

**BS02-B**  
(Repolished, Recoated)

**LIGO-T990135-01-D**

**BLANK**

A. DCN: LIGO-T970201-00-D LIGO DETECTOR OPTICSPage 1 of 2B. LIGO S/N: BS02 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.

C. LIGO Contract No.: PC208421 D. Glass Mfg./Order No: Heraeus/5001652  
E. Core optic Material: (BS) FM / ITM / ETM / RM F. Glass Mfg. Part No.: 50785  
G. LIGO Drawing No.: D960793-B-D H. Manufacturer's Boule No.: M.F.F 8921  
I. Date Received at Caltech: 12-01-97

J ☒ Verify glass manufacturer's <sup>inspection report</sup> ~~Certification~~ against LIGO Component Specification No. E960094-A-D  
Attach the applicable Component Specification Verification sheet.

K ☒ Attach a copy of the glass manufacturer's <sup>inspection report</sup> ~~Certification~~ to check-off sheet.

L ☒ Attach the glass manufacturer's birefringence map, ~~inclusion map~~, and data sheet per the above Component Specification. Inclusion map not present

M ☒ Visually inspect for shipping container for damage. If applicable, describe the damage on attached.

N ☒ Visually inspect the blanks for damage, for chips on surfaces and edges, or for other defects. If applicable, describe damage/defects on attached sheet.

O ☒ Verify core optic blank physical dimensions per applicable LIGO drawing.

☒ Inspection of material diameter. Diameter 10.11 in 256.70 mm

☒ Inspection of material thickness. Thickness 2.08 in 52.84 mm

P ☐ Verify that the Registration Mark is present (with arrow pointing to the first surface) as required by LIGO Component Specification. Not present

Q ☐ Verify receipt of 25mm X 25mm cylinder Witness Sample(s) required by the LIGO Component Specification and visually inspect for damage. Describe damage on the attached sheet. Shipped direct to Heraeus (France).

R ☒ Sign and date original packing slip (shipper) and distribute per paragraph 3.R.

Inspect By: [Signature] Date Inspected: 12-02-97

Reviewed and/or accepted by:

Cognizant Engineer: \_\_\_\_\_ Date: \_\_\_\_\_

LIGO QA Officer or Designee: \_\_\_\_\_ Date: \_\_\_\_\_

**LIGO DETECTOR OPTICS**  
**Incoming Inspection Check-off Sheet**Page 2 of 2**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.) \_\_\_\_\_No registration marksNo data discNo birefringence or inclusion map (report  $\phi$  inclusions)witness sample is being sent directly to Heraeus (France) by direction.~~Thickness out of spec.~~ OK  $\text{\textcircled{SE}}$ OH not reportedS/N marked incorrectly - wrong serial number**SKETCHES:****DISPOSITIONS:** \_\_\_\_\_12-30-97 Received additional data package and OH-content  
report.

# LIGO Component Specification Verification Sheet

## Mirror Blanks, Beam Splitter

<b>Mirror Blanks, Beam Splitter</b>	<b>Serial Number:</b> BS02		<b>Specification</b>	<b>Reported Value</b>	✓
	<b>Requirements</b>	<b>Physical Dimensions</b>	LIGO-D960793 -B	?	
		<b>Diameter</b>	256mm +1.0mm, -0mm	256.7mm	✓
		<b>Thickness</b>	52.61mm +1.0mm, -0mm	52.84mm	✗
		<b>Chamfer</b>	2.0mm Max 2pl	—	-
		<b>Clear Aperture</b>	Central 235mm	—	
		<b>Material</b>	Fused Silica Suprasil #3115	Certification	✓
		<b>Registration Mark</b>	"Top" of Optic, 80mm Arrow Points to Side 1	Certification	No
		<b>Witness Sample</b>	25mm dia. x 25mm cylindrical	Shipped direct	✓
		<b>Witness Sample Map</b>		Map Attached	✓
		<b>Defect Depth</b>	< 0.5mm	Hand Sketch w/location & dim.	
		<b>Homogeneity Within the Central 150mm</b>	$\leq 5.0 \times 10^{-7}$ p-v $\lambda = 632.8\text{nm}$	Interferogram Homogeneity Map	✓
		<b>Homogeneity Within the Central 225mm</b>	$\leq 2.5 \times 10^{-6}$ p-v $\lambda = 632.8\text{nm}$	Interferogram Homogeneity Map	✓
		<b>Homogeneity Data</b>	ASCII Format	PC Compatable 3½ in. Disk	No
		<b>Birefringence Within the Central 150mm</b>	$\leq 1$ nm/cm	Certification, Birefringence Map	✓
		<b>Birefringence Within the Central 225mm</b>	$\leq 5$ nm/cm	Certification, Birefringence Map	✓
		<b>Bubble &amp; Inclusion within the clear aperture. Max. Inclusion Diameter</b>	Total $\leq 0.03\text{mm}^2$ Per $100\text{cm}^3$ of Glass. $\leq 0.1\text{mm}$	Hand Sketch w/location & dim.	No
		<b>Absorption</b>	2ppm/cm $\lambda = 1.06\text{nm}$	Certification	No
		<b>Striae within the Clear Aperture</b>	Grade A per MIL-G-174	Inspection Report	✓

Blk\_BS.doc

OH : \_\_\_\_\_

Project LIGO

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Customer : HERAEUS Amersil Inc. Duluth, Ga 30136-5821  
Order No. : 45000023300dtd 30.09.96 as  
HAI-Order No. : none  
HQS-Order No. : 94908401  
Item No. : 2  
Quality : Fused silica Suprasil 311 S  
HQS melt No. : MF.F 8921  
Marking : 960095-IM 14 - B502 BN 5057

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Diameter : 256,7mm  
CA Diameter :  $\varnothing 200 \text{ mm} = 0,71 \times 10^{-6}$   
Thickness : 52,84 mm  
Edge : 0,3 - 0,5 mm  
Parallelism : 0,08 mm  
Roughness : ground  
 $R_a$  : 1,08  $\mu\text{m}$   
 $R_t$  : 8,86  $\mu\text{m}$   
Bubble class : 0 ; none bubbles  
Birefringence : CA  $\varnothing 200 \text{ mm} \leq 5 \text{ nm/cm}$ ;  
Homogeneity : see Interferogram  
Striae Grade : A  
Granularity : none  
Remark : Test Sample ( $\varnothing 25 \times 25 \text{ mm}$ ) with the same marking

**POL - Qualitätsprüfung Optik**

Date : 06.10.1997

Inspector : Wink

**Heraeus**  
QUARZGLAS

POL-QW

Order Nr.: 94908401 Pos.: 2  
Ø 256,7 mm x 52,84 mm  
Quality: Suprasil 311  
Plate No.: 960095-1M 14/ 5057

Date: 6.10.97

Inspector: 

*defect depth: none*  
*Bubble: none*  
*Inclusion: none*  
*Striae: none*

Diameter	0,03mm	0,05mm	0,08mm	0,12mm	0,2mm	0,31mm	Sum
piece							
mm <sup>2</sup>							

TBCS=

mm<sup>2</sup>  
/100cm<sup>3</sup>

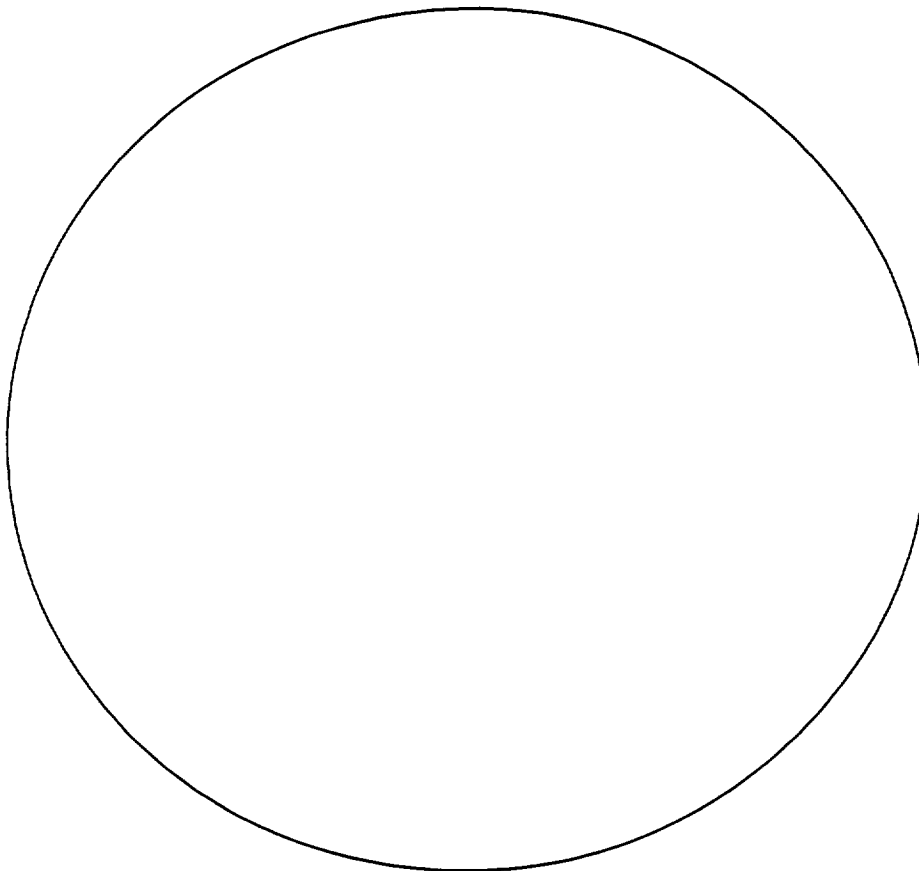
**Heraeus**  
QUARZGLAS

POL - QW

Order No.: 94908401 Pos.: 2  
Ø 256,7 mm x 52,84 mm  
Plate No.: 960095-1414/5057  
Residual strain- Report

Date: 6.10.97

Inspector: *[Signature]*



Edge	Center						Pos.
10							nm
2	< 1						nm/cm

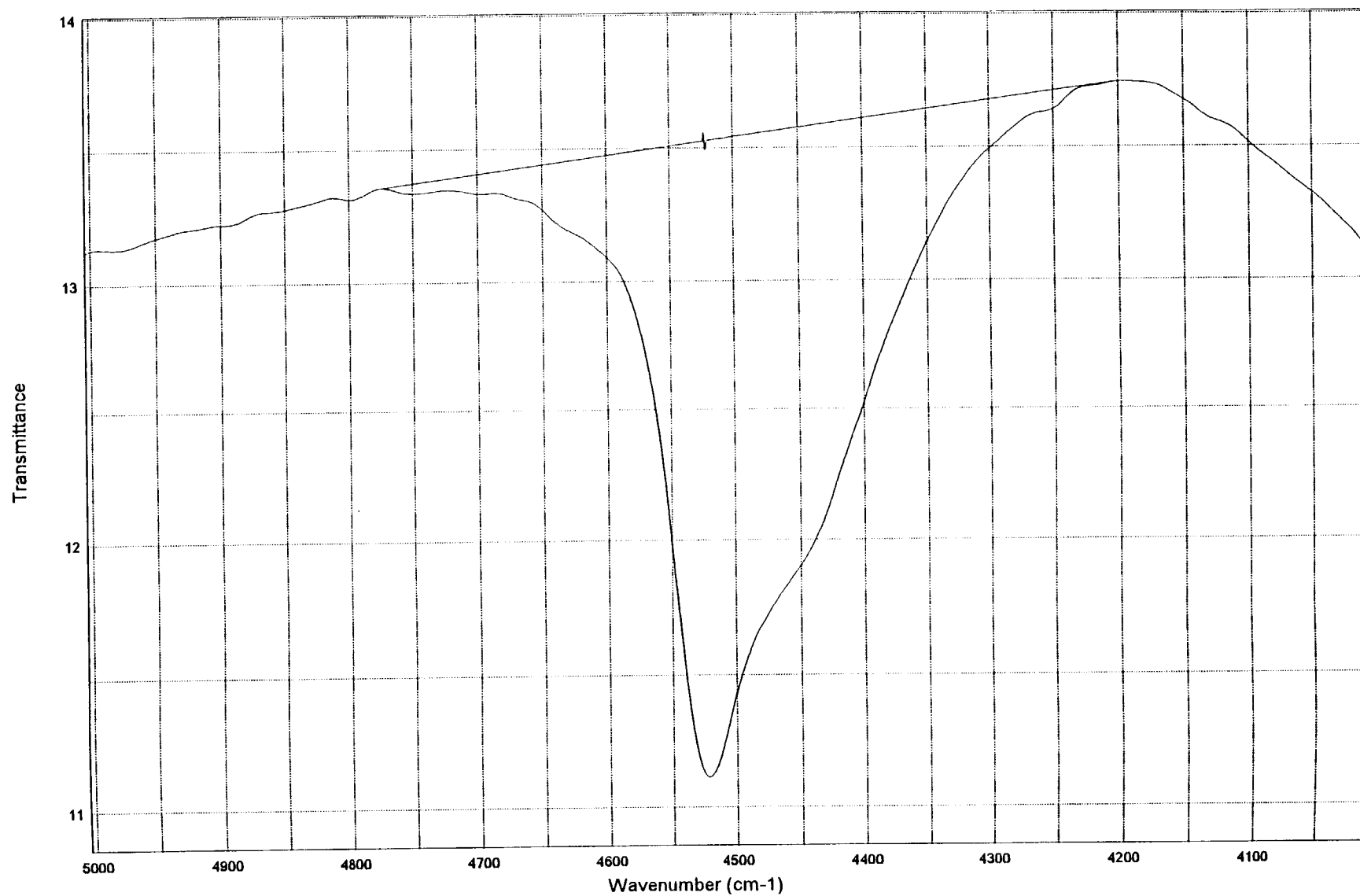


IO=13.5271 , I1=11.1148 at x=4522

OH-content: 142.2 ppm

**Heraeus**  
QUARZGLAS

MEASURE NO. : 5057  
DATE : 05.09.1997 TIME : 12:20  
MEASURE START : 10000 1/cm  
MEASURE END : 2500 1/cm  
OP-DISK-PATH LENGTH : Ko-203-PL: 2.64 cm / Order No.: 9930 3974 / Material: 5057—OH-content: 142.2 ppm at x=4522



# Heraeus

QUARZGLAS

## POL-QW

Data taken at 632.8 nm

Date: 04.09.97

Operator: Rt

ID: 505700

No.:

HQS-Order-No.: 98492874

Customer: HAI

Product: LIGO

Pos.-No.: 2

Order-No.:

Comment: 960094-im-xx

thickness: 53.0 mm

sample diameter: 280.0 mm

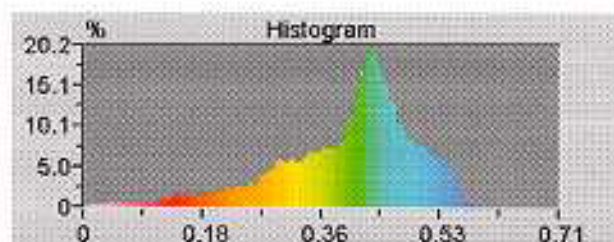
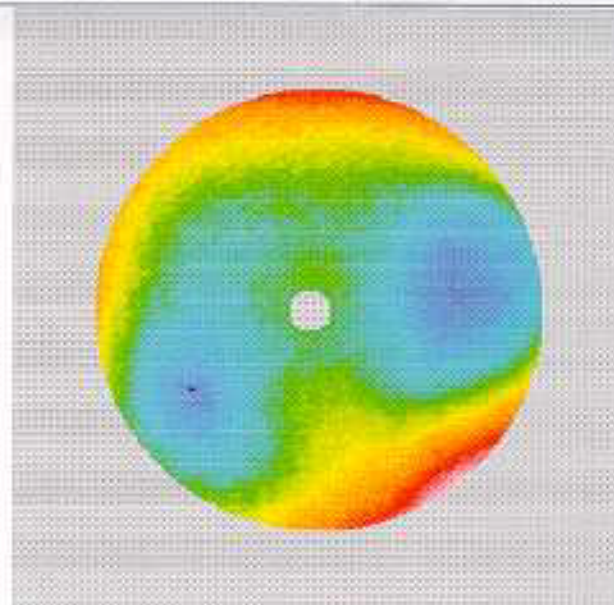
CA diameter: 200.0 mm

examined diameter: 200.3 mm

Center: (0.0mm,0.0mm)

Radius: 100.1mm

Points: 69729



Sub. Terms	Magn.	Angle
XTilt	0.0556	-117.1828
Focus	-0.0985	
Astigm.	0.1663	-69.7358
Coma	0.0212	29.3450
SA3	-0.0616	

Phase Data

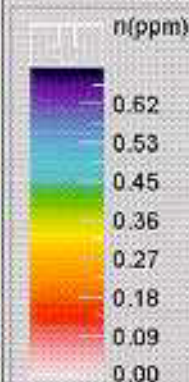
Unit: n(ppm)

PV: 0.71

RMS: 0.100

Scale: 0.5

Contrast



Reset

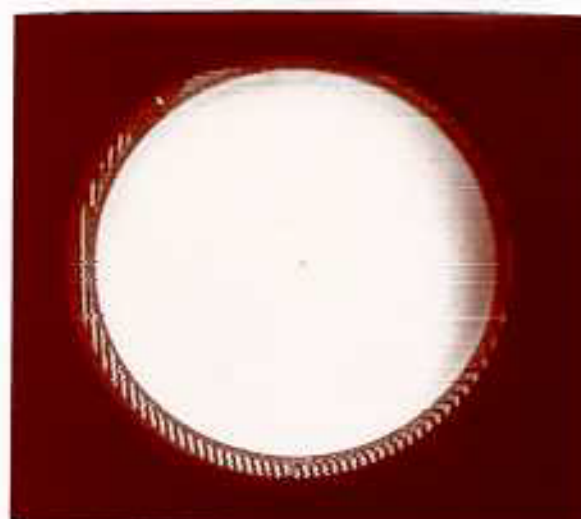
UpperL: 0.713

LowerL: 0.000

File: 505700.tif, 04.09.97, 16:32

XPS-12"

BSØ2



Heraeus Amersil Inc  
3473 Satellite Blvd.  
Duluth, GA 30096

# Heraeus AMERSIL

Sales Order #: 5001652  
Delivery #: 30039279

## Delivery Note/ Packing List

Terms: FOB Duluth  
Customer PO #: pc208421

**SOLD TO:** Customer # 1658  
**CALIFORNIA INST OF TECH**  
**ACCOUNTS PAYABLE 201-6**  
**PASADENA, CA 91125**  
**USA**

**SHIP TO: CUSTOMER # 5594**  
**CALIFORNIA INST OF TECH**  
**Attn: Gari Billingsley**  
**391 SOUTH HOLLISTON**  
**PASADENA, CA 91125**  
**USA**

Order Date: 09/24/1996  
Account #:  
Tracking #: 1Z3944240200060485  
0476 0467 0458 0449 0430

Salesman: 00000020 MARC SCHNEIDER  
Route: UPS002 UPS Blue 2 Day PPA  
Total Weight: 252.000 LB  
Shipping Cartons: 00006

LINE ITEM	MATERIAL NUMBER	DESCRIPTION	UOM	SHIP DATE	NOTICE	CURRENT SHIPMENT
000001	50785	DISC, SUP 311, G, 256 X 52 SUPRASIL 311 DISC, GROUND, 256MM DIA X 61MM THK. PER LIGO PROJECT DRAWING D960793-A-D REV A AND SPECIFICATION LIGO-E960094 REV A  <i>Received complete</i> <i>12-02-97</i> <i>[Signature]</i>	EA	11/24/1997	<p>Open cartons and compare to bill of lading and packing list promptly. Claims for shortages or breakage must be made within 15 days after receipt of goods.</p> <p>Unpack with great care. Please do not discard the packing case nor any of the packing material until contents of case have been carefully checked and found correct and in good order.</p> <p>In case of damaged materials regardless of the external condition of the cartons, the consignee must institute the following procedure. Where shipments are made FOB Point of Shipment, it is the consignee's responsibility to file claim with the carrier and obtain an inspection report from the carrier for truck, air freight or parcel post shipments. For UPS shipments or FOB Destination shipments, all requests for inspection of damaged material should be made by the shipper and the consignee must notify Heraeus-Amersil Inc. promptly of such breakage to institute a claim. Damaged material, packing material, and packing case must be retained for carrier's inspection.</p> <p>Return no goods unless authorized. If material is not satisfactory, notify us and hold material subject to our order.</p>	6.000

**SUBSTRATE**

A. DCN: LIGO- T970200-01-D LIGO DETECTOR OPTICSPage 1 of 3B. LIGO S/N: BS02-8

Incoming Inspection Check-off Sheet

Core Optics Polished Substrate

Re polish

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: CSIROE. Core optic Material: (BS) FM / 2ITM / 4ITM / ETM / RM F. Date Received: \_\_\_\_\_

G ☒ Verify glass polisher's Certification with LIGO Component Specification No. E960100-B-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

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.

No changes from previous polish

<input type="checkbox"/>	Inspection of material diameter.	Diameter	_____ in	_____ mm
<input type="checkbox"/>	Inspection of material thickness	Thickness	_____ in	_____ mm
<input type="checkbox"/>	Wedge Angle	_____		

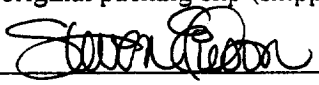
N ☒ Verify that the Serial Number is present in the proper format as required by LIGO Component Specification.

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.

Inspection By:  Date Inspected: \_\_\_\_\_

Reviewed and/or accepted by:

Cognizant Engineer: \_\_\_\_\_ Date: \_\_\_\_\_

LIGO QA Officer or Designee: \_\_\_\_\_ Date: \_\_\_\_\_

FM1300

Figure 1

**LIGO DETECTOR OPTICS**  
**Incoming Inspection Check-off Sheet**

Page 3 of 3

**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.) \_\_\_\_\_

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**SKETCHES:**

**DISPOSITIONS:** \_\_\_\_\_

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		Serial Number: BSØ2-B	Specification	Reported Value	✓
Substrate, Beam Splitter	Surface 1	Surface Figure Over Central 200mm dia.	Flat		
		Radius of Curvature	> 200 km convex > 720 km concave	- 907 Km (-5.8 nm)	✓
		Astigmatism	< 16nm p-v	- 5.6 nm	✓
	Surface 2	Surface Figure Over Central 200mm dia.	Nominally Flat		
		Radius of Curvature of the Wavefront	> 140 km convex > 500 km concave	(-12.6 nm) - 403 Km	✓
		Astigmatism	< 23nm p-v	- 6.3 nm	✓
	Surface Errors	Low Spatial Frequency Band Central 80mm	$\leq 4.3 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 1.6\text{nm}$	1.1 nm	✓
		Low Spatial Frequency Band Central 200mm	$\leq 4.3 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 3.2\text{nm}$	1.1 nm	✓
		High Spatial Frequency Band Central 80 & 200 mm	$\leq 4.3 - 7,500 \text{ cm}^{-1}$ $\sigma_{\text{rms}} < 0.4\text{nm}$	0.15 - 0.19 nm	✓

wave front = 315 km

		Specification	Certification	✓
Scratches, Point Defects & Polish	Scratches	The Total Area of scratches within the central 80mm diameter shall not exceed $75 \times 10^3$ square micrometers (width x length). 10,000	Hand Sketch w/dimensions	
		The total area of scratches outside the central 80 mm diameter shall not exceed $750 \times 10^3$ square micrometers. 20,000	Hand Sketch w/dimensions	
	Point Defects	There shall be no more than 30 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 Beam Splitter



## LIGO Certification Report

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This Certification Package relates to the following substrate: **Beamsplitter (Re-worked)**

**Serial number: BS02-B**

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 and transmitted wave front
HABA - LIGO - C - SL:	Certification of Surface Errors - Low Frequency, for Sides 1 and 2
HABA - LIGO - C - SH:	Certification of Surface Errors - High Frequency, for Sides 1 and 2
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 2A	Hard copy print out of LADI data for Side 2 with piston, tilt, removed and also for piston, tilt, power, astigmatism removed
Attachment 2B	Hard copy print out of LADI data for transmitted wave front in measurement configuration where beam enters through side 2, reflects from side 1 and exits through side 2, with piston, tilt removed and also for piston, tilt, power, astigmatism removed
Attachment 3	Hard copy printouts of TOPO 2D data obtained with 2.5X and 40X heads at three central positions (side 1)
Attachment 4	Hard copy printouts of TOPO 2D data obtained with 2.5X and 40X heads at three central positions (side 2)

\* No change from previous certification - not included here.

## LIGO Certification Report

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### 2. Electronic data

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

LADI data:	BS2B1R.zip	(Side 1)	BS2B2R.zip (Side 2) BS2B2AR.zip (wave front)
TOPO data: (2.5X)	T2BS21AR.asc	(Side 1)	T2BS22AR.asc (Side 2)
	T2BS21BR.asc		T2BS22BR.asc
	T2BS21CR.asc		T2BS22CR.asc
(40X)	T4BS21AR.asc		T4BS22AR.asc
	T4BS21BR.asc		T4BS22BR.asc
	T4BS21CR.asc		T4BS22CR.asc

## LIGO Certification Report     Side and Bevel Polish

1	Substrate Type:	Beamsplitter
2	Serial Number:	BS02-B
3	Physical quantity certified:	Side and Bevel Polish
4	LIGO specification reference:	E960100-B-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	LN00062
8	Team member responsible for measurement/inspection:	E Pavlovic
9	Measurement/inspection results reviewed by:	J Seckold

### 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 after repolish; some small scratches noted on return of substrate to CSIRO, adjacent to arrow on side of optic.**

### 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:

  
22 Dec 98

Chris Walsh

Date:

1	<b>Substrate Type:</b>	<b>Beamsplitter</b>
2	<b>Serial Number:</b>	<b>BS02-B</b>
3	<b>Physical quantity certified:</b>	<b>Scratches and Point Defects</b>
4	<b>LIGO specification reference:</b>	<b>E960100-B-D</b>
5	<b>CSIRO measurement/inspection procedure reference:</b>	<b>HABA-LIGO-M-SP-A</b>
6	<b>Variations to the measurement/inspection procedure:</b> (indicate Yes/No and attach separate sheet if Yes)	<b>No</b>
7	<b>CSIRO Log Book Reference</b>	<b>LN00062</b>
8	<b>Team member responsible for measurement/inspection:</b>	<b>E Pavlovic</b>
9	<b>Measurement/inspection results reviewed by:</b>	<b>C Walsh</b>

## 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)
<b>Surface 1</b>	nil	nil	<10,000	<20,000
<b>Surface 2</b>	nil	nil	<5,000	<10,000

## 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:

*C Walsh*  
22 Dec 98

Chris Walsh

Date:

BSO2 SIDE 1

↑ Thin

100

100 100

2000

2002

2002

4000

3000

100

100

↑ THIN

B S O 2

S I D E 2

1600

2000

2000

4000

1000

1	<b>Substrate Type:</b>	<b>Beamsplitter</b>
2	<b>Serial Number:</b>	<b>BS02-B</b>
3	<b>Physical quantity certified:</b>	<b>Surface Figure</b>
4	<b>LIGO specification reference:</b>	<b>E960100-B-D</b>
5	<b>CSIRO measurement/inspection procedure reference:</b>	<b>HABA-LIGO-M-SF-A</b>
6	<b>Variations to the measurement/inspection procedure:</b> (indicate Yes/No and attach separate sheet if Yes)	The measurement of wave front as per E960100-B-D has been replaced by a specification on the wave front transmitted through the substrate, and is calculated as a sum of the measurement on side 1 and the wave front measured as per E960100-B-D (refer CSIRO/Caltech fax correspondence)
7	<b>CSIRO Log Book Reference</b>	<b>LLN/0137-02 p 60</b>
8	<b>Team member responsible for measurement/inspection:</b>	<b>E Pavlovic</b>
9	<b>Measurement/inspection results reviewed by:</b>	<b>B Oreb</b>

## 10. Results

	<b>Radius of Curvature in km (Parabolic sag in nm)</b>	<b>Astigmatism (nm)</b>	<b>Electronic data file reference</b>
<b>Surface 1</b>	<b>-907 km (-5.8 nm)</b>	<b>-5.6</b>	BS2B1R.zip
<b>Surface 2</b>	<b>-403 km (-12.6 nm)</b>	<b>-6.3</b>	BS2B2R.zip
<b>Wave front*</b>	<b>315 km (16.2 nm)</b>		BS2B2A.zip

\* Measured as per the test procedure in E960100-B-D. Figure quoted and phase map are for the equivalent of a single pass.

**Transmitted wave front (single pass):** The parabolic sag equivalent to that of a wave front transmitted through the beam splitter can be found by adding the sag measured for surface 1 to that measured for the single pass-equivalent of a wave front double passing the material after reflection from side 1 (shown in the table above).

The combined sag is **10.4 nm**, which lies within the tolerance band agreed with Caltech of  $14 \text{ nm} > \text{Sag} > -50 \text{ nm}$ .

Hardcopies of the phase maps are attached to this certification as part of Attachment 1 for Side 1, Attachment 2A for Side 2 and Attachment 2B for the wave front measured as per E960100-B-D. The phase of the wave front shown in Attachment 2B is equivalent to a single pass measurement. 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), modified during subsequent discussions and fax correspondence. 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:

22 Dec 98



# LADI CERTIFICATION DATA

Title: BS\_21R

Date: 12/08/98

Diameter: 200 mm

Astig: -5.6 nm

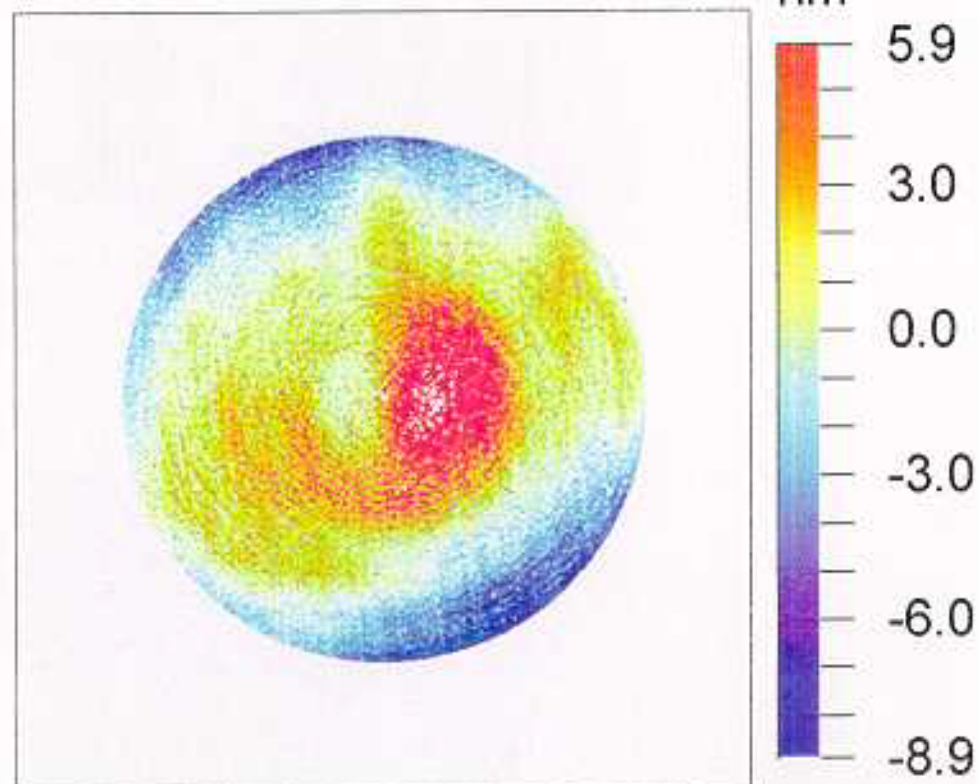
Power: -5.8 nm



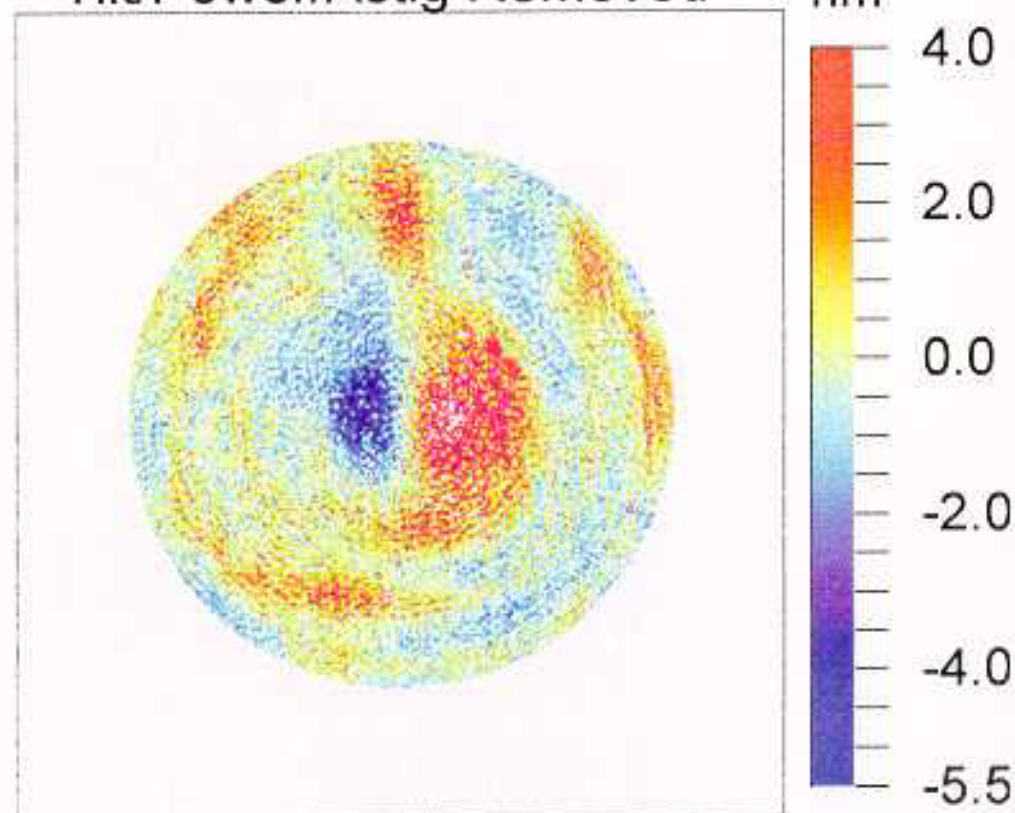
PV: 9.5 nm

RMS: 1.1 nm

Tilt Removed



Tilt/Power/Astig Removed



# LADI CERTIFICATION DATA

Title: BS\_22R

Date: 12/08/98

Diameter: 200 mm

Astig: -6.3 nm

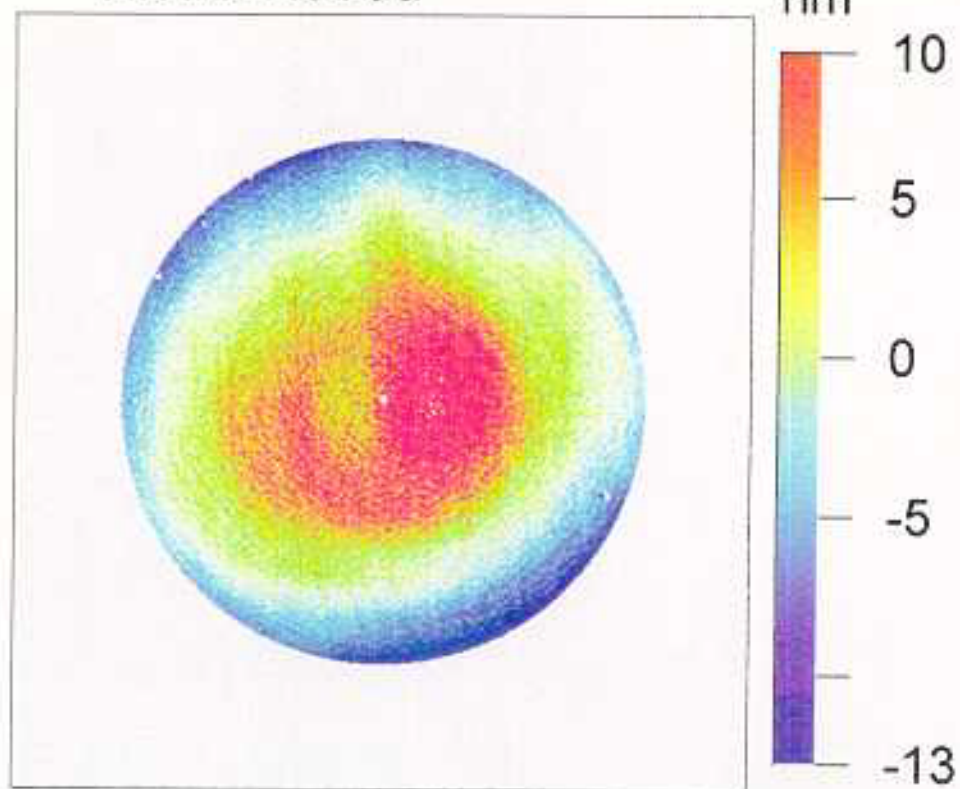
Power: -12.6 nm



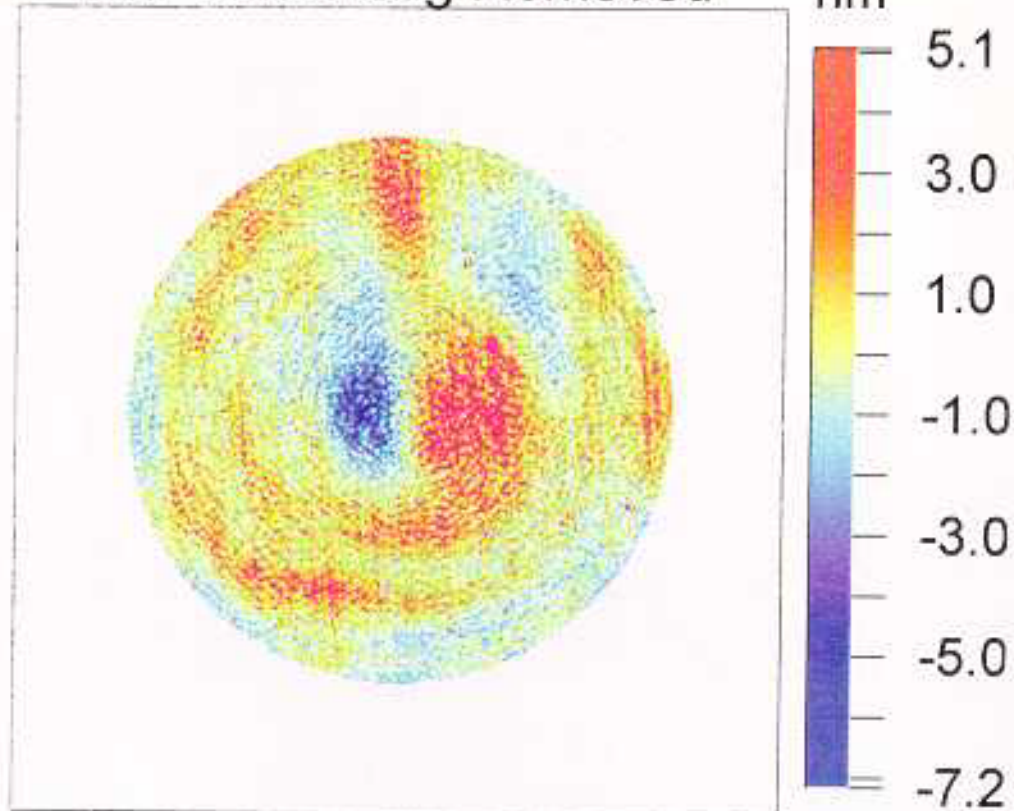
PV: 12.2 nm

RMS: 1.1 nm

Tilt Removed



Tilt/Power/Astig Removed





# LADI CERTIFICATION DATA

Title: BS\_2TR

Date: 12/08/98

Astig: 10.0 nm

Diameter: 200 mm

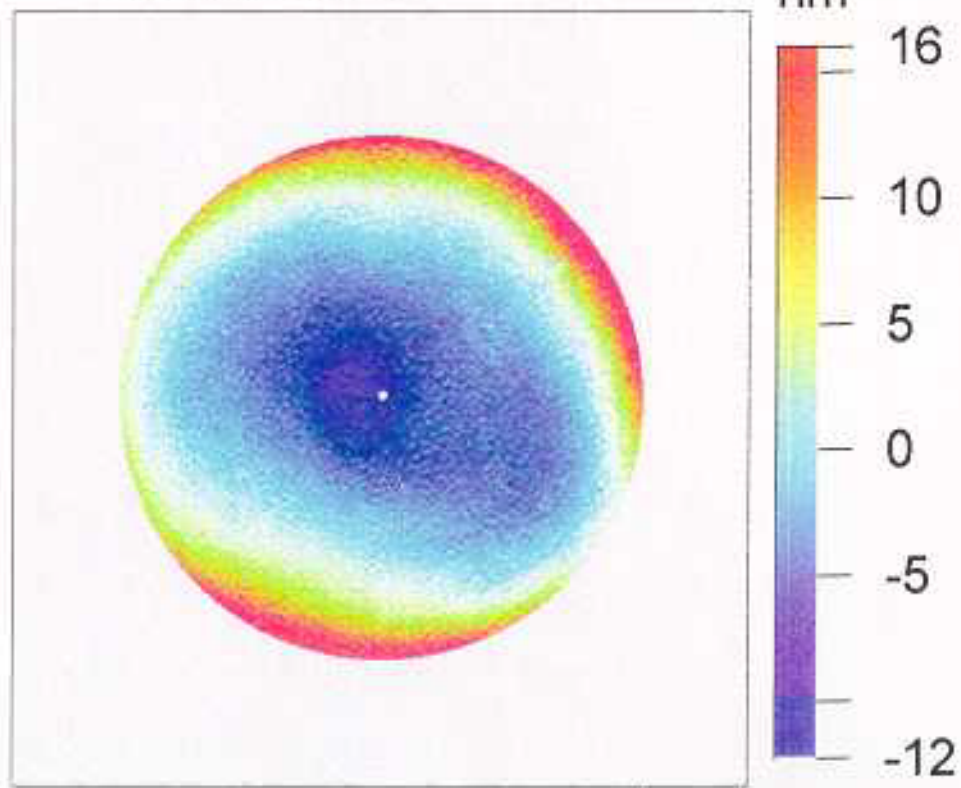
Power: 16.2 nm



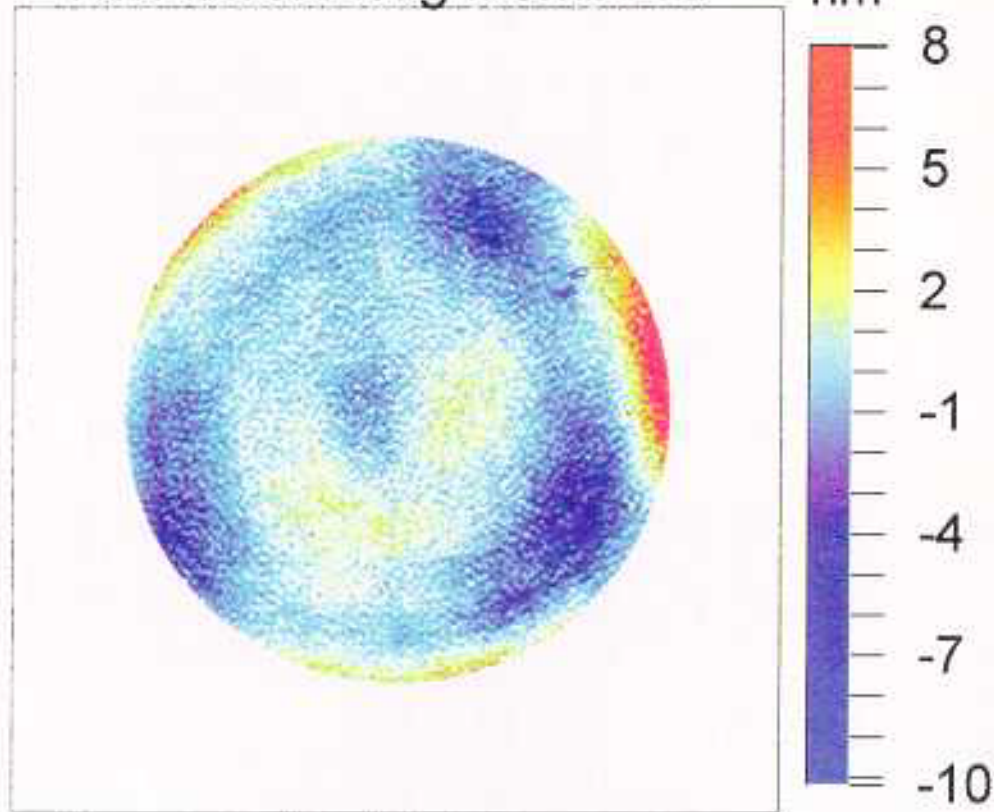
PV: 18.2 nm

RMS: 1.4 nm

Tilt Removed



Tilt/Power/Astig Removed



# LIGO Certification Report      Surface Errors - Low

1	<b>Substrate Type:</b>	<b>Beamsplitter</b>
2	<b>Serial Number:</b>	<b>BS02-B</b>
3	<b>Physical quantity certified:</b>	<b>Surface Errors - Low Spatial Frequency</b>
4	<b>LIGO specification reference:</b>	<b>E960100-B-D</b>
5	<b>CSIRO measurement/inspection procedure reference:</b>	<b>HABA-LIGO-M-SL-A</b>
6	<b>Variations to the measurement/inspection procedure:</b> (indicate Yes/No and attach separate sheet if Yes)	<b>No.</b>
7	<b>CSIRO Log Book Reference</b>	<b>LLN/0137-02 p. 60</b>
8	<b>Team member responsible for measurement/inspection:</b>	<b>E Pavlovic</b>
9	<b>Measurement/inspection results reviewed by:</b>	<b>B Oreb</b>

## 10. Results

	<b>Low Frequency Surface Errors (nm)</b>	
	<b>80 mm aperture</b>	<b>200 mm aperture</b>
<b>Surface 1</b>	1.1	1.1
<b>Surface 2</b>	1.1	1.1

Hardcopies of the phase maps over the central 200 mm with piston, tilt, power and astigmatism removed are enclosed with this certification in Attachment 1 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:

22 Dec 98

1	Substrate Type:	Beamsplitter
2	Serial Number:	BS02-B
3	Physical quantity certified:	Surface Errors - high spatial frequency
4	LIGO specification reference:	E960100-B-D
5	CSIRO measurement/inspection procedure reference:	HABA-LIGO-M-SH-A
6	Variations to the measurement/inspection procedure: (indicate Yes/No and attach separate sheet if Yes)	Data were analysed using PC-based software routines rather than HP-based routines.
7	CSIRO Log Book Reference	LLN/091
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:            0.15**

**Side 2:            0.15**

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

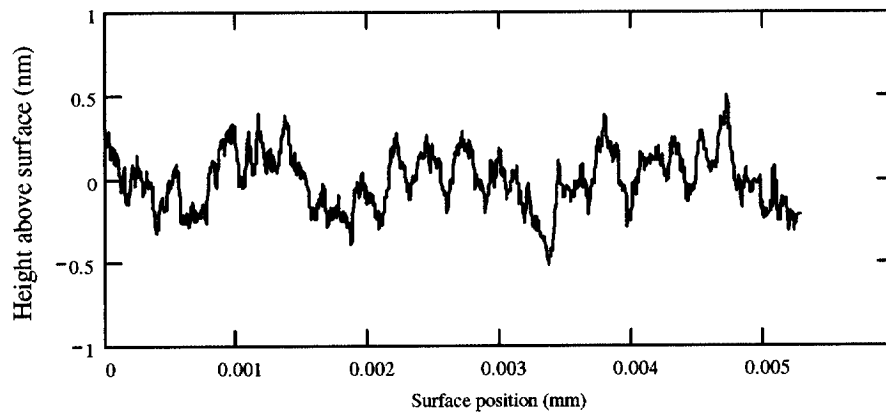
**Side 1:            0.19**

**Side 2:            0.15**

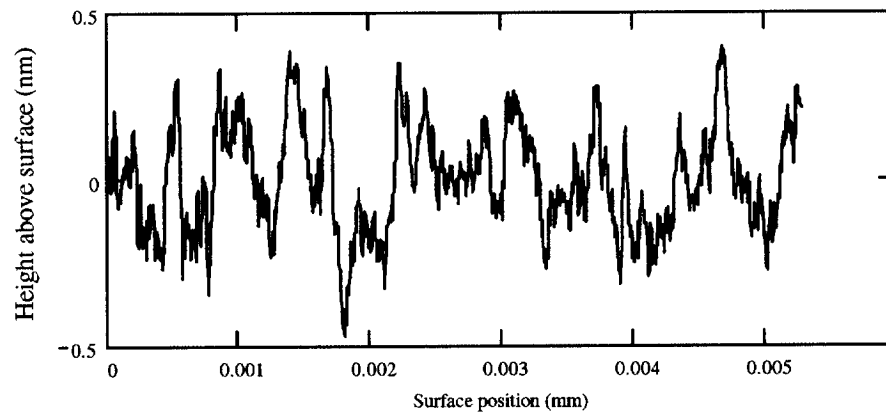
*10.3 Surface errors in nanometres at different positions A through H on surface:*

	A	B	C	D	E	F	G	H
<b>Surface 1</b>	<b>0.20</b>	<b>0.09</b>	<b>0.16</b>	<b>0.15</b>	<b>0.12</b>	<b>0.39</b>	<b>0.22</b>	<b>0.20</b>
<b>Surface 2</b>	<b>0.16</b>	<b>0.17</b>	<b>0.13</b>	<b>0.15</b>	<b>0.14</b>	<b>0.14</b>	<b>0.18</b>	<b>0.15</b>

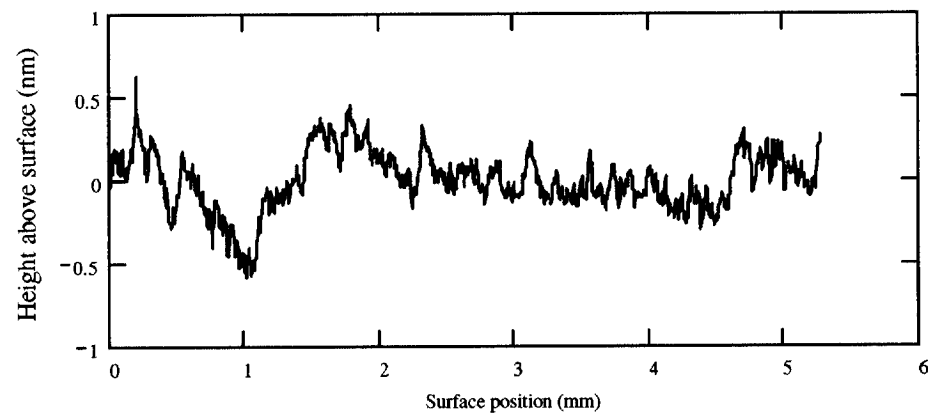
Two - dimensional surface maps at three central locations are available at the CSIRO ftp site under filenames of the form TMBS0YZAR.asc, where M is the objective used (M=2 for 2.5X, 4 for 40X), BS is the substrate type, 0Y is the number, Z = 1 or 2 is the side and A = A, B, C, ... is the sampling position and R denotes measurements on the re-worked surface. Hard copies of the data are at Attachment 3 (Side 1) and Attachment 4 (Side 2).



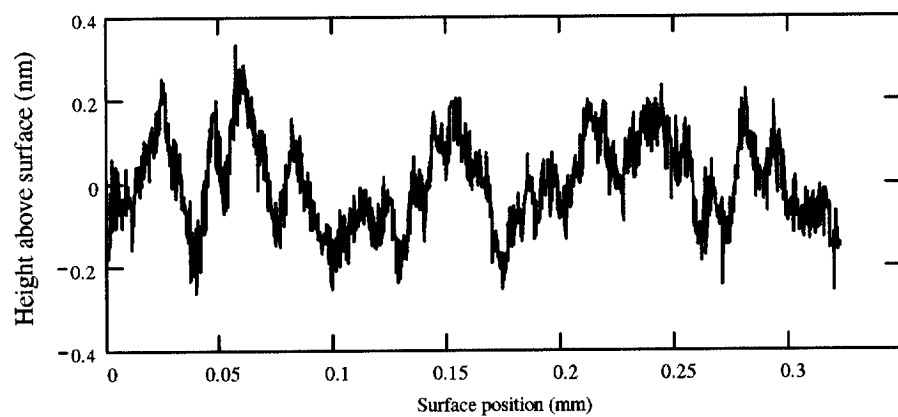
T2BS21AR.asc



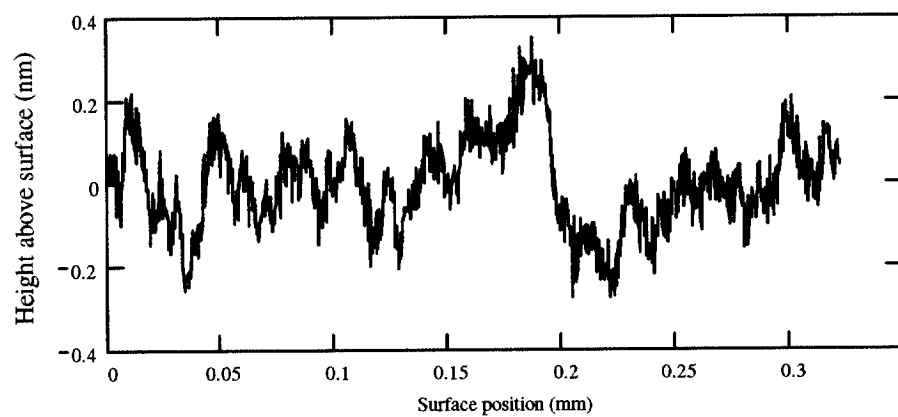
T2BS21BR.asc



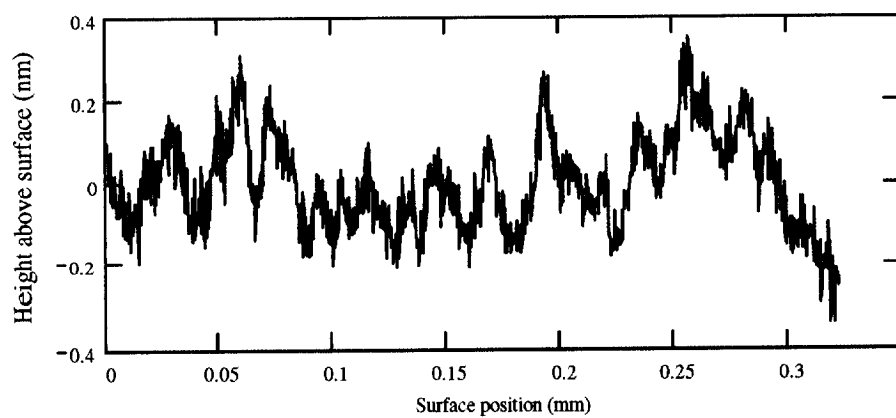
T2BS21CR.asc



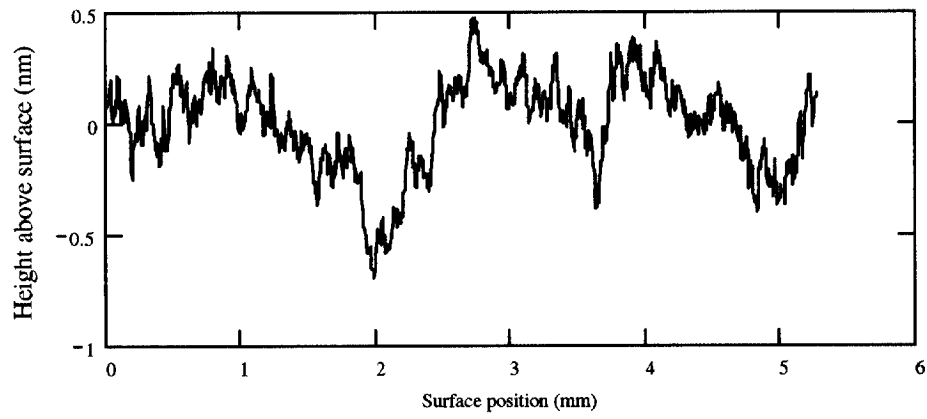
T4BS21AR.asc



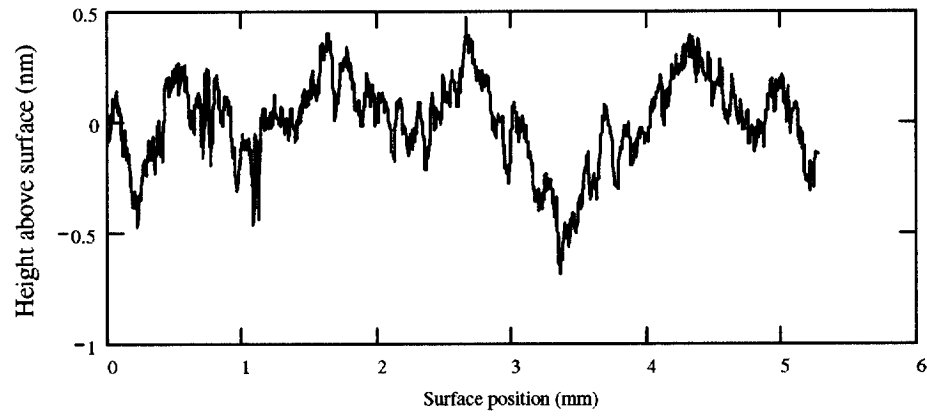
T4BS21BR.asc



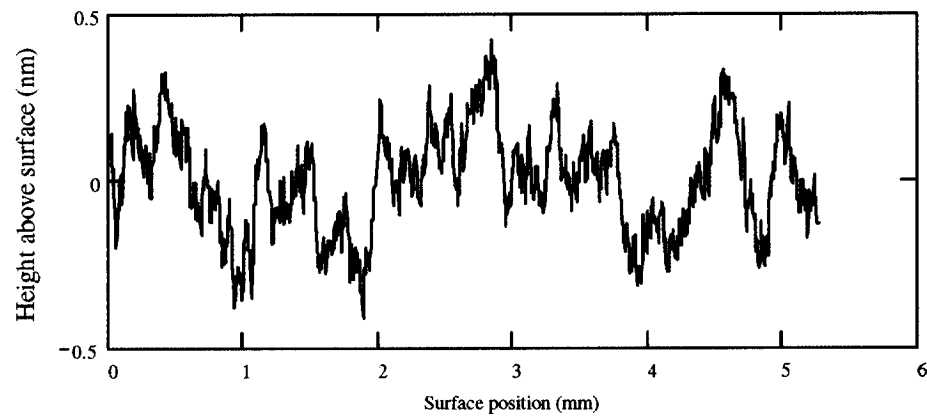
T4BS21CR.asc



T2BS22AR.asc

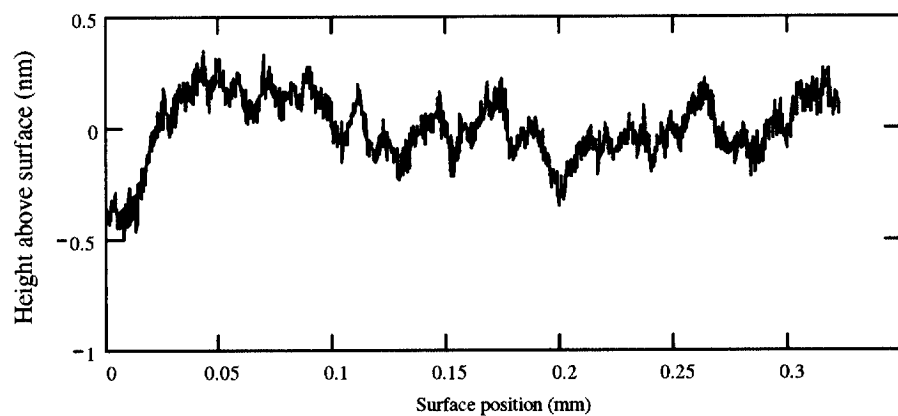


T2BS22BR.asc

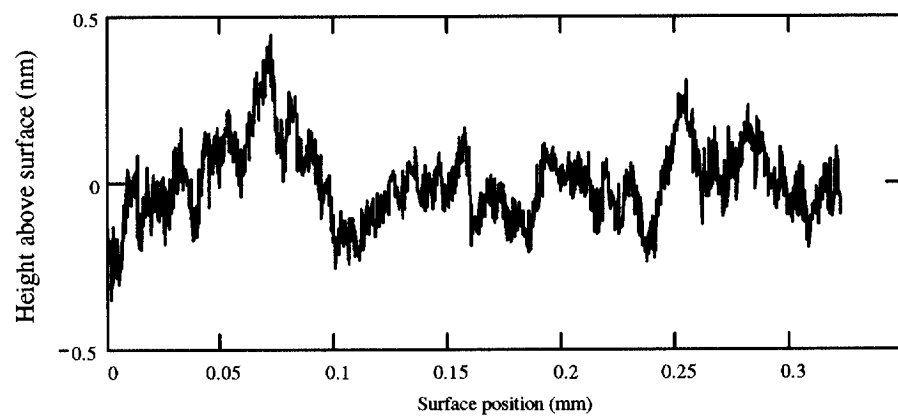


T2BS22CR.asc

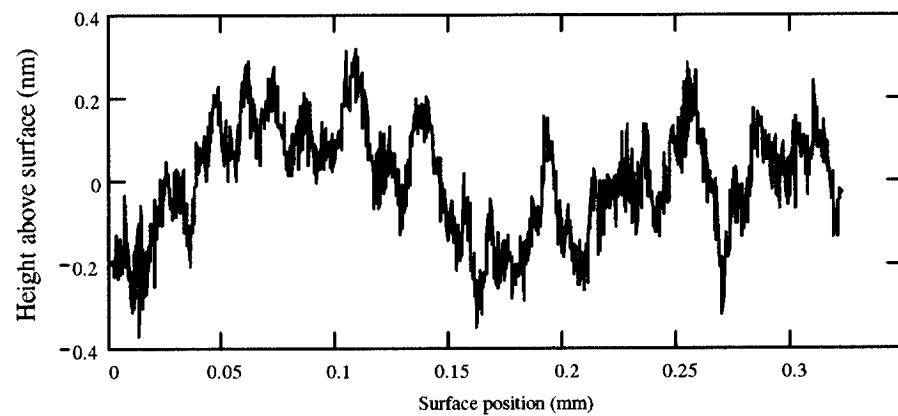




T4BS22AR.asc



T4BS22BR.asc



T4BS22CR.asc

**MIRROR**



Research Electro-Optics Inc.

## CERTIFICATE OF CONFORMANCE

Section 3.14/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 : 22 Feb 99
- Customer Name, Purchase Order No. : Cal Tech / Ligo PC162519
- Customer Part Number & Revision : LIGO-980069-00-D
- Part Description : Beam Splitter
- REO Job No. : OPT05831 Run No.: 51: 0X916  
OP500743 52: 0X918
- Qty. Shipped/Lot No. : 2 ea Beam splitter BS01, BS02  
2 ea FS witness PC.

☒ Test data (included)

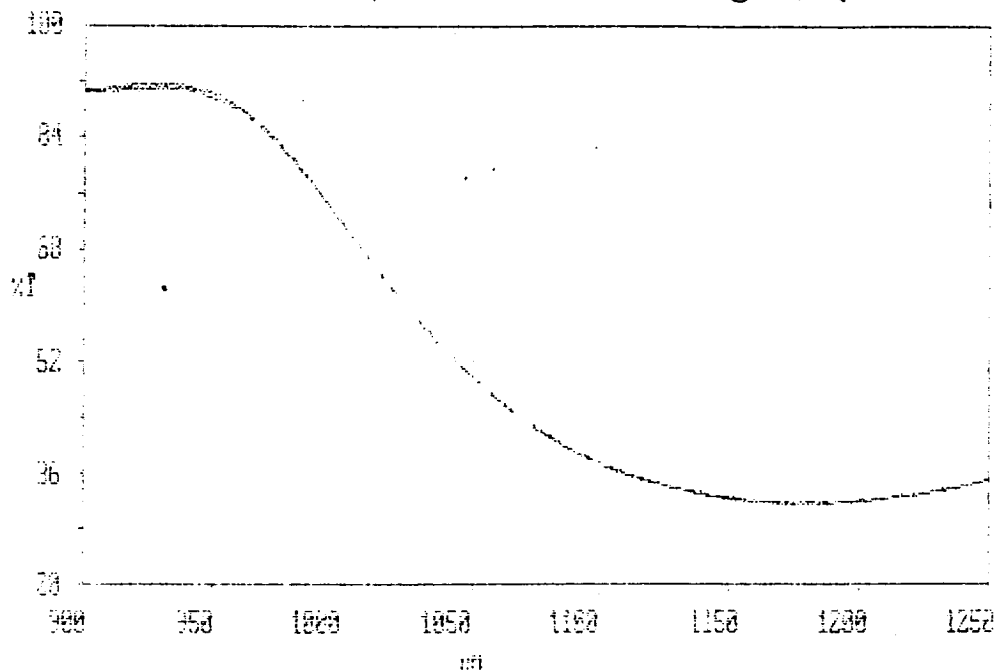
Comment: BS02 has a 2mm x 3mm area of scuff marks on side 1, which is 5.5cm in from the edge of the part. Damage was caused by customer dropping a tool on the part.

Certified by: [Signature], 22 Feb 99  
Quality Assurance  
Verified by: DC Hess, 22 Feb 99  
Engr/Tech

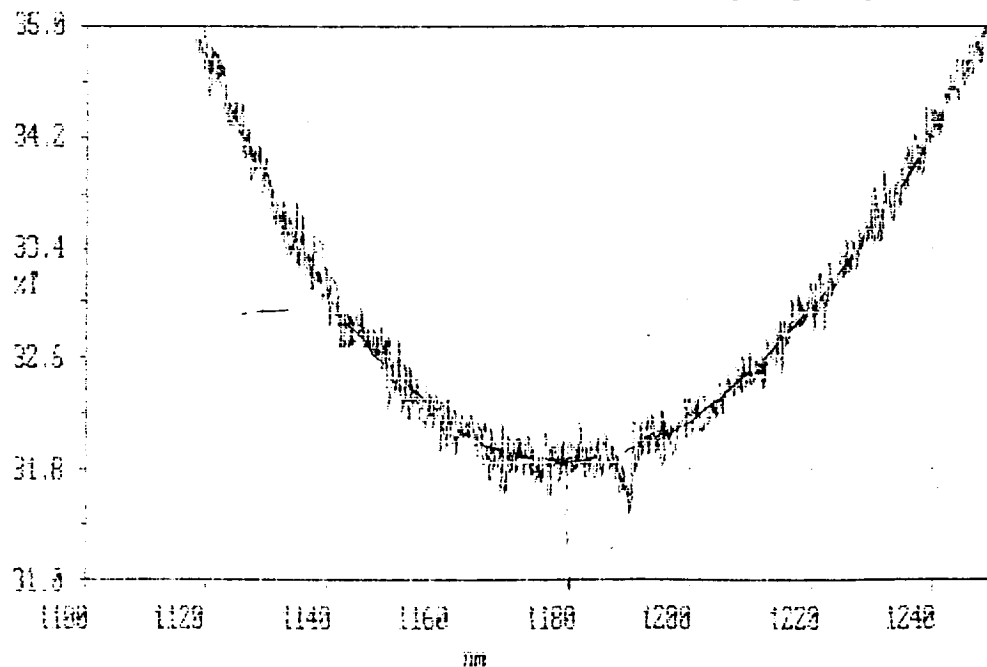
NOTE

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.

X: user011: 1250.0 - 900.0 nm; pts 3501; int 0.10; ord 31.515 - 91.485 %T  
 Inf: 40X916, Parts run for BS01, BS02, FS witness baked. 0° Scan



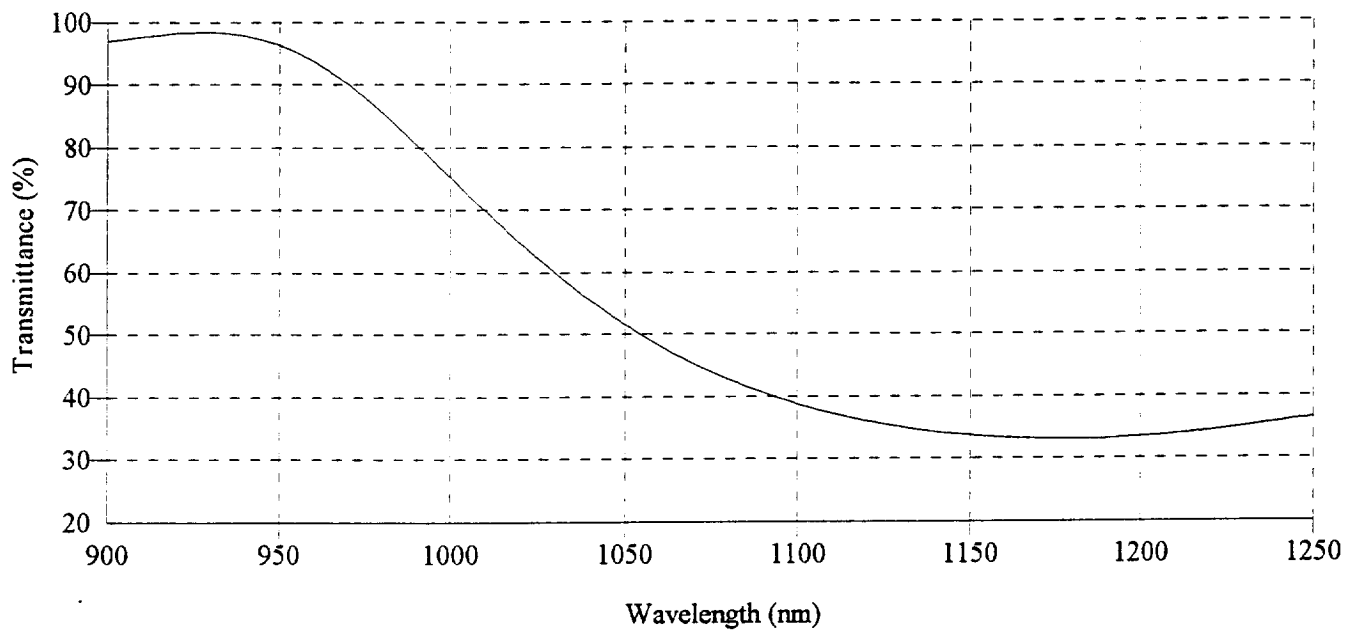
Y: user011: 1250.0 - 900.0 nm; pts 3501; int 0.10; ord 31.515 - 91.485 %T  
 Inf: 40X916, Parts run for BS01, BS02, FS witness baked. 0° Scan



$\lambda_c = 1180 \text{ nm}$

4

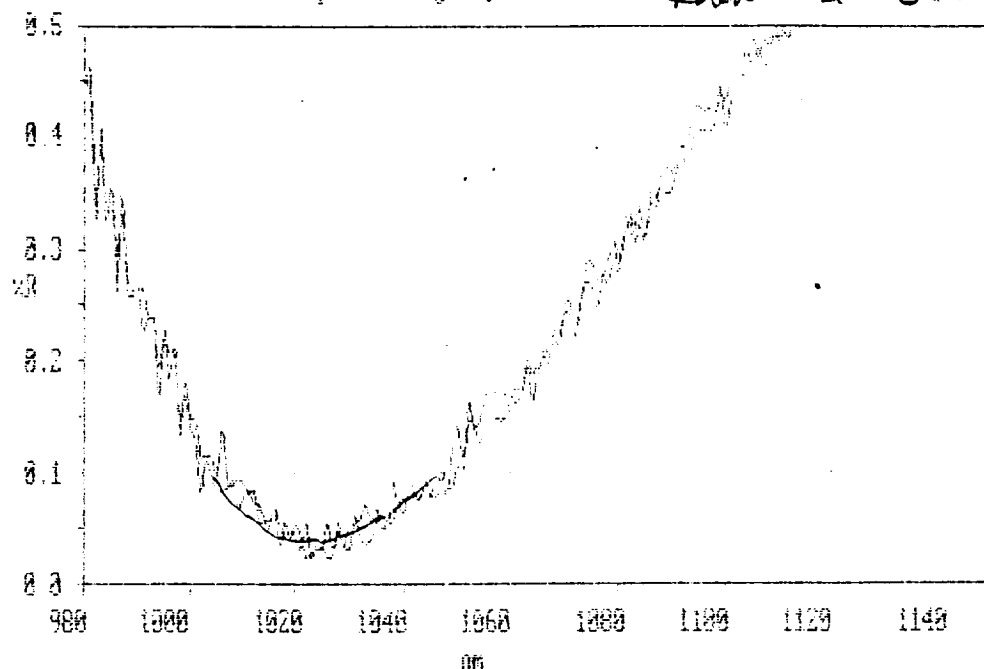
BSTEST6: Transmittance



Model of 0X916 @ 0°

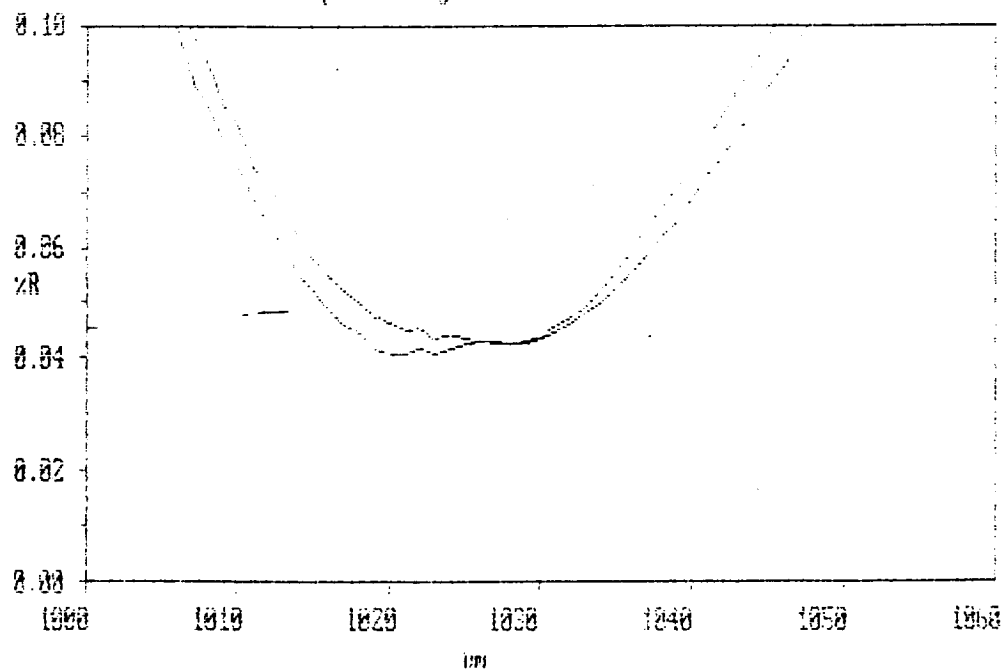
Y: user002; 1150.0 - 980.0 nm; pts 171; int 1.00; ord 0.0250 - 0.6959 %R

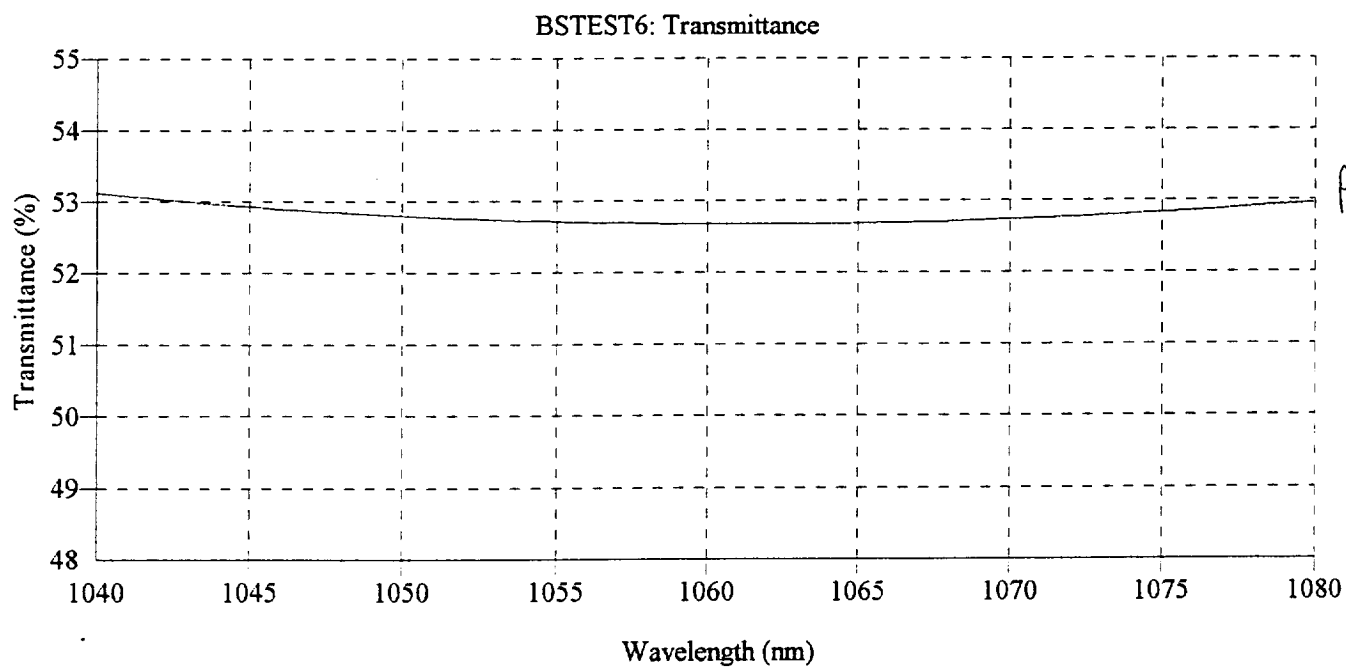
Inf: ox910 AR01064nm after processing. *Normal Incidence Scan*



Y: user002; 1150.0 - 980.0 nm; pts 171; int 1.00; ord 0.0425 - 0.6767 %R

Inf: ox910 AR01064nm after processing.





Model of 0X916 @ 45°  
Witness piece Measured with Laser  
@ 1053nm  $T_p = 50.5\%$   
 $R_p = 49.5\%$