



# SPECIFICATION

## Coated Substrate aLIGO+ Filter Cavity Input Mirror (FIM)

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

### Applicable Documents

- D1900148-v1 Filter Cavity Input Mirror Substrate (Substrate Drawing)
- E1900148-v2 Substrate, aLIGO+ Filter Cavity Input Mirror (Polish Specification)

### Physical Configuration

Fabricated from: D1900148 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 E1900148-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 0.001 ± 10ppm (goal), 0.001 ± 50ppm (required) at the designed angle of incidence.

Transmission at 532 nm Matched to D190149 FEM 532 transmissivity (Goal), 0.01 ± 500 ppm at the designed angle of incidence.

Surface Electric Field Design for minimum surface electric field

Absorption at 1064 nm < 1 ppm (Requirement)



### Coated Substrate aLIGO+ Filter Cavity Input Mirror (FIM)

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 witness sample for each run, the coating manufacturer will provide spectrophotometer graphs of the Reflectance and Transmittance of each surface after the coatings have been applied (Surface 1 – HR coating and Surface 2 - AR coating) at the specified angles of incidence. The range or ranges scanned must include and designate to 1nm the data points for the desired 1064nm and 532nm wavelengths.
4. SURFACE DEFECT ANALYSIS - Scratches and point defects:  
Hand Sketch for visual inspection and digital images for microscope inspection.



## Coated Substrate aLIGO+ Filter Cavity Input Mirror (FIM)

### 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

The total area of defects within the central 40 mm diameter shall not exceed 2800 square micrometers when weighted per Appendix A Defect Analysis.

## 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
3. Find the weighting factor for the radius measured in step 2, from the table below.



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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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## Coated Substrate aLIGO+ Filter Cavity Input Mirror (FIM)

Inspection radius for FIM (mm)	Position dependent defect Weighting Factor	
	Surface 1	Surface 2
1	None allowed	4.9
2	None allowed	4.6
3	None allowed	4.1
4	None allowed	3.5
5	None allowed	2.9
6	None allowed	2.3
7	None allowed	1.7
8	None allowed	1.2
9	None allowed	0.8
10	None allowed	0.55
11	None allowed	0.34
12	None allowed	0.21
13	None allowed	0.12
14	None allowed	0.065
15	None allowed	0.034
16	None allowed	0.017
17	None allowed	0.008
18	None allowed	0.004
19	None allowed	0.0017
20	None allowed	0.0007
21	0.0007	
22	0.0003	
23	0.0001	
24	4.0E-05	
25	1.4E-05	
26	4.8E-06	
27	1.4E-06	
28	4.0E-07	
29	1.1E-07	