Coated Substrate aLIGO+ Filter Cavity End Mirror (FEM)

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
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Name: **FEM**

Applicable Documents

D1900149-v1 Filter Cavity End Mirror Substrate (Substrate Drawing)
E1900149-v2 Substrate, aLIGO+ Filter Cavity End Mirror (Polish Specification)

Physical Configuration

Fabricated from: D1900149 Filter Cavity Input Mirror Substrate

General to Surfaces 1 and 2

Coating Area: Less than 5 mm from the bevel to the edge of the coating.

Coating Method: Ion Beam Sputtering

Surface Quality: To comply with section 1.1 of this document "Surface Quality: Maximum scratch, sleek and point defect area." This section was copied verbatim for convenience from the corresponding section of E1900149-v2.

Figure Change Before/After Coating

Coating uniformity and stress for the coating process shall not change the saggita more than 50 nm over the central 35 mm diameter aperture, and more than 5 nm over the central 10 mm diameter aperture (ROC > 30 Km).

Also, coating process shall not add surface figure Zernike terms higher than the second order with amplitude > 0.5 nm over the central 30 mm diameter.

Coating Durability

1. Coating to resist adhesion test per MIL-C-48497A 4.5.3.1 Adhesion (snap tape.)
2. Coating to resist humidity test per MIL-C-48497A 4.5.3.2 Humidity (120 F and 95% to 100% relative humidity for 24 hours).
3. Coating to resist abrasion test per MIL-C-48497A 4.5.3.3 Moderate Abrasion (cheese cloth rub)

Surface 1: HR Coating **Note: Arrow on the optic Barrel points in the direction of Surface 1.**

Coating type: Highly Reflective at 1064 nm, Highly reflective at 532nm

Angle of incidence: Normal (0.0 degrees)

Transmission at 1064 nm: 2-4 ppm at the designed angle of incidence.

Transmission at 532 nm: Matched to D190148 FIM 532 transmissivity (Goal), or 0.01 ± 500 ppm at the designed angle of incidence (requirement).

Surface Electric Field: Design for minimum surface electric field

Absorption at 1064 nm: < 1 ppm (Requirement)

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Optical Performance Uniformity	The specified single surface reflectance at the specified wavelength and angle of incidence must be maintained over at least 40 mm diameter aperture.

Surface 2: AR coating

Coating type	Antireflective at 1064 nm, Antireflective at 532 nm
Angle of Incidence	0 to 2 degrees on the vacuum side, S and P polarization
Reflection at 1064 nm	< 50 ppm (Goal) < 100 ppm (Requirement) at the designed AOI
Reflection at 532 nm	< 50 ppm (Goal) < 100 ppm (Requirement) at the designed AOI
Absorption at 1064 nm	< 3 ppm
Optical Performance Uniformity	The specified single surface reflectance at the specified wavelength and angle of incidence must be maintained over at least 40 mm diameter aperture.

ADDITIONAL DELIVERABLES: Coating manufacturer to provide:

1. 1" WITNESS SAMPLES for Surfaces 1 and 2:
   Two 1-inch fused silica witness plates (provided by the vendor) from each coating run, which undergo the same coating process as the main optic: HR on one side and AR on the other side. The witness pieces should be superpolished on the HR side and nominally polished and wedged at 0.5 deg on the AR side. The 1-inch coated witness plates should be representative for the individual coating runs.

2. LAYER THICKNESS DESIGN VALUES
   For all layers in the design, designed thickness, and measured indices of refraction over the entire dispersion range (including at 1064 nm) for both coating materials (based on individual layers).

3. SPECTRAL SCANS – Surfaces 1 and 2
   On a representative 1-inch witness sample for each run, the coating manufacturer will provide the following data: a. Spectrophotometer graphs of the Reflectance and Transmittance of each surface (Surface 1 – HR coating and Surface 2 - AR coating) at the specified angles of incidence, over the over the entire spectrometer range, with minimum range covered of 500-1400 nm. The scans will be taken before the sample is coated, between the Surface 1 and Surface 2 coating and after the coating is completed. All spectrometer data to be provided in Excel spreadsheet format, with columnar data in increments of approximately 1 nm.

4. SURFACE DEFECT ANALYSIS - Scratches and point defects:
   Hand Sketch for visual inspection and digital images for microscope inspection.

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1.1 Surface Quality: Maximum scratch, sleek and point defect area

1.1.1 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 fiber optic illumination system of at least 150 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 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 10mm of the center of the surface.

b. Equally spaced along the circumference of a centered, 30 mm diameter circle.

1.1.2 Surface 1, inside 40 mm diameter

Zero defects within the central 40 mm diameter.

1.1.3 Surface 1, between 40 and 60 mm diameter

The total area of defects, within the annular region between 40 and 60 mm diameter, shall not exceed 1400 square micrometers when weighted per Appendix A Defect Analysis.

1.1.4 Surface 1, outside 60 mm diameter

Shall appear transparent with no grey, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background.

1.1.5 Surface 2

Shall appear transparent with no grey, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background.

2 Appendix A. Defect Analysis

The surface defects in weighted areas are to be evaluated as follows.

1. Measure the area of the defect in square micrometers

2. Measure the distance of the defect from the center of the optic

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3. Find the weighting factor for the radius measured in step 2, from the table below.
4. Multiply the measured area found in step 1 with the weighting factor found in step 3.
5. Sum all weighted defects found within the analysis zone.

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Inspection radius for FEM (mm)	Position dependent defect Weighting Factor, Surface 1
1	None allowed
2	None allowed
3	None allowed
4	None allowed
5	None allowed
6	None allowed
7	None allowed
8	None allowed
9	None allowed
10	None allowed
11	None allowed
12	None allowed
13	None allowed
14	None allowed
15	None allowed
16	None allowed
17	None allowed
18	None allowed
19	None allowed
20	None allowed
21	0.11
22	0.075
23	0.05
24	0.033
25	0.021
26	0.013
27	0.008
28	0.005
29	0.003
30	0.0017