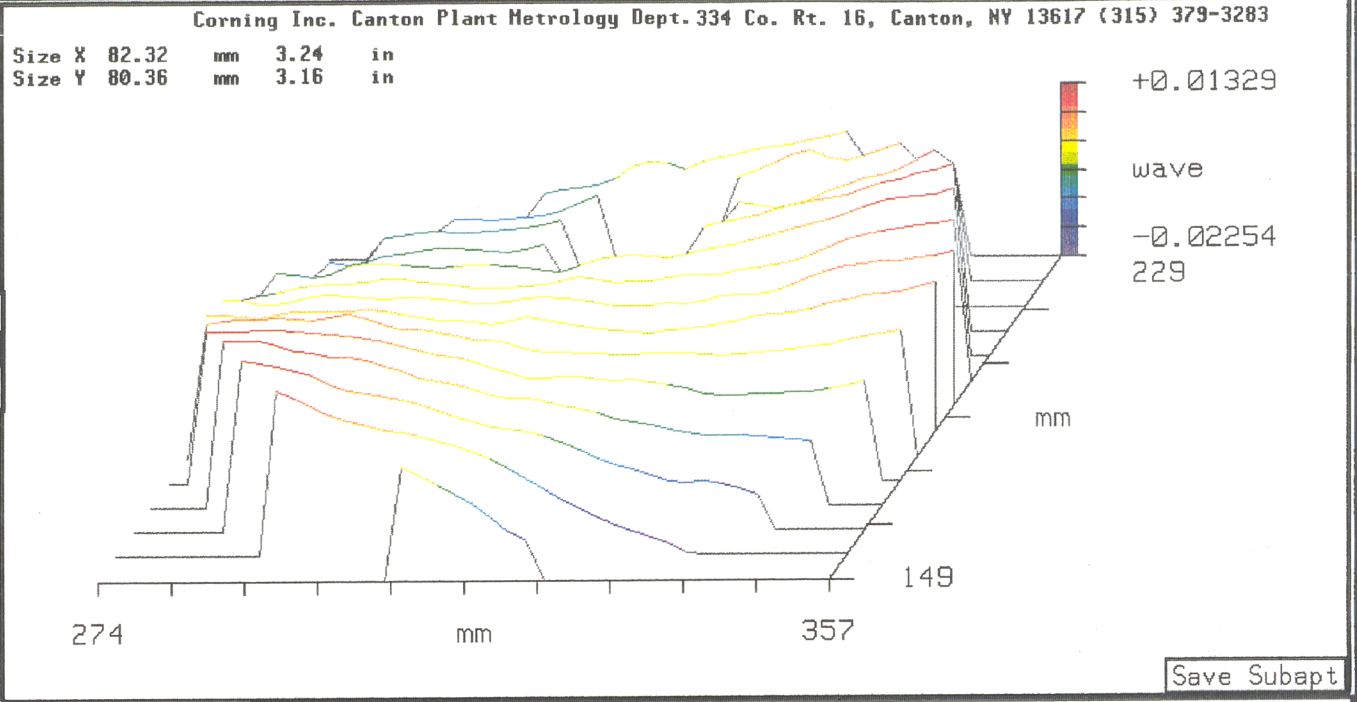
Homogeneity

1.93E-07

24622D

SN-FE08

Lg Aperture
 PV 0.036 wave
 rms 0.006 wave
 Power 0.000 wave
 Homogeneity 1.93E-07
 Points 1269
 AstMag (Z) 0.027 wave
 zygo Spike
 Remove Spikes: Off (xRMS): 3.00
 Data Fill: Off Data Fill Max: 25
 Removed:
 PST TLT PWR
 PST TLT PWR AST CMA SA3
 Zern Terms: 36



Zernike Coefficients from 1268 data points
 Order: 10th Terms: 36 rms: 0.001

0.000	0.000	-0.001	0.000						
0.005	0.012	0.000	0.002	-0.001					
0.005	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000		
0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	-0.001	0.000	0.000	0.001	0.000	0.000	0.000

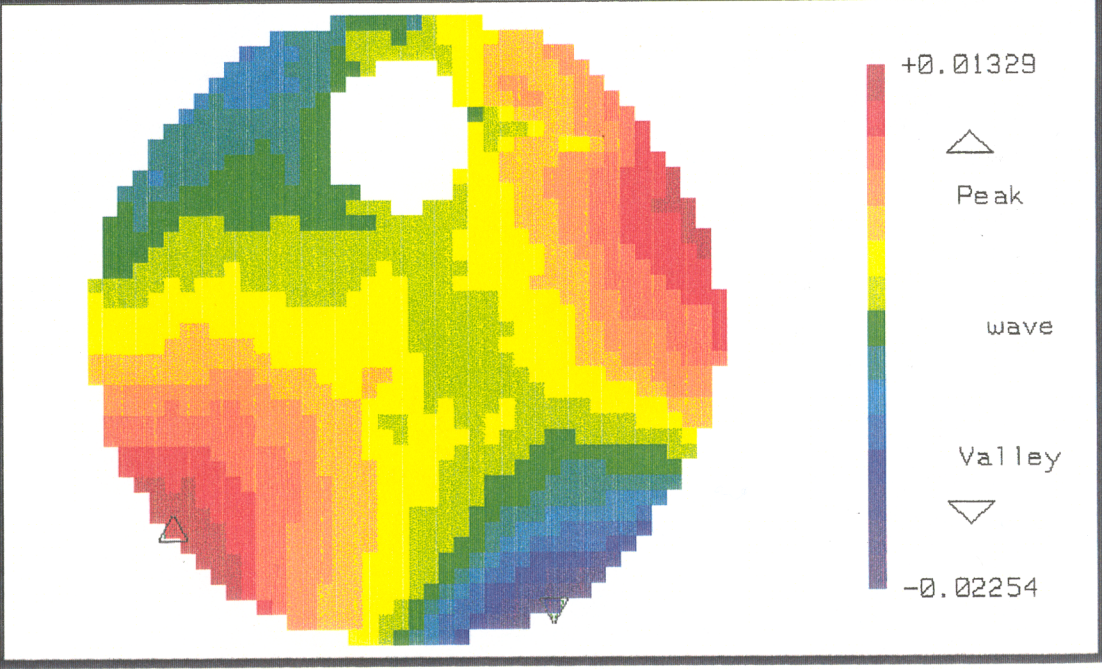
Measure Mask Data Save Data DBSAVE
 Analyze Calibrate Load Data

zygo File Data

Subtract Sys Err: On Min Mod (%): 1
 Sys Err File: r121396.8a2 Phase Res: High
 Part Thickness: 4.61 in Scale: 0.500
 Boule #: 24622 AGC: Off
 Suffix: D Light Level: 110

Comment:
 CAL TECH SN-FE08

Data File: 24622D2.ct Phase Avgs: 6
 Camera Res: 1.9600 mm Intens Avgs: 6
 Time: Sat Jan 04 23:37:00 1997



pertains to serial numbers
FE01 - FE09 - JB

Canton Plant
334 County Rt 16
Canton, New York 13617

Corning Incorporated

February 17, 1997

California Institute of Technology
LIGO Project
51-33 East Bridge Laboratory
Pasadena, CA 91125

Dear Ms. GariLynn Billingsley:

This letter is in response to concerns indicated in your reference to: Review of Data Packages for first 9 Pieces.

- 1) Diameter and thickness to reference drawing # D960794-A-D.
QA Inspectors are aware of this requirement. Change will be made on shipment of next parts.
- 2) Registration Mark and Serial number should reference specification E960097-A-D.
QA Inspectors are aware of this requirement. Change will be made on shipment of next parts.
- 3) Blanks FE04, FE05, FE06 & FE08 had no arrow to point to side 1, but commenced at a surface where there was a reasonable amount of writing.
Your assumption is correct. The surface with the reasonable amount of writing is side 1.
- 4) Specification for arrow and registration mark will be followed on shipment of next parts.
- 5) Any exceptions to specifications will be noted on data pack in future. QA Inspectors are aware of this requirement.
- 6) Birefringence readings are indicated on the defect and inclusion maps. This map serves both purposes.
- 7) Absorption reading not necessary for part # E970097-A-D. This column on Data Package will be marked N/A for balance of these parts.
- 8) The Certification of Compliance applies to all pieces shipped with order. This will be noted on the C of C in the future.
- 9) Serial Numbers will be included on the shipment.
- 10) Specification revision number referenced on Data Pack.
QA Inspectors aware of requirement. Will be done on next shipment of parts.

CC:
Petrae
Camp
Elieson
Tyler

.....

- 11) Data Disk not sent with pieces of glass.
Missing information will be forwarded. QA Inspectors will double check contents of Data Packs.
- 12) Deviation Approval Form sent with initial material shipment.
Approval of first 3 pieces analyzed via Standard Boule Testing. All other parts analyzed separately.

Other:

Standard Boule Testing could be acceptable to the LIGO project given confirmation by Corning Metrology that the interferometer used for SBT is the same used to test individual pieces, and that there is no change in magnification.

This response from Mr. Andy Fanning, Corning, Canton, Metrology Dept.
"The standard process Corning-Canton uses in metrology is compliant with the CIT/LIGO fax to Randy VanBrocklin, dated January 31st, 1997. The interferometer and magnification will be the same regardless if the part is shot at it's final dimension or in boule form".

If additional clarification is required on this subject, please let me know.

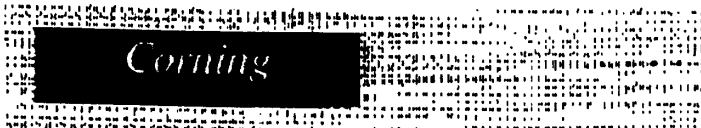
Hopefully this document addresses the current issues between CalTech -LIGO project and Corning-Canton. If there are any additional issues that need to be addressed by Corning, please do not hesitate to contact me.

Thank you for your patience in this matter.

Sincerely,

Randy VanBrocklin
Applications Engineer

Tel: 315-379-3381
Fax: 315-379-3317



CALIFORNIA INSTITUTE OF TECHNOLOGY

LIGO Project, 51-33 East Bridge Laboratory, Pasadena, California 91125
818-395-2129, Fax 818-304-9834

Date: January 31, 1997

Refer to: LIGO-C970148-00-D

Corning Incorporated
Canton Plant
334 Country Route 16
Canton, New York 13617
Attention: Randy VanBrocklin, Brian Bush

Subject: Review of Data Packages for first 9 pieces

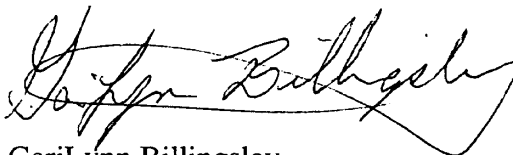
Some clarification of preferences and some discrepancies came to light during examination of the data packages for the first 9 blanks delivered to LIGO. While none of these compromise the integrity of the blanks, they can make for a confusing or misleading data package. Please let us know how you expect to address these issues for subsequent glass deliveries.

1. Data sheet; Diameter and Thickness should reference the drawing D960794-A-D
2. Data sheet; Registration Mark and Serial number should reference the Specification E960097-A-D
3. Blanks FE04, FE05, FE06 and FE08 had a registration mark which was between 12-15 mm in length and had no arrow to point to side 1, but commenced at the surface on which there was a reasonable amount of writing. We have presumed this to be side 1 but would appreciate a confirmation that this is indeed the case
4. Also, on these blanks the serial number is written immediately adjacent to the registration mark and is parallel to the (presumed) side 1, rather than as shown in the drawing. This is not a problem for us as the serial number is clear, but strictly speaking it is not in compliance with the specification.
5. We have a data package that arrived with no witness sample map, yet this item was stamped off on the data sheet, with no note of exception. An exception had been granted for this part, that exception was included in the data package. Please note the presence of an exception on the data sheet.
6. All data packages have arrived without defect or inclusion maps yet the box next to "see attached map" was stamped. How should LIGO interpret the stamp column? Please provide defect and inclusion maps.
7. Data packages arrived with the "Actual" column for Absorption reading "see attached cert", yet there was no attached certification, nor was one required for this part. There was a stamp.
8. The Certification of Compliance does not reference serial number(s) are we to assume that it applies to all pieces in the shipment?
9. Would you please include serial numbers on the shipper?

10. Would you please reference the Specification Revision number on the data sheet?
11. A data disk is required with the package, yet one piece has arrived without it. Should there be a checkoff sheet for each piece of glass stating the contents of the data package?
12. A Deviation Approval form accompanied the shipment of FE01 approving standard boule testing for 11 pieces. The form does not indicate which pieces are affected. LIGO has no record of approving this deviation. Please confirm all future Deviation Approvals in writing.

NOTE: Standard Boule Testing could be acceptable to the LIGO project given confirmation by Corning Metrology of the following information. The Interferometer used for SBT is the same interferometer which is used for single piece testing and there is no change in interferometer magnification between SBT and single piece homogeneity measurements. Deviation approval for SBT will be considered by LIGO following this clarification.

Sincerely,

A handwritten signature in black ink, appearing to read "GariLynn Billingsley". The signature is fluid and cursive, with a long horizontal flourish extending to the right.

GariLynn Billingsley
Technical Representative

SUBSTRATE

A. DCN: LIGO-T970016-00-D

LIGO DETECTOR OPTICS
Incoming Inspection Check-off Sheet
Core Optics Polished Substrate

Page 1 of 3B. LIGO S/N: ETM02-A

The purpose of this sheet is to verify material physical dimensions, perform visual and microscopic inspection, and to facilitate material traceability of LIGO Detector optics. This sheet is to be included in the LIGO Quality Assurance traceability file. Complete a check-off sheet for each optic blank received and inspected.

C. LIGO Contract/Purchase No.: PC 167159D. Substrate Polisher: CSIROE. Core optic Material: BS / FM / 2ITM / 4ITM (ETM) / RMF. Date Received: 11-03-97

G Verify glass polisher's Certification with LIGO Component Specification No. E960102-A-D.
 Attach the completed LIGO Component Specification Verification Sheet.

H Attach a copy of the glass polisher's Certification Document and data sheet to check-off sheet.

I Verify receipt of an IBM PC compatible disc in ASCII format of all Surface Data per the applicable LIGO Component Specification sheet. Data files are available at CSIRO ftp site

J Attach the surface maps supplied by vendor per above Component Specifications to the check off sheet.

K Visually inspect for shipping container damage. If applicable, describe damage on attached sheet and notify the Cognizant Engineer

L Visually inspect the polished substrate for shipping damage, for chips on surfaces and edges, or for other defects. If applicable, describe damage/defects on attached sheet and notify Cognizant Engineer.

M Verify polished substrate's physical dimensions per applicable LIGO drawing.

Inspection of material diameter. Diameter 9.88 in 250.88 mm

Inspection of material thickness Thickness 3.93 in 99.93 mm

N Verify that the Serial Number is present in the proper format as required by LIGO Component Specification.

O Verify that the Registration Mark (line with arrow pointing toward surface #1) is present as required by LIGO Component Specification.

P Inspect the sides and bevels with the naked eye in normal room light and against a black background to verify that there is no gray, scuffs or scratches per the applicable LIGO Component Specification.

Q Use a dark field microscope at 5X magnification to inspect the polished optic for scratches and defects over the central 80 mm diameter per the applicable LIGO Component Specification.

R Sign and date original packing slip (shipper) and distribute per paragraph 3.R. *Did not find a packing slip*

Inspection By: *[Signature]* Date Inspected: 11-06-97

Reviewed and/or accepted by:

Cognizant Engineer: _____ Date: _____

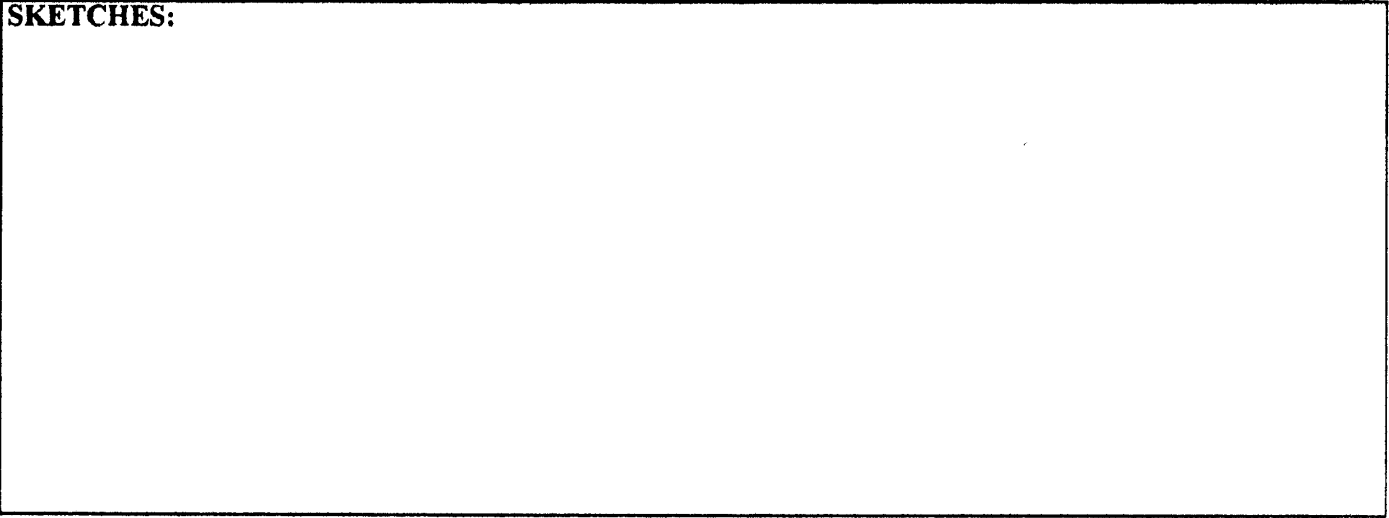
LIGO QA Officer or Designee: _____ Date: _____

LIGO DETECTOR OPTICS
Incoming Inspection Check-off Sheet

Core Optics Polished Substrate

COMMENTS/DISCREPANCIES: (Disposition damage/discrepancies per LIGO Quality Assurance Plan (LIGO M960076-00-P) paragraphs 5.12 and 5.12.1.) _____

SKETCHES:



DISPOSITIONS: _____

Substrate, End Test Mass		Serial Number:	Specification	Reported Value	✓
				ETMØ2-A	
Surface 1	Surface Figure Over Central 200mm	Spherical, Concave	Concave	✓	
	Absolute Radius of Curvature Tolerance	220 7,400m 220 +150m -150m	7,240 Km	✓	
	Variation of Radius of Curvature from Average	+111m -111m			
	Astigmatism	< 10nm p-v	2.3 nm	✓	
Surface 2	Surface Figure Over Central 200mm	Flat	convex	✓	
	Radius of Curvature	> 80 Km	>1960 Km	✓	
	Astigmatism	< 64nm p-v	1.5 nm	✓	
Surface Errors Surface 1	Low Spatial Frequency Band Central 80mm	$\leq 4.3 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 0.8\text{nm}$	0.46nm	✓	
	Low Spatial Frequency Band Central 200mm	$\leq 4.3 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 1.6\text{nm}$	0.91 nm	✓	
	High Spatial Frequency Band Central 80 & 200 mm	$\leq 4.3 - 7,500 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 0.2\text{nm}$	0.16 nm 0.17nm	✓	

Scratches, Point Defects & Polish Side 1		Specification	Certification	✓
Scratches	The Total Area of scratches within the central 80mm diameter shall not exceed 25×10^3 square micrometers (width x length).	none	Hand Sketch w/dimensions	✓
	The total area of scratches outside the central 80 mm diameter shall not exceed 250×10^3 square micrometers.	none	Hand Sketch w/dimensions	✓
Point Defects	There shall be no more than 10 point defects within the central 80mm diameter.		Hand Sketch w/dimensions	✓
	There shall be no more than 100 point defects on the entire surface. Point defects of radius greater than 25 micrometers are treated like scratches for the purpose of this specification. Point defects of radius less than 2.5 micrometers are disregarded.		Hand Sketch w/dimensions	✓
Side/Bevel Polish	Sides and bevels shall be polished from a three micrometer grit finish. These surfaces shall appear transparent with no gray, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background.		Inspection Report	✓

LIGO Component Specification Verification Sheet End Test Mass

Scratches, Point Defects & Polish Side 2	Specification		Certification	✓
	Scratches	The total area of scratches shall not exceed 1×10^6 square micrometers over the central 235 mm. <i>none</i>	Hand Sketch w/dimensions	✓
	Point Defects	There shall be no more than 100 point defects within the central 80mm diameter.	Hand Sketch w/dimensions	✓
		There shall be no more than 300 point defects on the entire optic. Point defects of radius greater than 25 micrometers are treated like scratches for the purpose of this specification. Point defects of radius less than 2.5 micrometers are disregarded.	Hand Sketch w/dimensions	✓
	Side/Bevel Polish	Sides and bevels shall be polished from a three micrometer grit finish. These surfaces shall appear transparent with no gray, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background.	Inspection Report	✓

**LIGO Component Specification Verification Sheet
End Test Mass**

This Certification Package relates to the following substrate: **End Test Mass**

Serial number: ETM02A

The Package consists of the following documents:

1. Printed documents

HABA - LIGO - C - PD:	Certification of Physical Dimensions and Registration Mark location, orientation and dimensions
HABA - LIGO - C - SB:	Certification of Side and Bevel Polish
HABA - LIGO - C - SP:	Certification of Scratches and Point Defects
HABA - LIGO - C - SN:	Certification of Serial Number location, dimensions
HABA - LIGO - C - SF:	Certification of Surface Figure for Sides 1 and 2
HABA - LIGO - C - SL:	Certification of Surface Errors - Low Frequency, for Side 1
HABA - LIGO - C - SH:	Certification of Surface Errors - High Frequency, for Side 1
Attachment 1	Hard copy print out of LADI data for Side 1 with piston, tilt removed and also for piston, tilt, power, astigmatism removed
Attachment 2	Hard copy print out of LADI data for Side 2 with piston, tilt, removed
Attachment 3	Hard copy printouts of TOPO 2D data obtained with 2.5X and 40X heads at three central positions (side 1)

2. Electronic data

Surface maps for sides 1 and 2 are available at the CSIRO ftp site under the following file names:

LADI data: ETM2A1.ASC (Side 1) ETM2A2.ASC (Side 2)

TOPO data: (2.5X) T2EM021A.ASC, T2EM021B.ASC, T2EM021C.ASC (Side 1)

(40X) T4EM021A.ASC, T4EM021B.ASC, T4EM021C.ASC

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Physical Dimensions and Registration Mark
4	LIGO specification reference:	D960791-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-PD
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00028, p.14
8	Team member responsible for measurement/inspection:	Carl Sona
9	Measurement/inspection results reviewed by:	Bob Oreb

10. Results

[Measurement errors ($\pm 1\sigma$) shown only where they are comparable to tolerances specified or when measurement is within 2σ of boundary of acceptability]

Physical Quantity	Result
Diameter	250.88 mm
Cylindricity	0.02 mm
Thickness (maximum - for FM, RM, ETM) (minimum - for BS)	99.93 mm
Bevel as per drawing (height, angle):	(S1) Height: 2.17 mm Angle: 44 ⁰ 49' (S2) Height: 2.26 mm Angle: 44 ⁰ 42'
Wedge angle:	2 ⁰ 0'
Location of registration mark (\pm angle with respect to minimum part thickness):	-3'
Location of other 3 marks (with respect to registration mark at minimum thickness)	89 ⁰ 57', 180 ⁰ 0', 270 ⁰ 02'
Registration mark dimensions (OK/ not OK)	OK

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

23.10.97

LIGO Certification Report Side and Bevel Polish

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Side and Bevel Polish
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SB-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00024
8	Team member responsible for measurement/inspection:	J Seckold
9	Measurement/inspection results reviewed by:	A Leistner

10. Results

Defects, if any, in the side and bevel polish compared to the LIGO specification (4 above) are detailed below (*team member to note defects here; if none seen, note "no defects observed"*).

No defects observed.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

23.10.97

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Serial Number and location
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SN-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00024
8	Team member responsible for measurement/inspection:	J Seckold
9	Measurement/inspection results reviewed by:	A Leistner

10. Results

Quantity inspected	Result of Inspection (OK / not OK)
Location of serial number as per drawing (sec. 4)	OK
Orientation of serial number as per drawing (sec. 4)	OK
Height of lettering	OK

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:


23.10.97

Chris Walsh

Date:

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Scratches and Point Defects
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SP-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00024
8	Team member responsible for measurement/inspection:	E Pavlovic
9	Measurement/inspection results reviewed by:	J Seckold

10. Results

	Numbers of point defects		Total Area of scratches (square micrometres)	
	Inside central 80 mm	Entire surface (235 mm)	Inside central 80 mm	Outside central 80 mm (235 mm)
Surface 1	None	None	None	None
Surface 2	None	None	None	None

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

23.10.97

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Surface Figure
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SF-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00060, pp. 104, 107
8	Team member responsible for measurement/inspection:	D Farrant
9	Measurement/inspection results reviewed by:	B Oreb

10. Results

	Radius of Curvature in km	Astigmatism (nm)	Electronic data file reference
Surface 1	7.24 (concave)	2.3	ETM2A1.ASC
Surface 2	> 960 (convex)	1.5	ETM2A2.ASC

Hardcopies of the phase maps are attached to this certification as part of Attachment 1 for Side 1 and Attachment 2 for Side 2. Phase map data is stored in electronic format at the CSIRO ftp site under the filenames shown in the third column.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

24 Oct 97

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Surface Errors - Low Spatial Frequency
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SL-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00060, pp 104, 107
8	Team member responsible for measurement/inspection:	D Farrant
9	Measurement/inspection results reviewed by:	B Oreb

10. Results

	Low Frequency Surface Errors (nm)	
	80 mm aperture	200 mm aperture
Surface 1	0.46	0.91
Surface 2	N/A	N/A

Hardcopies of the phase maps over the central 200 mm with piston, tilt, power and astigmatism removed are attached to this certification in Attachment 2 for Side 1 and Attachment 2 for Side 2.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

23.10.97

1	Substrate Type:	End Test Mass
2	Serial Number:	ETM-02A
3	Physical quantity certified:	Surface Errors - high spatial frequency
4	LIGO specification reference:	E960102-A-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SH-B
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	No
7	CSIRO Log Book Reference	LN00066, pp. 5 -13
8	Team member responsible for measurement/inspection:	C Walsh
9	Measurement/inspection results reviewed by:	B Oreb

10. Results

10.1 Surface errors in nanometres averaged over sampling locations within central 80 mm:

Side 1: 0.16 nm

Side 2: N/A

10.2 Surface errors in nanometres averaged over all sampling locations on surface:

Side 1: 0.17 nm

Side 2: N/A

10.3 Surface errors in nanometres at different positions A through H on surface:

	A	B	C	D	E	F	G	H
Surface 1	0.13	0.16	0.18	0.20	0.16	0.16	0.18	0.19
Surface 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Two - dimensional surface maps at three central locations are available at the CSIRO ftp site under filenames of the form TOEM0YZA.asc, where O is the objective used (O=2 for 2.5X, 4 for 40X), EM refers to End Test Mass, 0Y is the number, Z = 1 or 2 is the side and A = A, B, C, ... is the sampling position. Hard copies of the data are at Attachment 3 (Side 1).

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:



Chris Walsh

Date:

23.10.97

LADI CERTIFICATION DATA

Title: ETM2A1

CSIRO

Date: 09/24/97

Astig: 2.3 nm

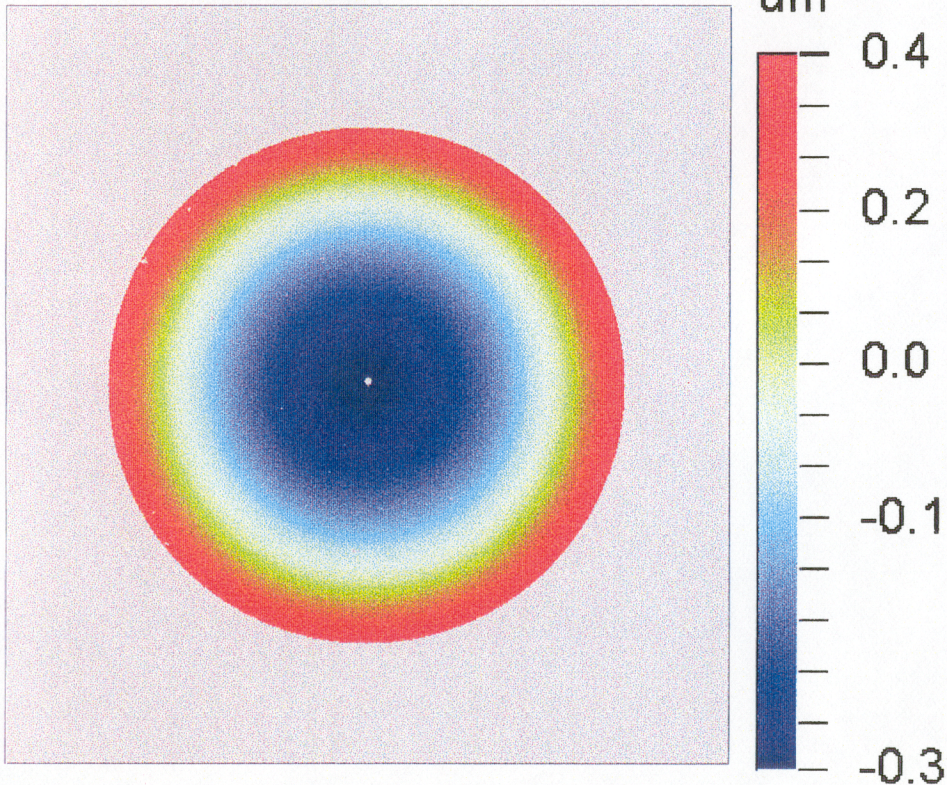
PV: 7.3 nm

Diameter: 200 mm

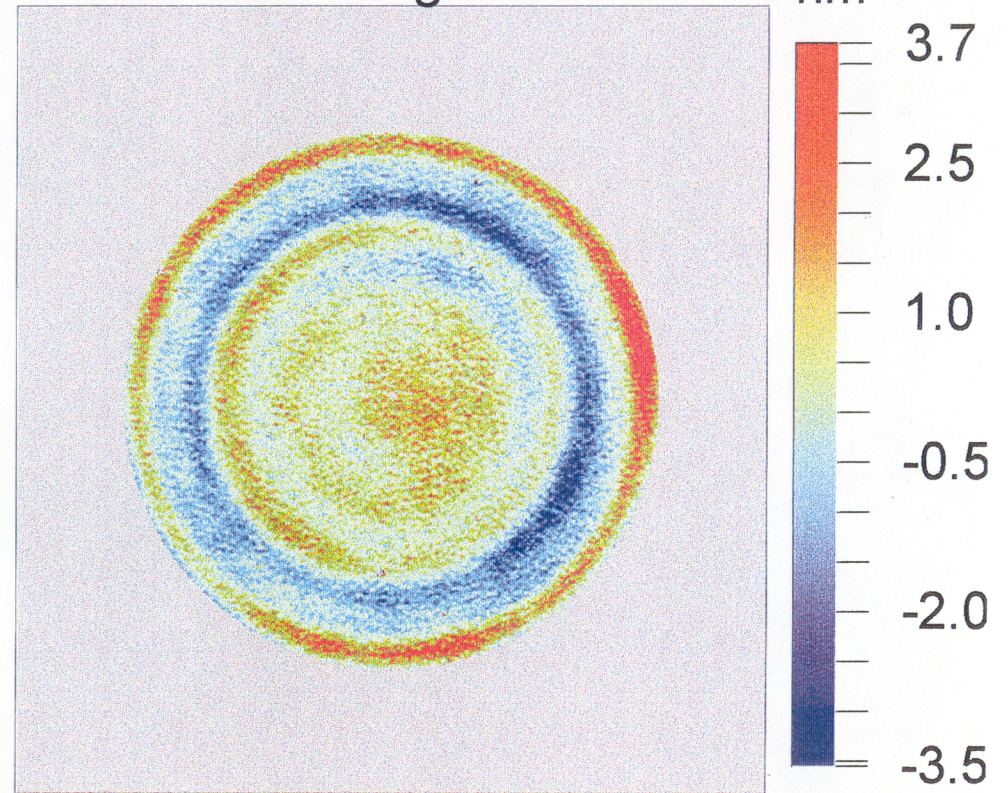
Power: 690.3 nm

RMS: 0.9 nm

Tilt Removed



Tilt/Power/Astig Removed



LADI CERTIFICATION DATA

Title: ETM2A2

CSIRO

Date: 09/30/97

Astig: -1.5 nm

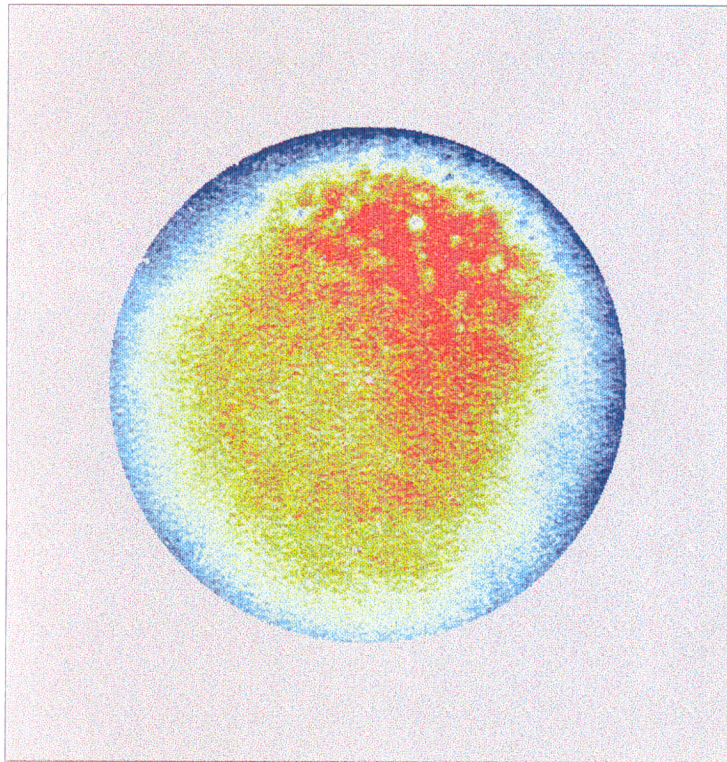
PV: 8.7 nm

Diameter: 200 mm

Power: -5.2 nm

RMS: 1.0 nm

Tilt Removed



nm

5.4

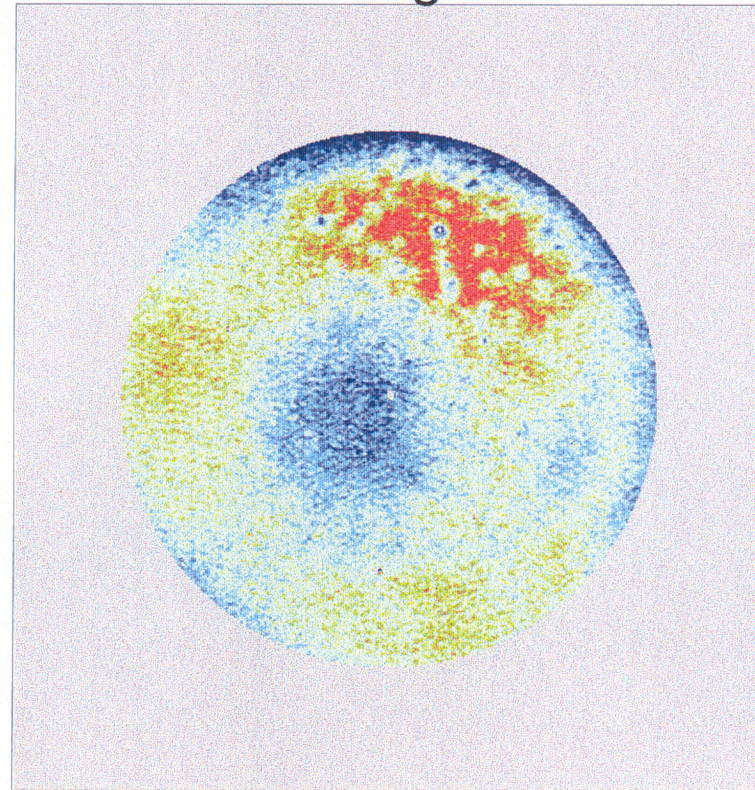
3.0

0.0

-3.0

-7.2

Tilt/Power/Astig Removed



nm

4.3

2.5

1.0

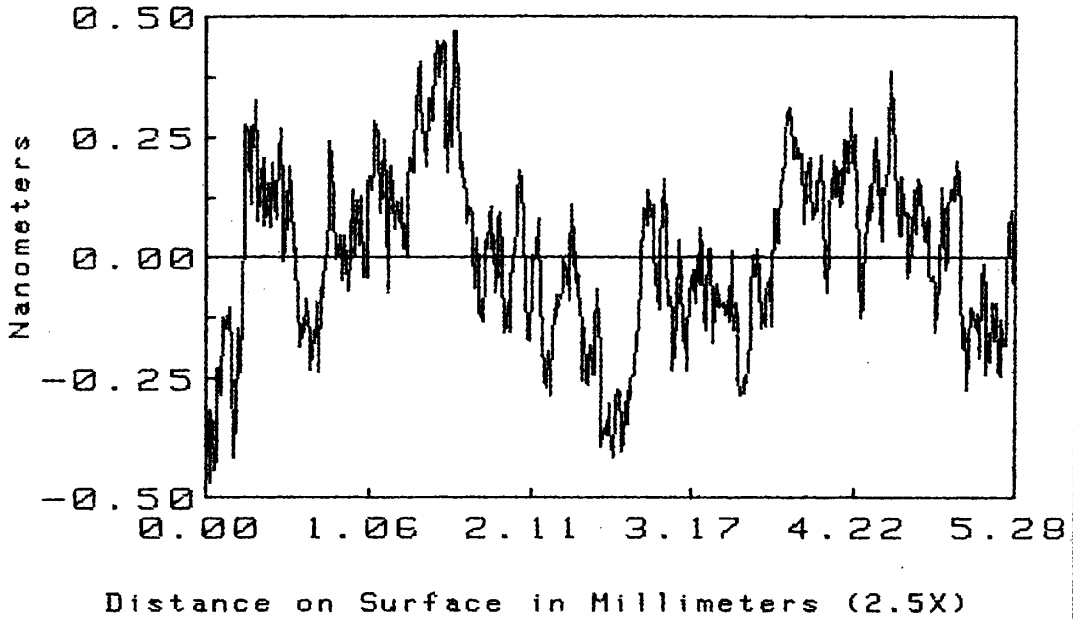
-0.5

-2.0

-4.4

Attachment 3

ETM31A4CJW Time: 14:42 Date: 9/18/97
RMS: 0.180nm Ref. **PROFILE** PV: 0.973nm
RA: 0.147nm RC: 33.1 km



TZEMOZIA.ASC

WYKO

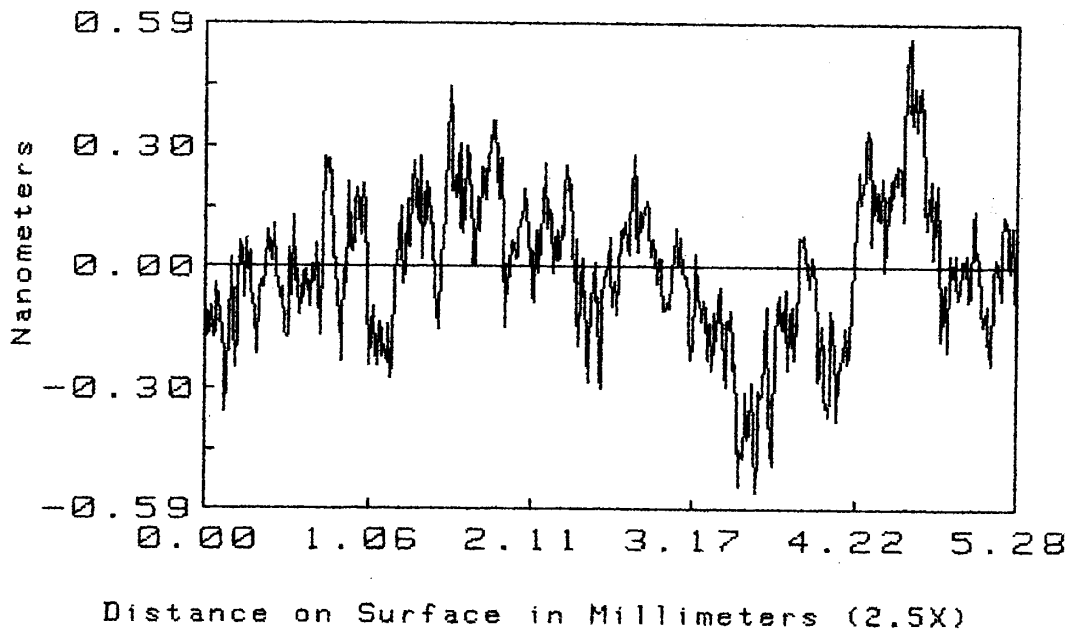
ETM31E3CJW
RMS: 0.178nm
RA: 0.140nm

Time: 15:05

Date: 9/18/97

PROFILE
Ref. Subtracted

PV: 1.14nm
RC: 43.9 km



TZEMO21B.ASC WYKO

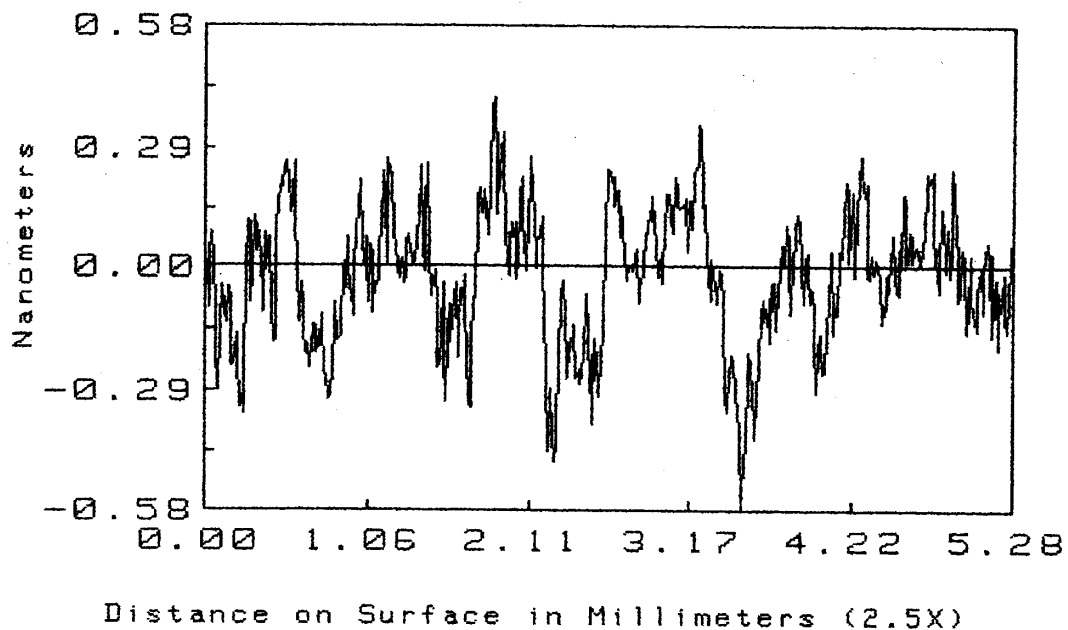
ETM31E3CJW
RMS: 0.164nm
RA: 0.129nm

Time: 16:33

Date: 9/18/97

PROFILE
Ref. Subtracted

PV: 1.02nm
RC: 9862 m



TZEMO21C.ASC WYKO

ETM21A6CJW

Time: 14:32

Date: 9/19/97

RMS: 0.098nm

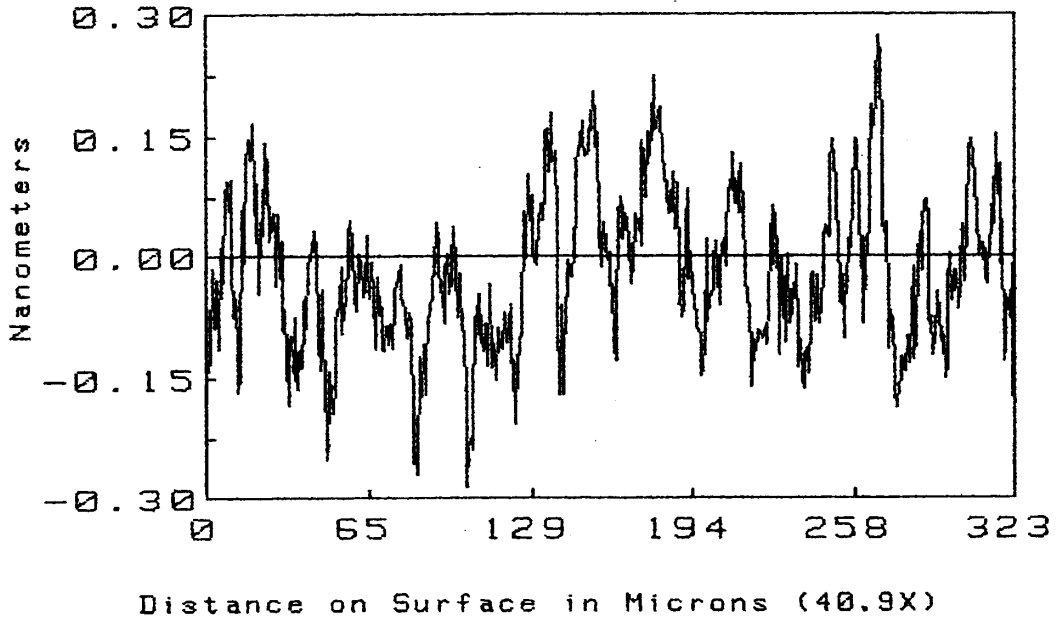
PV: 0.588nm

RA: 0.079nm

Ref. Subtracted

RC: -52.3 m

PROFILE



T4EMO21A.ASC

WYKO

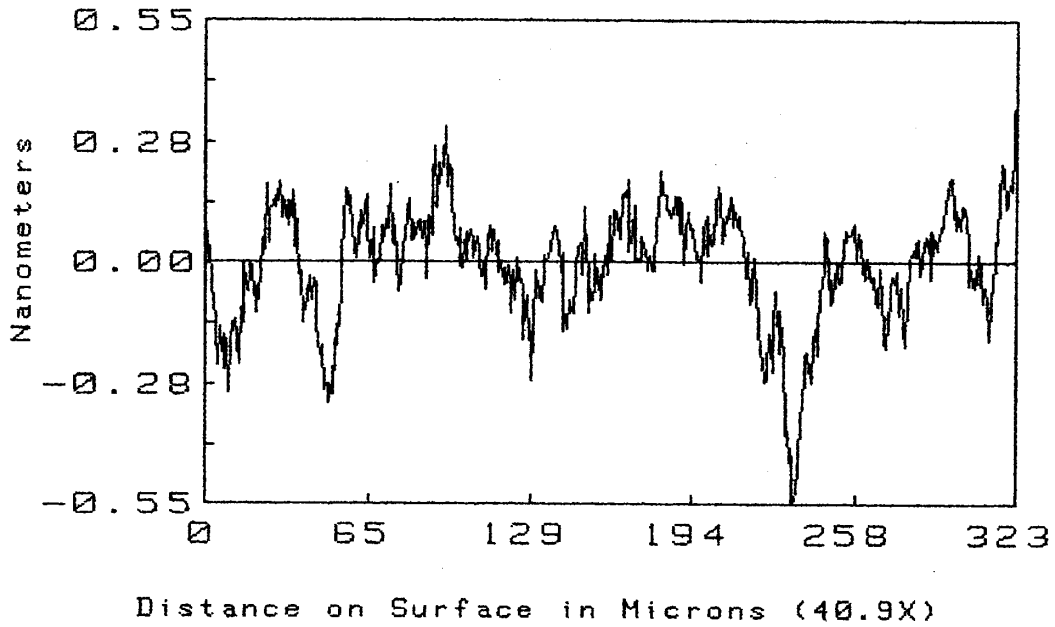
ETM21B5CJW
RMS: 0.133nm
RA: 0.100nm

Time: 14:53

Date: 9/19/97

PROFILE
Ref. Subtracted

PV: 1.03nm
RC: -38.1 m



T4EMO21B.ASC WYKO

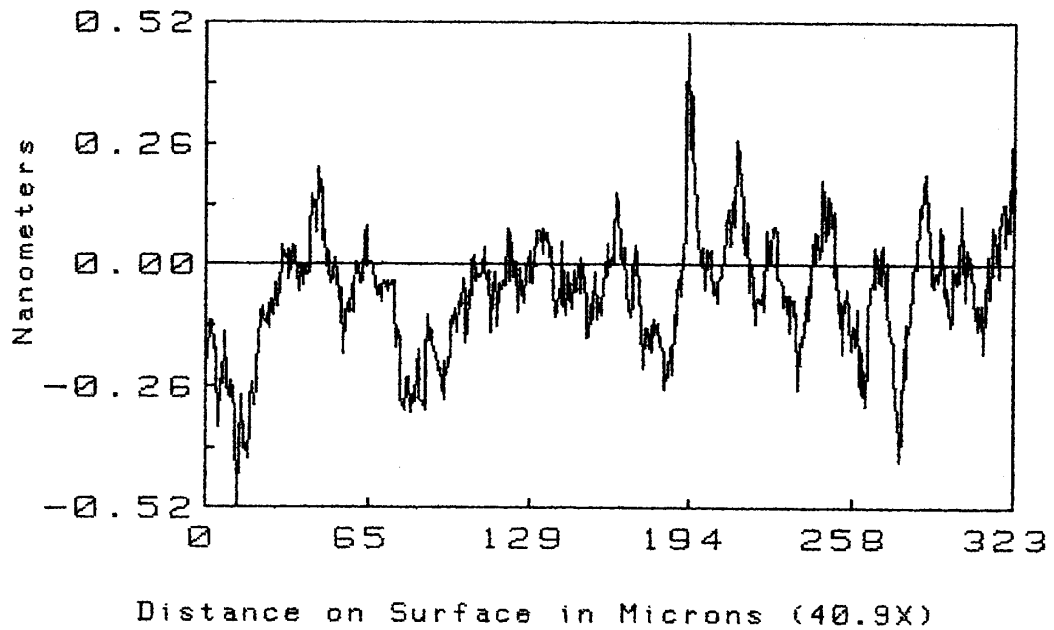
ETM21C6CJW
RMS: 0.140nm
RA: 0.107nm

Time: 15:18

Date: 9/19/97

PROFILE
Ref. Subtracted

PV: 1.02nm
RC: 64.7 m



T4EMO21C.ASC WYKO

MIRROR



Research Electro-Optics Inc.

CERTIFICATE OF CONFORMANCE

Section 1.4/REO QC Manual, Q-001, Doc. No. V:QA:REO 014, Rev. "B", 09/13/96

Certificate of Conformance from: **Research Electro-Optics (REO) Inc.**
1855 South 57th. Court
Boulder, Colorado 80301
(303) 938-1960, Fax (303) 447-3279

Research Electro-Optics (REO), Inc. hereby certifies that the items listed below have been inspected and tested to the extent necessary to conform with all the requirements of the noted Purchase Order, drawing, and applicable specification(s). Inspection and test data are on file at our facility and will be furnished to customer upon request.

- Date of shipment : MAY 26, 1998
- Customer Name, Purchase Order No. : PO# PC160519
CALIFORNIA INSTITUTE OF TECHNOLOGY
- Customer Part Number & Revision : ETM L1A0-E98 0068-00-D
- Part Description : END TEST MASS COATED
- REO Job No. : OPT#5831-015 Run No.: 0X739/0X740
- Qty. Shipped/Lot No. : 2 PIECES
SCRIP# : 01 & 02

Test data (included)

Comment:

WE'RE ALSO CHARGING CARRIED FGD 50% OF
L1A0 E980069, L1A0 E980066 & L1A0 E980067. (work# 36, 37 & 38)

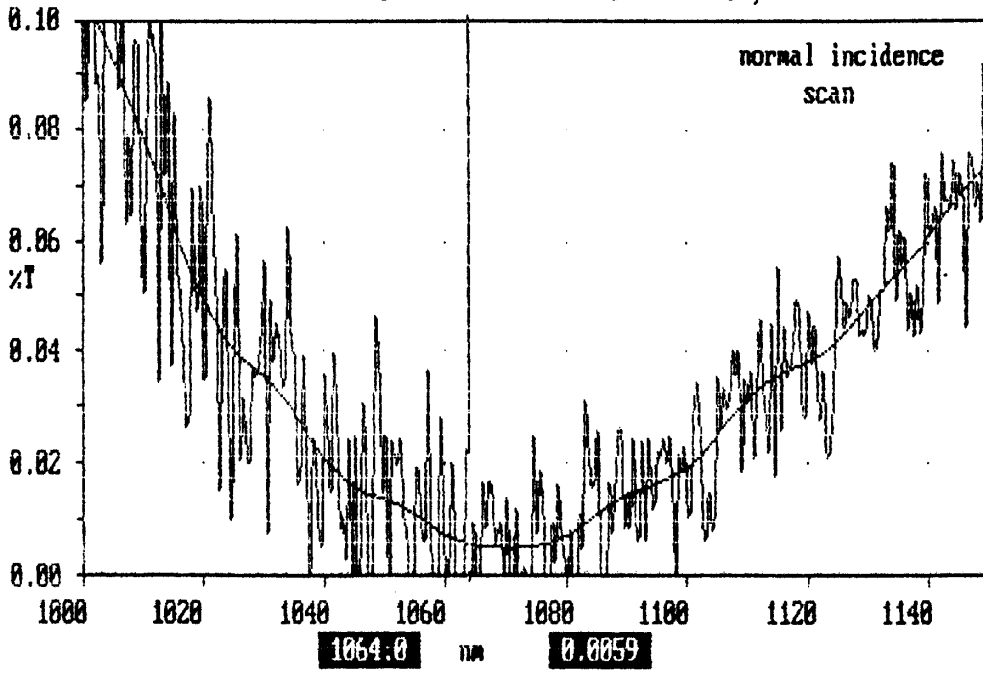
Part#
Certified by: [Signature] 5/26/98
Quality Assurance

Verified by: [Signature] 5/26/98
Engr/Tech

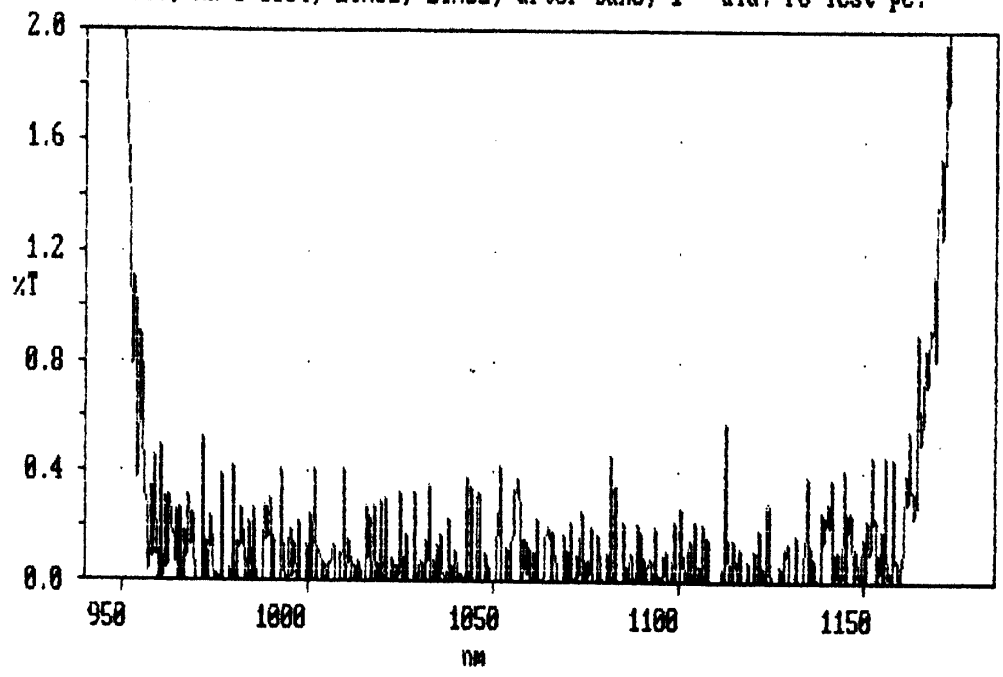
NOTE

Certificate must accompany the package to be shipped or attached to the outside of the same box to which the "Packing Slip" envelope is attached.

Y: user002; 1150.0 - 950.0 nm; pts 401; int 0.50; ord 0.0052 - 0.4697 %T
Inf: #0X742, AR at 1064nm at 2deg, witness, after processing ,ETM01, ETM02



Y: user004; 1200.0 - 900.0 nm; pts 3001; int 0.10; ord -0.405 - 84.935 %T
Inf: Run #OX739, HR @ 1064, ETM01, ETM02, after bake, 1 " dia. FS Test pc.



$\lambda_c = 1048 \text{ nm}$



**Research
Electro-Optics, Inc.**

PAGE NO: 1
 ORDER NO: 1000000000
 INVOICE DATE: 05/26/1998

INVOICE

CUSTOMER NO: 201004
 CUSTOMER P/N: 626-395-6281
 BILL TO:

YOUR ORDER NO: PC162519
 OUR ORDER NO: 1000000000
 SHIP TO:

CALIFORNIA INST. OF TECHNOLOGY
 L. P. TRAC, B.C.: 10-54 L160
 51-53 EAST BRIDGE LANE, L160
 PASADENA, CA 91125

CALIFORNIA INST. OF TECHNOLOGY
 51-53 EAST BRIDGE LANE, L160
 41115 BRIDGE AVENUE, L160
 PASADENA, CA 91125

TERMS: CASH #1: DISC: SHIPPED: 05/26/1998
 CASH #2: DISC: SHIP VIA: FED-EX PI
 NET DUE DATE: 06/25/98 F.O.B.: FACTORY
 YOUR CUSTOMER REP IS: JM SHIPMENT NO: 005079 REF:
 PRO NO:

QTY ORDERED	QTY SHIPPED	QTY S.O.	ITEM NUMBER	UNIT PRICE	EXTD PRICE
-------------	-------------	----------	-------------	------------	------------

THIS ORDER IS A CHANGE ORDER TO RED QUOTE

PER QUOTES 000-2403 & 000-

REFERENCE: CALTECH L160-C95-000/L160-C98090
 L160-C950494-05

Technical Contact:
 Helena Armadillo Tel: 626-395-2070
 Mail Code 18-34

Contractual Representative:
 Irena Petrac Tel: 626-395-2975
 Mail Code 18-34

Items #001 thro' #014 is per PO# PC162519

Items #015 thro' #039 is per PO# PC162519
 Per RED quote #000-2537. No Item #027 on the
 acknowledgment. Rec'd 06-05-98 *[Signature]*

2 END TEST MASS, COATED
 2 L160-980058
 ETMØ2

Remit to: Accounts Receivable Department, P.O. Box 0543, Denver, CO 80256-0543
 (303) 938-1960 FAX (303) 447-3279