



**SUBSTRATE, ALIGO PRE-MODE MATCHING TELESCOPE MIRROR #2 (PMMT2)  
for L1 and H1 interferometers - unfolded**

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**Applicable Documents**

- D080161-v2-D ALIGO Pre-Mode Matching Telescope Mirror #2 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 D080161-v2-D ALIGO Pre-Mode Matching Telescope Mirror #2 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:  
 PMMT2-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 D080161-v2-D ALIGO Pre-Mode Matching Telescope Mirror #2 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 D080161-v2-D ALIGO Pre-Mode Matching Telescope Mirror #2 Substrate

**Wedge angle**

Specified according to drawing D080161-v2-D ALIGO Pre-Mode Matching Telescope Mirror #2 Substrate



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**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  $20 \times 10^2$  square micrometers, width times length.

The total area of scratches and sleeks outside the central 40 mm diameter shall not exceed  $10 \times 10^3$  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  $4 \text{ mm}^2$  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, **convex**

Radius of curvature: -6.24 meters +/- 0.06 meters

Astigmatism:  $< 15$  nanometers (surface peak to valley)

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Radius of curvature: &gt; 10 kilometers

Astigmatism: &lt; 40 nanometers (surface peak to valley)

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

The following root mean square standard deviation ( $\sigma_{\text{rms}}$ ) 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.

**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.