ETM04

LIGO-T990143-00-D

BLANK

DCN: LIGO- T970020-00-D
LIGO S/N: FE12

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

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.: PP207573
Core optic Material: (BS /(FM)/ ITM /(ETM)/ RM)
LIGO Drawing No.: D960794-B-D

Glass Mfg./Order No: Corning/QD10624801
Glass Mfg. Part No.: F855306
Manufacturer's Boule No.: 34639 BCT
Date Received at Caltech: 03-13-97

☑ 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. Deviation Approval Form

☑ Attach the glass manufacturer's optical ~~phase~~ homogeneity 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: 03-17-97

☑ Verify core optic blank physical dimensions per applicable LIGO drawing.

☑ Inspection of material diameter. Diameter 10.107 in 256.72 mm

☑ Inspection of material thickness. Thickness 4.280 in 108.71 mm

☑ Verify that the Registration Mark is present (with arrow pointing at the first surface) as required by LIGO Component Specification. No Arrow

☑ 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: 03-17-97

Reviewed and/or accepted by:

Cognizant Engineer: _____ Date: _____

LIGO QA Officer or Designee: _____ Date: _____

FM300

Figure 1

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.)

(1) There are no pictures

(2) There is no data disc

(3) The is no arrow on Registration Mark pointing to the first surface

(4) Wrong boule number on the deviation form.

SKETCHES:

DISPOSITIONS: (1); (2); (3); (4) Vendor notified (LIGO-C970504-00-D) "Deviation approval form" signed and on file-

CALIFORNIA INSTITUTE OF TECHNOLOGY

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

Date: April 8, 1997
Refer to: LIGO-C970504-00-D

Corning Incorporated
Route 1 Box 28
Canton, NY 13617

Attention: Jane Fernandez

Subject: Problems with the Corning Quality Assurance for the LIGO project.

Dear Ms. Fernandez,
I represent the LIGO project, an advanced interferometric observatory funded by the Federal Government through the National Science Foundation (NSF). LIGO is responsible to, and subject to the scrutiny of the NSF and its technical review committee. Technical issues of LIGO have high visibility at national and international levels. It is imperative that LIGO have accurate and complete certification for the core optics, its most critical components.

The LIGO requirements are indeed unique due to the nature of the observatory. In light of this I made a trip to Corning at the start of the program to discuss the specifications and quality requirements with Brian Bush and Randy VanBrocklin and had thought that our requirements were well understood and achievable.

Corning QA processing of glass for the LIGO core optics has been consistently substandard. The paperwork and data accompanying the first lot of deliveries were both incomplete and inaccurate, bringing the integrity of the glass into question. I have included a copy of the first lot of discrepancies and the Corning reply for your reference. There was a second trip to Corning at the beginning of March where LIGO and Corning management discussed these issues. However, the second lot appears to have similar problems. Following is the second list of discrepancies.

FE10

- Drawing and Specification numbers are still reversed. These were redlined during the March 3rd meeting at Canton.
- No certification was included for Material or Striae, yet the data sheet is stamped and says "see attached cert"
- "Defects" is stamped yet, the piece is known to be out of spec. and is here for our analysis and potential approval.
- The data disk is missing 2 files, the one file present is not in ASCII format as is required and as all previous data have been.

FE11

- All three data files present but are in the wrong format (not ASCII)
- Incorrect registration mark (no indication of side one)

FE12

- No data disk at all.
- No certification was included for Material or Striae, yet the data sheet is stamped and says "see attached cert"
- Incorrect registration mark (no indication of side one)
- An incorrect boule number called out on Deviation Approval form
- Deviation number is not sequential

The following Replacement disks are still incorrect:

FE05
Data disk is missing file 24622E.asc
FE06
Data disk is missing file 24622F.asc
FE08
Data disk is missing file 24622D.asc

The Original discs for (FE05 and FE06) arrived blank. The Original disk for FE08 had three files on it, yet the first file (24622D.asc) was corrupt. It is this same file that is now missing on the new FE08 disc. These phase maps are used in the modeling and construction of the observatory and it is absolutely imperative that they be delivered.

I expect to receive correct and complete data packages for serial numbers FE10, FE11 and FE12 along with correct replacement disks for FE05, FE06 and FE08. I also expect all future data packages to be correct. The ability of Corning to deliver a quality product is of great concern to the LIGO project, and therefore the National Science Foundation. The status of both delivery and Quality are reviewed weekly at the highest level within LIGO. This level of scrutiny will continue for the duration of the Corning contract.

Sincerely,

GariLynn Billingsley
Technical Representative

cc at LIGO: Document Control Center, Camp, Fischer, Petrac, Tyler, Whitcomb
cc at Corning: Bush, Sutton, VanBrocklin

DEVIATION APPROVAL FORM

Customer Name: California Institute of Technology

Customer P.O. Number: PP207573

Corning Order Number: 106248

Corning Part Number: F855306

✓ *Drawing Number:* D-960794-B-D

Boule Number: 34639 BCT (SE) ~~24701 CCT (SE)~~ - ~~FE10 (SE)~~ FE 12 (SE)

Quantity Affected: 2

✓ *Deviation Description:* *(attach backup information as deemed necessary)*

chip penetrates min. blank .017" check in bevel on bottom surface.

Sari Lynn Billingsley
Customer Contact (print)

Randy VanBrackle
Authorizing Signature

3/4/97
Date

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

Billing Status

- ☐ Bill Now
- ☐ Bill in 30 Days
- ☐ Other

Deviation Number: 0013 - 97
(sequential number) *(year)*

Q704 rev. A

cc: Shipping Clerk
Customer Service

Canton Plant
334 County Rt 16
Canton, New York 13617

Corning Incorporated

March 19, 1997

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

Dear Ms. GariLynn Billingsley:

This letter is to document the agreement between California Institute of Technology and Corning, Inc. concerning the acceptance of two damaged mirror blanks which CalTech has agreed to process further.

Caltech Part #	Corning Part #	Corning WO #	Reference #	Defect
E960097	855306	24701 CCT	FE11	Edge Chips
E960097	855306	34639 BCT	FE12	Edge Check

It is agreed that these two parts will be shipped to CalTech via a ship memo. The parts will only be billed after successful polishing and finishing to customers requirements. After processing, CalTech will either; 1) Accept the parts as good and be billed by Corning Inc. 2) Not accept the parts and ship the part(s) back to Corning Inc., Canton Plant.

Signed

Randy VanBrocklin
Applications Engineer - Corning Inc.

CalTech Authorized Signature

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

cc: L. Sutton

HAS NEW DATA SHEET FROM CORNING

Corning

NEW DATA SHEET RECEIVED 5-13-97 GB

DATA SHEET - CAL TECH LIGO MIRROR BLANKS

Cal Tech Purchase Order Number: PP207573

Cal Tech Specification Number LIGO-E960097-A

Attribute	Spec/Drawing #	Requirement	Actual	Stamp	
Diameter	LIGO-D960794-B-D	√ 10.079", -0.0"/+0.040	10.107 / 10.107		QA
Thickness	LIGO-D960794-B-D	√ 4.252",- 0.0" / + 0.040	4.280/4.280/4.280/4.280		QA
Registration Mark	LIGO-D960794-B-D	Top center of optic	See Attached Cert.		M
Serial & Boule #	LIGO-D960794-B-D	Boule and Serial No.	34639-FE - 12		M
Material	Fused Silica 7980		See Attached Cert.		M
Witness Sample Map			See Attached Map		M
Defects		< 0.5 mm	See Attached Map	See Note 1 Below	QA
Inclusions		<0.1;<0.03mm /100cm ;<0.06mm disregard	See Attached Map		QA
Homogeneity - central		1.0 x 10-6	0.140 x 10-6		M
Homogeneity - outside		2.5 x 10-6	0.560 x 10-6		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 Map		QA
Striae	MIL G-174 Section 4.4.6, Method 1 or 2	GRADE A	Inspection Report	See Note 2 Below	M
Absorption		< 20 ppm / cm @ λ = 1.06 μm	N/A		M

Comments: Note 1: Check on bottom surface - Deviation #0016-97. Note 2: C of C will be provided after evaluation & billing.

Inspected by: Gail Andrews Date: 3/6/97

CORNING INCORPORATED

DATA SHEET - CAL TECH LIGO MIRROR BLANKS

Cal Tech Purchase Order Number: PP207573

Cal Tech Specification Number LIGO-E960097 Rev.A

Attribute	Spec/Drawing #	Requirement	Actual	Stamp	
Diameter	LIGO-D960794-B-D	10.079", -0.0"/+0.040	10.107/10.107		QA
Thickness	LIGO-D960794-B-D	4.252",- 0.0" / + 0.040	4.280/4.280/4.280/4.280		QA
Registration Mark	LIGO-D960794-B-D	Top center of optic	See Attached Cert.		M
Serial & Boule #	LIGO-D960794-B-D	Boule and Serial No.	34639-FE11		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		0.5x10E-6	0.140x10-6		M
Homogeneity - outside		2.5x10E-6	0.560x10-6		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 Map		QA
Striae	MIL G-174 Section 4.4.6, Method 1 or 2	GRADE A	Inspection Report		M
Absorption		< 20 ppm / cm @ λ = 1.06 μm	N/A		M

Comments:

Inspected by: Gail Andrews Date 3/6/97

CORNING INCORPORATED

CORNING

Shipping Plant Canton

City & State Canton, N.Y.

SHIP TO

L160 Dowmark Center
Attn Mr Lowell Jones
391 S. Hollister
Pasadena, CA 91186

SHIPPING MEMORANDUM
Corning Incorporated
Miscellaneous and Sample Articles

No. 267727 SM

DATE PREPARED	CUSTOMER	OUR ORDER NUMBER	REQ. NO.	ORDERING PARTY & PHONE NO.
3/6/97	Cal Tech	106248		Name Irene Retter

SHIPPING INSTRUCTIONS	COLL.	PREPAID	BEST WAY	FASTEST	CHEAPEST
Next day UPS Red		✓			

Phone 818 395-2975

LOC.	DEPT.	ACCT.	SUB	PROJECT	SUF.	VALUE	INSURE
						.	☐Y ☐N

TYPE I. Must be approved by Patent, Research, and Sales Dept.

APPROVED

UNCODED ARTICLE* OR UNRELEASED GLASS**

Reason

Pat. Dept.
Research
Sales Dept.

TYPE II.
CODED ARTICLE* AND RELEASED GLASS**

SINGLE APPROVAL ADEQUATE

_____Replacements _____Cash Sales _____Experimental and Display _____ Samples
Other (Specify) Defect to be examined by customer

APPROVED

TYPE III. OTHER THAN CORNING PRODUCTS

SINGLE APPROVAL ADEQUATE

_____Return for Credit _____ Return to Vendor _____ Consignee's Property
_____Corning property for repairs, rebuilding, etc.
_____Items to be used in producing tools and equipment for Corning
_____Other (Specify) _____

* 6 Digit Article Code ** 4 Digit Glass/Material Code

APPROVED

QUANTITY	Code (for glass items) ARTICLE	GLASS	DESCRIPTION
1	F35536	7980	34639 BCT

Rec'd 1 pc. 3/17/97

LIGO-C970471-02-D

Canton Plant
334 County Rt 16
Canton, New York 13617

Corning Incorporated

April 28, 1997

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

Dear Ms. GariLynn Billingsley:

This letter is to document the agreement between California Institute of Technology and Corning, Inc. concerning the acceptance of three damaged mirror blanks which CalTech has agreed to process further.

Caltech Part #	Corning Part #	Corning WO #	Reference #	Defect
E960097	855306	24701 CCT	FE10	Edge Chips
E960097	855306	34639 BCT	FE12	Edge Check
E960096	855307	24702 E	RM01	Edge Chips

It is agreed that these three parts will be shipped to CalTech via a ship memo. The parts will only be billed after successful polishing and finishing to customers requirements. After processing, CalTech will either; 1) Accept the parts as good and be billed by Corning Inc. 2) Not accept the parts and ship the part(s) back to Corning Inc., Canton Plant.

Signed

Randy VanBrocklin
Applications Engineer - Corning Inc.

CalTech Authorized Signature
4-29-97

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

cc: L. Sutton

Corning

Canton Plant
334 County Rt 16
Canton, New York 13617

Corning Incorporated

March 19, 1997

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

Dear Ms. GariLynn Billingsley:

This letter is to document the agreement between California Institute of Technology and Corning, Inc. concerning the acceptance of two damaged mirror blanks which CalTech has agreed to process further.

Caltech Part #	Corning Part #	Corning WO #	Reference #	Defect
E960097	855306	24701 CCT	FE11	Edge Chips
E960097	855306	34639 BCT	FE12	Edge Check

It is agreed that these two parts will be shipped to CalTech via a ship memo. The parts will only be billed after successful polishing and finishing to customers requirements. After processing, CalTech will either; 1) Accept the parts as good and be billed by Corning Inc. 2) Not accept the parts and ship the part(s) back to Corning Inc., Canton Plant.

Signed

Randy VanBrocklin
Applications Engineer - Corning Inc.

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

CalTech Authorized Signature

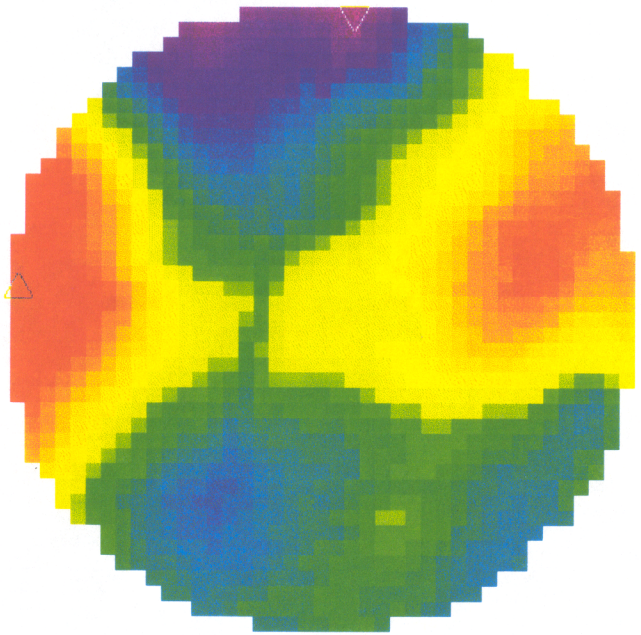
cc: L. Sutton

Corning

zygo

Layout Application

No Aperture



PV 0.030 wave

rms 0.0054 wave

Power -0.011 wave

Homogeneity 1.40E-07

Points 1353

Histogram

PST | TLT | PWR | AST | CMA | SA3

Removed: PST TLT PWR

Controls

Analyze | Mask Data | Calibrate | Save Data | Load Data

Seidel Coefficients

From 36 term Zernike fit

Aberration	Magnitude waves	Angle degs.
TILT	0.018	-125
FOCUS	-0.013	
ASTIGMATISM	0.022	6
COMA	0.010	-163
SPHERICAL	0.002	

Filter: Off

Filter Type: Average

Filter Window Size: 5

Remove Spikes: On

Zernikes

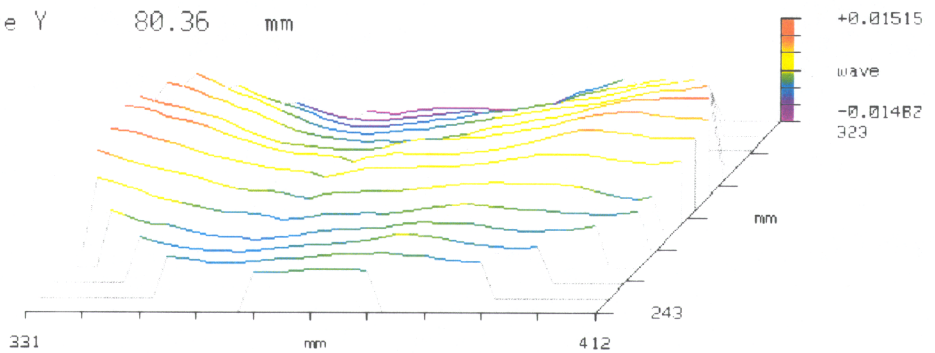
Zernike Terms: 36

Homogeneity 1.40E-07

Save Subapt

Size X 80.36 mm

Size Y 80.36 mm



Controls

Intf Scale Factor: 0.500

Camera Res: 1.9600 mm

Phase Res: High

Phase Avgs: 6

Mask Location:

Data Sign: Normal

Sys Err File: r111596.802

Part Thickness: 135.74 mm

Part Num: F855306

Part Ser Num: 34639BCT

Comment: CAL TECH

Data File: 34639BCT

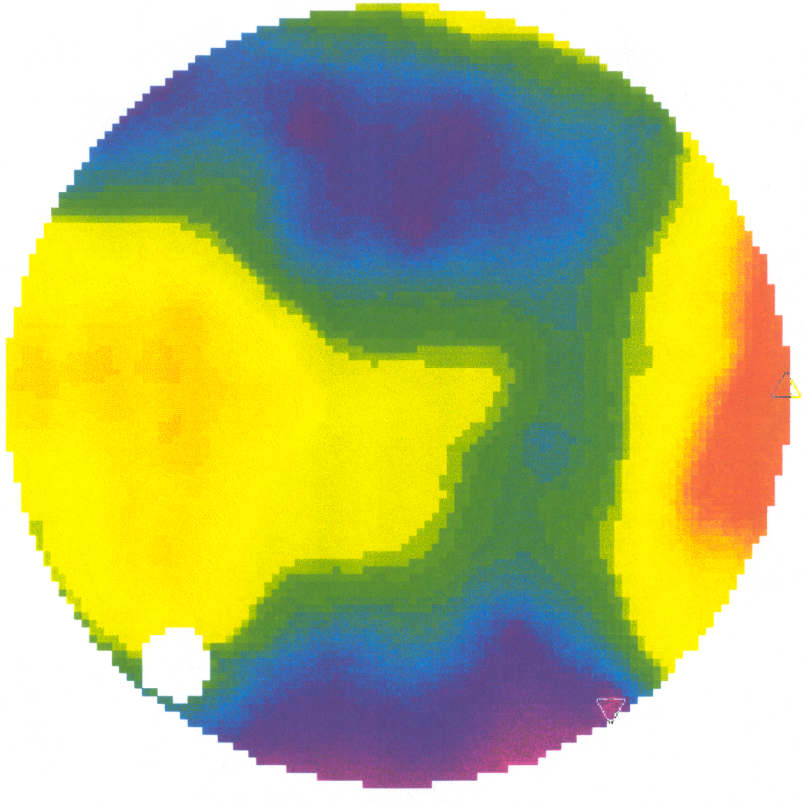
Time: Wed Nov 20 01:37:07 1996

Slope Mag Map | Profile Plot | Synthetic Fringe Map | Intensity Map | Report | File Utilities | Zernike Generate | Manipulate

zygo

Layout Application

No Aperture



PV 0.120 wave

rms 0.0203 wave

Power -0.004 wave

Homogeneity 5.60E-07

Points 8174

Histogram

PST | TLT | PWR | AST | CMA | SA3

Removed: PST TLT PWR

Controls

Analyze | Mask Data | Calibrate | Save Data | Load Data

Seidel Coefficients

From 36 term Zernike fit

Aberration	Magnitude waves	Angle degs.
TILT	0.070	-138
FOCUS	-0.027	
ASTIGMATISM	0.081	3
COMA	0.071	41
SPHERICAL	0.023	

Filter: Off

Filter Type: Average

Filter Window Size: 5

Remove Spikes: On

Zernikes

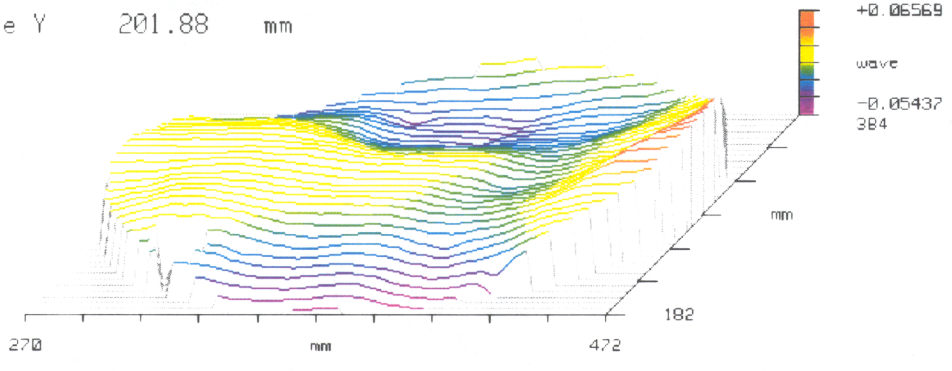
Zernike Terms: 36

Homogeneity 5.60E-07

Save Subapt

Size X 201.88 mm

Size Y 201.88 mm



Controls

Intf Scale Factor: 0.500

Camera Res: 1.9600 mm

Phase Res: High

Phase Avgs: 6

Mask Location:

Data Sign: Normal

Sys Err File: r111596.802

Part Thickness: 135.74 mm

Part Num: F855306

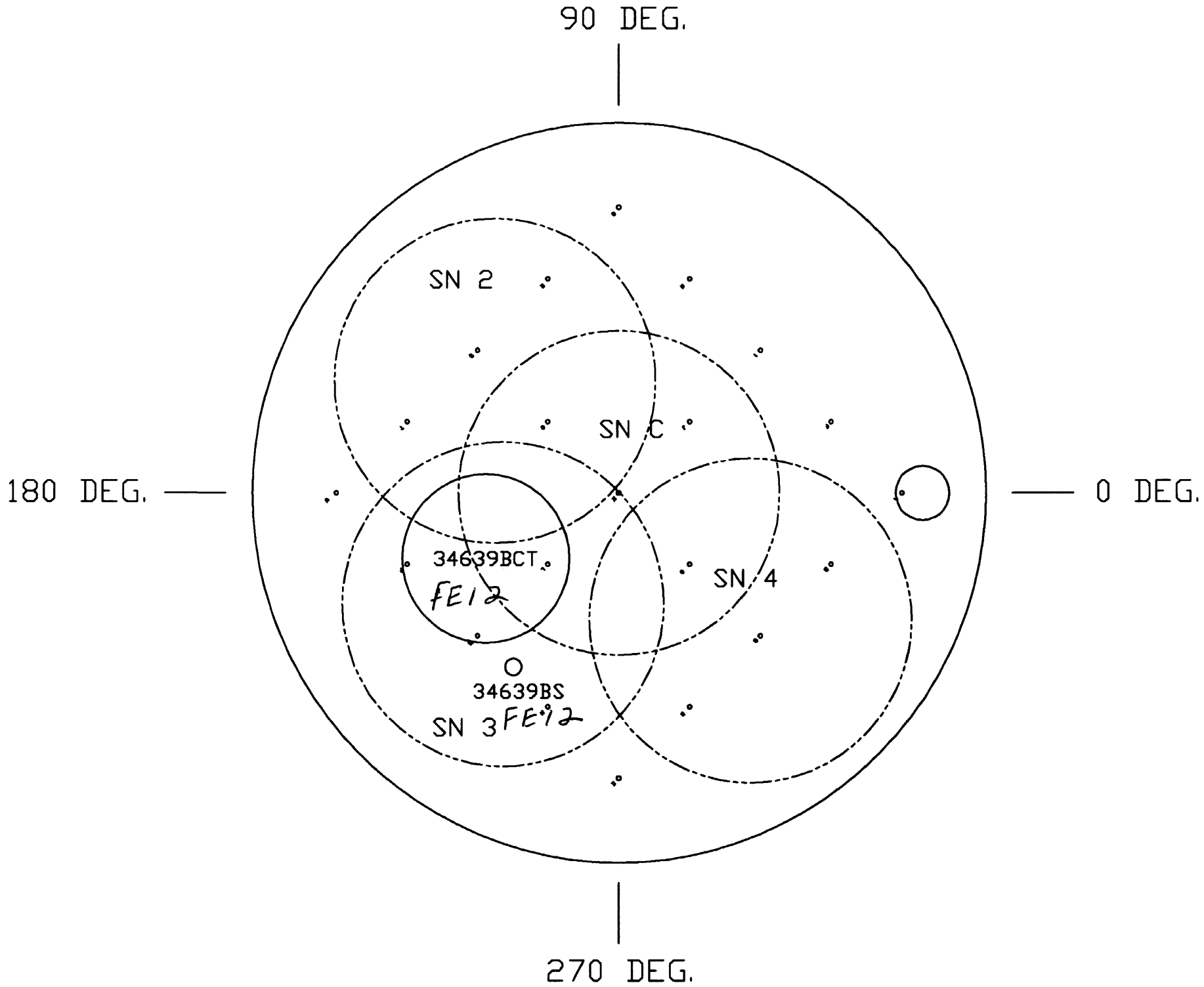
Part Ser Num: 34639BCT

Comment: CAL TECH

Data File: 34639BCT

Time: Wed Nov 20 01:37:07 1996

Slope Mag Map | Profile Plot | Synthetic Fringe Map | Intensity Map | Report | File Utilities | Zernike Generate | Manipulate


90 DEG.
180 DEG.
0 DEG.
270 DEG.
SN 2
SN C
34639BCT
FE12
SN 4
34639BS
SN 3 FE12


SUBSTRATE

A. DCN: LIGO-T970019-00-D
B. LIGO S/N: ETMØ4-A

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

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.: PC167159 D. Substrate Polisher: CSIRO
E. Core optic Material: BS / FM / 2ITM / 4ITM / (ETM) / RM F. 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 compatable 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	9.85	in	250.13 mm
☑	Inspection of material thickness	Thickness	3.95	in	99.75 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. shipper not found

Inspection By: Steve Gibson Date Inspected: 11-11-97

Reviewed and/or accepted by:

Cognizant Engineer: _____ Date: _____

LIGO QA Officer or Designee: _____ Date: _____

FM300

Figure 1

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.)

Small subsurface crack (side 1) - see scan inclosed with CSIRO documents

Roc exactly at spec. min of 7180Km

SKETCHES:

DISPOSITIONS:

Substrate, End Test Mass	Serial Number: ETM04		Specification	Reported Value	✓
	Surface 1	Surface Figure Over Central 200mm	Spherical, Concave	Concave	✓
		Absolute Radius of Curvature Tolerance	~~220~~7,400m +~~150~~m - ~~150~~m 220	7180m	✓
		Variation of Radius of Curvature from Average	+ 111m - 111m		
		Astigmatism	< 10nm p-v	4.3 nm	✓
	Surface 2	Surface Figure Over Central 200mm	Flat	Concave	✓
		Radius of Curvature	> 80 Km	>|1301|m	✓
		Astigmatism	< 64nm p-v	0.9 nm	✓
	Surface Errors Surface 1	Low Spatial Frequency Band Central 80mm	≤ 4.3 cm^{-1} σ_{rms} < 0.8nm	0.45 nm	✓
		Low Spatial Frequency Band Central 200mm	≤ 4.3 cm^{-1} σ_{rms} < 1.6nm	0.75 nm	✓
		High Spatial Frequency Band Central 80 & 200 mm	≤ 4.3 – 7,500 cm^{-1} σ_{rms}<0.2nm	0.20nm 0.20nm	✓

Scratches, Point Defects & Polish Side 1		Specification	Certification	✓
	Scratches	The Total Area of scratches within the central 80mm diameter shall not exceed 25 X 10^3 square micrometers (width x length). o	Hand Sketch w/dimensions	✓
		The total area of scratches outside the central 80 mm diameter shall not exceed 250 x 10^3 square micrometers. o	Hand Sketch w/dimensions	✓
	Point Defects	There shall be no more than 10 point defects within the central 80mm diameter. o	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. 1	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

		Specification	Certification	✓
Scratches, Point Defects & Polish Side 2	Scratches	The total area of scratches shall not exceed 1 X 10^6 square micrometers over the central 235 mm. 8000	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: ETM04A

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: ETM4A1.ASC (Side 1) ETM4A2.ASC (Side 2)

TOPO data: (2.5X) T2EM041A.ASC, T2EM041B.ASC, T2EM041C.ASC (Side 1)

(40X) T4EM041A.ASC, T4EM041B.ASC, T4EM041C.ASC

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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.20**
8	**Team member responsible for measurement/inspection:**	**Carl Sona**
9	**Measurement/inspection results reviewed by:**	**Bob Oreb**

10. Results

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

Physical Quantity	Result
Diameter	250.13 mm
Cylindricity	0.02 mm
Thickness (maximum - for FM, RM, ETM) (minimum - for BS)	99.75 mm
Bevel as per drawing (height, angle):	(S1) Height: 2.03 mm Angle: $44^0 42'$ (S2) Height: 2.12 mm Angle: $44^0 51'$
Wedge angle:	$2^0 01'$
Location of registration mark (± angle with respect to minimum part thickness):	-25' **(NB: outside the spec. as published but within revised tolerance for optics from RM on)**
Location of other 3 marks (with respect to registration mark at minimum thickness)	$90^0 02'$, $180^0 02'$, $270^0 0'$
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: 24 Oct 97

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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: 24 Oct 97

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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: Chris Walsh

Date: 24 Oct 97

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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

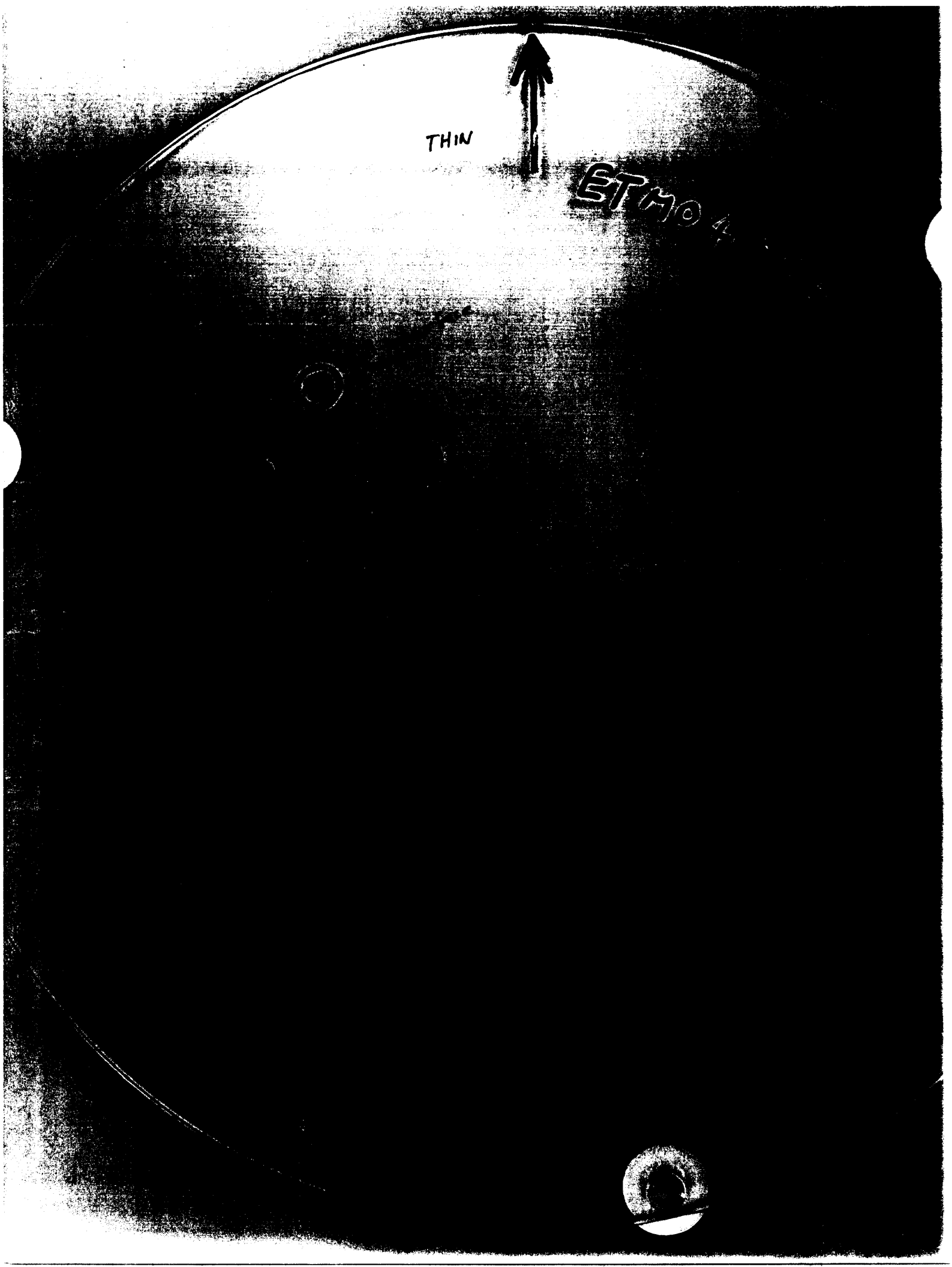
	Numbers of point defects		**Total Area of scratches (square micrometres)**	
	Inside central 80 mm	**Entire surface (235 mm)**	**Inside central 80 mm**	**Outside central 80 mm (235 mm)**
Surface 1	**None**	**1**	**None**	**None**
Surface 2	**None**	**None**	**None**	**8000**

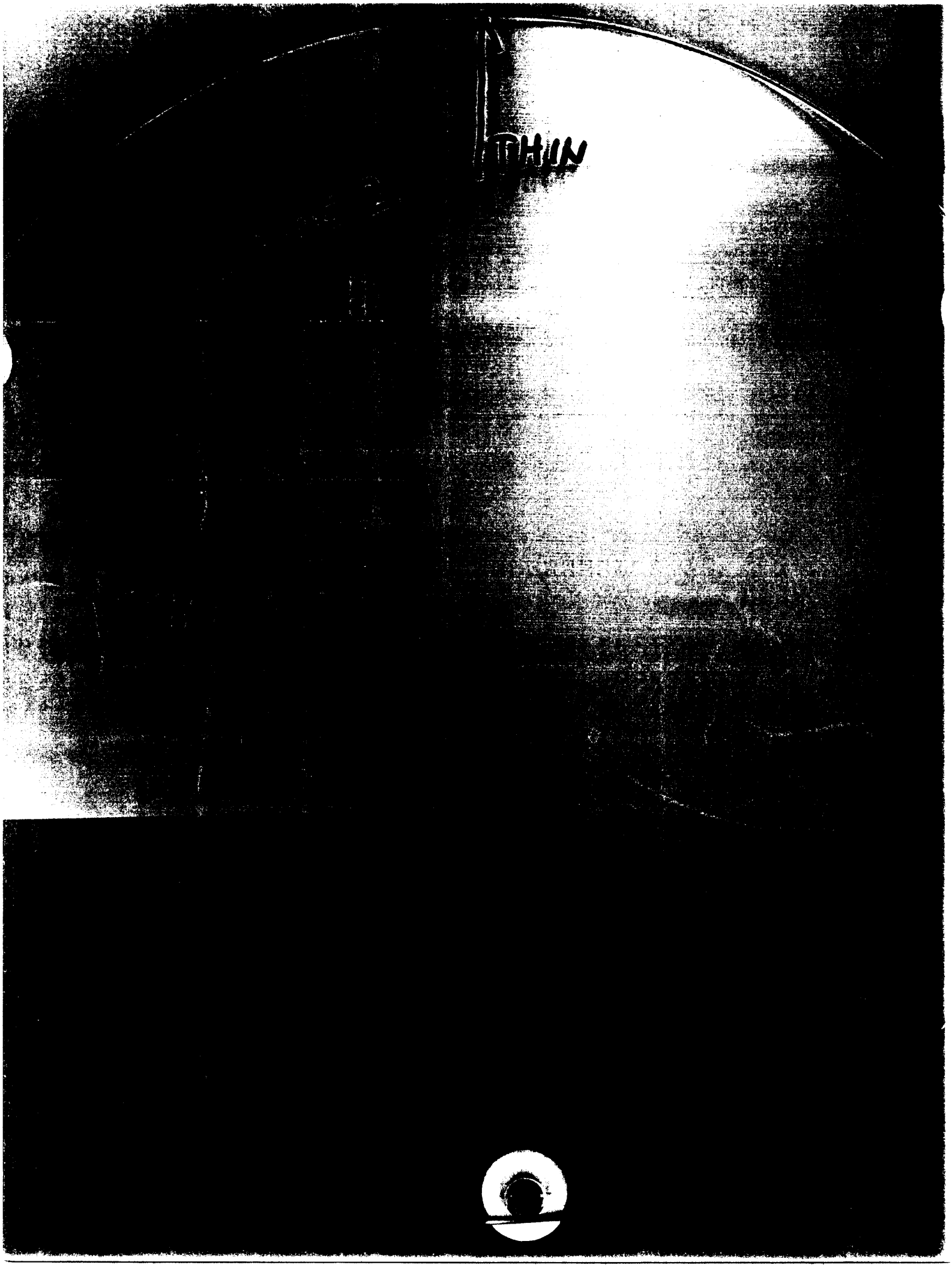
11. Certification

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


THIN


THIN

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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. 105, 113**
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	**7.18 (concave)**	**4.3**	**ETM4A1.ASC**
Surface 2	**>|130| (concave)**	**0.9**	**ETM4A2.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-04A**
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. 105, 113**
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	0.45	0.75
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: 24 Oct 97

1	**Substrate Type:**	**End Test Mass**
2	**Serial Number:**	**ETM-04A**
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. 14 - 17, 44 - 47**
8	**Team member responsible for measurement/inspection:**	**F Lesha**
9	**Measurement/inspection results reviewed by:**	**C Walsh**

10. Results

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

Side 1: **0.20 nm**

Side 2: **N/A**

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

Side 1: **0.20 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	**0.17**	**0.20**	**0.20**	**0.21**	**0.20**	**0.23**	**0.22**	**0.21**
Surface 2								

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: 24 Oct 97

LADI CERTIFICATION DATA

CSIRO

Title: ETM4A1

Date: 09/25/97

Diameter: 200 mm

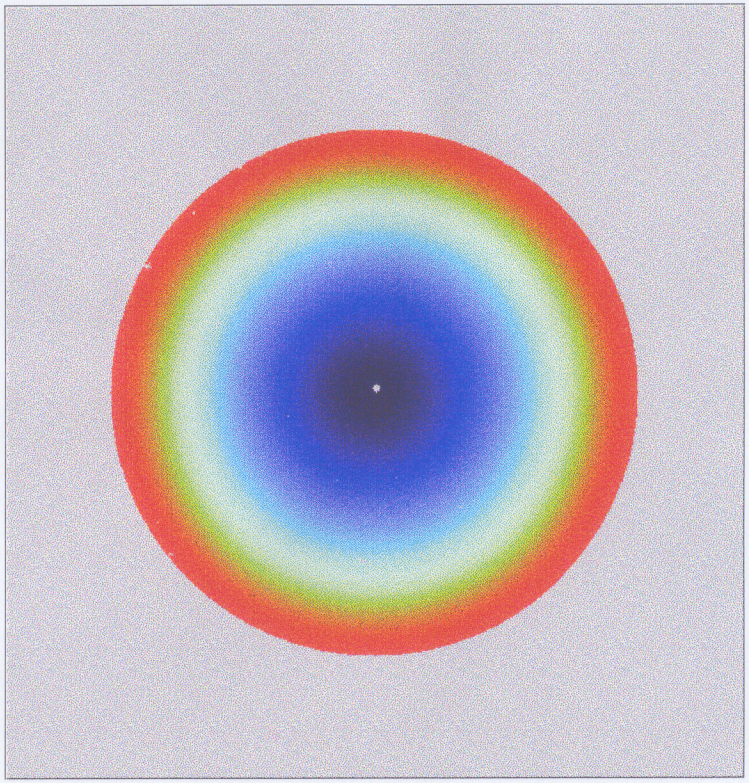
Astig: 4.3 nm

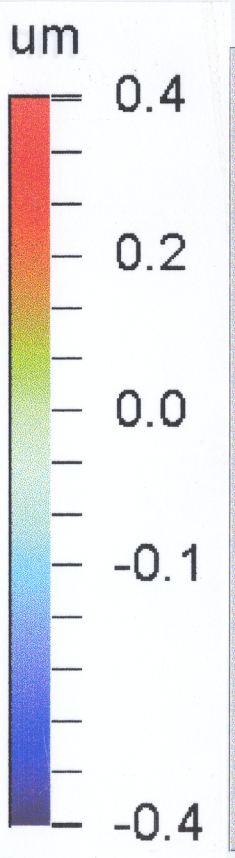
Power: 696.3 nm

PV: 8.5 nm

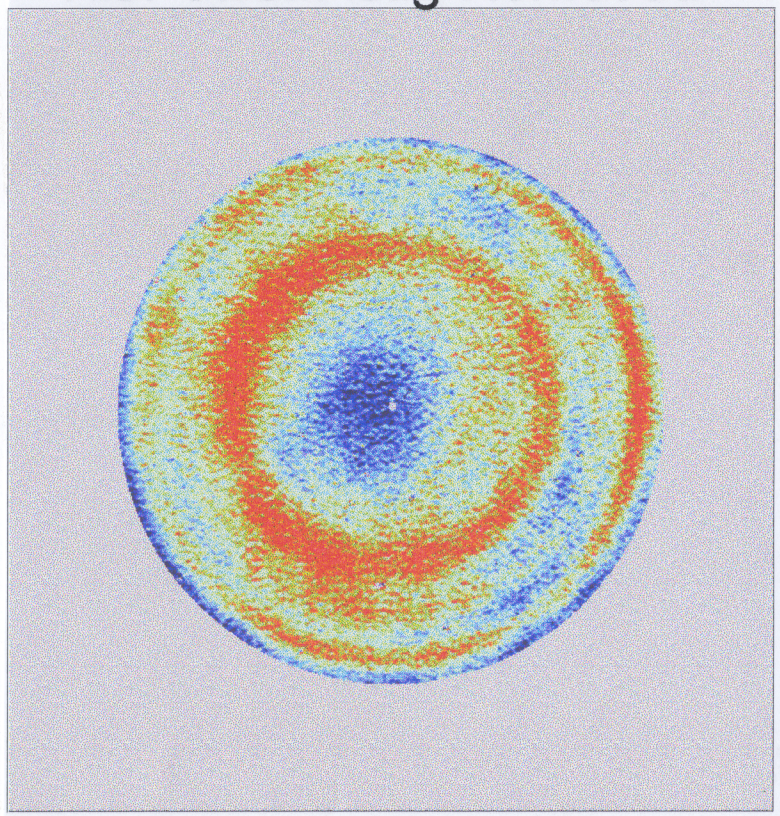
RMS: 0.7 nm

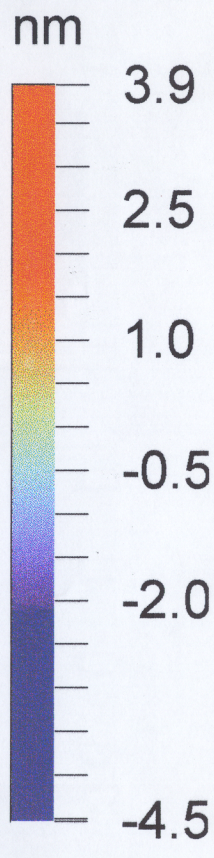
Tilt Removed





Tilt/Power/Astig Removed





Attachment 1

LADI CERTIFICATION DATA

CSIRO

Title: ETM4A2

Date: 10/13/97

Diameter: 200 mm

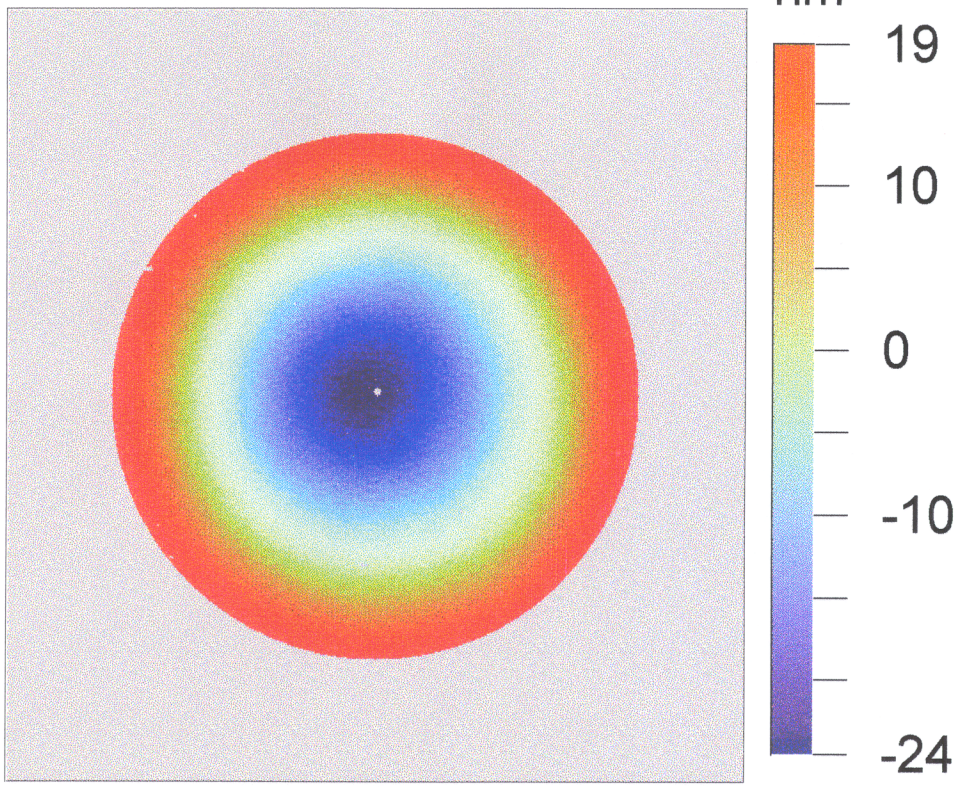
Astig: 0.9 nm

Power: 36.9 nm

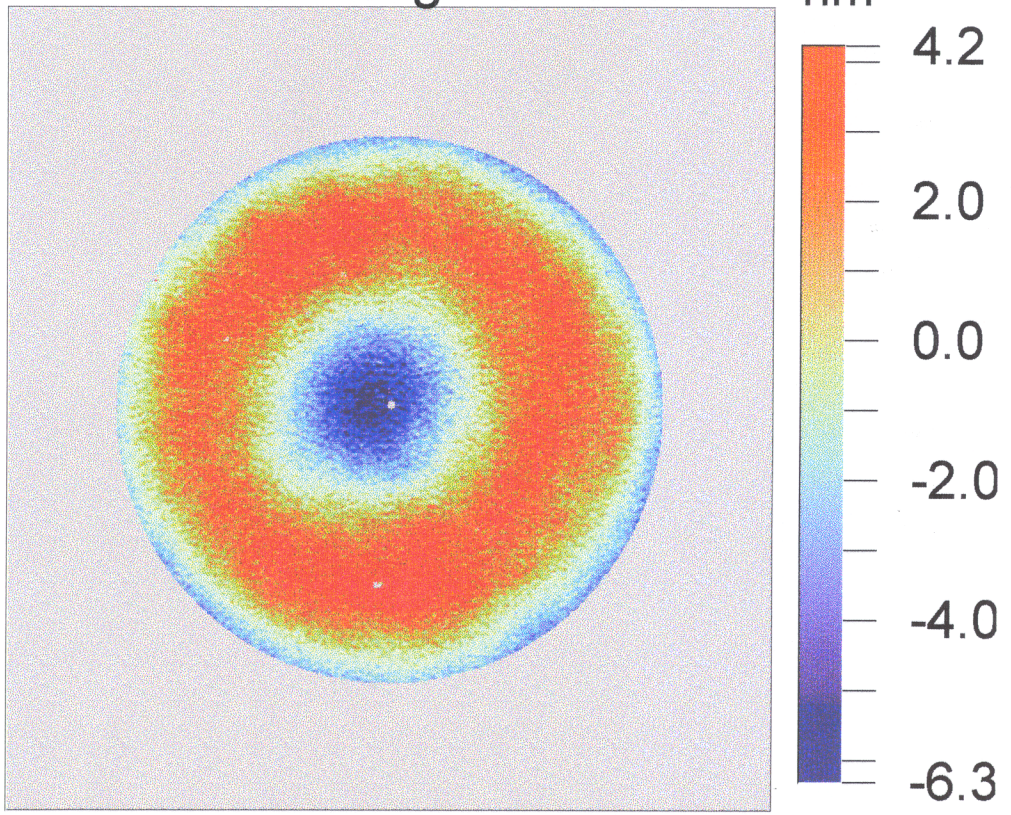
PV: 10.5 nm

RMS: 1.7 nm

Tilt Removed

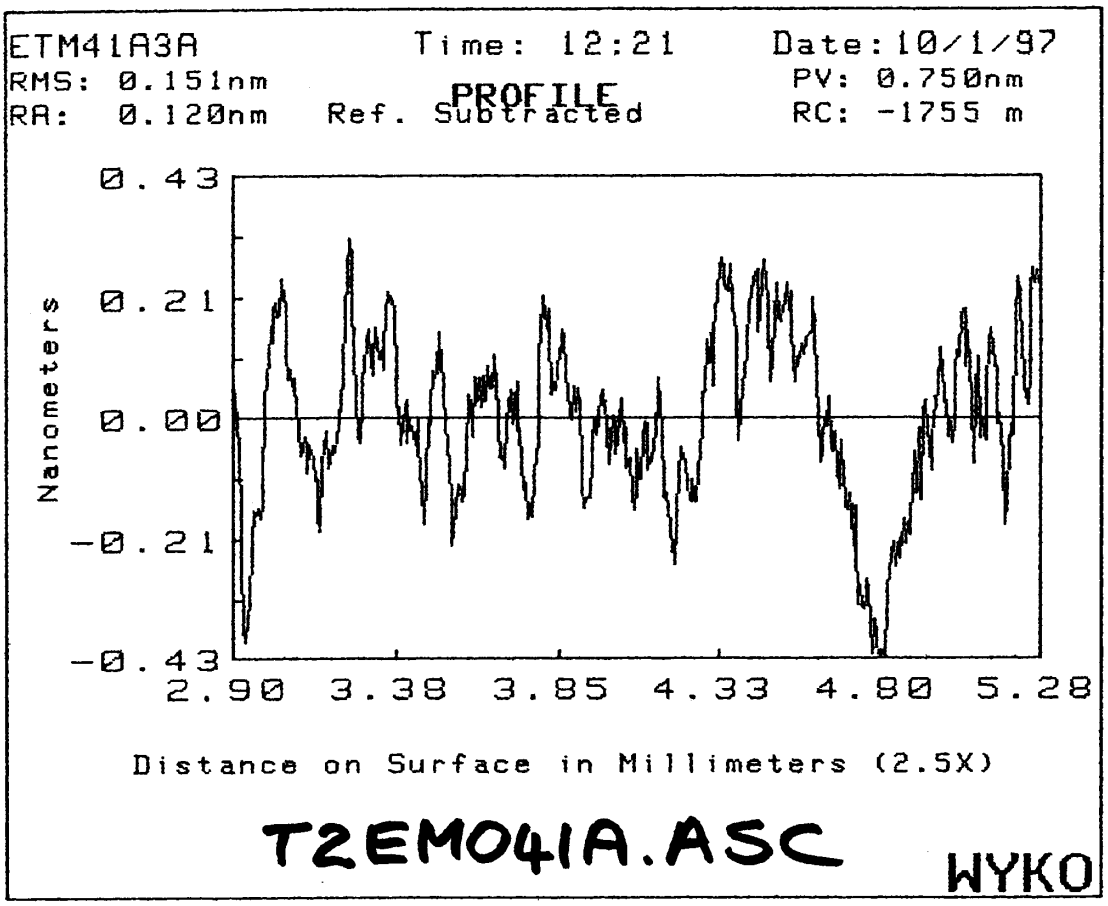


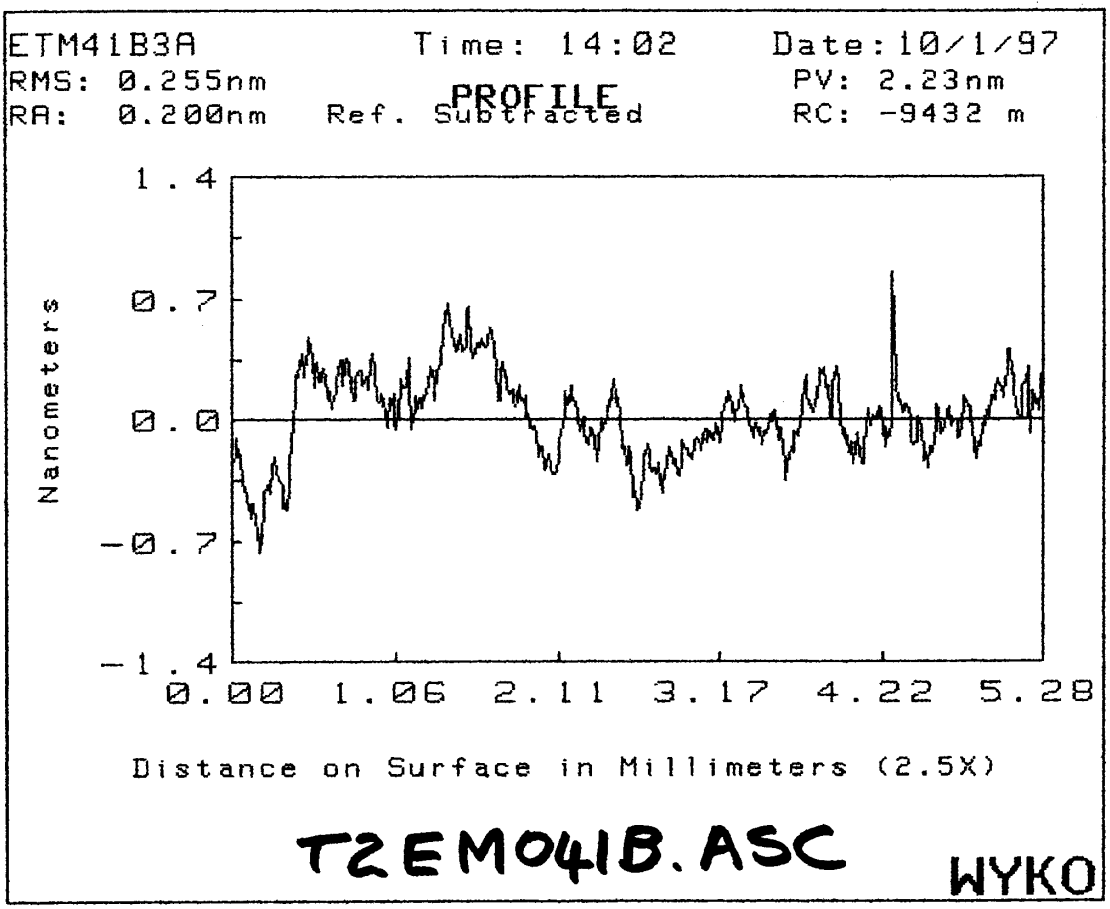
Tilt/Power/Astig Removed

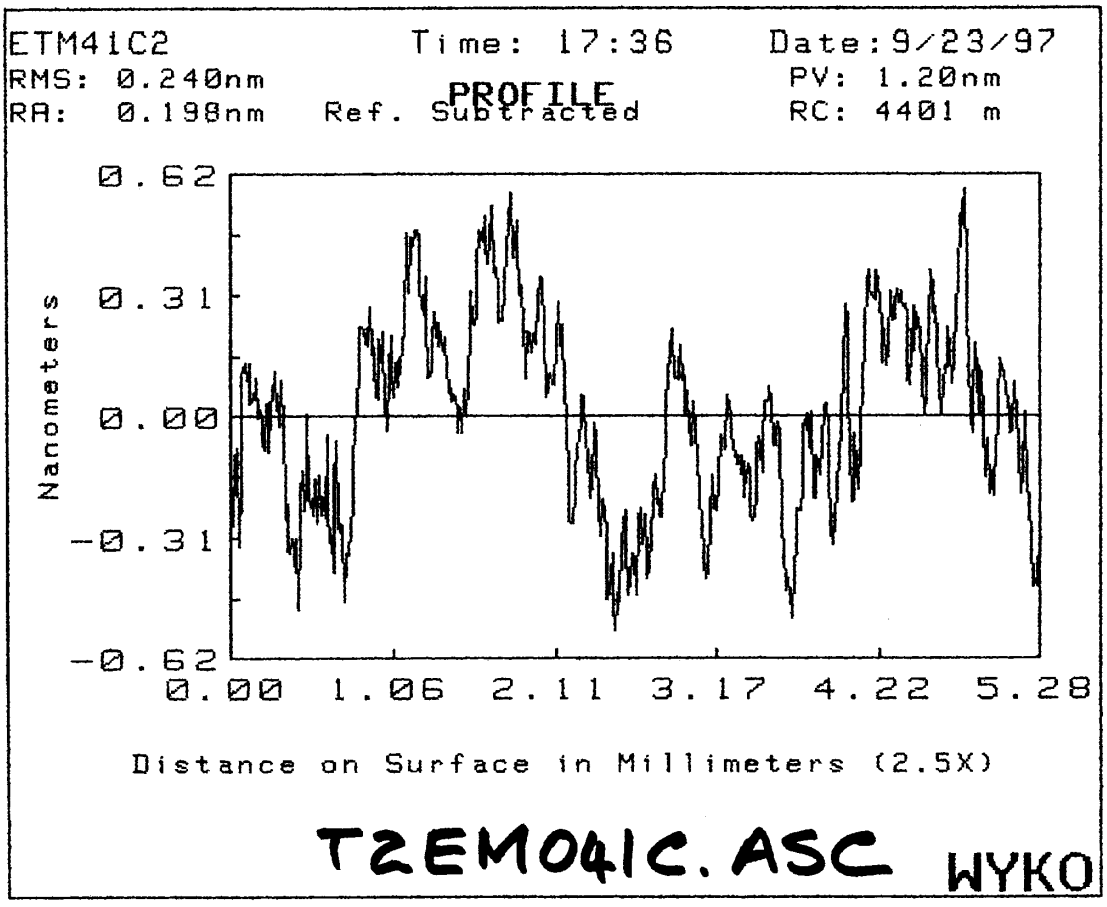


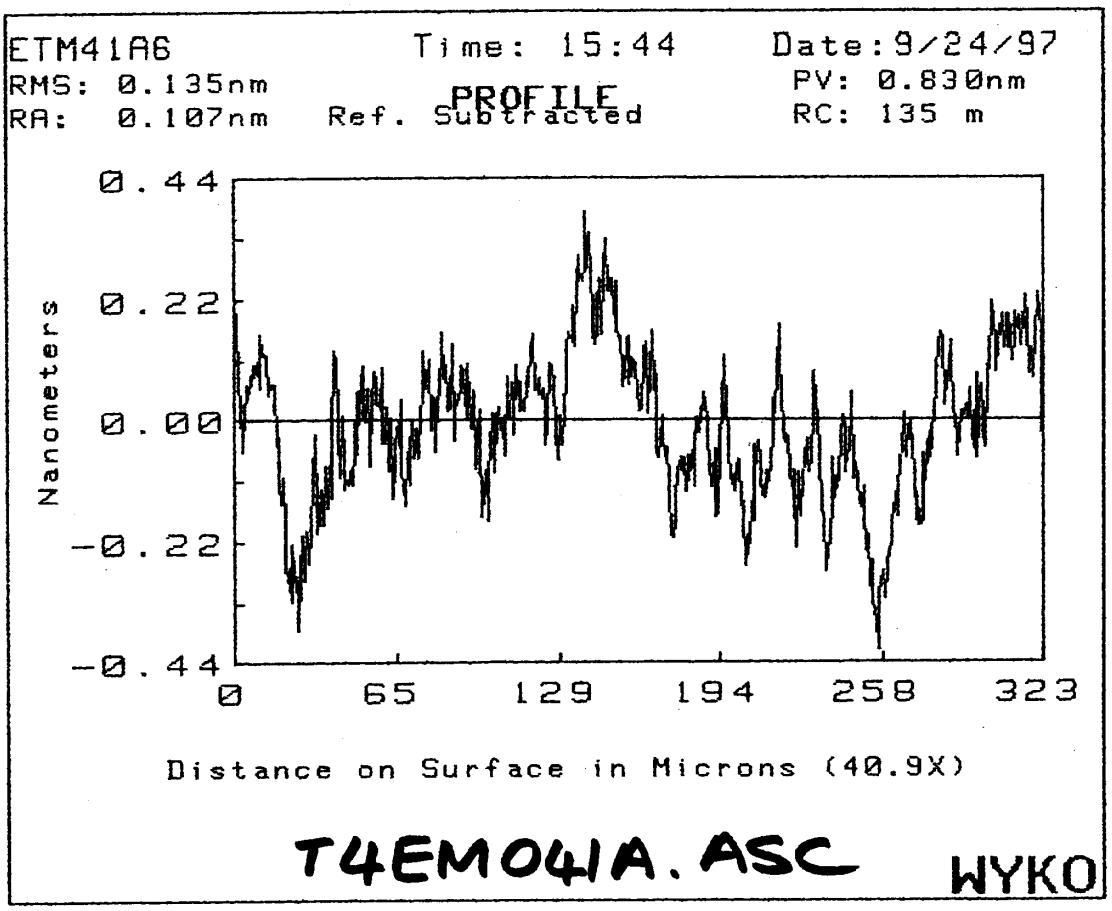
Attachment 2

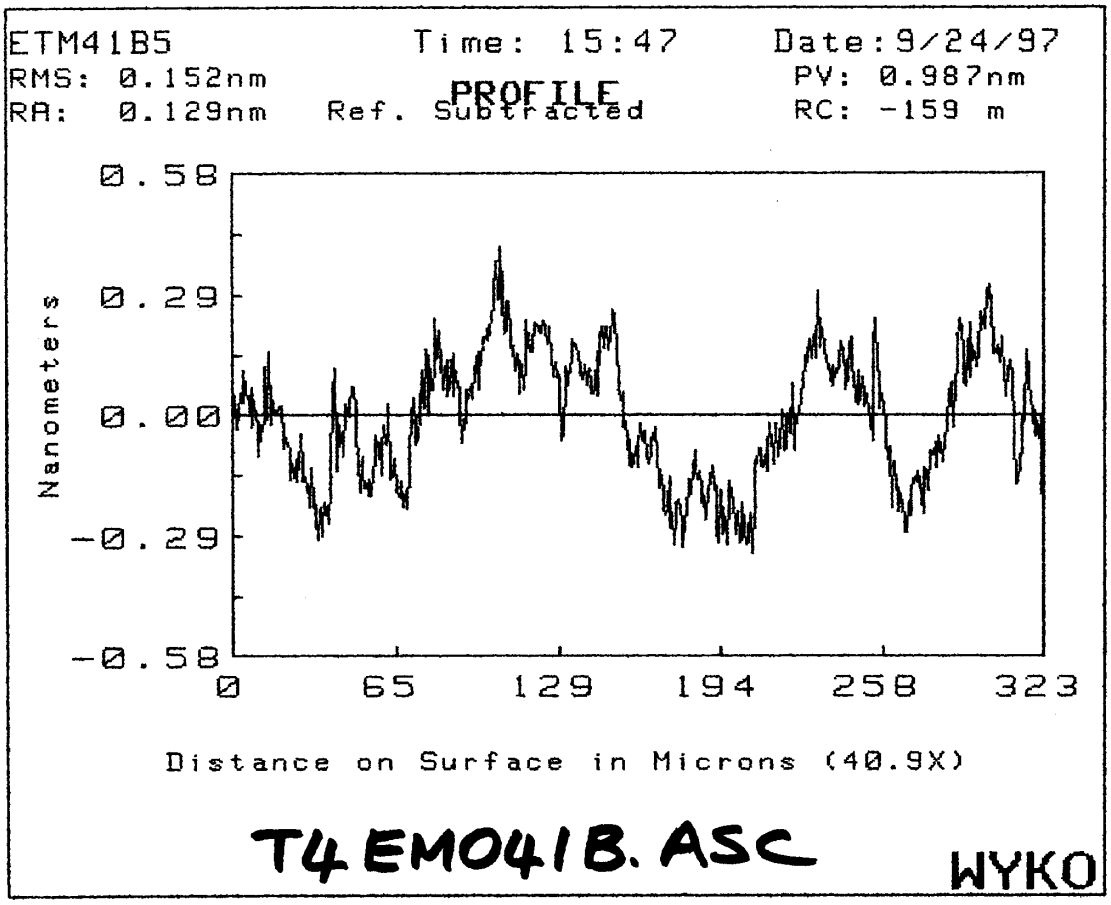
Attachment 3

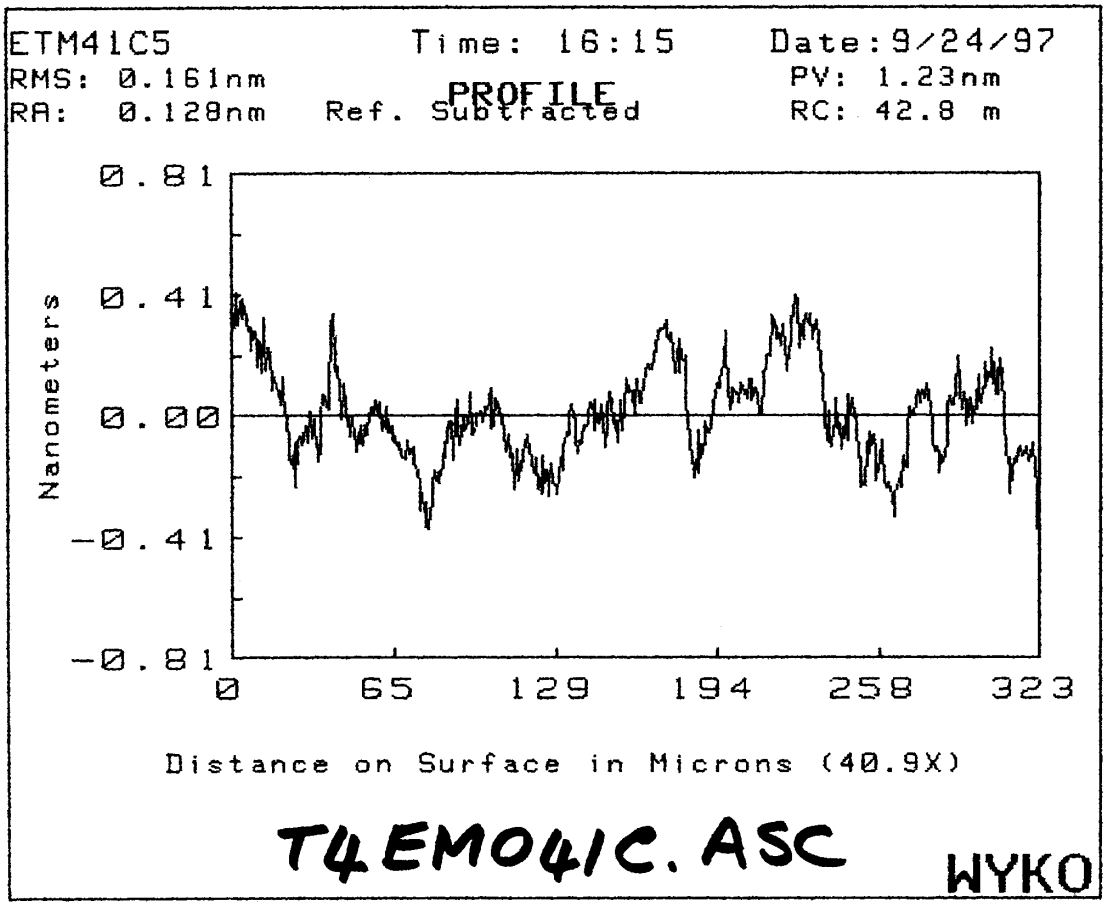



ETM41B3A
Time: 14:02
Date:10/1/97
RMS: 0.255nm
PROFILE
PV: 2.23nm
RA: 0.200nm
Ref. Subtracted
RC: -9432 m
1.4
0.7
0.0
-0.7
-1.4
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2EM041B.ASC
WYKO


ETM41C2
Time: 17:36
Date:9/23/97
RMS: 0.240nm
PROFILE
PV: 1.20nm
RA: 0.198nm
Ref. Subtracted
RC: 4401 m
0.62
0.31
0.00
-0.31
-0.62
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2EM041C.ASC
WYKO


ETM41A6
Time: 15:44
Date:9/24/97
RMS: 0.135nm
PROFILE
PV: 0.830nm
RA: 0.107nm
Ref. Subtracted
RC: 135 m
0.44
0.22
0.00
-0.22
-0.44
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4EM041A.ASC
WYKO


ETM41B5
Time: 15:47
Date:9/24/97
RMS: 0.152nm
PROFILE
PV: 0.987nm
RA: 0.129nm
Ref. Subtracted
RC: -159 m
0.58
0.29
0.00
-0.29
-0.58
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4EM041B.ASC
WYKO


ETM41C5
Time: 16:15
Date:9/24/97
RMS: 0.161nm
PROFILE
PV: 1.23nm
RA: 0.128nm
Ref. Subtracted
RC: 42.8 m
0.81
0.41
0.00
-0.41
-0.81
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4EM041C.ASC
WYKO


MIRROR

Research Electro-Optics Inc.

CERTIFICATE OF CONFORMANCE

Section3.14/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 27, 1998
- Customer Name, Purchase Order No. : LIGO PO#PC162519/CON05
- Customer Part Number & Revision : E98006800D
- Part Description : ETM03, ETM04; HR/AR@1064NM
- REO Job No. : OPT05831-016 Run No.: OX740, OX741
- Qty. Shipped/Lot No. : 2 PCS

☒ **Test data (included)**

Comment:

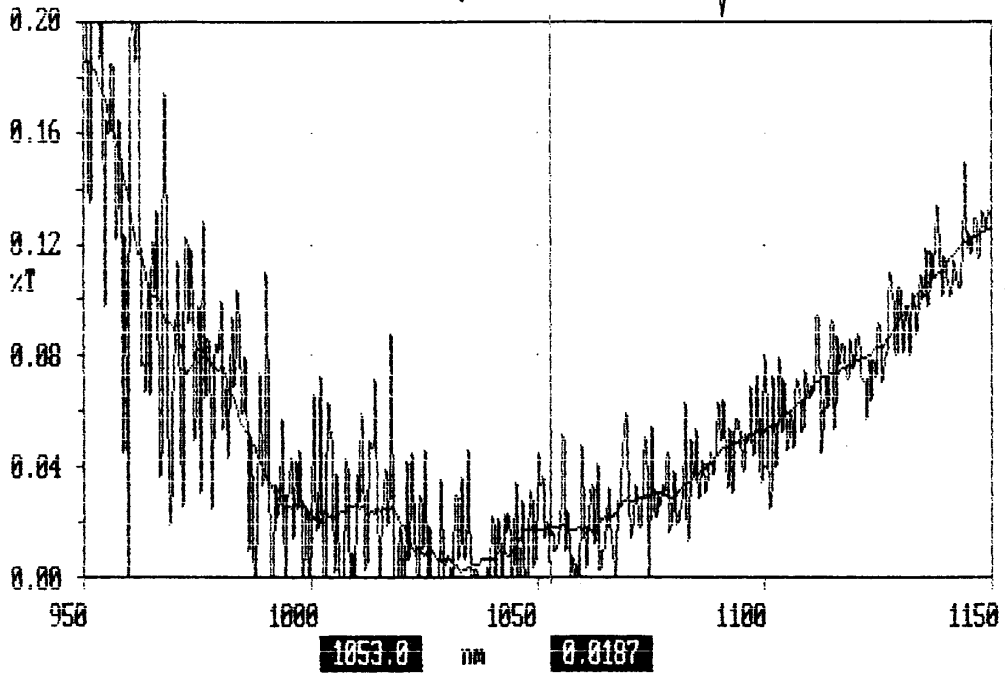
Certified by: _____, 5/27/98
Quality Assurance

Verified by: _____, 5/27/98
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.

ETM03, ETM04

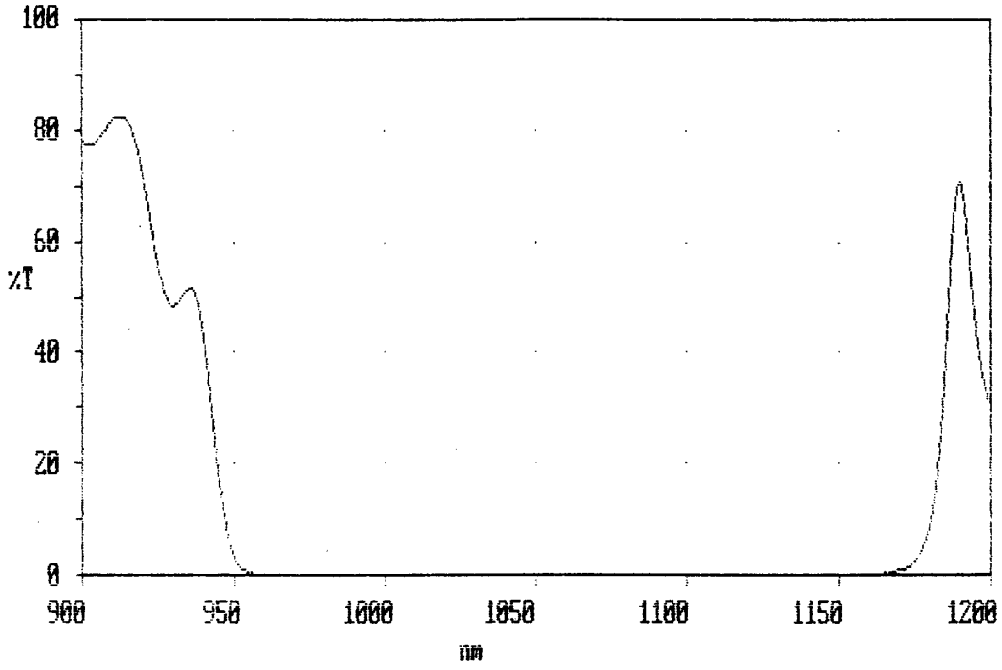
Y: user002: 1150.0 - 950.0 nm; pts 401; int 0.50; ord 0.0026 - 0.1862 %T
Inf: #0X741. AR at 1064nm, after bake, 1" FS witness piece



measured with Laser @ 1053nm
R = 114 ppm @ 5°

ETM03, ETM04

X: USER001; 1200.0 - 900.0 nm; pts 301; int 1.00; ord -0.205 - 82.780 %T
Inf: RUN #0X740 HR@1064NM AFTER PROCESSING



X: USER001; 1200.0 - 900.0 nm; pts 301; int 1.00; ord -0.205 - 82.780 %T
Inf: RUN #0X740 HR@1064NM AFTER [redacted] processing