Customized Lens for Advanced LIGO Thin Compensation Plate (CP)

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Applicable Documents

LIGO-D1000979-v3	ALIGO, COC TCP (THIN COMPENSATION PLATE) SUBSTRATE
LIGO-E080037-A	Fused Silica Blank, Advanced LIGO Compensation Plate

REQUIREMENTS

Physical Configuration

According to LIGO-D1000979-v3 ALIGO, COC TCP (THIN COMPENSATION PLATE) SUBSTRATE

Fabricate from

LIGO-D1000979-v3	ALIGO, COC TCP (THIN COMPENSATION PLATE) SUBSTRATE Serial numbers CP03 and CP04
LIGO-E080037-A	Fused Silica Blank, Advanced LIGO Compensation Plate

Registration Marks

Existing registration marks may remain unchanged.

Surfaces, Sides and Bevel Polish

All Surfaces, Sides and Bevels shall be polished using a progression of smaller grit sizes. Optical surfaces, S1 and S2 should be prepared to minimize subsurface damage, using progressively smaller grit, ending with a grit of 5 micrometers or less. These surfaces shall appear transparent with no grey, checks or fractures visible to the naked eye when viewed in normal room light against a black background. Scuffs on the sides are limited to a total sum area of less than 8 square millimeters. Scratches on the sides are limited to a total sum area of less than 4 square millimeters.

Bevel

Bevel for safety per D1000979-v3

Serial Number

Serial Number is to remain unchanged.

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Surface Defects, Surfaces 1 and 2

The total area of surface defects (scratches, sleeks and digs) within the central 120 mm diameter shall not exceed 500 X 10^3 square micrometers (width times length) on each surface.

Surface defects of small height may be allocated to the **High Spatial Frequency Error** allowance as described in Appendix A.

Inspection Method

1. The surface is examined visually by two observers independently. The examination is done against a dark background using a fiber optic illumination system of at least 150 W total power. A 100% inspection of the surface is carried out. Defects 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.

Figure, measured in transmission over the central 160 mm diameter, measured at 632 nm.

Nominally Flat. Radius of curvature in transmission +68.6 Km ± 15 Km (ref: converging, 47 nm saggita OPD) Astigmatism: < 2 nm Amplitude of the Zernike coefficients $Z_{2,2}$ and $Z_{2,-2}$ as defined in Born and Wolf 7th ed. pp. 523-525.

Root mean square residual < 1.0 nm, after subtracting the best fit Zernike terms $Z_{0,0}$, $Z_{1,1}$, $Z_{2,0}$, $Z_{2,-2}$ and $Z_{2,2}$ or corresponding Seidel aberrations from the phase map.

Figure, measured in transmission over the central 266 mm diameter

Root mean square residual < 3 nm, after subtracting the best fit Zernike terms $Z_{0,0}$, $Z_{1,1}$, $Z_{2,0}$, $Z_{2,-2}$ and $Z_{2,2}$ or corresponding Seidel aberrations from the phase map.

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

Surfaces 1 and 2 HSF error $\sigma_{rms} \leq 0.3$ 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.

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Inspection

Table 1: Inspections

Specification	Test Method and frequency	Data Delivered
Thickness and wedge	Measurement 100%	Measurement Results
Scratches and Point defects methods 1 and 2	Visual Inspection 100%	Hand sketch including scratch/pit dimensions
Figure, in Transmission	Interferometry 100%	Phase map
Surface Error - High Spatial Frequency	Interferometry 100%	Surface maps for 3 central locations. Numerical values included with certification

Orientation: For the purpose of full surface phase maps the data shall be oriented such that the substrate registration mark (arrow) is 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 .dat format.

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Appendix A: Allocating surface defects to RMS roughness on LIGO surfaces

In order for a defect to be counted as part of the surface roughness specification allocation, it must be measurable by phase measuring microscope, have an amplitude of less than 100 nm, and its contribution to the local surface RMS roughness must be quantifiable. It is expected that sleeks may qualify for this but not scratches. Scratches will be counted as part of the area exclusion allocation.

To properly add the contribution of a single defect to the total accumulated RMS surface roughness the RMS of local defect area must be statistically added to the total surface area roughness.

The following equation is believed to accurately make this calculation. The RMS is assumed to be the RMS deviation, relative to a best fit plane.

$$RMS_{Total} = \sqrt{\frac{AREA_{Full} * RMS_{Full}^2 + AREA_{Local} * RMS_{Local}^2}{AREA_{Full} + AREA_{Local}}}$$

RMS_{Local} = RMS of local area containing the sleek
$AREA_{Local}$ = Area of local RMS

RMS_{Full} = RMS surface roughness of total area, excluding the effect of the defect
$AREA_{Full}$ = Total Area of surface, excluding the area of the sleek

RMS_{Total} = RMS surface roughness of total area, including the effect of the defect

Example 1:
RMS of 1 PMM image containing $1/20^{th}$ of the defect = 3nm. The defect is 5mm, and extends over 20 PMM images
Size of PMM image = 0.25mm x 0.25mm

RMS_{Local} = 3.0nm
$AREA_{Local}$ = 0.25 x 0.25 x 20 = 1.25mm^2. This is the total estimated area of the affected zone, represented by the 3.0nm RMS.

RMS_{Full} = 0.12nm
$AREA_{Full}$ = 11309.7mm^2 - 1.25mm^2

RMS_{Total} , RMS surface roughness of total area plus defect = 0.124nm

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Example 2:
The system also works using only the 3D diminutions of only the defect it self.
Sleek 20mm long, 1micron wide, 10nm deep
In center 120mm Aperture of R1

RMS_{Local} = 10nm
$AREA_{Local}$ = 0.02mm^2

RMS_{Full} = 0.12nm
$AREA_{Full}$ = 11309.7mm^2 - 0.02mm^2

RMS_{Total} , RMS surface roughness of total area plus defect = 0.121nm