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| LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY COMPONENT SPECIFICATION | E080135 V2 D |
| | Drawing No Rev. Group |
| | Sheet 1 of 4 |
| SUBSTRATE, ALIGO PRE-MODE MATCHING TELESCOPE MIRROR #1 (PMMT1) for L1 and H1 interferometers - unfolded | |

| AUTHOR: | CHECKED: | DATE | APPROVALS | | |
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Applicable Documents

- D080160-v2-D ALIGO Pre-Mode Matching Telescope Mirror #1 Substrate
- D080158-A-D ALIGO Pre-Mode Matching Telescope Mirror Blank
- E080133-A-D Mirror Blank Material, ALIGO Pre-Mode Matching Telescope Mirror (PMMT)

Requirements

Physical Configuration

According to D080160-v2-D ALIGO Pre-Mode Matching Telescope Mirror #1 Substrate

Fabricate from

- D080158-A-D ALIGO Pre-Mode Matching Telescope Mirror Blank
- E080133-A-D Mirror Blank Material, ALIGO Pre-Mode Matching Telescope Mirror (PMMT)

Serial Number

The Serial number shall be of the format:

PMMT1-YY-ZZ Where

YY is incremental for each optic starting at 01.

ZZ is the current revision of this specification.

Registration Marks

Registration mark and Serial Numbers shall be etched, ground or sandblasted as specified in D080160-v2-D ALIGO Pre-Mode Matching Telescope Mirror #1 Substrate.

Arrow indicates Surface 1, the highly reflective surface.

Surface, Side and Bevel Polish

All Surfaces, Sides and Bevels shall be polished using a progression of smaller grit sizes. The last step before final polish shall be equal to or less than a five micrometer grit finish. These surfaces shall appear transparent with no grey, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background.

Bevel

Bevel for safety per D080160-v2-D ALIGO Pre-Mode Matching Telescope Mirror #1 Substrate

Wedge angle

Specified according to drawing D080160-v2-D ALIGO Pre-Mode Matching Telescope Mirror #1 Substrate



**SUBSTRATE, ALIGO PRE-MODE MATCHING TELESCOPE
MIRROR #1 (PMMT1)
for L1 and H1 interferometers - unfolded**

Scratches, Sleeks and Point Defects:

Point defects of radius greater than 25 micrometers are treated like scratches for the purpose of this specification.

Scratches and Sleeks, Surface 1:

There shall be no scratches and sleeks within central 15 mm diameter.

The total area of scratches and sleeks within the central 40 mm diameter shall not exceed 20×10^2 square micrometers, width times length.

The total area of scratches and sleeks outside the central 40 mm diameter shall not exceed 10×10^3 square micrometers.

Point Defects, Surface 1:

There shall be no point defects of radius > 2 micrometers within central 15 mm diameter.

There shall be no more than 8 point defects of radius > 2 micrometers within the central 40 mm diameter.

There shall be no more than 60 point defects of radius > 2 micrometers on the entire surface.

Average density of defects less than 2 micrometers radius must be less than or equal with 1 per 4 mm^2 within the central 15 mm diameter. Point defects of radius less than 2 micrometers are disregarded outside the central 15 mm diameter.

Inspection Method

1. The surface is examined visually by two observers independently. The examination is done against a dark background using a three-bundle fiberoptic illumination system of 200 W total power. A 100% inspection of the surface is carried out. Pits and scratches down to 2 micrometers in width can be detected using this method of inspection. Any scratches that are detected will be measured using a calibrated eyepiece.
2. Further inspection will be done with a 6X eyeglass using the same illumination conditions, again, with two observers. Sleeks down to 0.5 micrometers wide can be detected using this method. The surface will be scanned along one or two chords from center to edge, then at ten positions around the edge, and ten to fifteen positions near the center.
3. An inspection is then carried out with a dark or bright field microscope, with 5x objective at four positions at each of the following locations:
 - a. Within 5 mm of the center of the surface.
 - b. Equally spaced along the circumference of a centered, 10 mm diameter circle.

Surface Figure, measured over the central 60 mm diameter

All specified quantities refer to the physical surface of the optic.

Surface 1: Spherical, concave

Radius of curvature: 12.80 meters +/- 0.13 meters

Astigmatism: < 15 nanometers (surface peak to valley)

**SUBSTRATE, ALIGO PRE-MODE MATCHING TELESCOPE
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Radius of curvature: > 10 kilometers

Astigmatism: < 40 nanometers (surface peak to valley)

Surface Error, Low Spatial Frequency: measurement aperture to 1 mm^{-1}

The following root mean square standard deviation (σ_{rms}) values are calculated from the phase maps which are to be provided with each optic. For this calculation the amplitudes for the best fit Zernike terms $Z_{0,0}$, $Z_{1,1}$, $Z_{2,0}$ and $Z_{2,2}$ or corresponding Seidel aberrations are subtracted from the phase map. Known bad pixels may be excluded from this calculation.

Surface 1, Frequency Band: $< 1 \text{ mm}^{-1}$ Measured over the central 10 mm diameter aperture: $\sigma_{\text{rms}} < 1.0$ nanometersMeasured over the central 60 mm diameter aperture: $\sigma_{\text{rms}} < 3.2$ nanometers**Surface 2**, Frequency Band: $< 1 \text{ mm}^{-1}$ Measured over the central 60 mm diameter aperture: $\sigma_{\text{rms}} < 32$ nanometers**Error, High Spatial Frequency: $1-750 \text{ mm}^{-1}$** **Surface 1**- HSF error $\sigma_{\text{rms}} \leq 0.2$ nanometers

Measured at the following locations:

1. Within 2 mm of the center of the surface.
2. Four positions equally spaced along the circumference of a centered, 10 mm diameter circle.

Surface 2- HSF error $\sigma_{\text{rms}} \leq 0.4$ nanometers

Measured within 2 mm of the center of the surface.


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Table 1: Verification Matrix – Method and Frequency

| Specification | Test Method | Frequency of Inspection | Data Delivered |
|---------------------------------------------|-----------------------------|-------------------------|------------------------------------------------------------------------------------|
| Physical Dimensions | Measurement | 100% | Diameter, Thickness, Bevel dimension, Wedge angle. |
| Side and Bevel Polish | Visual Inspection | 100% | Certification |
| Scratches and Point defects methods 1 and 2 | Visual Inspection 100% | 100% | Hand sketch including scratch/pit dimensions |
| Scratches and Point defects method 3 | Visual Inspection 100% | 100% | Digital image of each inspection location |
| 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 Phase 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 (arrow) shall be at the top center of the optic.

Format: All Data shall be delivered according to Table 1. In addition to the hard copy the Surface Data shall be delivered in electronic form in ASCII, OPD or .DAT format. Include a data description: aperture size, pixel size, height units. Phase difference data shall be in units of nanometers.