Advanced LIGO Pathfinder Polish

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Applicable Documents

LIGO-D060513-A	Fused Silica Substrate, Advanced LIGO Pathfinder
LIGO-D050337-A	Fused Silica Blank, Input Test Mass
LIGO-E050071-C	Fused Silica Blank, Input Test Mass

Requirements

Polished 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.

Physical Configuration

According to LIGO-D060513-A Fused Silica Substrate, Advanced LIGO Pathfinder

Fabricate from

LIGO-D050337-A	Fused Silica Blank, Input Test Mass
LIGO-E050071-C	Fused Silica Blank, Input Test Mass

Bevel

Bevel for safety per D060513

Serial Number

Serial Number “PF X” shall be written in indelible ink on the barrel of the optic, where X is specified by Caltech when the material is delivered from LIGO to vendor.

Registration Marks

A registration arrow shall be drawn in indelible ink on the barrel of the optic, pointing toward Surface 1. This mark is used to reference the top orientation of the delivered data, and for measurement comparison.

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

The total area of scratches and sleeks within the central 120 mm diameter shall not exceed 20×10^3 square micrometers (width times length.)

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The total area of scratches and sleeks outside the central 120 mm diameter shall not exceed 500 X 10^3 square micrometers (width times length.)

Scratches and Sleeks, Surface 2

The total area of scratches and sleeks within the central 120 mm diameter shall not exceed 240 X 10^3 square micrometers (width times length.)

Point Defects, Surface 1

There shall be no more than 10 point defects of radius greater than 2 μm within the central 120 mm diameter. There shall be no more than 100 point defects of radius greater than 2 μm on the entire surface. Average density of defects less than 2 μm radius must be less than or equal to 1 per $4mm^2$

Point Defects, Surface 2

There shall be no more than 100 point defects of radius > 2 μm within the central 120 mm diameter

Scratch and Point Defect Inspection Method

1. The surface is examined visually by two observers independently. The examination is done against a dark background using a fiberoptic illumination system of at least 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 or sleeks that are detected will be measured using a calibrated eyepiece.

2. Further inspection will be done with a minimum 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 centre to edge, then at ten positions around the edge, and ten to fifteen positions near the centre.

3. An inspection is then carried out with a dark field microscope with a similar sampling frequency as described in section 2.

Optical Surface Figure, measured over the central 150 mm diameter

Surface 1: Spherical, concave. Radius of curvature: 2098 m +36 m, -22 m absolute.
Reproducibility Goal: 2098 m ± 3 m Requirement: 2098 m ± 9 m
Astigmatism: < 3 nm Amplitude of the Zernike coefficient $Z_{2,2}$ as defined in Born and Wolf pp. 523-525.

Surface 2: Nominally flat. Curvature of the transmitted reflected wavefront off of Surface 1 as measured through Surface 2 must be within ± 15m of the calculated curvature accounting for the bulk of the material. The calculated curvature is based on the Surface 1 measurement and ideal homogeneous index of refraction.

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 mm^{-1}
Measured over the central 300 mm diameter aperture: σ_{rms} < 2.1 nanometers
Measured over the central 150 mm diameter aperture: σ_{rms} < 0.7 nanometers

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Surface 2 - Frequency Band: $< 1\ mm^{-1}$
Measured over the central 300 mm diameter aperture: $\sigma_{rms} < 4$ nanometers
Measured over the central 150 mm diameter aperture: $\sigma_{rms} < 2$ nanometers

Error, High Spatial Frequency: $1– 750\ mm^{-1}$

Surface 1 HSF error $\sigma_{rms} \leq 0.16$ nanometers measured at the following locations:

1. Within 2mm of the center of the surface.
2. Four positions equally spaced along the circumference of a centered, 60 mm diameter circle.
3. Three positions equally spaced along the circumference of a centered, 120 mm diameter circle.

Surface 2 HSF error $\sigma_{rms} \leq 0.4$ nanometer measured at the following location:

1. Within 2mm of the center of the surface.

Inspection

Table 1: Inspections

Specification	Test Method	Data Delivered
Scratches and Point defects	Visual Inspection	Hand sketch including scratch/pit dimensions
Figure	Interferometry	Surface phase maps
Errors - Low Spatial Frequency	Interferometry	Surface phase maps
Errors - High Spatial Frequency	Interferometry	Surface maps for 3 central locations. Numerical values included with certification

Orientation: For the purpose of full surface phase maps the substrate shall be oriented such that the registration mark shall be at the top center of the data.

Format: All Data shall be delivered according to Table 1. In addition to the hard copy an electronic data set of the phase maps shall be delivered in either ASCII or Vision.OPD format.