# Metrology Plan for Advanced LIGO IOO Suspended Mirrors

| APPROVALS | DATE | REV | DCN NO. | BY | CHECK | DCC | DATE |
|---|---|---|---|---|---|---|---|
| AUTHOR: Rodica Martin | 03/30/08 | | | | | | |
| CHECKED: | | | | | | | |
| APPROVED: | | | | | | | |
| DCC RELEASE | | | | | | | |

## 1. Overview

This document presents a metrology plan for the IOO suspended optics to verify that all mirrors meet the Advanced LIGO specifications. These specifications will be certified by vendors as well as measured at LIGO for the most critical specifications.

## 2. Scope

The scope of this document is to list all the measurements to be done by LIGO on the IOO suspended optics. This includes reflection and transmission at the design angle of incidence, absorption mapping, surface scatter, radius of curvature, surface errors and microroughness.

## 3. Applicable Documents

| IO Mirror | Blanks Drawings | Blanks Specifications | Substrates Drawings | Substrates Specifications | Coatings Specifications |
|---|---|---|---|---|---|
| MC1 | D070083-01-D | E070071-01-D | D070091-01-D | E070078-01-D | E070085-01-D |
| MC2 | D070084-01-D | E070072-01-D | D070092-01-D | E070079-01-D | E070086-01-D |
| MC3 | D070085-01-D | E070073-01-D | D070093-01-D | E070080-01-D | E070087-01-D |
| PRM | D080038 -A- D | E080028 -A- D | Not Available | Not Available | Not Available |
| PR2 | D080052 -A- D | E080039 -A- D | Not Available | Not Available | Not Available |
| SRM | Not Available | Not Available | Not Available | Not Available | Not Available |
| SR2 | Not Available | Not Available | Not Available | Not Available | Not Available |
| SM1 | D070089-01-D | E070077-01-D | D070097-01-D | E070084-01-D | E070091-01-D |
| SM2 | D070089-01-D | E070077-01-D | D070097-01-D | E070084-01-D | E070092-01-D |
| SM3* | D070089-01-D | E070077-01-D | D070097-01-D | E070084-01-D | pending |
| PMMT1 | D080158-00-D | E080133-00-D | D080160-00-D | E080135-00-D | E080137-00-D |
| PMMT2 | D080159-00-D | E080134-00-D | D080161-00-D | E080136-00-D | E080138-00-D |

## 4. Logistics

1. Blank material will be purchased and inspected by IO then sent for polishing.
2. Polished substrates are inspected by IO and then shipped to coating.
3. Coated substrates will be shipped to Caltech for metrology and then sent to LIGO observatories for storage.

## 5. Special Tests at LIGO:

1. Polished substrates: Interferometric mapping of the optical surfaces to determine radius of curvature (ROC) and surface errors.
2. Coated substrate:
   a. Reflection and transmission at the design angle of incidence
   b. Absorption in the HR coating at 1064 nm;
   c. Scattering on AR and HR surfaces

# Metrology Plan for Advanced LIGO IOO Suspended Mirrors

The following table summarizes the main specifications and the metrology tests to be performed by LIGO on each IO suspended mirror. The last table lists the quality conformance inspections to be received from the vendor.

**Color code:** red - very likely to change, green – IO procures, Core Optics has design specification responsibility, blue – specs and drawings updated

## 6. Main Specifications and Required Metrology at LIGO:

| IO Mirror | MC1/3 | MC2 | SM1 | SM2 | SM3* | PMMT1 | PMMT2 | PRM | PR2 | SRM | SR2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Material | Fused Silica Corning 7980 | | | | | | | | | | |
| Grade (Corning HPFS) | 0AA | 2F | 0C | 0C | 0C | 0C | 0C | 0AA | 0AA | 0AA | 0AA |
| Mirror thickness (mm) | 75 | 75 | 25 | 25 | 25 | 25 | 25 | 75 | 75 | 75 | 75 |
| Mirror diameter (mm) | 150 | 150 | 75 | 75 | 75 | 75 | 75 | 150 | 150 | 150 | 150 |
| Wedge Angle (deg) | 2 | 2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Aperture, HR side (mm) | 80 | 80 | 40 | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 |
| ROC (m) - H2<br>- H1, L1 | Flat | 26.77 | Flat | Flat | Flat | -5.04 | 5.3 | 10.256<br>11.375 | -1.559<br>-1.479 | 40.627<br>-15.000 | -1.691<br>-3.264 |
| ROC Tolerance | >80 Km | 0.025 m | >80 Km | >80 Km | >80 Km | 1% | 1% | 1% | 1% | 1% | 1% |
| Microroughness in clear aperture (nm rms) | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| HR Surface Errors (rms , P-V) | 1/200, 1/40 wave | 1/200, 1/40 wave | 1/200, 1/40 wave | 1/200, 1/40 wave | 1/200, 1/40 wave | 1/200, 1/40 wave | 1/200, 1/40 wave | <2 nm | <2 nm | <2 nm | <2 nm |
| HR Transmission (ppm) | 6000 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | 3.6% | <10 | 20% | **<10?** |
| AR reflectivity (ppm) | <300 | <300 | <300 | <300 | <300 | <300 | <300 | <300 | <300 | <300 | <300 |
| Coating Absorption (ppm) | <0.5 | <0.5 | <1 | <1 | <1 | <1 | <1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Scatter (ppm) | <22 | <22 | <22 | <22 | <22 | <22 | <22 | <15 | <15 | <15 | <15 |
| Blank Specification DCC# | E070071 | E070072 | E070077 | E070077 | E070077 | E080133 | E080134 | E080028 | E080039 | | |
| Blank Drawing DCC# | D070083 | D070084 | D070089 | D070089 | D070089 | D080158 | D080159 | D080038 | D080052 | | |
| Substrate Specification DCC# | E070078 | E070079 | E070084 | E070084 | E070084 | E080135 | E080136 | | | | |
| Substrate Drawing DCC# | D070091 | D070092 | D070097 | D070097 | D070097 | D080160 | D080160 | | | | |
| Coating Specification DCC# | E070085 | E070086 | E070091 | E070092 | pending | E080137 | E080138 | | | | |
| Required Metrology | RT,A, ROC,S, SE, MR | RT,A, ROC,S, SE, MR | RT | RT | RT | RT, ROC | RT,ROC | RT,A, ROC,S, SE, MR | RT,A, ROC,S, SE, MR | RT,A, ROC,S, SE, MR | RT,A, ROC,S, SE, MR |
| Metrology Priority | High | High | Low | Low | Low | Low | Low | High | High | High | High |

*SM3 may not be needed - pending design

RT=reflection and transmission at design AOI, A = absorption, ROC=radius of curvature, S=scatter, SE = Surface Errors (TPA removed), MR = microroughness. S, SE and MR will be measured on both AR and HR surfaces for transmissive optics (IMC1/3, PRM and SRM and SR2) and on HR only for reflective optics (IMC2, PR2)

# Metrology Plan for Advanced LIGO IOO Suspended Mirrors

## 7. Vendor Measurement Matrix - Frequency and Method

| | Specification | Test Method | Frequency of Inspection | Data Delivered |
|---|---|---|---|---|
| **Blanks** | Physical Dimensions | Visual Inspection | 100% | Diameter, Thickness |
| | Serial Number | Visual Inspection | 100% | Inspection Report included with Certification |
| | Material | Process Control Material Certification | 100% | Certification |
| | Defect Depth | Visual Inspection | 100% | Certification |
| | Homogeneity | Interferometric Measurement | 100% | Phase Map (MC flats, RMs) or Certification (MC2, SMs) |
| | Birefringence | MIL-G-174, Section 4.4.5 | 100% | Inspection Report included with Certification |
| | Inclusions | Visual Inspections | 100% | Hand sketch indicating location and dimensions |
| | Striae | MIL-G-174, Section 4.4.5, method 1 or 2 (in optical axis only) | 100% | Inspection Report included with Certification (MC flats, RMs) or Certification (MC2 and SMs) |
| | Absorption at 1.06 μm | Material Certification | 100% | Certification |
| **Substrates** | Specification | Test Method | Frequency of Inspection | Data Delivered |
| | Physical Dimensions | Visual Inspection | 100% | Diameter, Thickness, Bevel dimension, Wedge angle. |
| | Side and Bevel Polish | Visual Inspection | 100% | Certification |
| | Scratches and Point Defects | Visual Inspection | 100% | Certification |
| | Registration Mark Location/Orientation | Visual Inspection | 100% | Certification |
| | Registration Mark Dimensions | Visual Inspection | 100% | Certification |
| | Identification Location | Visual Inspection | 100% | Certification |
| | Identification Serial Number | Visual Inspection | 100% | Certification |
| | Surface Figure | Interferometry | 100% | Surface Map |
| | Surface Errors – Low Spatial Frequency | Interferometry | 100% | Surface Map |
| | Surface Errors – High Spatial Frequency | High Resolution Surface Map | 100% | Surface maps for 3 central locations. Numerical values included with Certification |
| | Data: For the purpose of all data collection the Registration mark shall be at the top center of the optic.<br>Format: All Data shall be delivered according to Table 1. In addition to the hard copy the Surface Data shall be delivered on IBM PC compatible disk or via electronic file transfer in ASCII format. Phase difference data shall be in units of nanometers. | | | |
| **Coatings** | Coating manufacturer to provide:<br>1. One (1 in.) witness plate from each coating run<br>2. Spectrophotometer graphs of Reflectance and Transmittance of HR coating | | | |