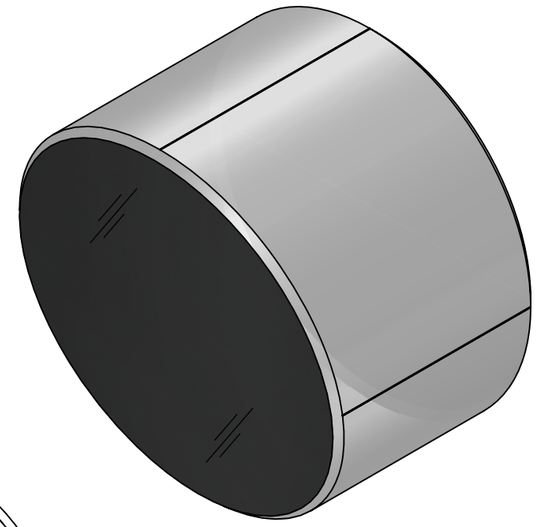
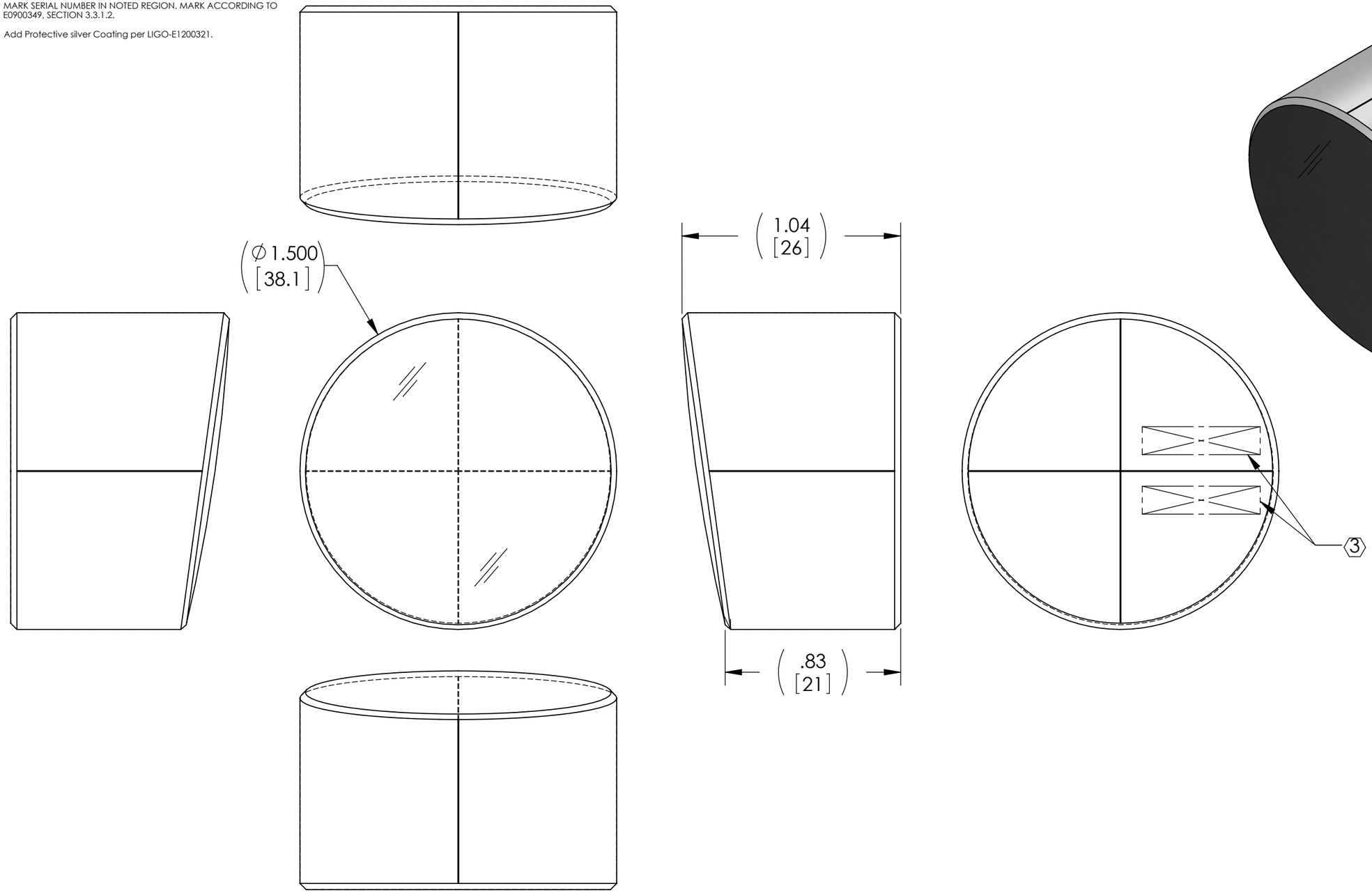
**NOTES :**

1. ALL PARTS AS SHOWN SHALL BE MANUFACTURED IN ACCORDANCE WITH LIGO SPECIFICATION E0900349.
2. MASS: 69.5 G [0.153 LB].
3. MARK SERIAL NUMBER IN NOTED REGION. MARK ACCORDING TO E0900349, SECTION 3.3.1.2.
4. Add Protective silver Coating per LIGO-E1200321.

| REV. | DATE | DCN # | DRAWING TREE # |
|---|---|---|---|
| v1 | 21 SEP 2011 | E1100351 | - |
| v2 | 08 FEB 2012 | E1101192 | - |
| v3 | 15 May 2012 | E1101192 | - |






| NOTES AND TOLERANCES: (UNLESS OTHERWISE SPECIFIED) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>.XX ± .02<br>.XXX ± .005<br>ANGULAR ± 1.0° | MATERIAL: ZERODUR | FINISH: N/A µinch | LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY MASSACHUSETTS INSTITUTE OF TECHNOLOGY | SYSTEM: ADVANCED LIGO | SUB-SYSTEM: AOS | NEXT ASSY: D1102361 | PART NAME: ETM TELESCOPE SECONDARY PARABOLIC MIRROR | | |
| | | | | | | | DESIGNER: M. SMITH 13 OCT 2009 | SIZE: B | DWG. NO.: D0901565 REV.: v3 |
| | | | | | | | DRAFTER: J. TERRAZAS 08 FEB 2012 | | |
| | | | | | | | CHECKER: SEE DCN | | |
| | | | | | | | APPROVAL: SEE DCN | SCALE: NONE | PROJECTION: SHEET 1 OF 1 |

D0901565_ADLIGO ETM TELE SECONDARY, PART PDM REV: X-024, DRAWING PDM REV: X-011

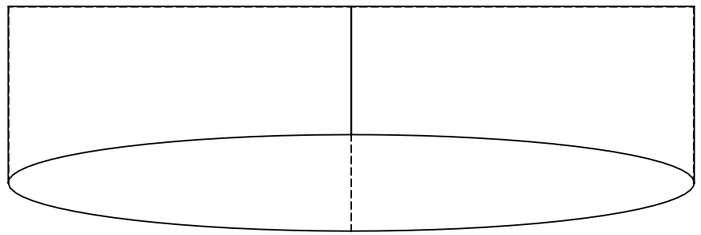
**NOTES:**

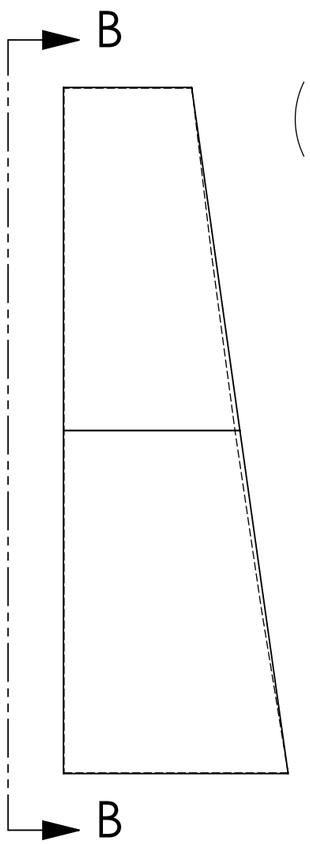
1. PART AS SHOWN SHALL BE MANUFACTURED IN ACCORDANCE WITH LIGO SPECIFICATION E0900347.
2. MASS: 6.132 KG [13.519 LB].

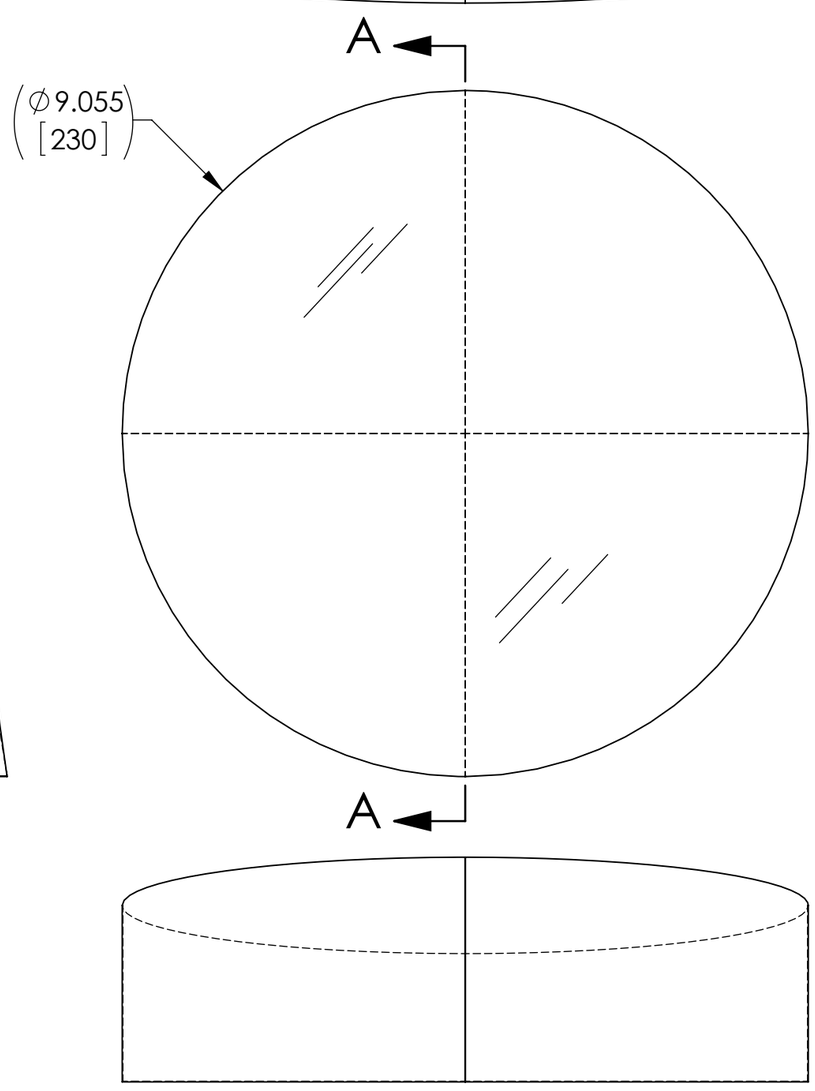
⟨3⟩ MARK SERIAL NUMBER IN NOTED REGION. MARK ACCORDING TO E0900347, SECTION 3.3.1.2.

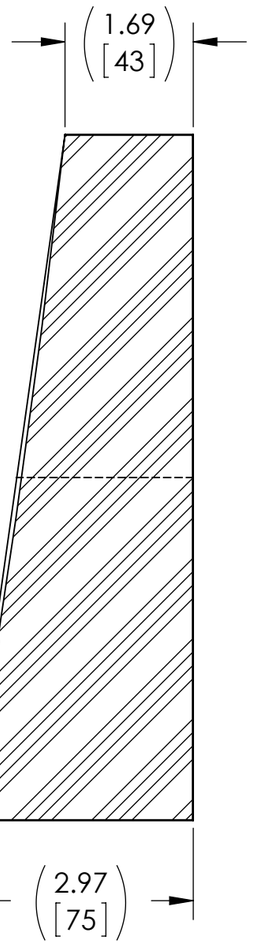
4 Add PROTECTED SILVER COATING PER LIGO-E1200321.

| REV. | DATE | DCN # | DRAWING TREE # |
|---|---|---|---|
| v1 | 21 SEP 2011 | E1100351 | - |
| v2 | 08 FEB 2012 | E1101192 | - |
| v3 | 15 MAY 2012 | E1101192 | - |

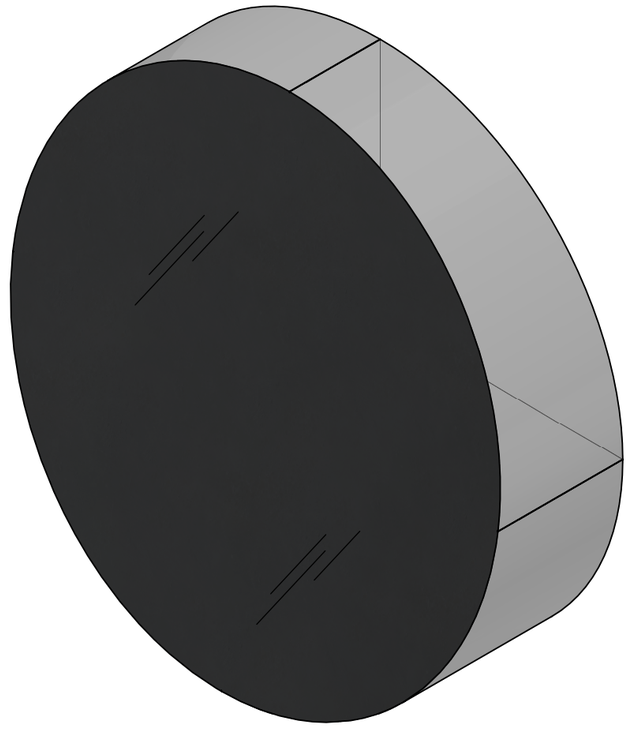




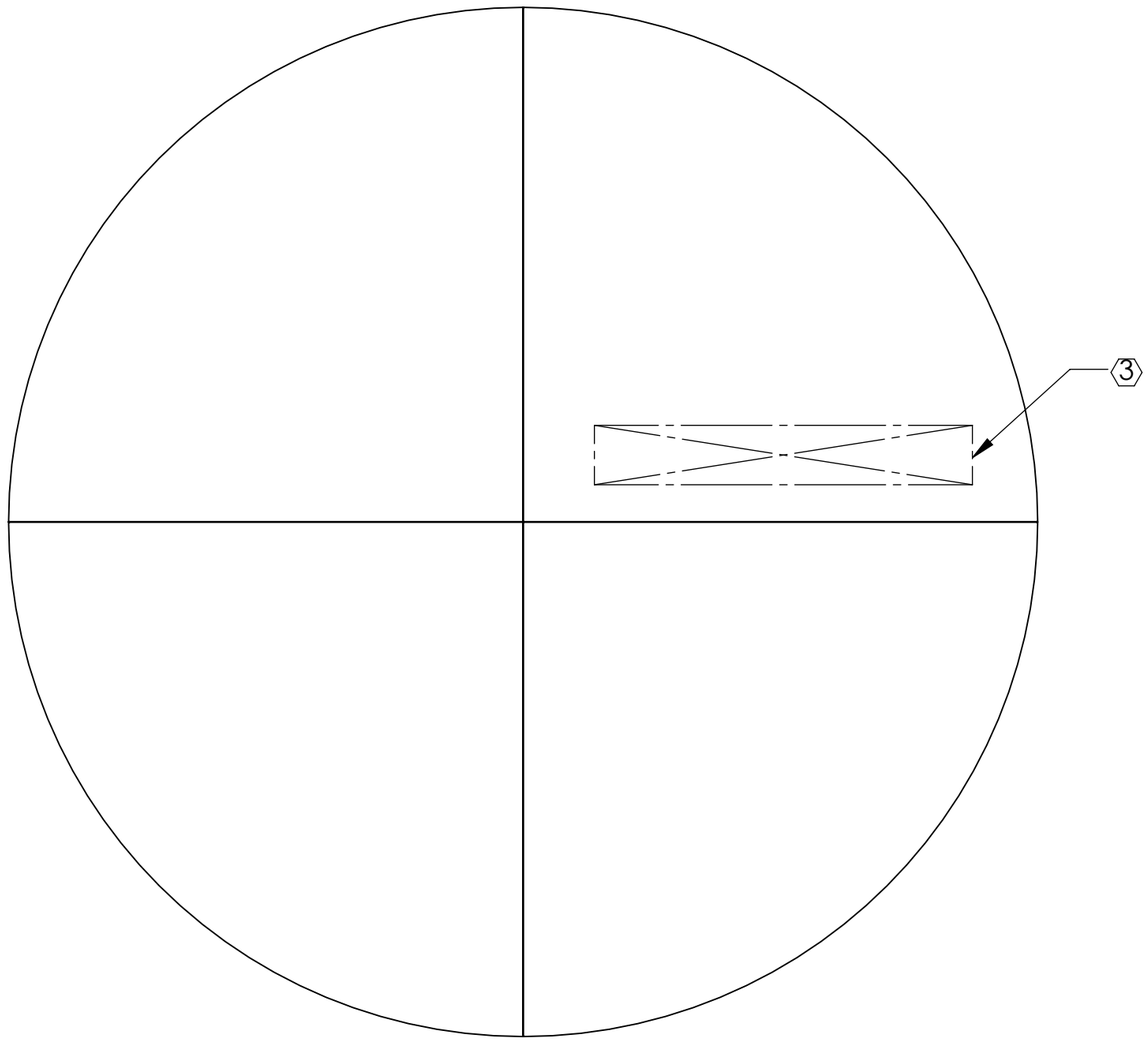




SECTION A-A



D1000075_aLIGO PRIMARY PARABOLIC MIRROR, PART PDM REV: X-021, DRAWING PDM REV: X-017

| NOTES AND TOLERANCES: (UNLESS OTHERWISE SPECIFIED) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>.XX ± .02<br>.XXX ± .005<br>ANGULAR ± 1.0° | | | LIGO | CALIFORNIA INSTITUTE OF TECHNOLOGY<br>MASSACHUSETTS INSTITUTE OF TECHNOLOGY | | PART NAME: aLIGO PRIMARY PARABOLIC MIRROR | | | | | |
| | | | SYSTEM: ADVANCED LIGO | | SUB-SYSTEM: AOS | DESIGNER | M. SMITH | 13 OCT 2009 | SIZE: B | DWG. NO.: D1000075 | REV.: v3 |
| MATERIAL: ZERODUR | | FINISH: N/A µinch | NEXT ASSY: D1102361 | | | DRAFTER | J. TERRAZAS | 08 FEB 2012 | | | |
| | | | | | | CHECKER | SEE DCN | | | | |
| | | | | | | APPROVAL | SEE DCN | | SCALE: NONE | PROJECTION: | SHEET 1 OF 2 |




VIEW B-B

| | | | |
|---|---|---|---|
| LIGO | CALIFORNIA INSTITUTE OF TECHNOLOGY<br>MASSACHUSETTS INSTITUTE OF TECHNOLOGY | | |
| SIZE<br>B | DWG. NO.<br>D1000075 | REV.<br>v3 | |
| SCALE:NONE | PROJECTION: | SHEET 2 OF 2 | |

**NOTES (UNLESS OTHERWISE SPECIFIED) CONTINUED:**

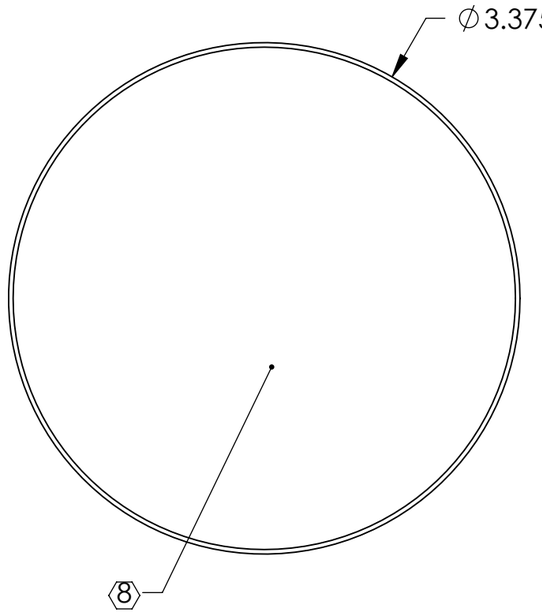
〈5〉 ETCH, GRIND, LASER MARK, OR SANDBLAST (NO INKS OR DYES) DRAWING PART NUMBER, REVISION (AND VARIANT OR "TYPE" IF APPLICABLE) ON NOTED SURFACE OF PART FOLLOWED ON THE NEXT LINE WITH A THREE DIGIT SERIAL NUMBER. SERIAL NUMBERS START AT 001 FOR THE FIRST ARTICLE AND PROCEED CONSECUTIVELY. USE MINIMUM 0.12" HIGH CHARACTERS, UNLESS THE SIZE OF THE PART DICTATES SMALLER CHARACTERS.
EXAMPLE: DXXXXXXX-VY, TYPE-XX, S/N XXX

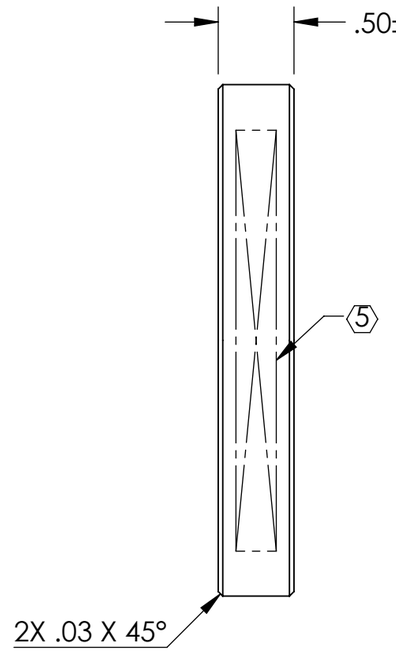
6. MASS: 0.184 KG [0.405 LB].

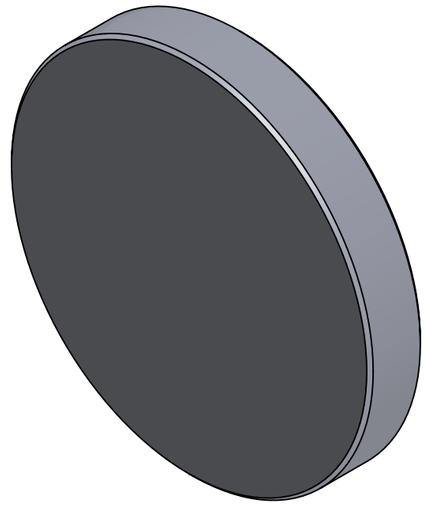
〈7〉 STANDARD GROUND SURFACE QUALITY ON NON-COATED FACES.

〈8〉 MIRROR FACE:
PROTECTED SILVER COATINGN PER LIGO-E1200321
SURFACE ACCURACY: 1/10 WAVE @ 532 NM
SURFACE QUALITY: 60-40

| REV. | DATE | DCN # | DRAWING TREE # |
|---|---|---|---|
| v1 | 28 MAR 2012 | E1101192 | - |
| - | - | - | - |
| - | - | - | - |



D1102334 aLIGO TMS Telescope Second Fold Mirror, PART PDM REV: X-007, DRAWING PDM REV: X-006

**NOTES AND TOLERANCES: (UNLESS OTHERWISE SPECIFIED)**

DIMENSIONS ARE IN INCHES

TOLERANCES:
.XX ± .01
.XXX ± .005

ANGULAR ± 1.0°

1. INTERPRET DRAWING PER ASME Y14.5-1994.
~~2. REMOVE ALL SHARP EDGES, .005 .015. FOR MACHINED PARTS. ROUND ALL EDGES APPROXIMATELY R.02 FOR SHEET METAL PARTS.~~
3. DO NOT SCALE FROM DRAWING.
4. ALL MACHINING FLUIDS MUST BE FULLY SYNTHETIC, FULLY WATER SOLUBLE AND FREE OF SULFUR, SILICONE, AND CHLORINE.

**MATERIAL** BK7

**FINISH** 〈7〉

LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

**SYSTEM** ADVANCED LIGO

**SUB-SYSTEM** AOS

**NEXT ASSY** D1200243

**PART NAME** aLIGO TMS TELESCOPE SECOND FOLD MIRROR

| | | |
|---|---|---|
| DESIGNER | K. MAILAND | 09 JAN 2012 |
| DRAFTER | C. CONLEY | 28 MAR 2012 |
| CHECKER | SEE DCN | |
| APPROVAL | SEE DCN | |

**SIZE** B **DWG. NO.** D1102334 **REV.** v1

**SCALE:** NONE **PROJECTION:** SHEET 1 OF 1

**NOTES (UNLESS OTHERWISE SPECIFIED) CONTINUED:**

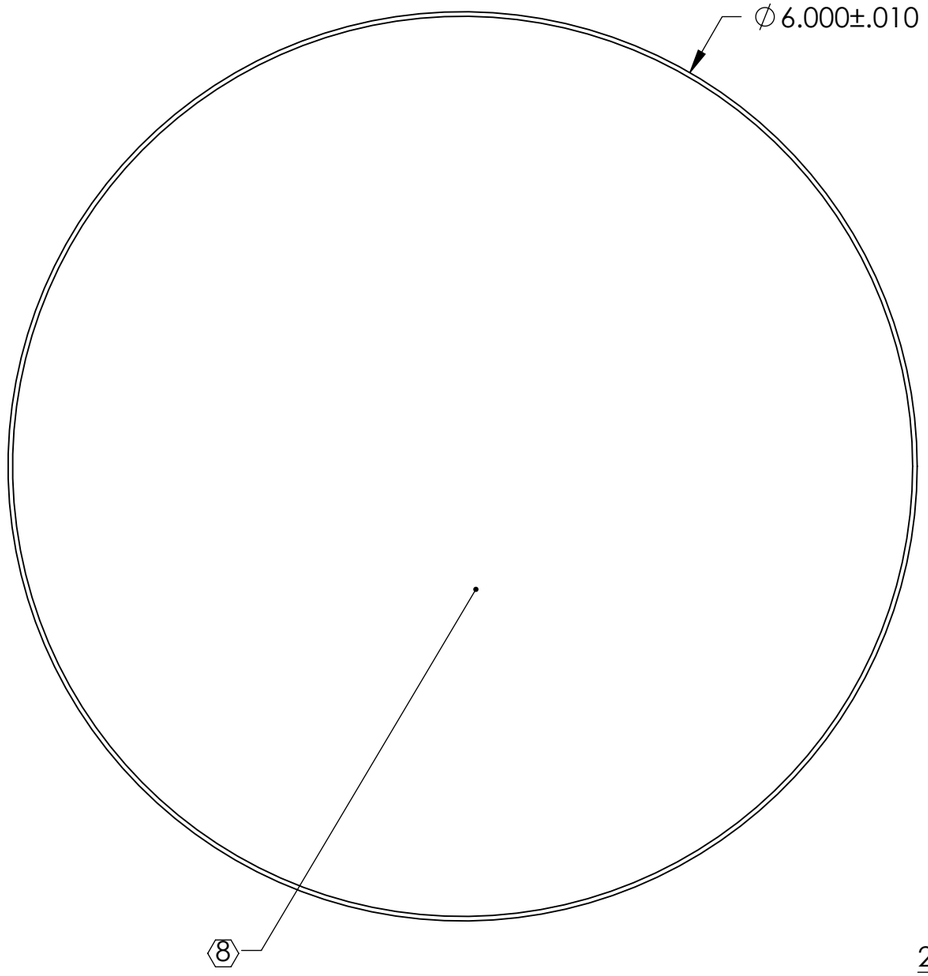
〈5〉 ETCH, GRIND, LASER MARK, OR SANDBLAST (NO INKS OR DYES) DRAWING PART NUMBER, REVISION (AND VARIANT OR "TYPE" IF APPLICABLE) ON NOTED SURFACE OF PART FOLLOWED ON THE NEXT LINE WITH A THREE DIGIT SERIAL NUMBER. SERIAL NUMBERS START AT 001 FOR THE FIRST ARTICLE AND PROCEED CONSECUTIVELY. USE MINIMUM 0.12" HIGH CHARACTERS, UNLESS THE SIZE OF THE PART DICTATES SMALLER CHARACTERS.
EXAMPLE: DXXXXXXX-VY, TYPE-XX, S/N XXX

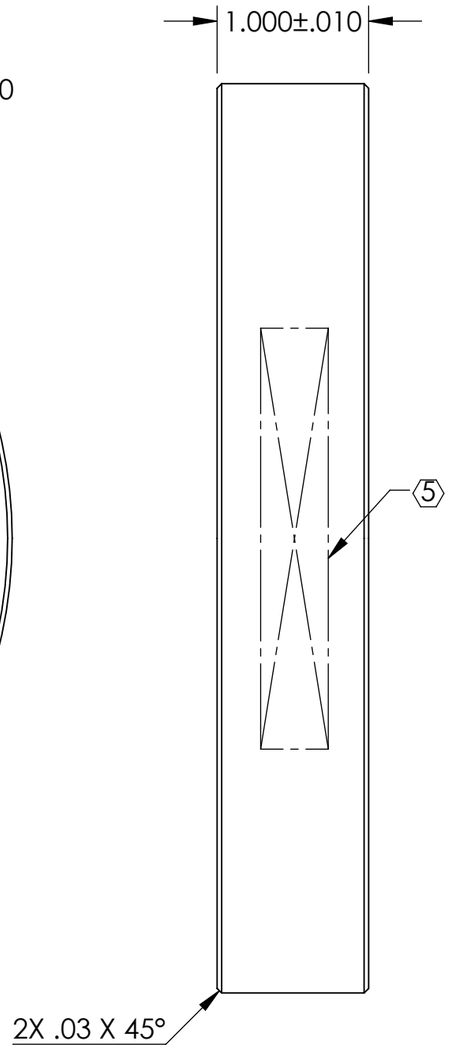
6. MASS: 1.161 KG [2.560 LB].

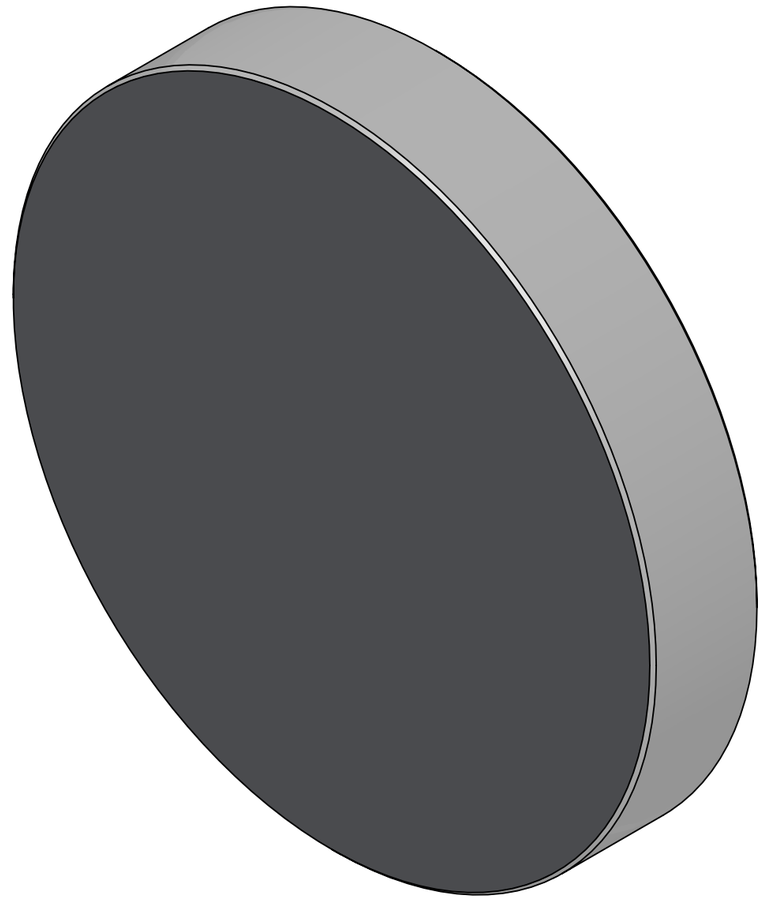
〈7〉 STANDARD GROUND SURFACE QUALITY ON NON-COATED FACES.

〈8〉 MIRROR FACE:
PROTECTED SILVER COATINGN PER LIGO-E1200321
SURFACE ACCURACY: 1/10 WAVE @ 532 NM
SURFACE QUALITY: 60-40

| REV. | DATE | DCN # | DRAWING TREE # |
|---|---|---|---|
| v1 | 28 MAR 2012 | E1101192 | - |
| - | - | - | - |
| - | - | - | - |



| NOTES AND TOLERANCES: (UNLESS OTHERWISE SPECIFIED) | | | |
|---|---|---|---|
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>.XX ± .01<br>.XXX ± .005<br>ANGULAR ± 1.0° | 1. INTERPRET DRAWING PER ASME Y14.5-1994.<br>~~2. REMOVE ALL SHARP EDGES, .005 - .015, FOR MACHINED PARTS. ROUND ALL EDGES APPROXIMATELY R.02 FOR SHEET METAL PARTS.~~<br>3. DO NOT SCALE FROM DRAWING.<br>4. ALL MACHINING FLUIDS MUST BE FULLY SYNTHETIC, FULLY WATER SOLUBLE AND FREE OF SULFUR, SILICONE, AND CHLORINE. | MATERIAL: BK7 | FINISH: 〈7〉 |

LIGO — CALIFORNIA INSTITUTE OF TECHNOLOGY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PART NAME | aLIGO TMS TELESCOPE FIRST FOLD MIRROR | | | | | | |
| SYSTEM: ADVANCED LIGO | SUB-SYSTEM: AOS | DESIGNER | K. MAILAND | 09 JAN 2012 | SIZE: B | DWG. NO.: D1102335 | REV.: v1 |
| NEXT ASSY: D1200244 | | DRAFTER | C. CONLEY | 28 MAR 2012 | | | |
| | | CHECKER | SEE DCN | | | | |
| | | APPROVAL | SEE DCN | | SCALE: NONE | PROJECTION: | SHEET 1 OF 1 |

D1102335 aLIGO TMS Telescope First Fold Mirror, PART PDM REV: X-004, DRAWING PDM REV: X-007

# ETM TELESCOPE PRIMARY PARABOLIC MIRROR ADLIGO

| APPROVALS | DATE | REV | DCN NO. | BY | CHECK | DCC | DATE |
|---|---|---|---|---|---|---|---|
| AUTHOR: MICHAEL SMITH | **01/05/11** | **V8** | | | | | |
| CHECKED: K MAILAND | **01/10/12** | **V9** | | | | | |
| APPROVED: | **05/15/12** | **V10** | **E1101192** | | | | |
| DCC RELEASE | | | | | | | |

## 1 SCOPE

This is a specification for the ADLIGO ETM TELESCOPE PRIMARY PARABOLIC MIRROR. This concave parabolic mirror is part of an off-axis reflecting beam-reducing telescope.

## 2 APPLICABLE DOCUMENTS

LIGO-E1200321 Protected Silver High Reflectance Coating
MIL-C-675C

## 3 REQUIREMENTS

## 3.1 PERFORMANCE CHARACTERISTICS

### 3.1.1 Mirror Fabrication

#### 3.1.1.1 Front Surface, S1

| | |
|---|---|
| Effective focal length | 2000 +/- 20 mm |
| Conic constant | -1.000 +/- 0.002 |
| Tilt tolerance, reference to back surface (S2) | +/- 0.0083 deg |
| Clear aperture diameter | 190 mm |
| Center displacement from optical axis | 562.2 +/- 1 mm |
| Diameter | 230.0 +0.0, -0.1 mm |
| Minimum edge thickness | 43 +/- 1 mm |
| Surface irregularity | < 1/8 wave, peak to valley @ 633 nm over clear aperture |
| Surface finish | 60/40 |
| Surface roughness | < 100 Angstrom |
| Chamfer edges | 0.5-1.0 mm, 45 +/- 10 deg |

#### 3.1.1.2 Back Surface, S2

| | |
|---|---|
| Surface quality | fine ground, > 300 grit |
| Chamfer edges | 0.5-1.0 mm, 45 +/- 10 deg |

#### 3.1.1.3 Mirror Coating

Refer to LIGO-E1200321 Protected Silver High Reflectance Coating

## 3.2 DESIGN AND CONSTRUCTION

### 3.2.1 Materials

| | |
|---|---|
| Substrate material | Zerodur or equivalent |

# ETM TELESCOPE PRIMARY PARABOLIC MIRROR ADLIGO

## 3.3 QUALITY ASSURANCE/CONTROL

### 3.3.1 Identification

Parts shall be serialized according to paragraph 3.3.1.2.

#### 3.3.1.1 Optical Alignment Marks

Edge orientation mark shall be placed to indicate maximum edge thickness within rotational tolerance of 1 deg, as shown in figure 1: 0.24 +/- 0.1 mm wide x FULL BARREL LENGTH.
ADDITIONAL MARKING @ 90 Deg. intervals +/-2 Degrees, on barrel, and on back face (full diameter length) as shown in Figure:2

#### 3.3.1.2 Serial Number

A serial number shall be etched, ground or sandblasted (ink marks shall not be allowed) on surface 2 with the following format:
D1000075-v? S/N nnn; where v? is the drawing revision number and nnn is the sequential serial number, 001 – 999 in the order produced.

### 3.3.2 Quality Assurance Provisions

A first article shall be produced and inspected.

### 3.3.3 Purchaser Access

The purchaser will have escorted access to quality control facility during all quality acceptance procedures.

### 3.3.4 QA Approval

LIGO Quality Assurance reserves the right to inspect and approve vendor/fabricator QA plans and processes.

## 4 TEST PROCEDURES

The telescope mirror performance shall be verified by the following test procedures

## 4.1 WAVEFRONT DISTORTION

Interferogram of reflected wavefront across the clear aperture @ 633 nm wavelength

## 5 DOCUMENTATION

- Compliance Certification for items: 3.1, 3.2, 3.3, 4.
- Interferogram, see 4.1 Wavefront Distortion.

## 6 ENVIRONMENTAL CHARACTERISTICS

The ETM Telescope will operate in a non-vibrational, ultra high vacuum environment , at 68 +/- 4 deg F.

# ETM TELESCOPE PRIMARY PARABOLIC MIRROR ADLIGO

## 7 HANDLING AND SHIPPING PROCEDURES

### 7.1 Cleaning

Approved cleaning procedures for UHV components are detailed in LIGO-E960022, Vacuum Compatibility, Cleaning Methods and Compatibility Procedures.
All optical surfaces shall be cleaned in accordance with good commercial practice. Nothing shall contact the optical surfaces after cleaning, except for lint-free lens tissue.

### 7.2 Packaging for Shipment

The cleaned optical components shall be protected with lint-free lens tissue. In addition, all components shall be placed in individual, sealed, clean polyethylene bags before shipping.
The shipping containers must ensure that the bag does not become punctured and that the parts are properly protected during transit.

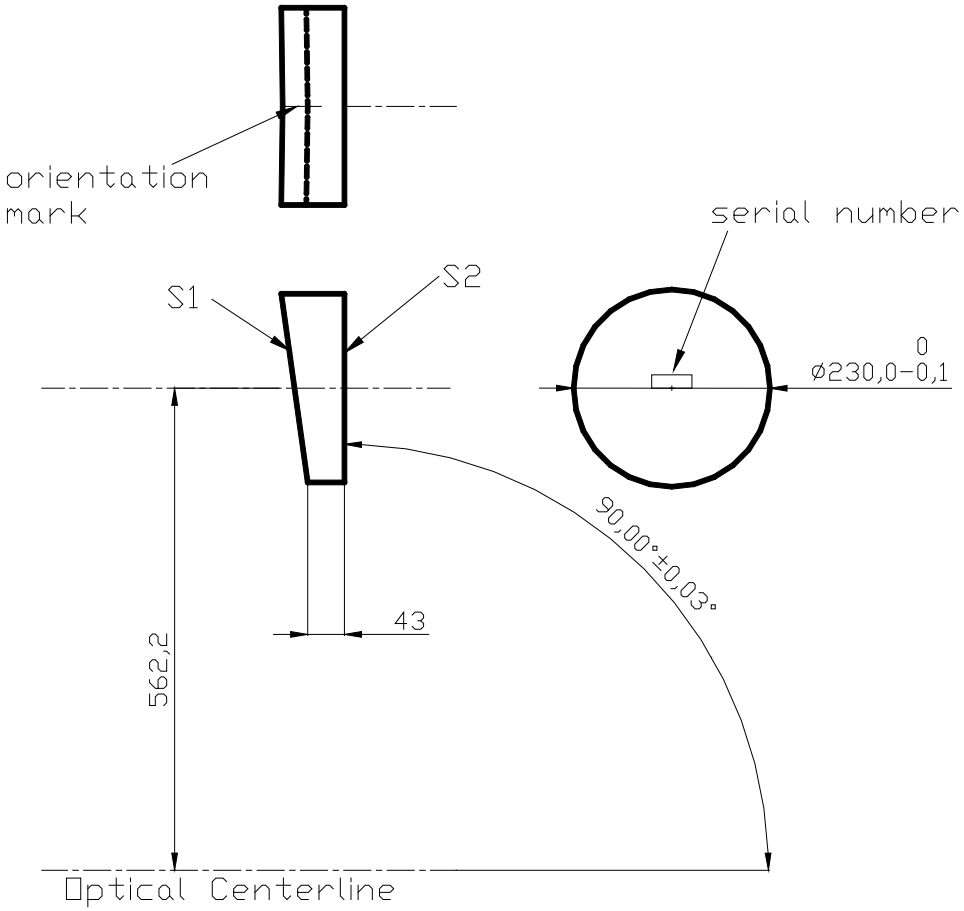



**Figure 1: Mirror drawing, Edge Mark parabolic primary mirror per 3.3.1.1**

# ETM TELESCOPE PRIMARY PARABOLIC MIRROR ADLIGO

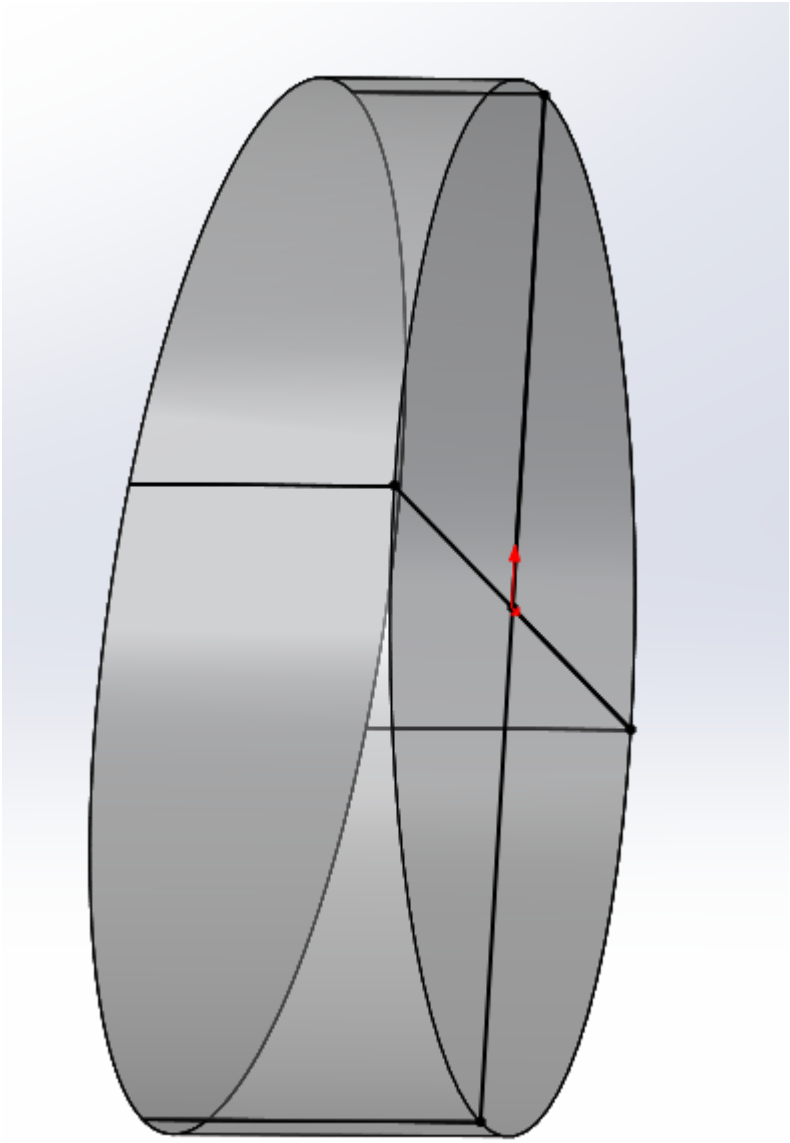


**Figure 2: Mirror drawing, Marking Parabolic Primary Mirror per 3.3.1.1**

# ETM TELESCOPE SECONDARY PARABOLIC MIRROR ADLIGO

| APPROVALS | DATE | REV | DCN NO. | BY | CHECK | DCC | DATE |
|---|---|---|---|---|---|---|---|
| AUTHOR: MICHAEL SMITH | **01/05/11** | **V10** | | | | | |
| CHECKED: K MAILAND | **01/10/12** | **V11** | | | | | |
| APPROVED: | **05/15/12** | **V12** | **E1101192** | | | | |
| DCC RELEASE | | | | | | | |

## 1 SCOPE

This is a specification for the ADLIGO ETM TELESCOPE SECONDARY PARABOLIC MIRROR. This convex parabolic mirror is part of an off-axis reflecting beam-reducing telescope.

## 2 APPLICABLE DOCUMENTS

LIGO-E1200321 Protected Silver High Reflectance Coating
MIL-C-675C

## 3 REQUIREMENTS

## 3.1 PERFORMANCE CHARACTERISTICS

### 3.1.1 Mirror Fabrication

#### 3.1.1.1 Front Surface, S1

| | |
|---|---|
| Effective focal length | -100.0 +/- 1.0 mm |
| Conic constant | -1.000 +/- 0.002 |
| Tilt tolerance, reference to back surface (S2) | +/- 0.0083 deg |
| Clear aperture diameter | 32 mm |
| Center displacement from optical axis | 28.1 +/- 0.3 mm |
| Diameter | 38.1 +0.0, -0.1 mm |
| Minimum edge thickness | 21 +/- 1 mm |
| Surface irregularity | < 1/8 wave, peak to valley @ 633 nm over clear aperture |
| Surface finish | 60/40 |
| Surface roughness | < 100 Angstrom |
| Chamfer edges | 0.5-1.0 mm, 45 +/- 10 deg |

#### 3.1.1.2 Back Surface, S2

| | |
|---|---|
| Surface quality | fine ground, > 300 grit |
| Chamfer edges | 0.5-1.0 mm, 45 +/- 10 deg |

#### 3.1.1.3 Mirror Coating

Refer to LIGO-E1200321 Protected Silver High Reflectance Coating

## 3.2 DESIGN AND CONSTRUCTION

### 3.2.1 Materials

| | |
|---|---|
| Substrate material | Zerodur or equivalent |

# ETM TELESCOPE SECONDARY PARABOLIC MIRROR ADLIGO

## 3.3 QUALITY ASSURANCE/CONTROL

### 3.3.1 Identification

Parts shall be serialized according to paragraph 3.3.1.2.

#### 3.3.1.1 Optical Alignment Marks

Edge orientation mark shall be placed to indicate maximum edge thickness within rotational tolerance of 1 deg, as shown in figure 1: 0.24 +/- 0.1 mm wide x FULL BARREL LENGTH.
ADDITIONAL MARKING @ 90 Deg. intervals +/-2 Degrees, on barrel, and on back face (full diameter length) as shown in Figure:2

#### 3.3.1.2 Serial Number

A serial shall be etched, ground or sandblasted (ink marks shall not be allowed) on surface 2:
D0901565-vX S/N 001; where vX is the current drawing revision number and 001 is the sequential serial number, 001 – 999 in the order produced.

### 3.3.2 Quality Assurance Provisions

A first article shall be produced and inspected.

### 3.3.3 Purchaser Access

The purchaser will have escorted access to quality control facility during all quality acceptance procedures.

### 3.3.4 QA Approval

LIGO Quality Assurance reserves the right to inspect and approve vendor/fabricator QA plans and processes.

## 4 TEST PROCEDURES

The telescope mirror performance shall be verified by the following test procedures

## 4.1 WAVEFRONT DISTORTION

Interferogram of reflected wavefront across the clear aperture @ 633 nm wavelength

## 5 DOCUMENTATION

- Compliance Certification for items: 3.1, 3.2, 3.3, 4.
- Interferogram, see 4.1 Wavefront Distortion.

## 6 ENVIRONMENTAL CHARACTERISTICS

The ETM Telescope will operate in a non-vibrational, ultra high vacuum environment, at 68 +/- 4 deg F.

# 7 HANDLING AND SHIPPING PROCEDURES

## 7.1 Cleaning

Approved cleaning procedures for UHV components are detailed in LIGO-E960022, Vacuum Compatibility, Cleaning Methods and Compatibility Procedures.
All optical surfaces shall be cleaned in accordance with good commercial practice. Nothing shall contact the optical surfaces after cleaning, except for lint-free lens tissue.

## 7.2 Packaging for Shipment

The cleaned optical components shall be protected with lint-free lens tissue. In addition, all components shall be placed in individual, sealed, clean polyethylene bags before shipping.
The shipping containers must ensure that the bag does not become punctured and that the parts are properly protected during transit.

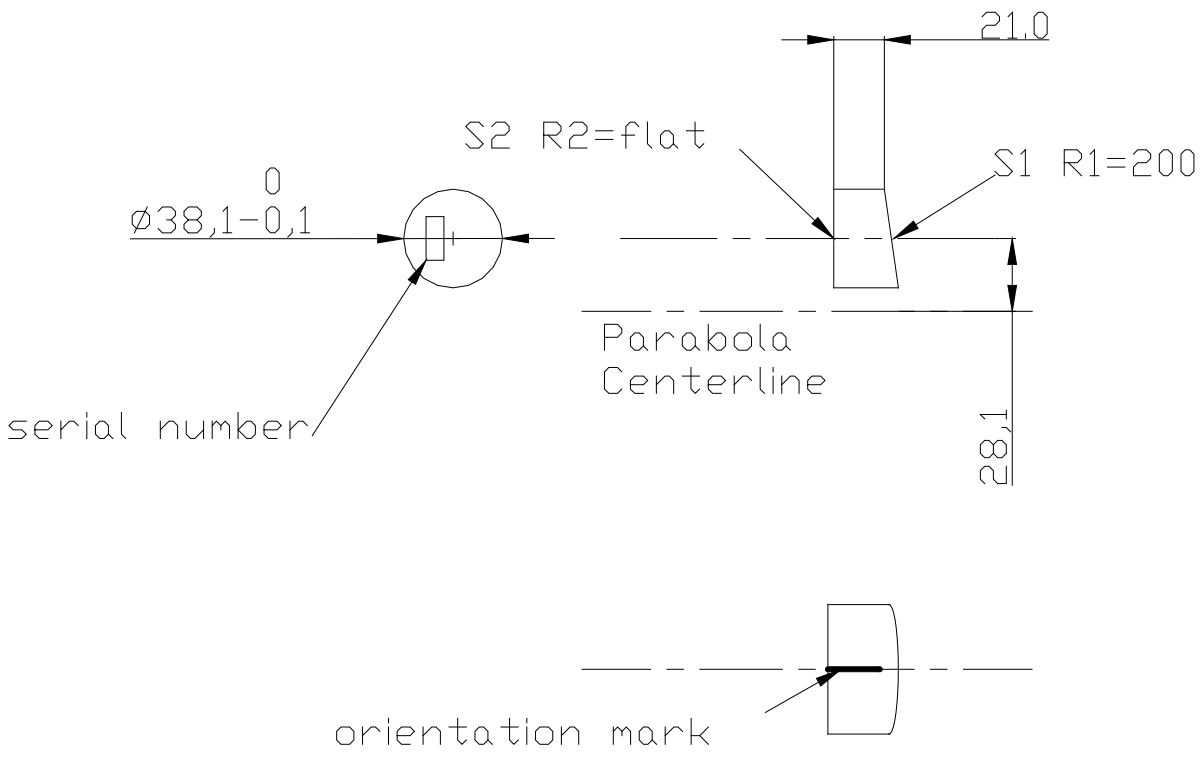



**Figure 1: Mirror drawing, Edge Mark parabolic Secondary mirror per 3.3.1.1**

# ETM TELESCOPE SECONDARY PARABOLIC MIRROR ADLIGO

.

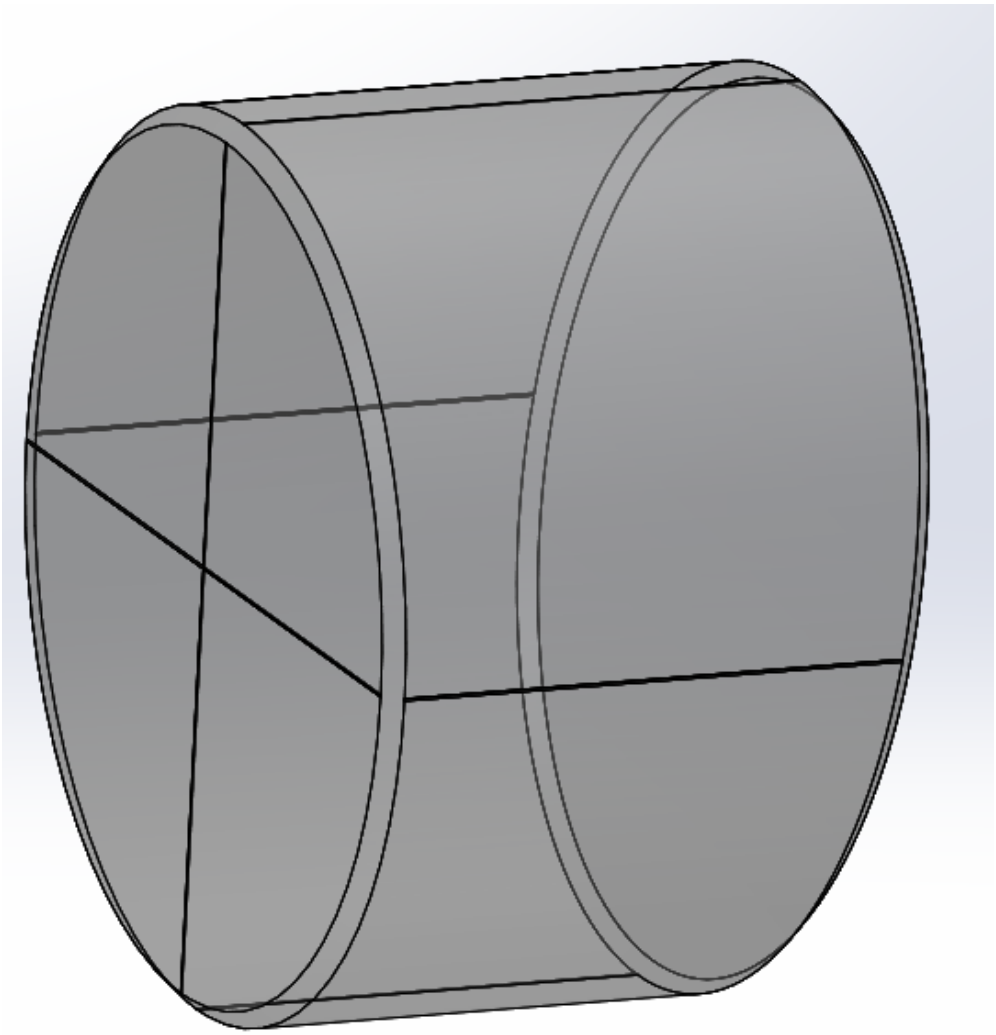


**Figure 2: Mirror drawing, Marking Parabolic Secondary Mirror per 3.3.1.1**

# Protected Silver High Reflectance Coating



| AUTHOR: | DATE | CHECKED: |
|---|---|---|
| Mike Smith | **3-26-12** | Ken Mailand |
| Lisa C. Austin | **05-15-2012** | See DCN E1101192 |
| | | |



This specification is for a protected silver high reflectance coating, to be applied to front surface mirrors.

## Applicable Documents

| | |
|---|---|
| LIGO- D0901565 | aLIGO TMS Telescope Secondary Parabolic Mirror |
| LIGO- D1000075 | aLIGO TMS Telescope Primary Parabolic Mirror |
| LIGO- D1102334 | aLIGO TMS Telescope Second Fold Mirror |
| LIGO- D1102335 | aLIGO TMS Telescope First Fold Mirror |

## Requirements

### Reflective Coatings

Applied to front surface S1, >80% clear aperture.

Durability per MIL-C-675C, Coating Adhesion and Durability, or current compatible standard, to be approved by LIGO.

Surface S1 will be used in an ultra-high vacuum environment.

Coating to be free from visual scattering or blemishes.

### Mirror Coating

Front surface S1only
Wavelength 1064 nm
Polarization Random
Incidence angle < 8 deg
Protected silver, reflectivity >98%
Durability per MIL-C-675C, Section 4.5.12

### Materials

Substrate material: Zerodur, BK7, or fused silica

## Testing and Documentation

| Specification | Test Method | Frequency of Inspection | Data Delivered |
|---|---|---|---|
| Surface Quality | Visual Inspection | 100% | Certification |
| HR Coatings | Spectrophotometer | Witness sample for each coating run | Spectral scans |