*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO- T1100446-v1 *LIGO* 10/10/11

# AOS SLC

# ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle

# Final Design

Michael Smith, Lisa C. Austin, Heidy Kelman, Tim Nguyen, Manuel Ruiz, Virginio Sannibale, Jesse Terrazas

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This is an internal working note
of the LIGO Laboratory.

**California Institute of Technology**
**LIGO Project – MS 18-34**
**1200 E. California Blvd.**
**Pasadena, CA 91125**
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

**Massachusetts Institute of Technology**
**LIGO Project – NW22-295**
**185 Albany St**
**Cambridge, MA 02139**
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

**LIGO Hanford Observatory**
**P.O. Box 159**
**Richland WA 99352**
Phone 509-372-8106
Fax 509-372-8137

**LIGO Livingston Observatory**
**P.O. Box 940**
**Livingston, LA 70754**
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

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# 1 INTRODUCTION

## 1.1 Scope

This document provides the final designs for the ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle for aLIGO.

## 1.2 Final Design Review Checklist

### 1.2.1 Final requirements – any changes or refinements from PDR?

The requirements for the ITM Elliptical Baffle, FM Elliptical Baffle, FM Beam Dump, and the Manifold Flat Baffle are listed in T070061 Stray Light Control Design Requirements. These baffles and beam dumps fall into the general category of Cavity Beam Dumps, and must meet the vignetting requirements specified in Sec. 4.8.

**Direct Requirements**

Phase noise due to scattered light fields injected into the interferometer is treated as a technical noise source. Therefore, the total scattered light phase noise, expressed in equivalent displacement noise, must be < 1/10th of the quadrature sum of the suspension thermal noise and the test mass thermal noise (referred to as the SRD), as given in Figure 1 of M060056-06, Advanced LIGO Reference Design.

**ITM Elliptical Baffle Requirements**

The ITM Elliptical Baffle shall block the IFO beam that passes from the PR3 mirror around the edges of the BS mirror. It shall form an elliptical aperture of a specified minor and major diameter that allows passage of the power recycling cavity beam from the BS mirror to the ITM mirror. It shall block the arm cavity beam exiting through the ITM AR face that exceeds the size of the elliptical aperture.

**FM Beam Dump Requirements**

The FM Beam Dump shall catch and trap the IFO beam that transmits through the AR surface of the FM mirror, from the BS direction and from the ITM direction.

**FM Elliptical Baffle Requirements**

The FM Elliptical Baffle shall allow unimpeded passage of the power recycling cavity beam from the BS mirror to the ITM mirror. It shall block the arm cavity beam exiting through the ITM AR face that passes around the ITM mirror and the portion of that beam that would hit the FM mirror structure.

**Clear Aperture Requirements**

The ITM Elliptical Baffle shall provide an elliptical aperture of 210 mm horizontal diameter and 260 mm vertical diameter. De-centration of the aperture shall not cause the power recycling cavity fractional power loss to exceed 100 ppm; this requirement results in the ancillary requirement that the elliptical aperture shall be positioned to within +/- 7mm of the recycling cavity beam centerline.

The FM Elliptical Baffle has a similar requirement for not vignetting the power recycling cavity beam.

### 1.2.2 Resolutions of action items from SLC PDR

Refer to: LIGO-L0900119-v1

**Lower BRDF Material for Baffles**
We suggest the team consider a lower-BRDF material for the more critical baffles;
and in particular, suggest looking at the electro-static frit black-enameled steel as an option
that would give better optical performance.
**Ans:** *The lowest BRDF material that is practical at the moment is oxidized polished stainless steel.*

### 1.2.3 Final Parts Lists and Drawing Package

TBD

### 1.2.4 Final specifications

E0900023-v11 PROCESS FOR MANUFACTURING CANTILEVER SPRING BLADES FOR AdvLIGO

E0900364-v8 Metal components intended for use in the Adv LIGO Vacuum System

E1100842 Specification for Mirror Finished (Super #8) Stainless Steel to be used in the LIGO Ultra-High Vacuum System

### 1.2.5 Final interface control documents

TBD The mechanical and optical interfaces of the Signal Recycling Cavity Baffles are described in E110XXX-v1AOS SLC ITM Ellip Baf, FM Elliptical Baffle, FM BD, and Manifold Flat Baffle Interface Control Doc.

### 1.2.6 Relevant RODA changes and actions completed

*Not applicable*

### 1.2.7 Signed Hazard Analysis

E1101018-v1 SLC ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Install Hazard Analysis

### 1.2.8 Final Failure Modes and Effects Analysis

*Not Required*

### 1.2.9 Risk Registry items discussed

*None for this subsystem*

### 1.2.10 Design analysis and engineering test data

See Section 3 Descriptions of Baffles and Section 4 Scattered Light Displacement Noise

### 1.2.11 Software detailed design

*Not applicable*

### 1.2.12 Final approach to safety and use issues

*No operational safety issues*

### 1.2.13 Production Plans for Acquisition of Parts, Components, Materials Needed For Fabrication

E1101002 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Production Plan

### 1.2.14 Installation Plans and Procedures

E1101021 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Installation Procedure

*This will be deferred until after FDR*

### 1.2.15 Final hardware test plans

- Blade stiffness measurement

See E1000892 Arm Cavity Baffle Fabrication, Installation, and Test Plan

- Other Testing

See E1101021 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Installation Procedure

### 1.2.16 Final software test plans

Not applicable.

### 1.2.17 Cost compatibility with cost book

See E1101002 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Production Plan

### 1.2.18 Fabrication, installation and test schedule

See E1101022 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Fabrication, Installation, and Test Plan

### 1.2.19 Lessons Learned Documented, Circulated

### 1.2.20 Porcelainizing

The baffles will be constructed of oxidized polished stainless steel to avoid shedding of the porcelain surface.

#### 1.2.21 Problems and concerns

There are presently no known problems or concerns with the recycling cavity baffles.

## 1.3 Applicable Documents

T070303 Arm Cavity Finesse for aLIGO

T070247 aLIGO ISC Conceptual Design

E0900364-v8 LIGO Metal in Vacuum

E1101022 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Fabrication, Installation, and Test Plan

T060073-00 Transfer Functions of Injected Noise

T070061-v2 Stray light Control Design Requirements

T0900269-v2 Stray Light Control (SLC) Preliminary Design

T1100056-v2 Arm Cavity Baffle Edge Scatter

E1101018 SLC ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Install Hazard Analysis

E1101002 ITM Elliptical Baffle, FM Beam Dump, FM Elliptical Baffle, & Manifold Flat Baffle Production plan

TBD E110XXX-v1AOS SLC ITM Ellip Baf, FM Elliptical Baffle, FM BD, and Manifold Flat Baffle Interface Control Doc.

# 2 BAFFLE DESCRIPTIONS

## 2.1 FUNCTION

### 2.1.1 ITM ELLIPTICAL BAFFLE

The ITM Elliptical Baffles catch the portion of light in the power recycling cavity directed from the PR3 mirror that spills around the BS; they also catch the light entering the power recycling cavity from the ITM mirror that would spill around the BS. The elliptical hole in the ITM Elliptical Baffle defines the profile of the beams inside the power recycling and signal recycling cavities and ensures that the overlap of the two arm beams at the BS is maximized.

### 2.1.2 FM ELLIPTICAL BAFFLE

The FM Elliptical Baffle catches the portion of the light entering the power recycling cavity from the H2 ITM mirror that would otherwise spill around the FM.

### 2.1.3 FM BEAM DUMP

The FM Beam Dumps catch the transmitted light through the FM AR surface from the direction of the BS and from the ITM.

### 2.1.4 MANIFOLD FLAT BAFFLE

The Manifold Flat Baffle catches some of the wide angle scattered light from the ETM mirror, and also hides the right angle corner where the viewport flange connects to the A-17 adapters, thereby mitigating the retroreflection back toward the ETM mirror.

## 2.2 H2 IFO ZEMAX LAYOUT

The H2 IFO ZEMAX layout of BSC8 is shown in Figure 1.

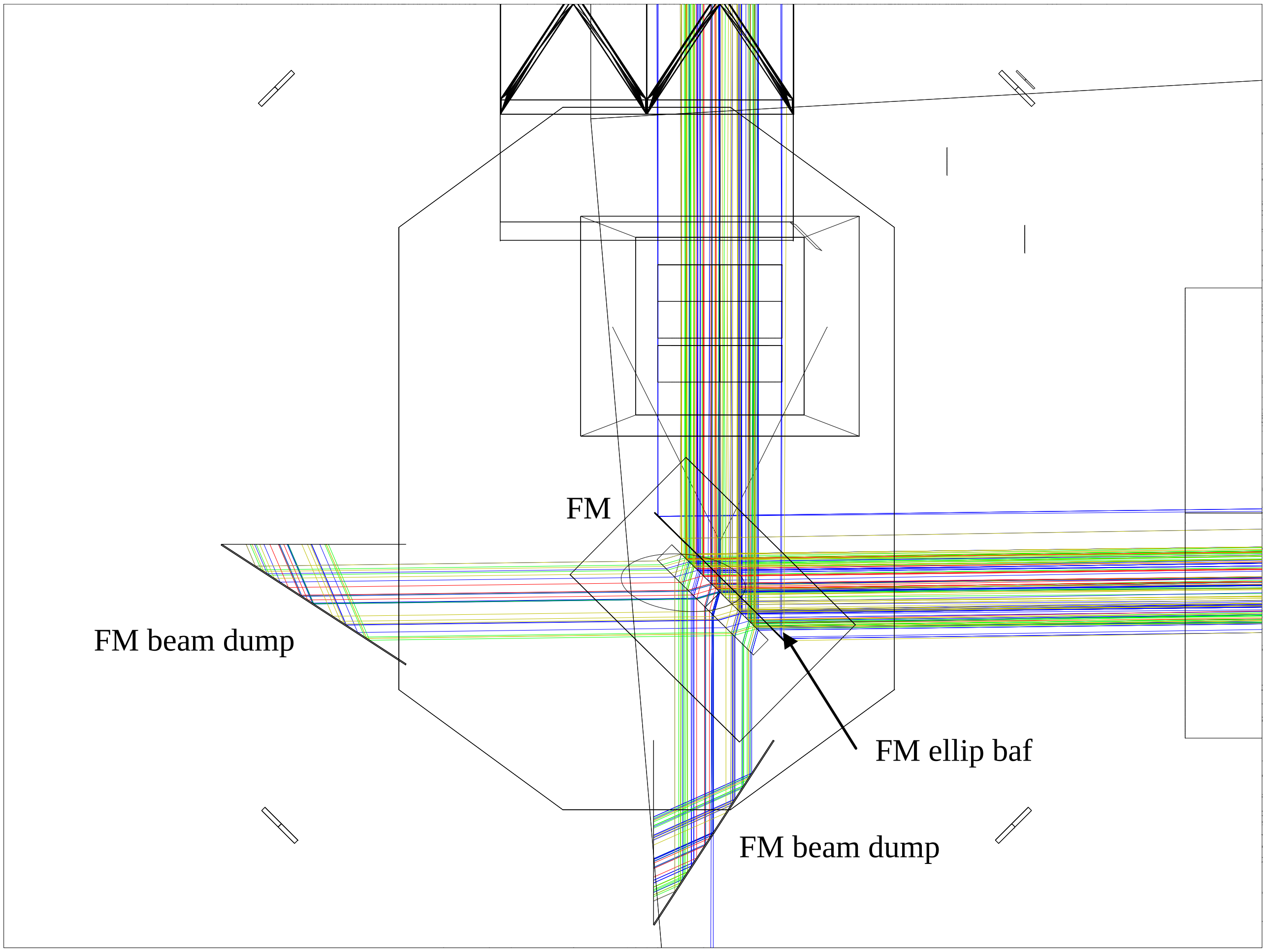


**Figure 1: BSC8: FM Elliptical Baffle, FM Beam Dumps**

The H2 IFO ZEMAX layout of BSC7 is shown in Figure 2.

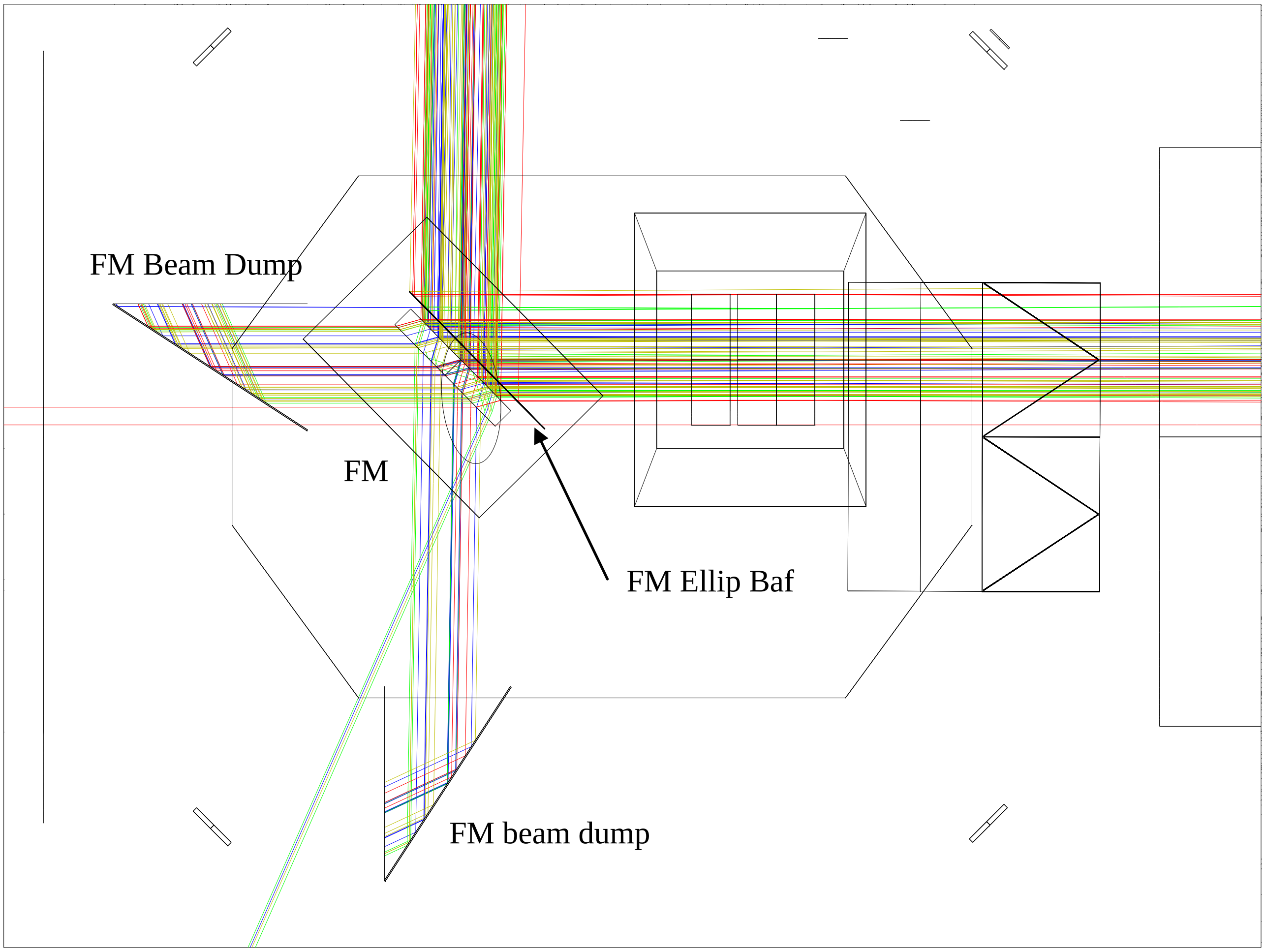


**Figure 2: BSC7: FM Elliptical Baffle, FM Beam Dumps**

The H2 IFO ZEMAX layout of BSC4 is shown in Figure 3.

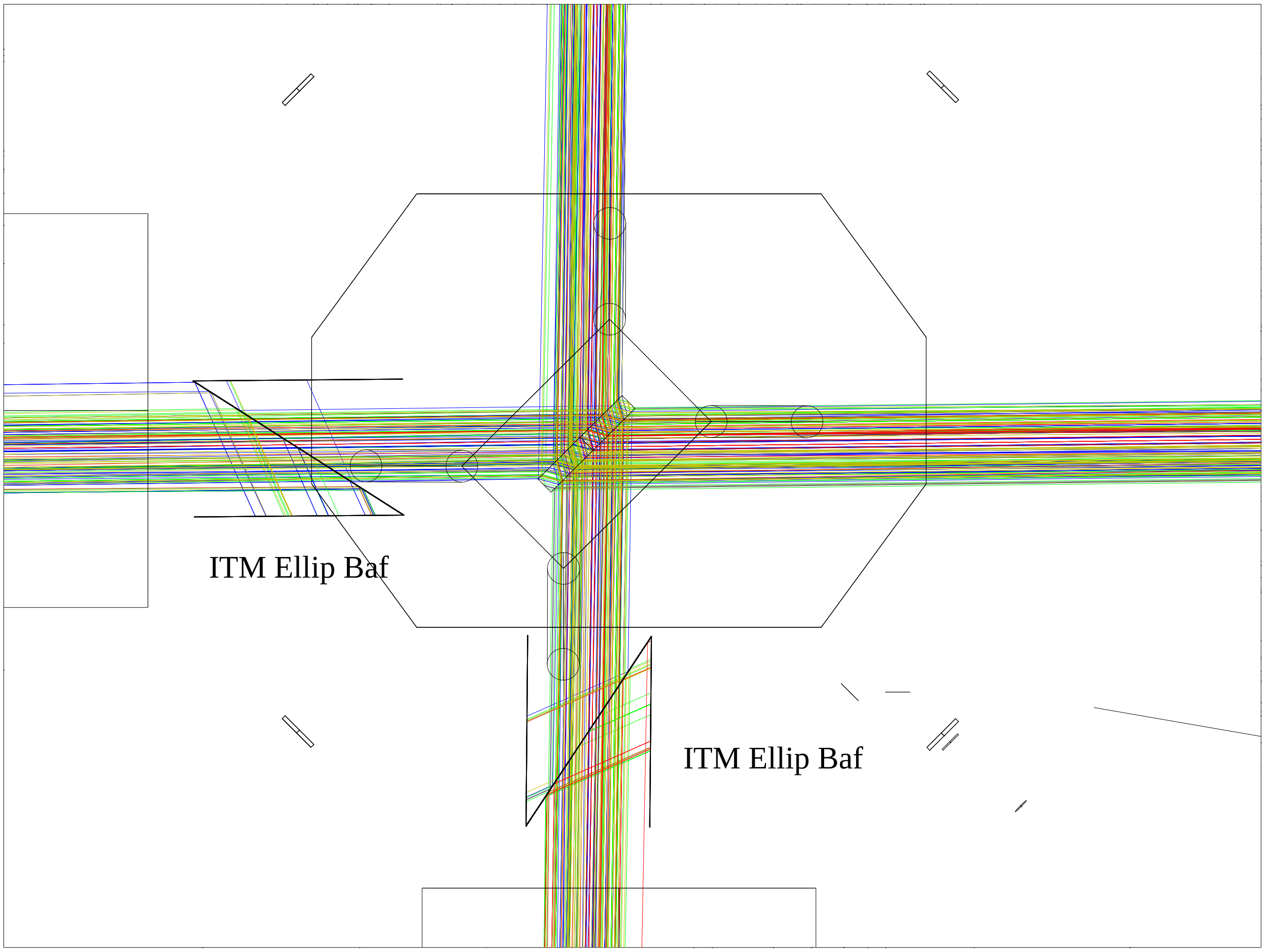


**Figure 3: BSC4: ITM Elliptical Baffles**

The H2 IFO ZEMAX layout of BSC5 is shown in Figure 4.

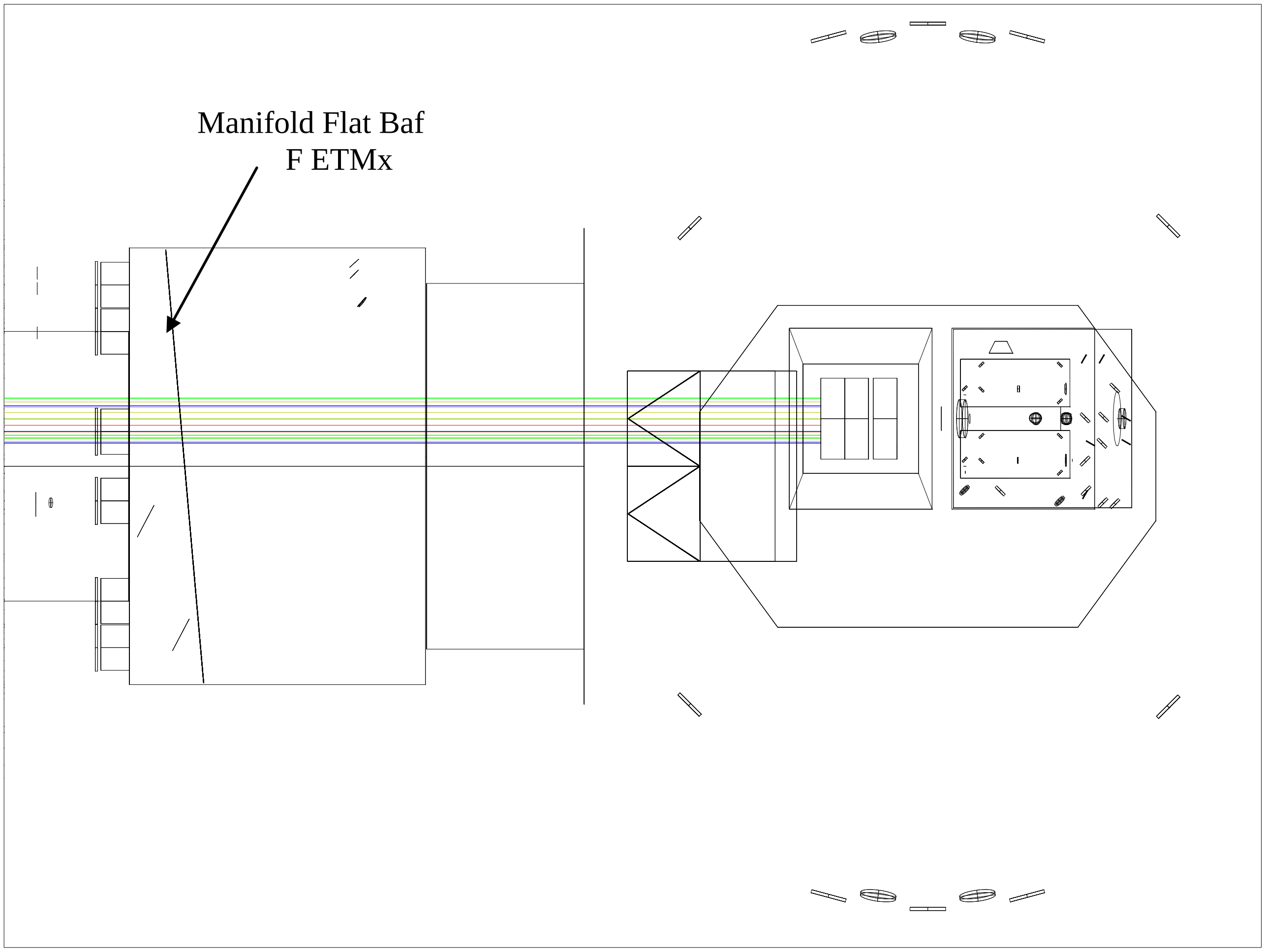


**Figure 4: BSC5: Manifold Flat Baffle F ETMx**

The H2 IFO ZEMAX layout of BSC6 is shown in Figure 5.

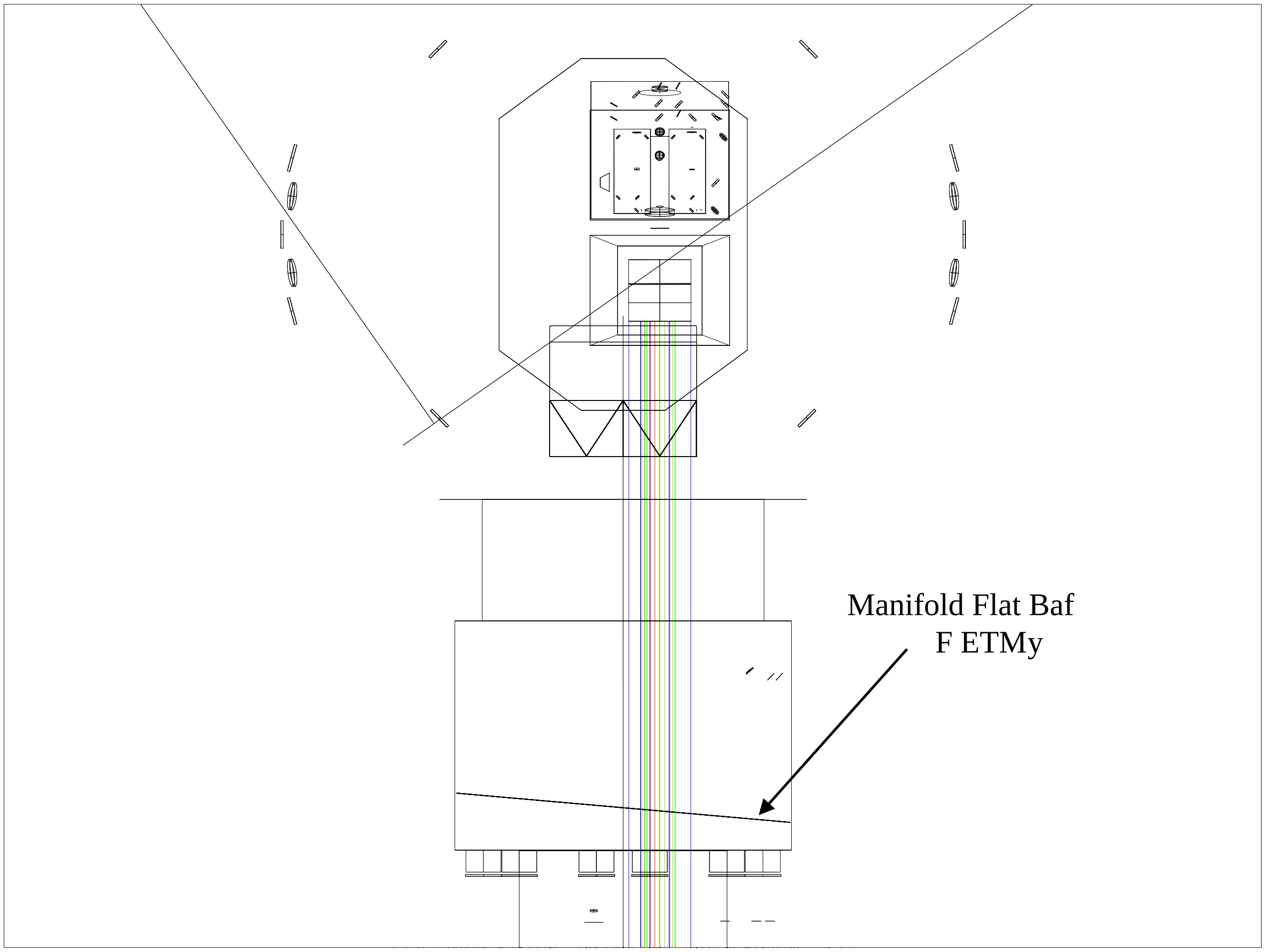


**Figure 5: BSC6: Manifold Flat Baffle F ETMy**

## 2.3 H1 & L1 IFO ZEMAX LAYOUT

The H1 & L1 IFO ZEMAX layout of BSC2 is shown in Figure 6.

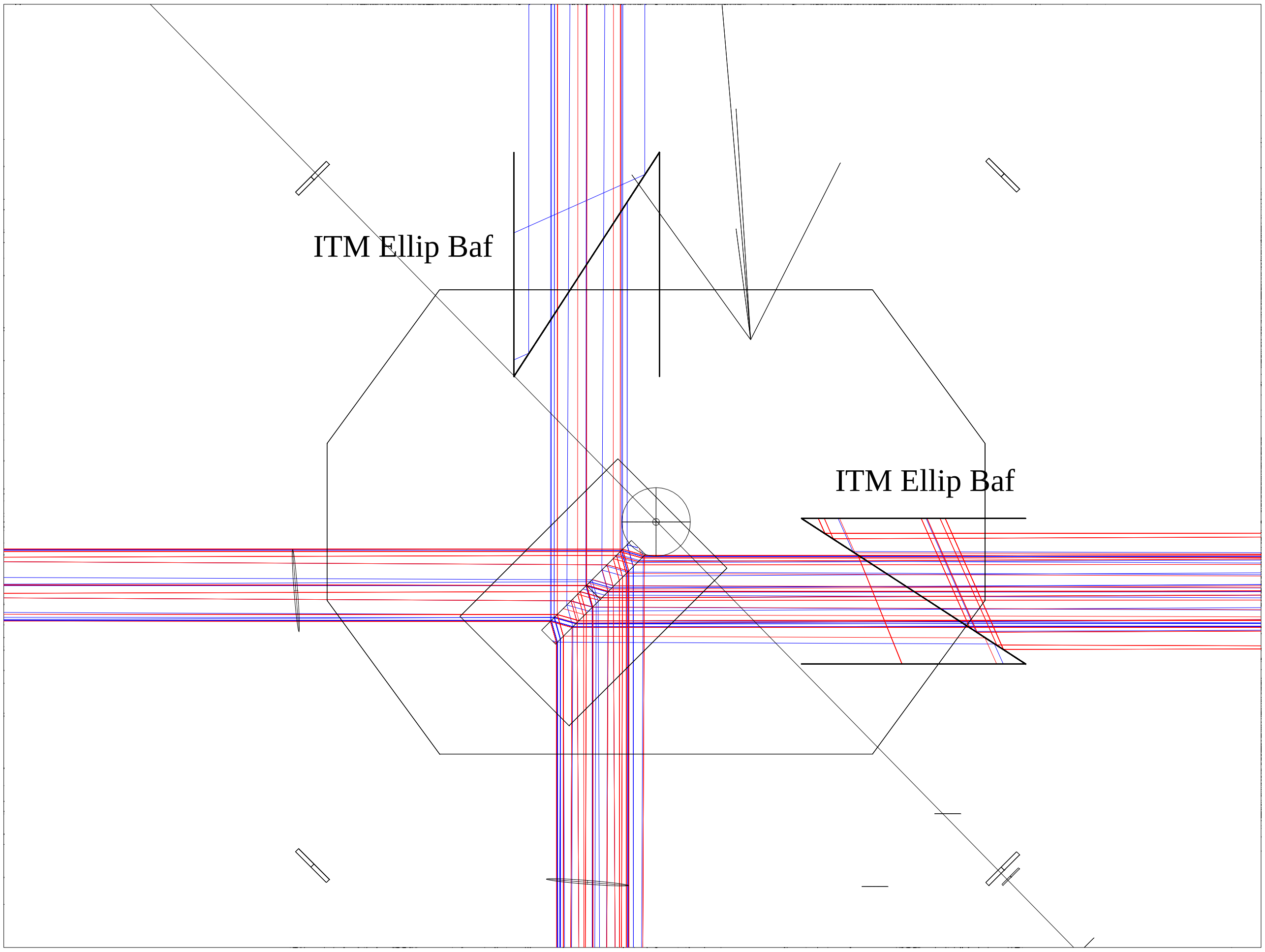


Figure 6: BSC2: ITM Elliptical Baffles

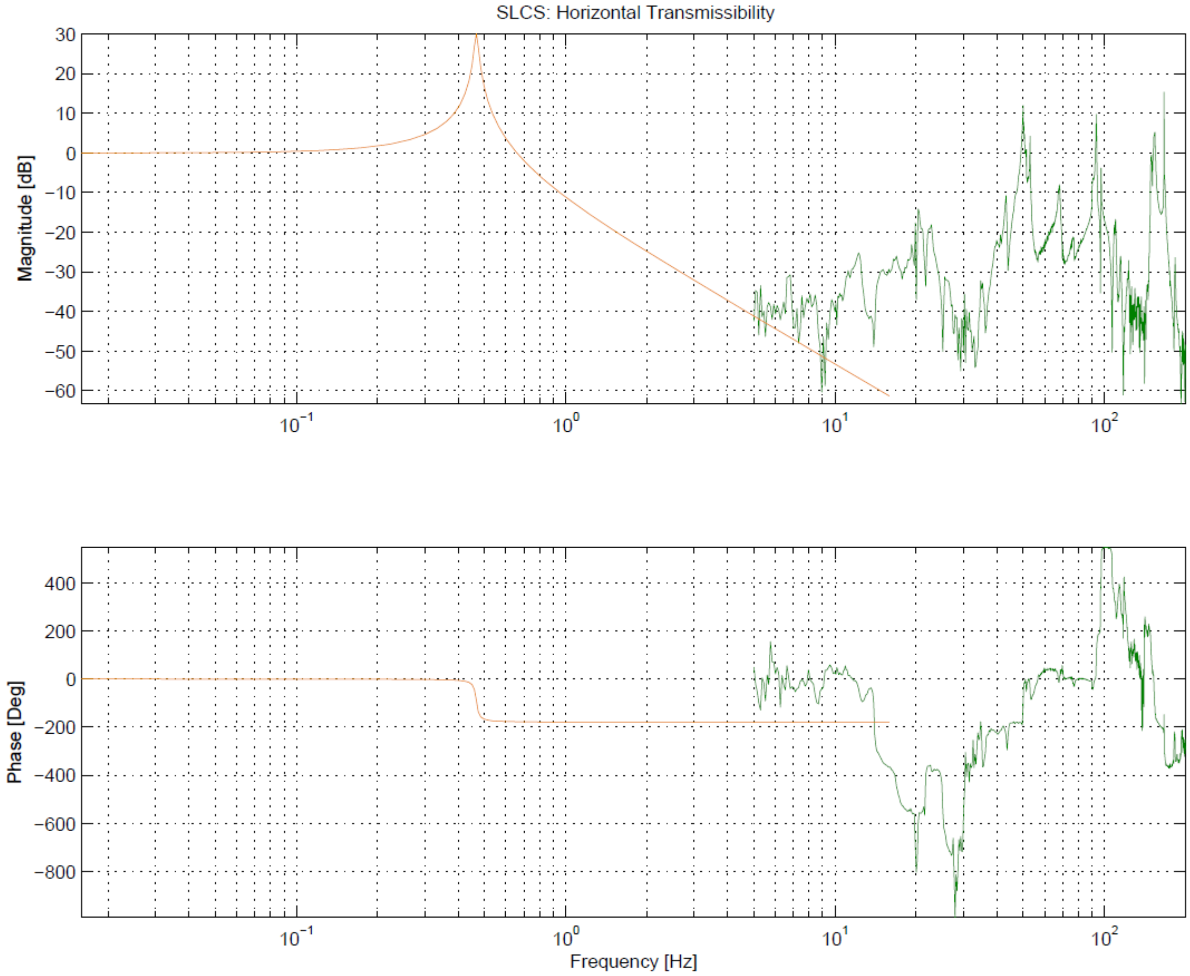
# 3 DESCRIPTIONS OF BAFFLES

## 3.1 SUSPENSION

### 3.1.1 Transmissibility Measurements

The ITM Elliptical Baffle and the FM Beam Dump use the same suspension structure as the Arm Cavity Baffle. The vibration attenuation characteristics of the suspension are shown in Figure 7.

The measured transmissibilities (green curve) are compared with the damped pendulum analytical model (red curve) in the vicinity of 10 Hz. The actual magnitudes agree reasonably well with the model. Beyond 10 Hz, the amplitude remains approximately constant at the background noise level, except for internal resonances of the baffle suspension.


SLCS: Horizontal Transmissibility
Magnitude [dB]
30
20
10
0
−10
−20
−30
−40
−50
−60
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
Phase [Deg]
400
200
0
−200
−400
−600
−800
Frequency [Hz]

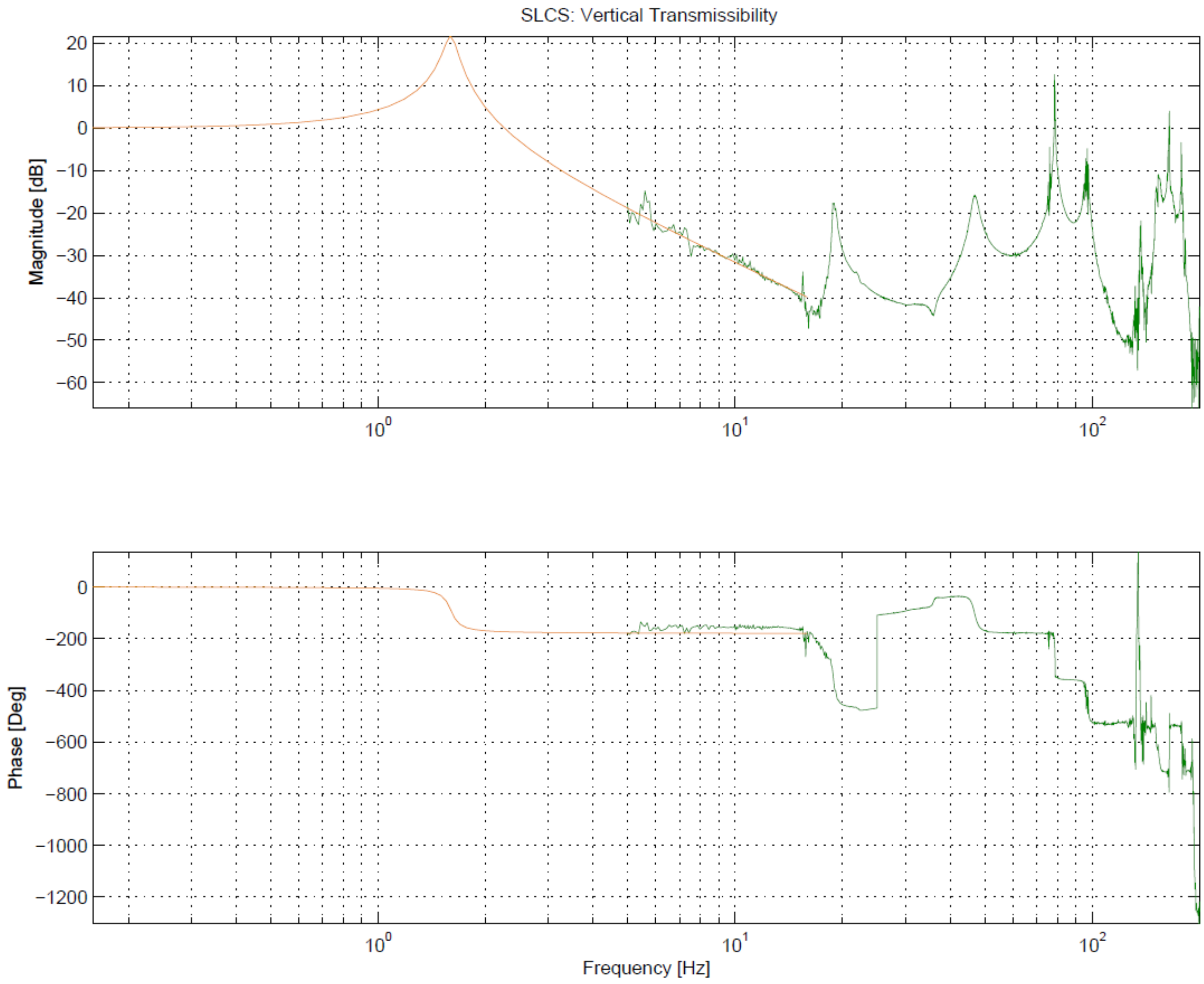


**Figure 7: Transmissibilities of ITM Elliptical Baffle Suspension**

### 3.1.2 Stray Magnetic Field Measurement

Two eddy current damper magnets will be used for the ITM Elliptical Baffle, and they will be placed > 0.7m distance from the magnets of the TM SUS magnets of the BS and the FM. The effect of the eddy current magnetic field on the TM SUS is negligible; see T1000738 SLC Magnetic Field Measurements of the Eddy Current Damper.

### 3.1.3 Earthquake Stops

The earthquake stops consist of travel-limiting rods mounted to the large down-tube that holds the eddy-current copper damping plates, which mount to the ISI Stage 0, as shown in Figure 8. The rods restrain the excess motion of the suspended baffle in three axes.

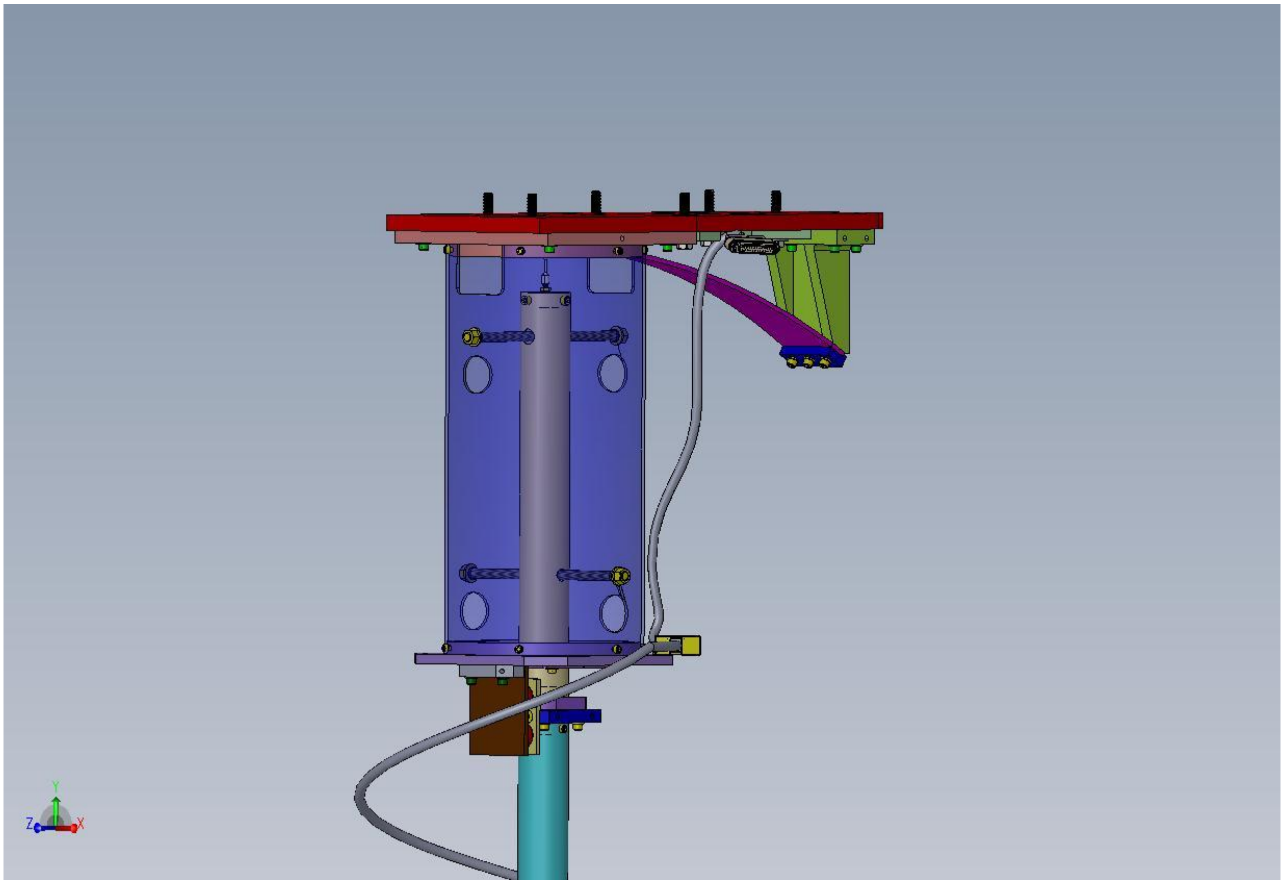


**Figure 8: Earthquake Stops**

### 3.1.4 Eddy Current Damping

The eddy current damping mechanism has permanent magnets mounted to the down tube of the baffle that move against a copper plate, which is fixed to the outer tube that is rigidly mounted to the upper stage 0 structure; see Figure 9. The currents induced in the copper plate dissipate the energy of motion of the baffle.

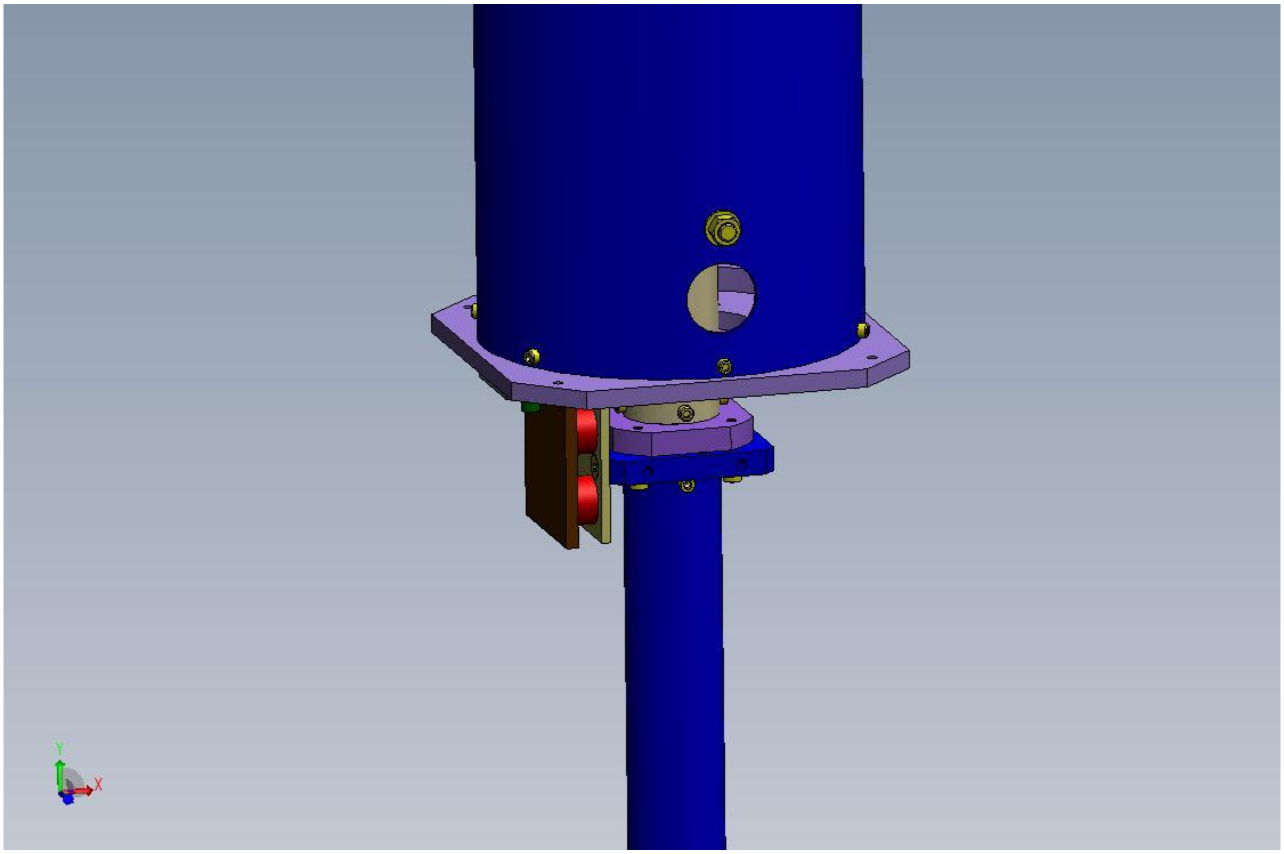


**Figure 9: Eddy Current Damping Apparatus**

## 3.2 FM ELLIPTICAL BAFFLE

A SW model of the FM Elliptical Baffle is shown in Figure 10.

The baffle mounts to the FM SUS structure, as shown in the transparent view in Figure 11, with the oxidized polished stainless steel surface facing toward the CP in the ITM SUS structure. In this drawing, the FM mirror is replaced with a dummy mass to represent the mirror. A side view of the mounted baffle is shown in Figure 12.

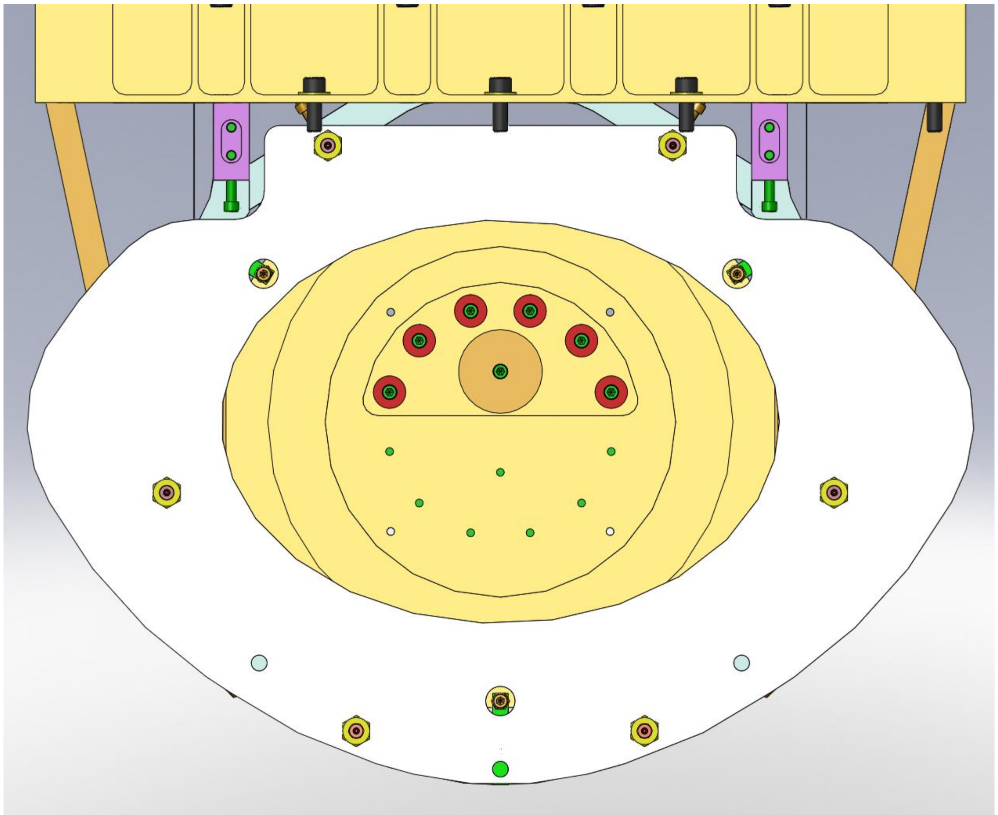


Figure 10: FM Elliptical Baffle, SW Model

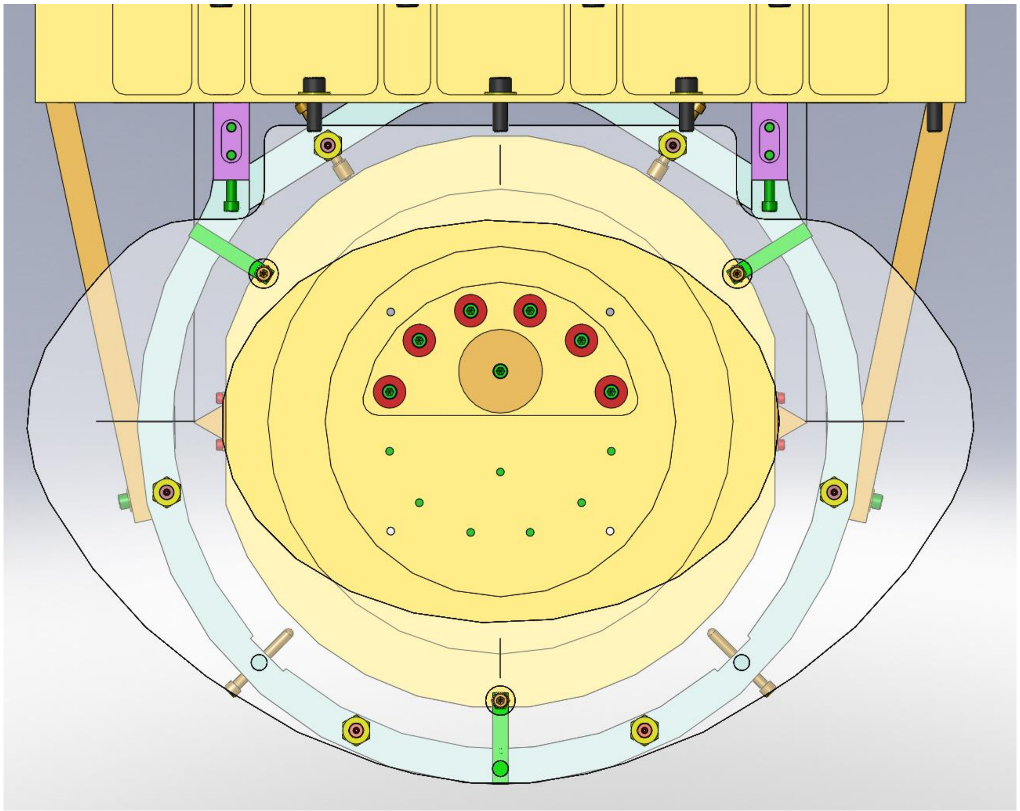


**Figure 11: Transparent View of FM Elliptical Baffle Mounting to FM SUS Frame**

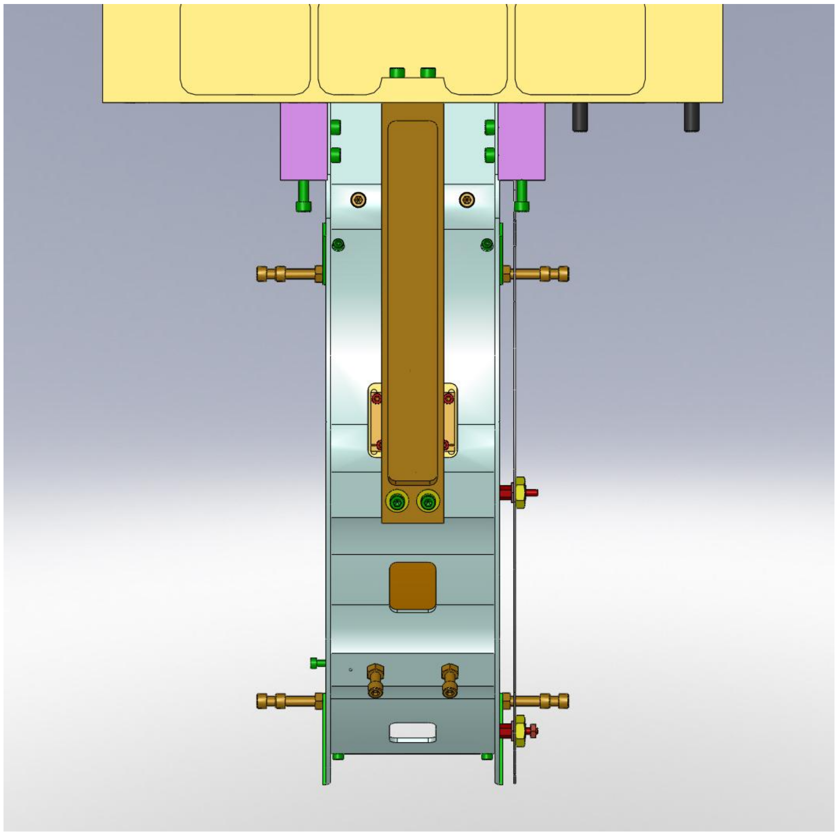


**Figure 12: Side View of FM Elliptical Baffle Mounted to the FM SUS Frame**

### 3.2.1 FM ELLIPTICAL BAFFLE Characteristics

The characteristics of the FM Elliptical Baffle are shown in Table 1.

**Table 1: FM ELLIPTICAL BAFFLE Characteristics**

| **Parameter** | **Value** |
|---|---|
| Location | BSC7 and BSC8 |
| Suspension | Mounted to FM SUS Frame |
| Aperture diameter (perpendicular to ITM HR) | 264 mm horizontal, 260 mm vertical |
| Material | Oxidized polished stainless steel |
| BRDF | <0.03 sr^-1 |
| Weight | 2.9 lbs |

## 3.3 FM BEAM DUMP

A SW model of the FM Beam Dump is shown in Figure 13.

The FM Beam Dump is suspended from the ISI Stage 0 by a vertical blade spring and a horizontal pendulum flexure. The motion of the suspended baffle is damped in six degrees of freedom by the eddy current damping apparatus.

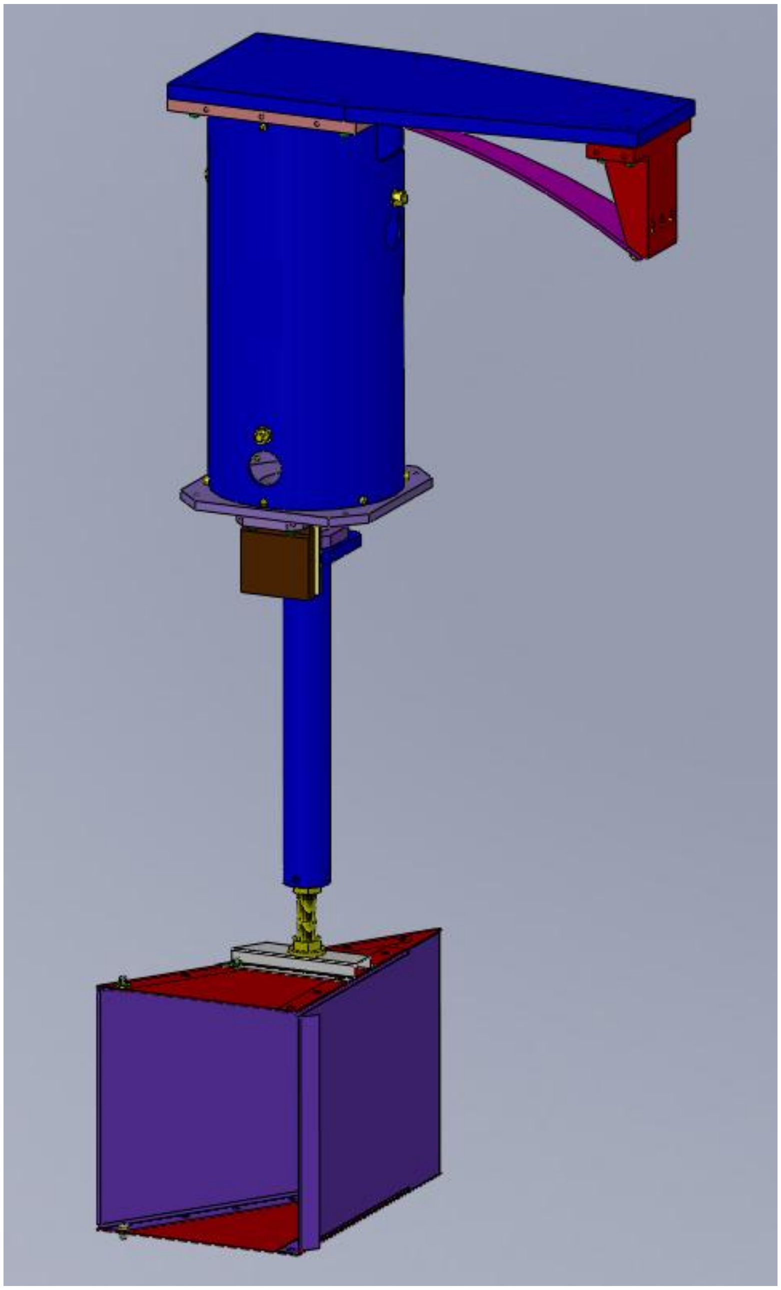


**Figure 13: FM Beam Dump**

The height of the baffle beam dump surface with respect to the ISI Stage 0 is set by a mechanical measurement of the distance between the baffle hole center and the top of the interface plate that mounts to Stage 0. The lateral (horizontal) position of the baffle is set by positioning the upper interface plate on the Stage 0 by means of a template that locates on pre-determined bolt holes.

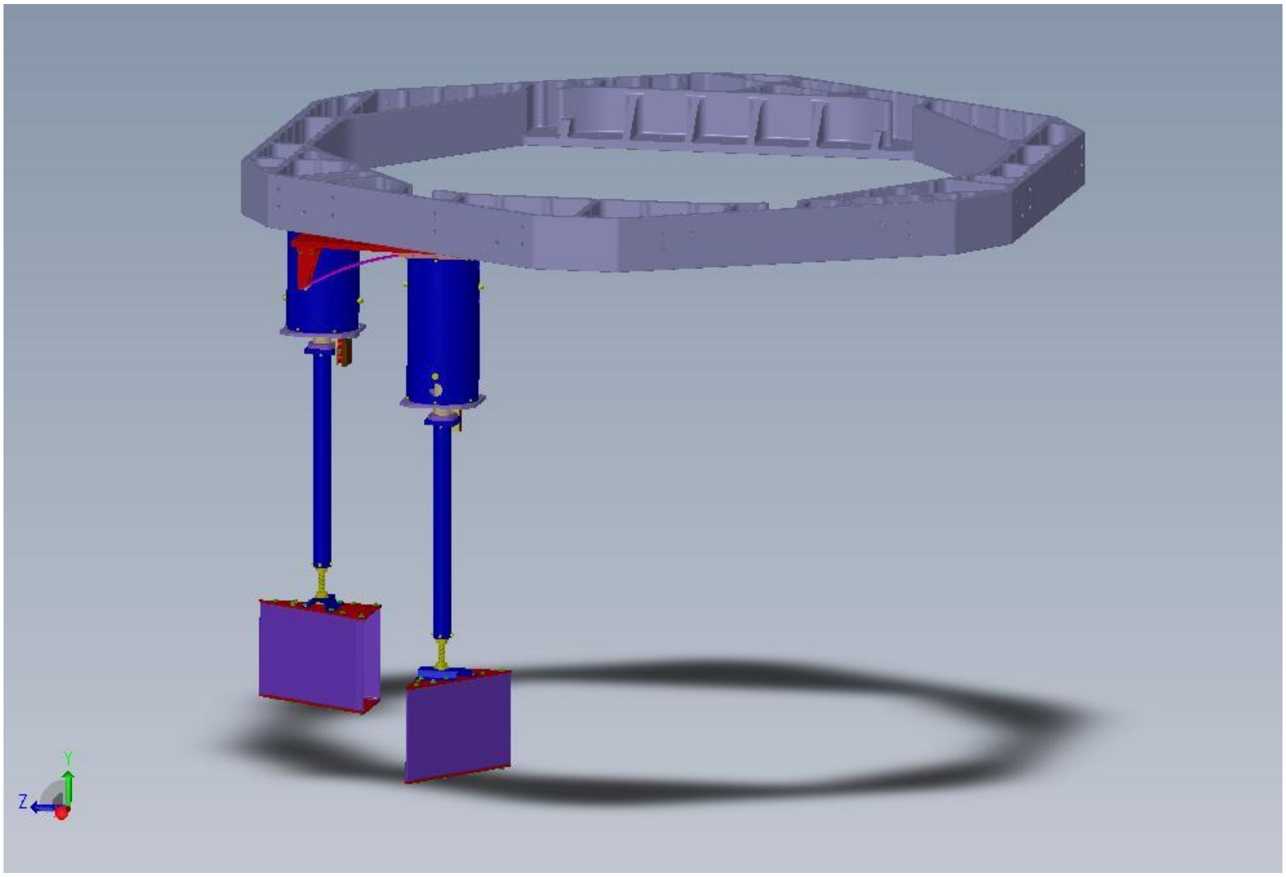


**Figure 14: FM Beam Dumps Suspended from ISI Stage 0, BSC7**

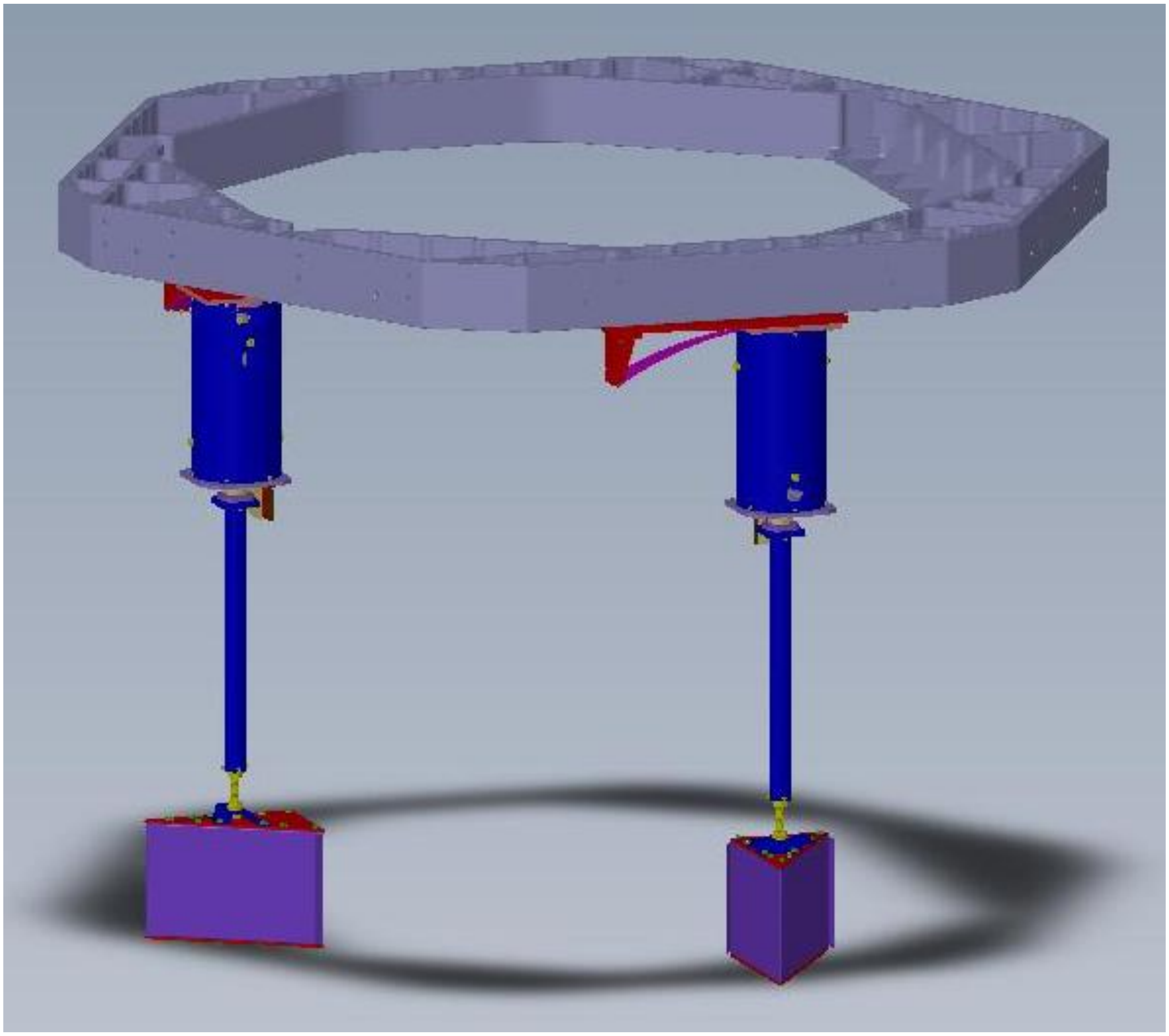


**Figure 15: FM Beam Dumps Suspended from ISI Stage 0, BSC8**

### 3.3.1 FM BEAM DUMP Characteristics

The characteristics of the FM Beam Dumps are shown in Table 2.

**Table 2: FM BEAM DUMP Characteristics**

| **Parameter** | **Value** |
|---|---|
| Location | BSC7 and BSC8 |
| Suspension | Vertical blade spring, flex-wire pendulum, eddy-current damping |
| Global Height | -81mm |

| Parameter | Value |
|---|---|
| Beam catching diameter | >260 mm |
| Material | Oxidized polished stainless steel |
| BRDF | <0.03 sr^-1 |
| Weight | 63 lbs |

## 3.4 ITM ELLIPTICAL BAFFLE

The ITM Elliptical Baffle is suspended from the ISI Stage 0 by a vertical blade spring and pendulum flexure, as shown in Figure 16.

The motion of the suspended baffle is damped in six degrees of freedom by the eddy current damping apparatus.

The height of the baffle hole with respect to the ISI Stage 0 is set by a mechanical measurement of the distance between the center of the hole and the top of the interface plate. The lateral (horizontal) position of the baffle hole is set by shifting the position of the interface plate mounted to Stage 0 while sighting at the edge of the hole with a reference theodolite, or by placing a target in front of the hole in the baffle and aligning the target with a projected reticle pattern from an aligned IR autocollimator that passes through the ITM mirror.

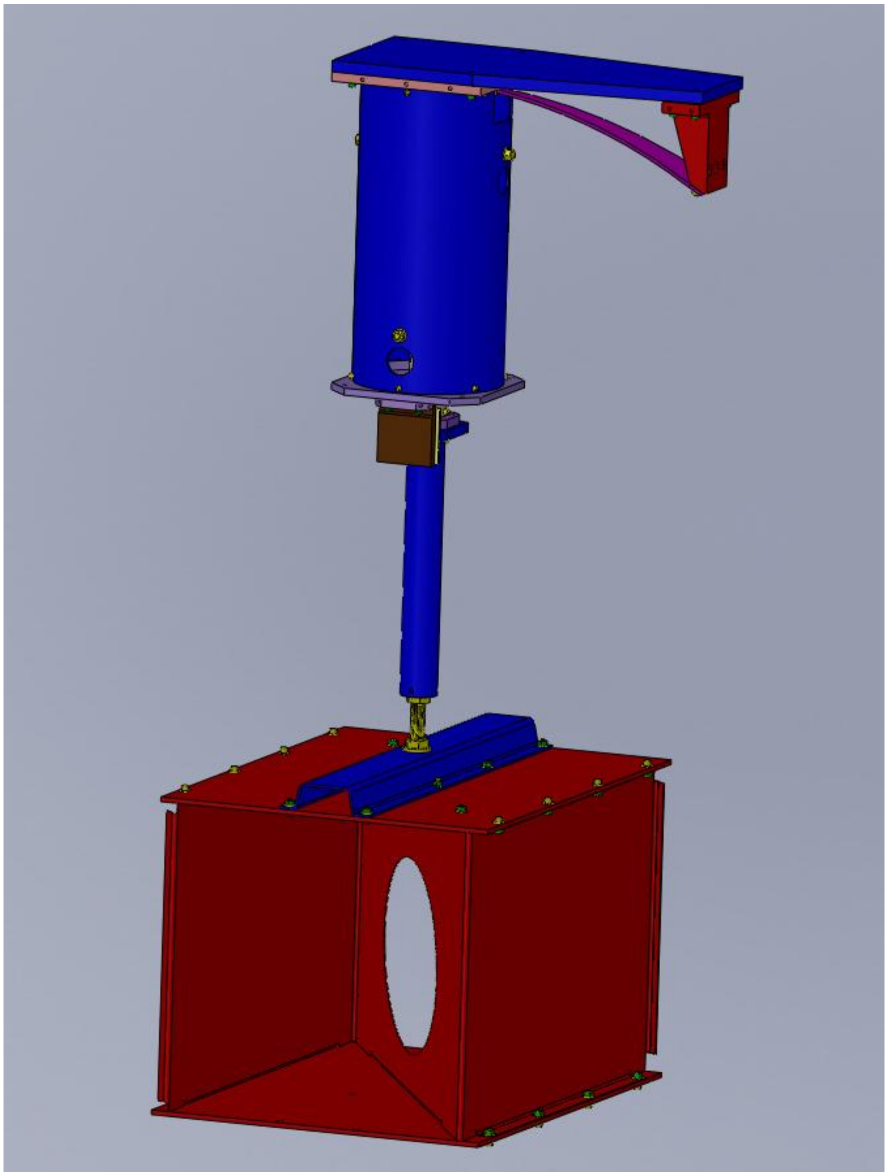


Figure 16: ITM Elliptical Baffle

### 3.4.1 ITM Elliptical Baffle Characteristics

The characteristics of the ITM Elliptical Baffle are shown in Table 3.

**Table 3: ITM Elliptical Baffle Characteristics**

| **Parameter** | **Value** |
|---|---|
| Location | BSC2 and BSC4 |
| Suspension | Vertical blade spring, flex-wire pendulum, eddy-current damping |

| **Parameter** | **Value** |
|---|---|
| Global Height | -89.5 mm |
| Aperture diameter | 210 mm horizontal, 260 mm vertical |
| Material | Oxidized polished stainless steel |
| BRDF | <0.03 sr^-1 |
| Weight | 93 lbs |

## 3.5 Manifold Flat Baffle

The Manifold Flat Baffles are placed in the A-17A adapter leading to BSC5 and in the A-17B adapter leading to BSC6 in the H2 IFO, as shown in Figure 17 and Figure 18.

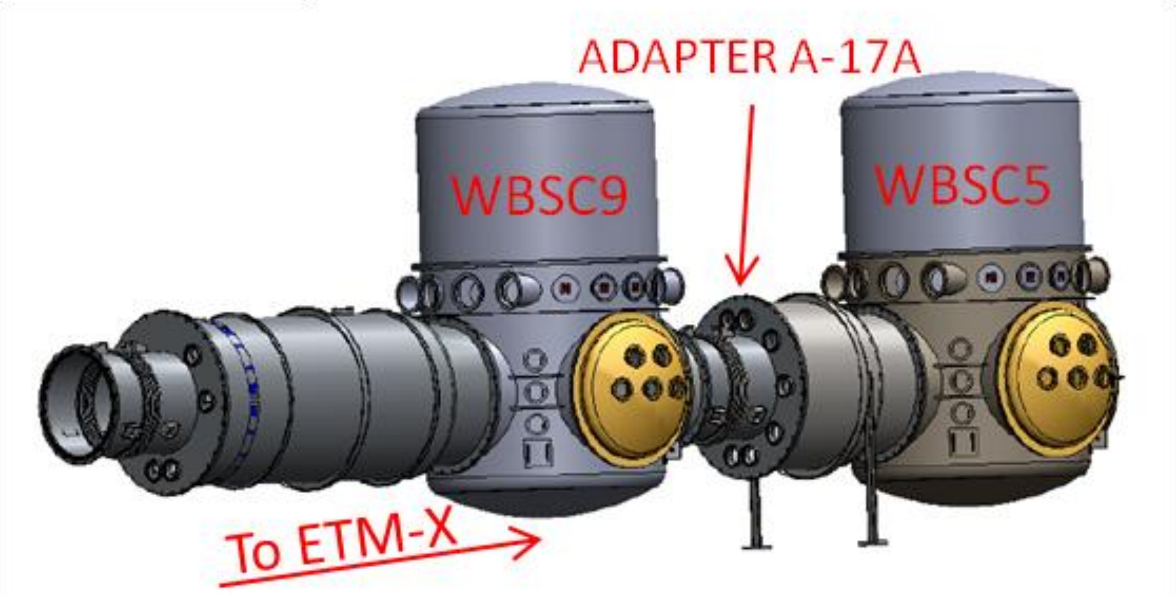


**Figure 17: Manifold Flat Baffle F ETMx Placed in Adapter A-17A**

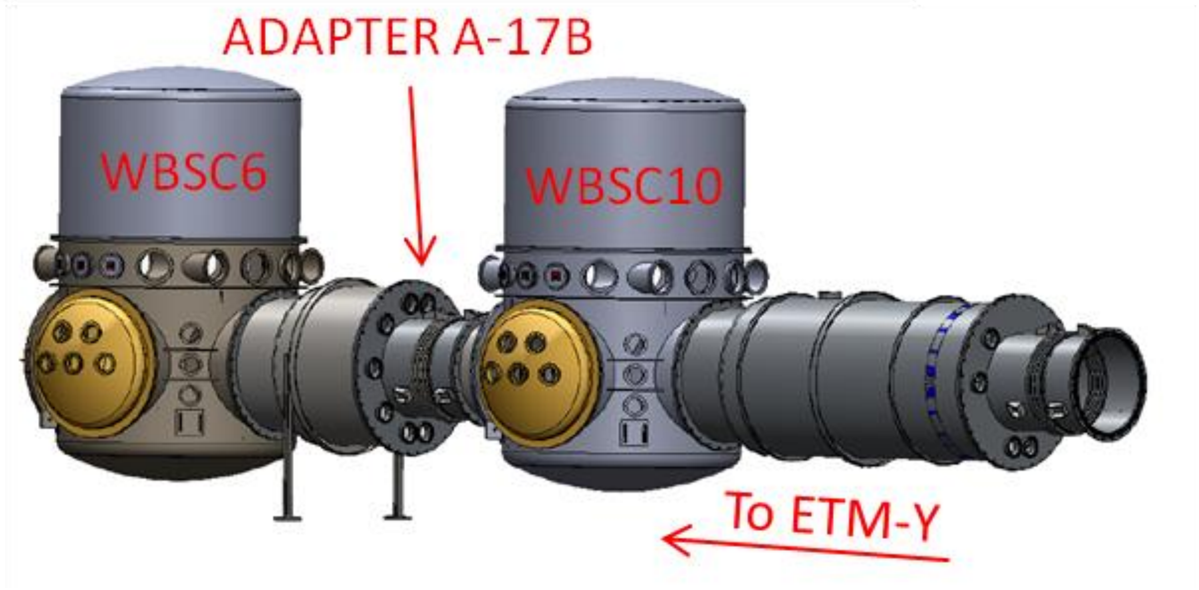


**Figure 18: Manifold Flat Baffle F ETMy Placed in Adapter A-17B**

A cut-away view of the ETMx Manifold Flat Baffle installed in the A-17A Adapter is shown in Figure 19. The spoked support structure for the manifold flat baffle faces toward the vertex, and the smooth side of the baffle faces toward the ETM. The baffle support ring is mounted 490mm distance from the viewport adapter flange.

Both sides of the ETMy Manifold Flat Baffle are shown in Figure 20 and Figure 21.

The ETMx baffle is a mirror image of the ETMy baffle.

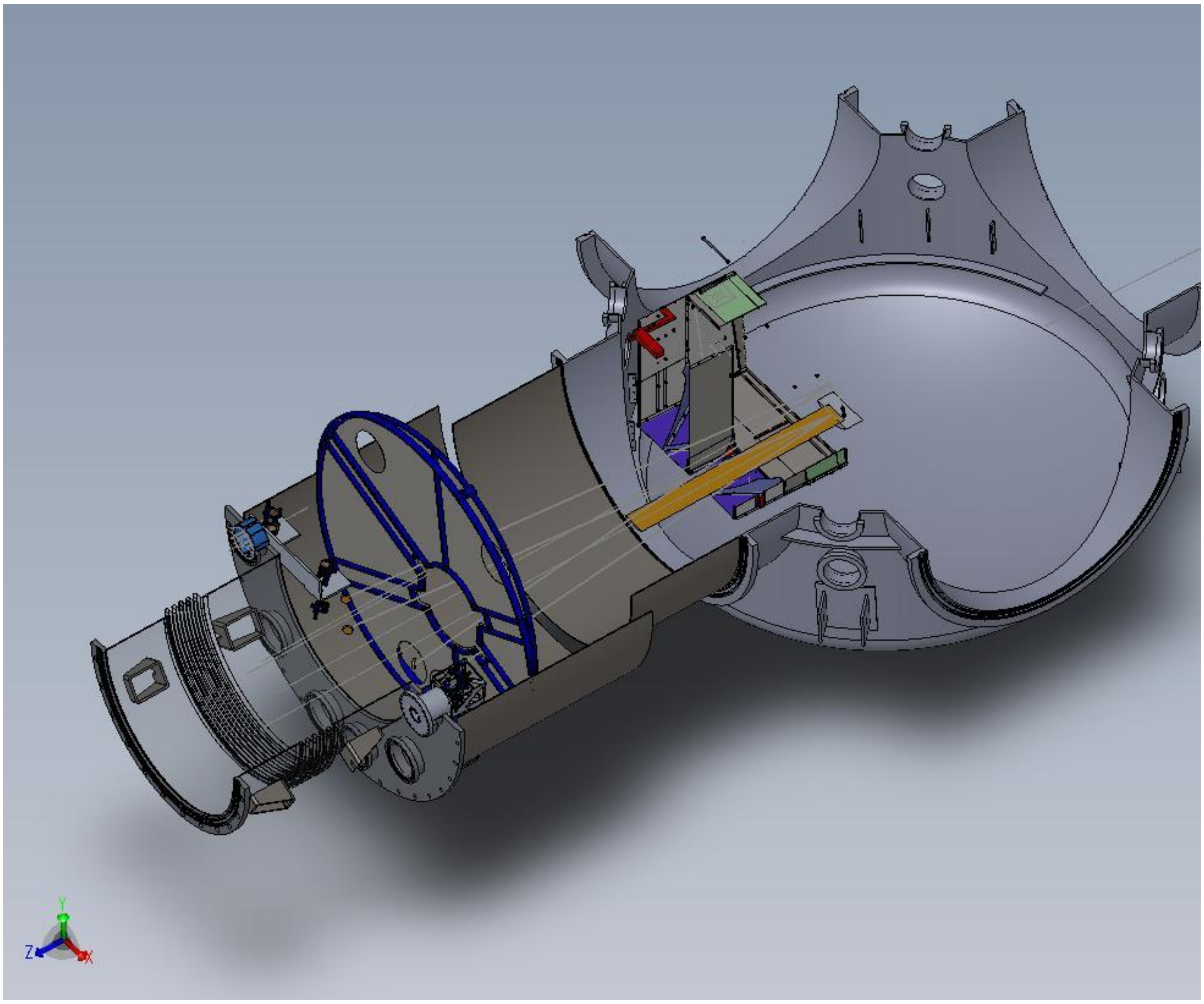


Figure 19: Manifold Flat Baffle, F ETMx, installed in the A17-A Adapter

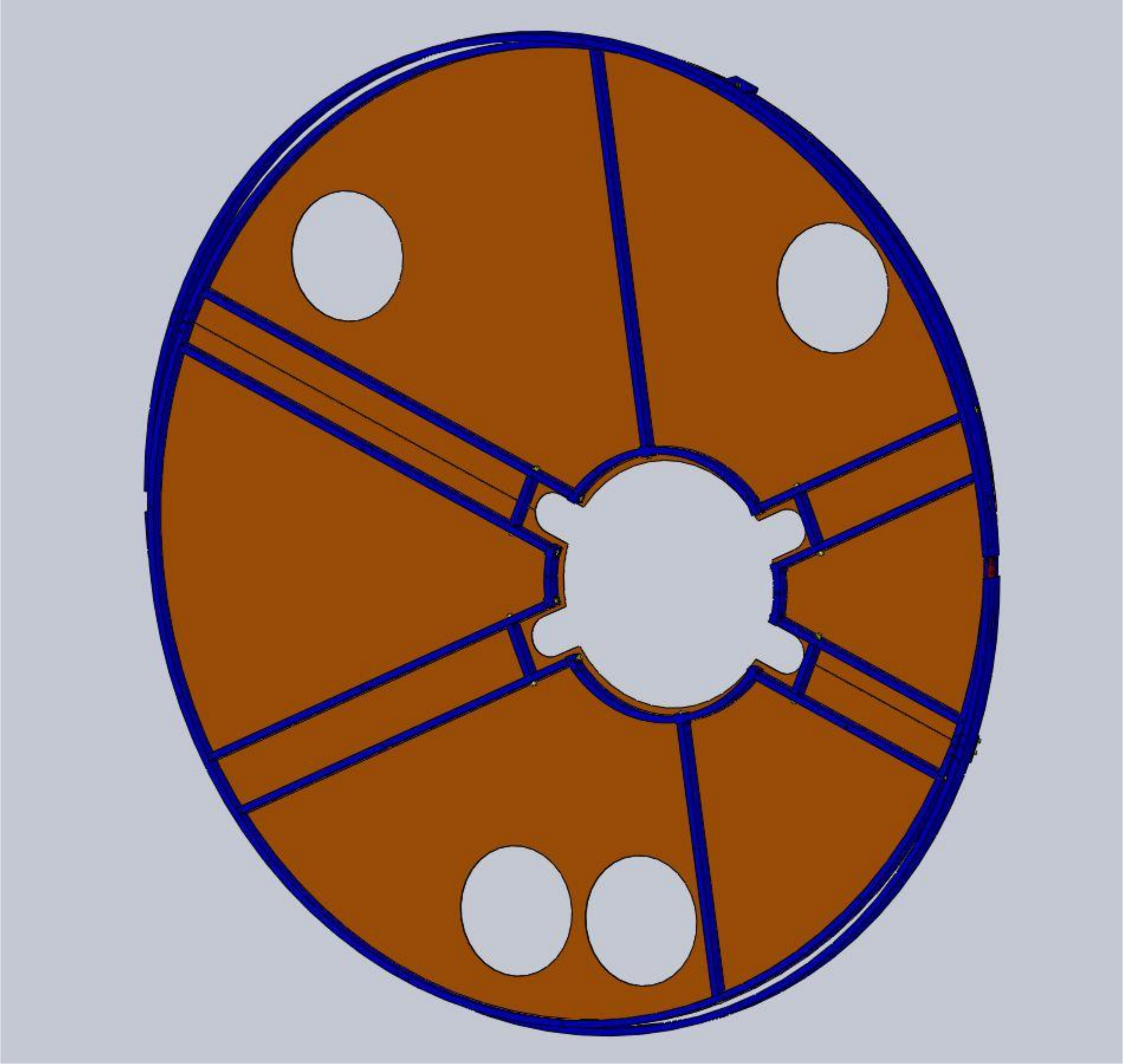


**Figure 20: Manifold Flat Baffle, ETMy, as Seen from the Vertex.**

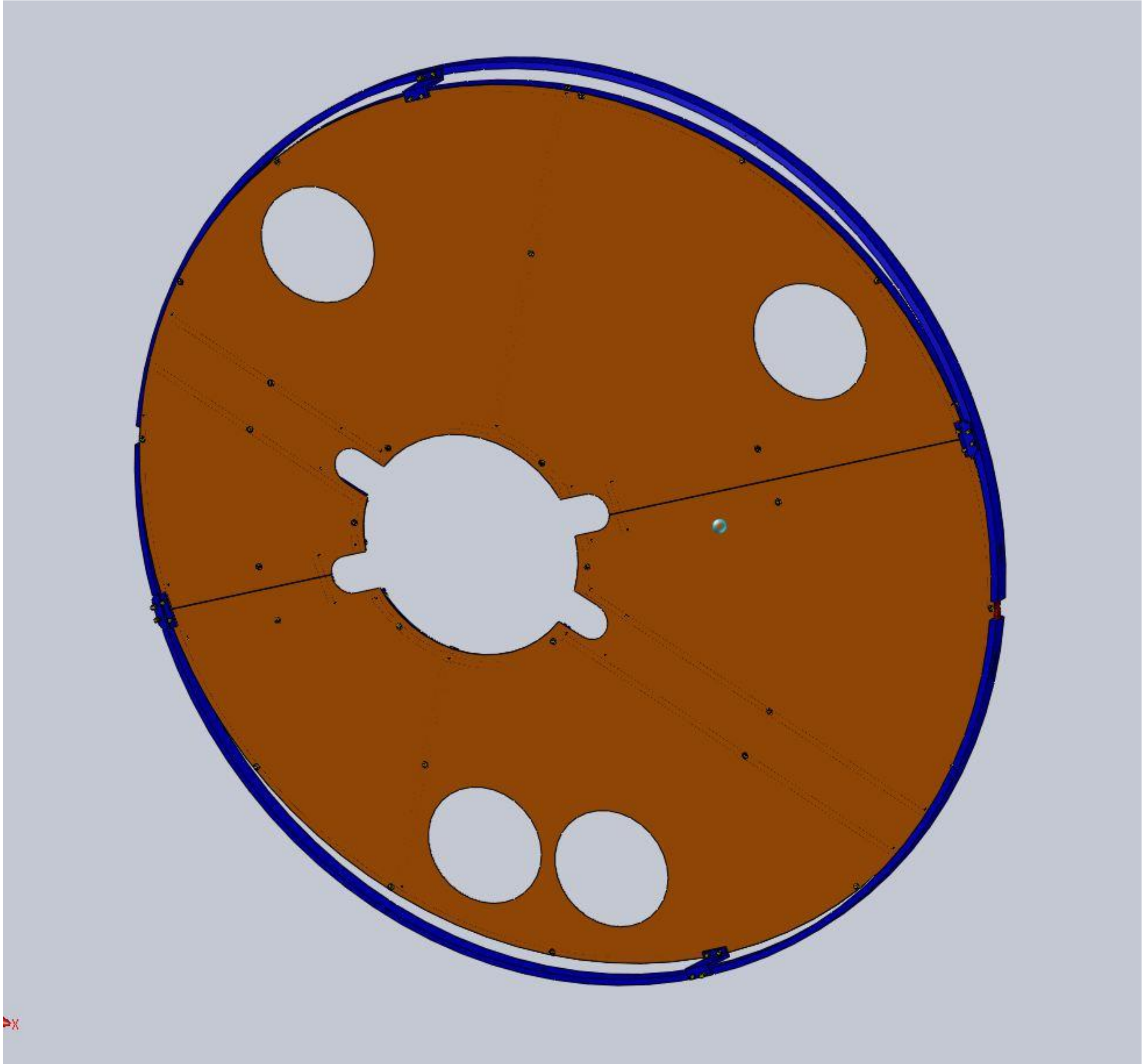


Figure 21: Manifold Flat Baffle, ETMy, as Seen from the ETMy.

### 3.5.1 Manifold Flat Baffle Characteristics

Table 4: Manifold Flat Baffle Characteristics

| Parameter | Value |
|---|---|
| Location | BSC5 and BSC6 |
| Aperture diameter | 450 mm |

| Parameter | Value |
|---|---|
| Material | Oxidized polished stainless steel |
| BRDF | <0.03 sr^-1 |
| Weight | 80 lbs |

## 3.6 OPTICAL INTERFACES

### 3.6.1 ITM Elliptical Baffle

The ITM Elliptical Baffle must be aligned with the optical centerline of the power recycling cavity beam so as to minimize the loss in the power recycling cavity.

horizontal displacement of ITM Elliptical Baffle, m $\delta x := 0$

vertical displacement of ITM Elliptical Baffle, m $\delta y := 0$

Power passing through the elliptical baffle, W

$$P_{itmellbaftran}(\delta x, \delta y) := \left( \int_{\delta y - b}^{\delta y + b} \int_{\delta x - a \cdot \sqrt{1 - \frac{y^2}{b^2}}}^{\delta x + a \cdot \sqrt{1 - \frac{y^2}{b^2}}} I_{itm}(x, y)\, dx\, dy \right)$$

$$P_{itmellbaftran}(0,0) = 1.1372 \times 10^4$$

Fractional change in power

$$\Delta fP_{itmellbaftran}(\delta x, \delta y) := \frac{\left(P_{itmellbaftran}(0,0) - P_{itmellbaftran}(\delta x, \delta y)\right)}{P_{itmellbaftran}(0,0)}$$

The fractional power loss in the power recycling cavity, as a function of the misalignment of the ITM Elliptical Baffle is shown in Figure 22. The requirement < 1E-4 is met with a misalignment of the baffle in the horizontal and vertical direction of < +/- 7mm.

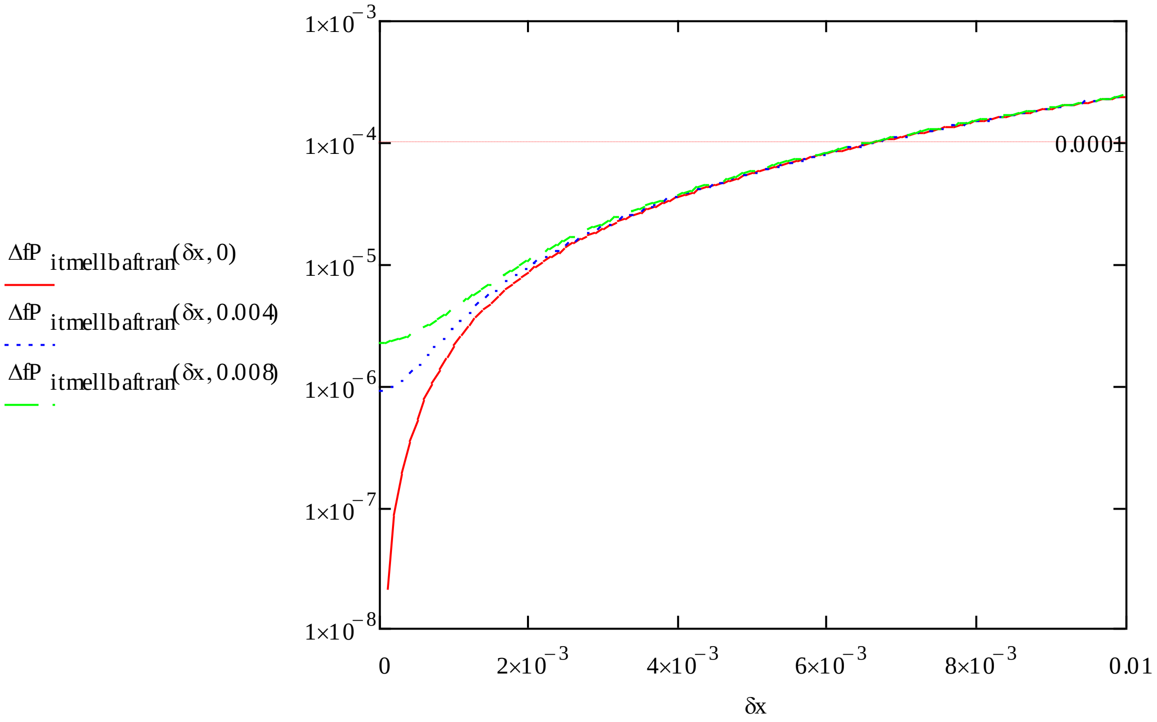


**Figure 22: Power Loss in Power Recycling Cavity vs Misalignment of ITM Elliptical Baffle**

### 3.6.2 FM Elliptical Baffle

The ITM Elliptical Baffle has a horizontal minor aperture diameter = 210mm, and a vertical major aperture diameter = 260mm. The FM Elliptical Baffle has an aperture diameter 264 mm perpendicular to the ITM beam; therefore, this baffle has a positioning tolerance of +/- 2mm in the vertical direction, and a tolerance of +/- 27mm in the horizontal direction before it becomes the limiting aperture.

### 3.6.3 FM Beam Dump

The FM Beam Dump surface has a projected horizontal extent of 327mm and a vertical extent of 280mm; therefore, it will catch the total transmitted beam through the FM AR surface, which has a diameter of 264mm. The vertical alignment tolerance of the FM Beam Dump is +/-24mm, and the horizontal alignment tolerance is +/-16mm.

### 3.6.4 Manifold Flat Baffle

The hole in the Manifold Flat Baffle is 450mm diameter. The Hole in the ACB, which is upstream of the baffle, is 344mm. Therefore, the Manifold Flat Baffle is completely obscured by the ACB in front of the H1 ETM mirror, and it causes no vignetting of the main IFO beam.

The alignment tolerance of the Manifold Flat Baffle must preclude vignetting of the photon calibrator (PC) beams that pass through openings in the baffle. The maximum radius of the PC beam is 25mm, and the opening in Manifold Flat Baffle for the PC beam is 37.5mm diameter; therefore, the alignment tolerance of the baffle is +/-12.5mm.

The alignment tolerances for the various baffles are summarized in Table 5.

**Table 5: Alignment Tolerances of the Baffles and Beam Dumps**

| IFO | Baffle | Horizontal alignment tolerance, mm | Vertical alignment tolerance, mm |
|---|---|---|---|
| H2 | | | |
| | ITM Elliptical Baffle | +/- 7 | +/- 7 |
| | FM Elliptical Baffle | +/- 27 | +/- 2 |
| | FM Beam Dump | +/- 16 | +/- 24 |
| | Manifold Flat Baffle | +/- 13 | +/- 13 |
| H1 | | | |
| | ITM Elliptical Baffle | +/- 7 | +/- 7 |
| L1 | | | |
| | ITM Elliptical Baffle | +/- 7 | +/- 7 |

# 4 SCATTERED LIGHT DISPLACEMENT NOISE

## 4.1 Scattered Light Requirement

A DARM signal is obtained when the differential arm length is modulated as a result of a gravity wave strain. The DARM signal was calculated in reference, T060073-00 Transfer Functions of Injected Noise, and is defined by the following expression:

$$V_{signal} := DARM \cdot L \cdot h_{SRD} \cdot \sqrt{P_0}$$

Where L is the arm length, hSRD is the minimum SRD gravity wave strain spectral density requirement, P0 is the input laser power into the IFO, and DARM is the signal transfer function.

In a similar manner, an apparent signal (scattered light noise) occurs when a scattered light field with a phase shift is injected into the IFO at some particular location, e.g. through the back of the ETM mirror. The scattered light noise is defined by the following expression:

$$V_{noise} := SNXXX \cdot \delta_{SN} \cdot \sqrt{P_{SNi}}$$

$P_{SNi}$ is the scattered light power injected into the IFO mode, $\delta_{SN}$ is the phase shift of the injected field, and SNXXX is the noise transfer function for that particular injection location.

The phase shift spectral density of the injected field due to the motion of the scattering surface is given by

$$\delta_{SNi} := \frac{4 \cdot \pi \cdot x_s}{\lambda}$$

where $x_s$ is the spectral density of the longitudinal motion of the scattering surface.

In general, the different scattering sources are not coherent and must be added in quadrature. The requirement for total scattered light displacement noise can be stated with the following inequality:

$$\sqrt{\sum_{i=1}^{n}\left(\frac{\mathrm{SNXXX}}{\mathrm{DARM}}\cdot\frac{4\cdot\pi\cdot x_s}{\lambda}\cdot\sqrt{\frac{P_{SNi}}{P_0}}\right)^2} < \frac{1}{10}\cdot L\cdot h_{SRD}$$

The SNXXX/DARM scattered light noise transfer function ratios for various injection locations within the IFO are shown in Figure 23: Scattered Light Noise Transfer Functions.

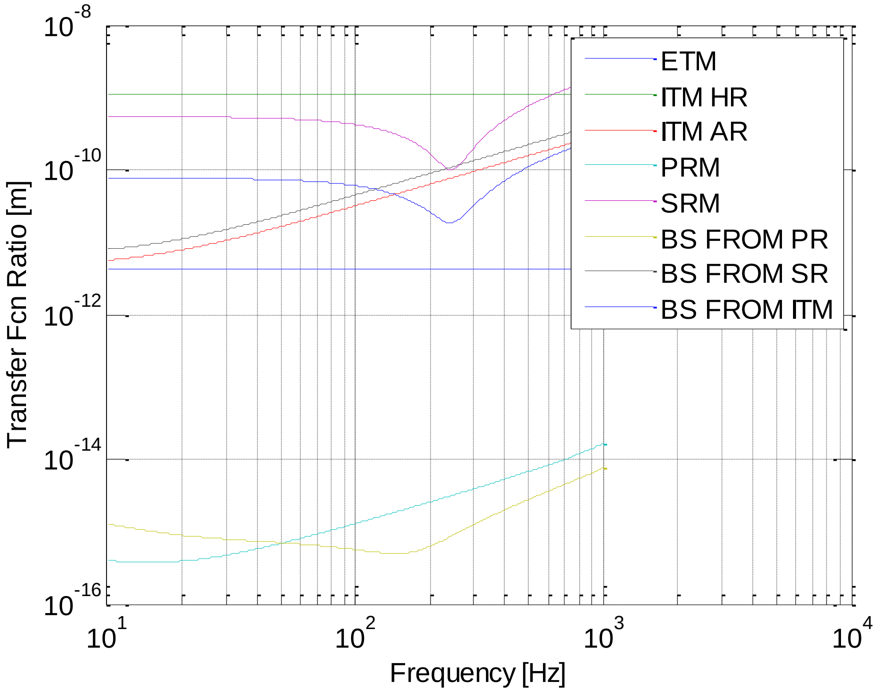


**Figure 23: Scattered Light Noise Transfer Functions**

## 4.2 Scattered Light Parameters

BRDF, sr^-1; CSIRO, surface 2, S/N 2

$$\mathrm{BRDF}_1(\theta) := \frac{2755.12}{\left(1+8.50787\,10^{8}\cdot\theta^2\right)^{1.23597}}$$

incidence angle at COC, rad

$$\theta_{coc} := \frac{120}{4\cdot10^{6}} \qquad \theta_{coc} = 3\times10^{-5}$$

| | | |
|---|---|---|
| BRDF of ellip baf, sr^-1 | $BRDF_{ellbaf} := 0.03$ | |
| BRDF of FM ellip baf, sr^-1 | $BRDF_{FMellipbaf} := 0.03$ | |
| BRDF of BD, sr^-1 | $BRDF_{bd} := 0.03$ | |
| BRDF of chamber wall, sr^-1 | $BRDF_{wall} := 0.1$ | |
| Motion of suspended baffle @ 100 Hz, m/rt Hz | $x_{baf} := 1\cdot 10^{-12}$ | |
| Motion of BSC chamber @ 100 Hz, m/rt Hz | $x_{bscchamber} := 2\cdot 10^{-11}$ | |
| Motion of FM frame @ 100 Hz, m/rtHz | $x_{sus} := 3.1\cdot 10^{-14}$ | |
| solid angle of IFO mode, sr | $\Delta_{ifo} := 2.72\cdot 10^{-9}$ | |
| laser wavelength, m | $\lambda := 1.064\cdot 10^{-6}$ | |
| wave number, m^-1 | $k := 2\cdot\frac{\pi}{\lambda}$ | $k = 5.9052\times 10^{6}$ |
| Transfer function @ 100 Hz, ITM AR | $TF_{itmar} := 3.16\cdot 10^{-11}$ | |
| ITM beam radius, m | $w_{itm} := 0.055$ | |
| IFO waist size, m | $w_{ifo} := 0.0120$ | |
| IFO arm length, m | $L := 4000.$ | |
| elliptical baffle minor semi-axis, m | $a := \frac{0.21}{2}$ | $a = 0.105$ |
| elliptical baffle major semi-axis, m | $b := \frac{0.26}{2}$ | $b = 0.13$ |

Reflectivity of Elliptical Baffle $R_{ellbaf} := 0.01^{4}$ $R_{ellbaf} = 1 \times 10^{-8}$

Transmissivity of ITM HR $T_{itmhr} := 0.0140$

Transmissivity of ETM HR $T_{etm} := 5 \cdot 10^{-6}$

Transmissivity of FM HR $T_{FMhr} := 10 \times 10^{-5}$

**Ref. T070247**

input laser power, W $P_{psl} := 125$

arm cavity gain $G_{ac} := 13000$

arm cavity power, W $P_a := \frac{P_{psl}}{2} \cdot G_{ac}$ $P_a = 8.125 \times 10^{5}$

**Ref. Hiro e-mail 8/29/11**

power in power recycling cavity arm, W $P_{rca} := \frac{P_a \cdot T_{itmhr}}{4}$ $P_{rca} = 3.08 \times 10^{3}$

Gaussian power parameter
in recycling cavity $P_{0rc} := 3.08 \times 10^{3}$

radius of ITM, mm $r_{itm} := 0.17$

exitance function from ITM

$$I_{itm}(x,y) := 2 \cdot \frac{4 \cdot P_{0rc}}{\pi \cdot w_{itm}^{2}} \cdot e^{-2 \cdot \left( \frac{x^2 + y^2}{w_{itm}^{2}} \right)}$$

### 4.2.1 BRDF of Baffle Surfaces

The baffle surfaces are oxidized polished stainless steel, with a measured BRDF < 0.03 sr^-1 @ > 5 deg incidence angle.

### 4.2.2 BSC Seismic Motion

The seismic motion spectrum of the BSC walls is shown in Figure 24. The motion spectrum of the ISI Stage 0 is shown in Figure 25.

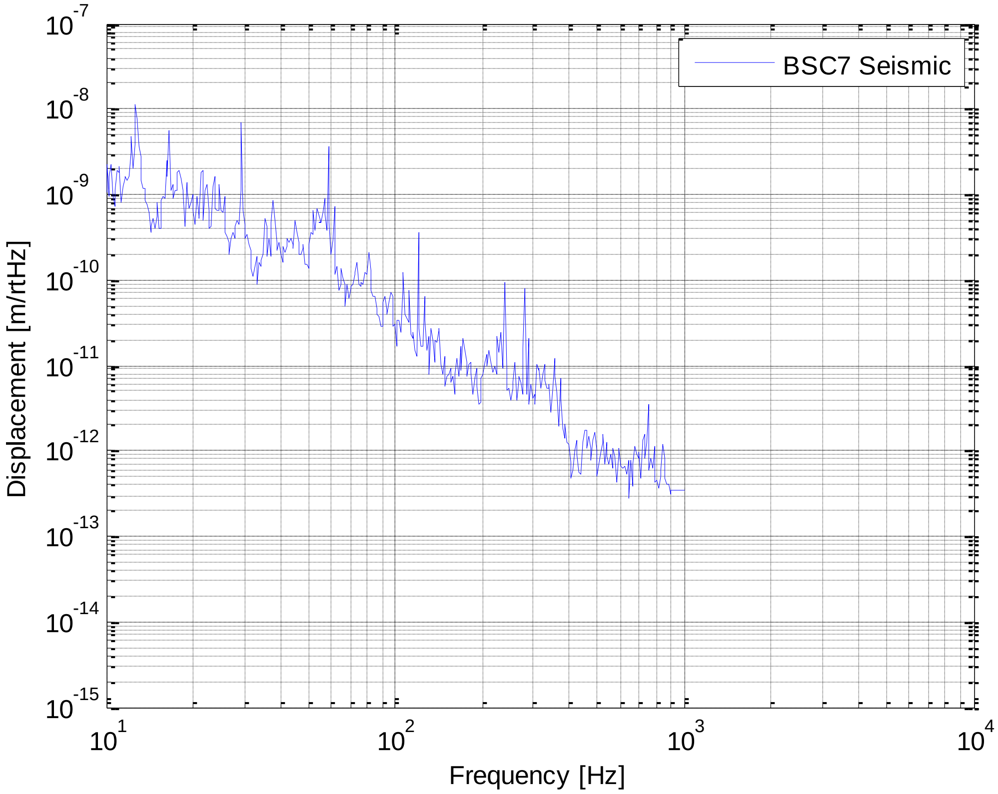


**Figure 24: BSC7 Seismic Motion, m/rtHz**

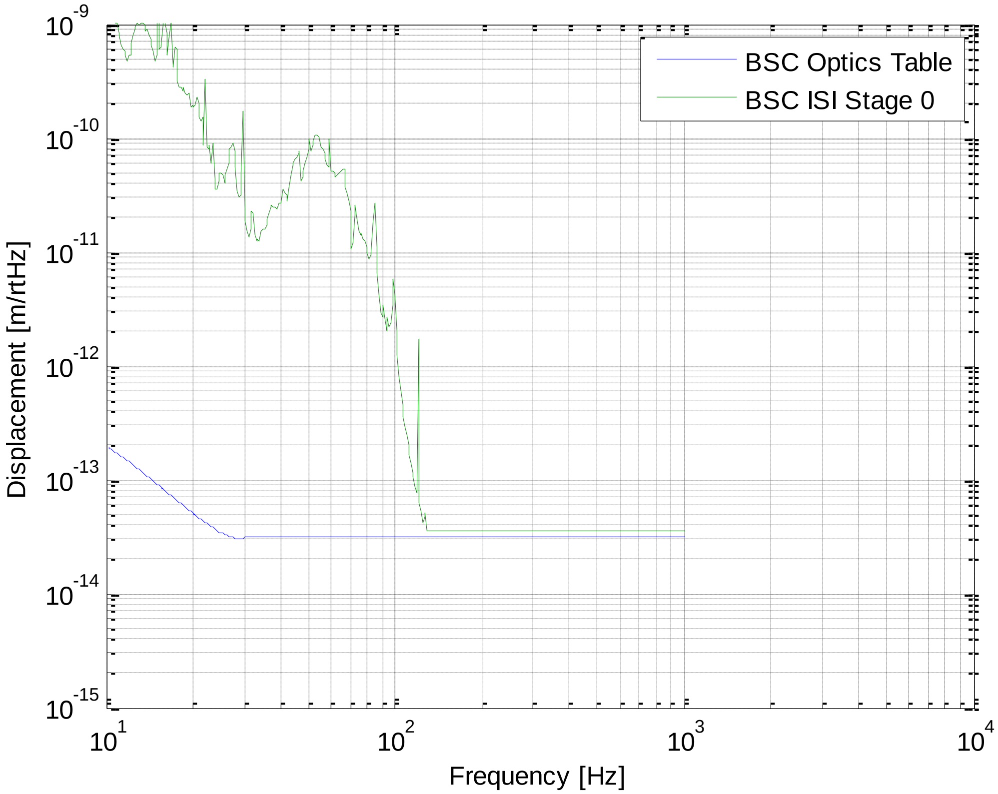


Figure 25: BSC ISI Optics Table Seismic Motion and ISI Stage 0, m/rtHz

## 4.3 ITM Elliptical Baffle

### 4.3.1 ITM Elliptical Baffle Scatter

power exiting from ITM toward elliptical baffle, W

$$P_{itm} := 4\cdot\int_0^{r_{itm}}\int_0^{r_{itm}\cdot\sqrt{1-\frac{y^2}{r_{itm}^2}}} I_{itm}(x,y)\,dx\,dy$$

$$P_{itm} = 1.1375\times 10^4$$

Power passing through the elliptical baffle, W

$$P_{itmellbaftran}(\delta x,\delta y) := \left(\int_{\delta y-b}^{\delta y+b}\int_{\delta x-a\cdot\sqrt{1-\frac{y^{2}}{b^{2}}}}^{\delta x+a\cdot\sqrt{1-\frac{y^{2}}{b^{2}}}} I_{itm}(x,y)\,dx\,dy\right)$$

$$P_{itmellbaftran}(0,0) = 1.1372\times 10^{4}$$

Power scattered into IFO mode from both arms, W

$$P_{itmellbafs}(\delta x,\delta y) := \sqrt{2}\cdot P_{itmellbaf}(\delta x,\delta y)\cdot BRDF_{ellbaf}\cdot\frac{\pi\cdot w_{ifo}^{2}}{L^{2}}\cdot BRDF_{1}\left(30\cdot 10^{-6}\right)\cdot\Delta_{ifo}$$

$$P_{itmellbafs}(\delta x,\delta y) = 1.2523\times 10^{-17}$$

displacement noise @ 100 Hz, m/rtHz

$$DN_{itmellbaf} := TF_{itmar}\cdot\left(\frac{P_{itmellbafs}(\delta x,\delta y)}{P_{psl}}\right)^{0.5}\cdot x_{baf}\cdot 2\cdot k$$

$$DN_{itmellbaf} = 1.1813\times 10^{-25}$$

### 4.3.2 ITM Elliptical Baffle Reflection Scatter

Power reflected from baffle, W

$$P_{itmellbafrefl}(\delta x,\delta y) := R_{ellbaf}\cdot P_{itmellbaf}(\delta x,\delta y)$$

$$P_{itmellbafrefl}(\delta x,\delta y) = 6.751\times 10^{-5}$$

Power scattered into IFO mode from both arms, W

$$P_{itmellbafrefls}(\delta x,\delta y) := \sqrt{2}\cdot P_{itmellbafrefl}(\delta x,\delta y)\cdot R_{ellbaf}\cdot BRDF_{wall}\cdot\frac{\pi\cdot w_{ifo}^{2}}{L^{2}}\cdot BRDF_{1}\left(30\cdot 10^{-6}\right)\cdot\Delta_{ifo}$$

$$P_{itmellbafrefls}(\delta x,\delta y) = 2.4044\times 10^{-26}$$

Motion of BSC chamber @ 100 Hz, m/rt Hz $x_{bscchamber} = 2\times 10^{-11}$

displacement noise @ 100 Hz, m/rtHz

$$DN_{itmellbafrefl} := TF_{itmar}\cdot\left(\frac{P_{itmellbafrefls}(\delta x,\delta y)}{P_{psl}}\right)^{0.5}\cdot x_{bscchamber}\cdot 2\cdot k$$

$$DN_{itmellbafrefl} = 1.0352\times 10^{-28}$$

## 4.4 H2 FM Elliptical Baffle Scatter

power hitting the FM elliptical baffle from ITM side $P_{FMellbaf} := P_{itmellbaf}(\delta x,\delta y)$

$$P_{FMellbaf} = 2.8129$$

Power scattered into IFO mode, W $P_{FMellbafs}(\delta x,\delta y) := P_{itmellbafs}(\delta x,\delta y)$

$$P_{FMellbafs}(\delta x,\delta y) = 1.2523\times 10^{-17}$$

displacement noise @ 100 Hz, m/rtHz $DN_{FMellbaf}(\delta x,\delta y) := TF_{itmar}\cdot\left(\frac{P_{FMellbafs}(\delta x,\delta y)}{P_{psl}}\right)^{0.5}\cdot x_{sus}\cdot 2\cdot k$

$$DN_{FMellbaf}(\delta x,\delta y) = 3.662\times 10^{-27}$$

## 4.5 H2 FM Beam Dump Scatter

Power hitting the FM, W $P_{FM} := P_{rca}\cdot T_{FMhr}$

$$P_{FM} = 0.2843$$

Power scattered into IFO mode from 4 FM beam dumps, W $P_{FMbds} := \sqrt{4\cdot P_{FM}\cdot BRDF_{bd}\cdot\frac{\pi\cdot w_{ifo}^{2}}{L^{2}}\cdot BRDF_{1}\left(30\cdot 10^{-6}\right)\cdot\Delta_{ifo}}$

$$P_{FMbds} = 1.79\times 10^{-18}$$

displacement noise @ 100 Hz, m/rtHz

$$DN_{FMbd} := TF_{itmar} \cdot \left(\frac{P_{FMbds}}{P_{psl}}\right)^{0.5} \cdot x_{baf} \cdot 2 \cdot k$$

$$DN_{FMbd} = 4.4661 \times 10^{-26}$$

## 4.6 H2 Manifold Flat Baffle Scatter

Approximately 8 percent of the wide angle scattered light from the end ETM HR, as shown in Figure 26 and Figure 27, will pass through the hole in the ACB and hit the Manifold Flat Baffle. This stray light will scatter from the baffle, re-scatter from the TM HR and enter the IFO mode causing scattered light displacement noise.

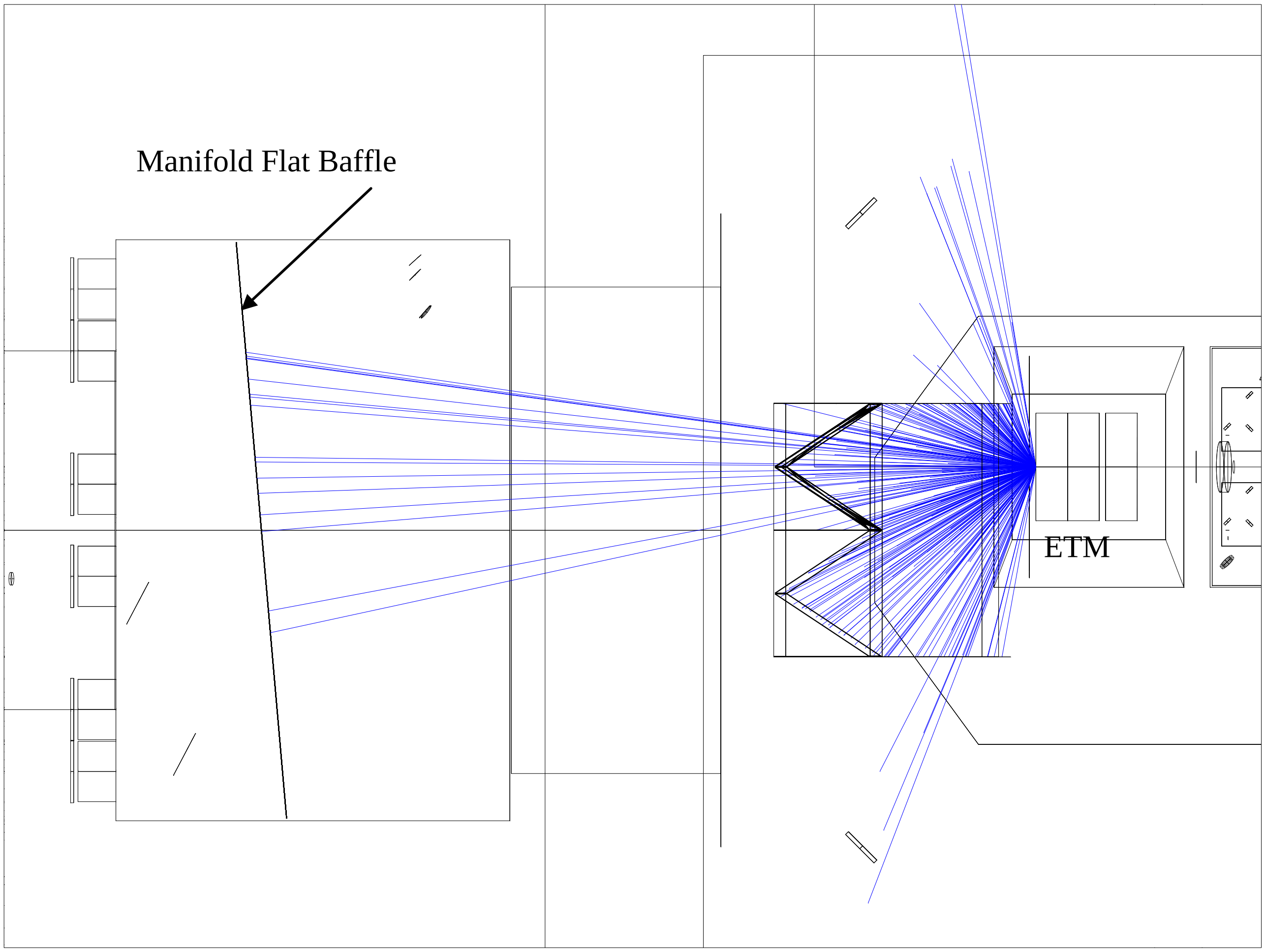


**Figure 26: Wide Angle Scattered Light from ETMx HR Hitting the Manifold Flat Baffle—Top View.**

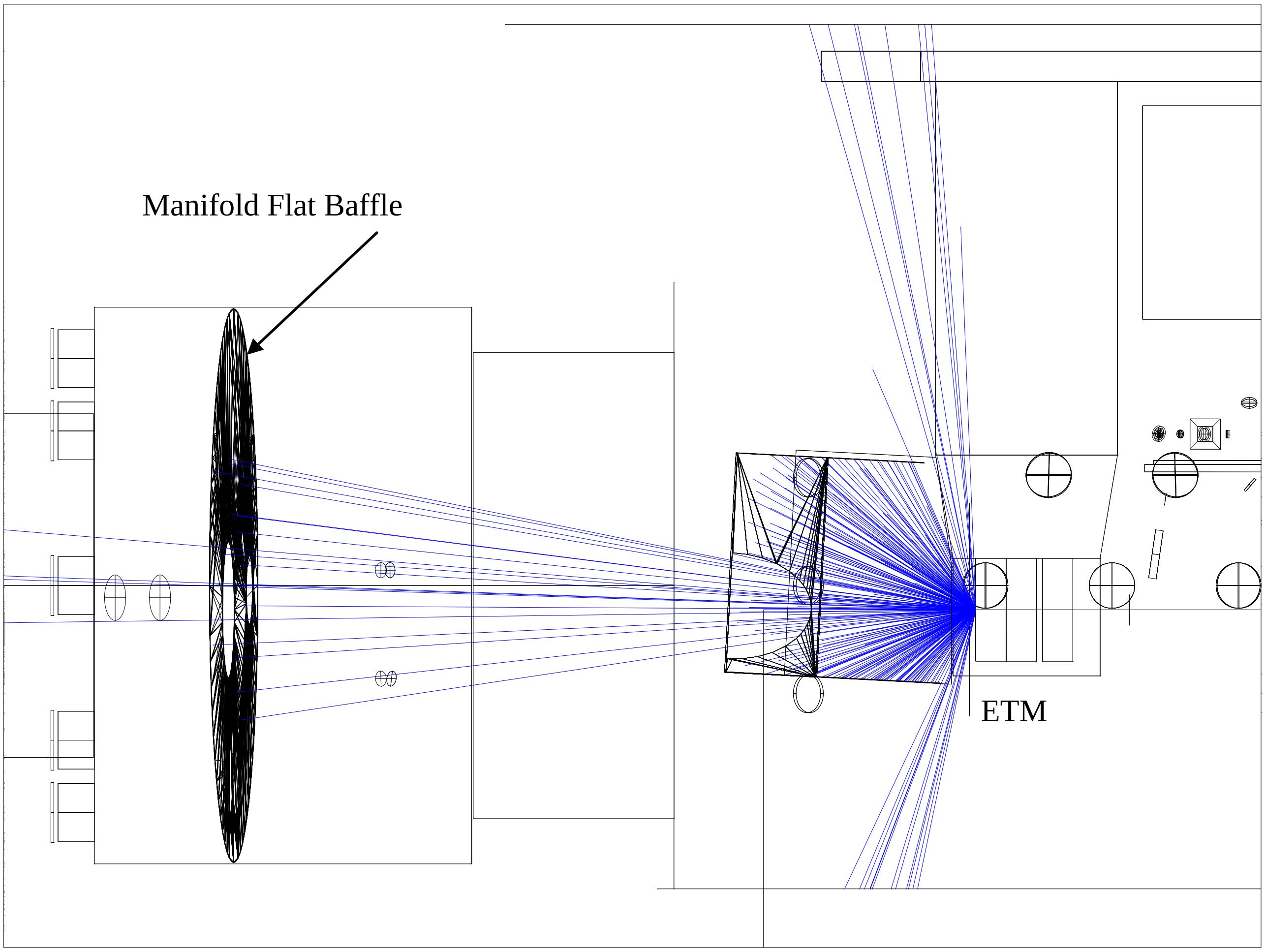


**Figure 27: Wide Angle Scattered Light from ETMx HR Hitting the Manifold Flat Baffle—Side View.**

The scattered light displacement noise calculation is similar to that for the ITM HR; see T1100113 Wide Angle Scatter from TM.

Incident power hitting baffle, W $P_{maniflat} := P_a \cdot PF_{maniflat} \cdot \alpha_{TM} = 0.301$

Power scattered into IFO mode from 2 baffles, W

$$P_{maniflatifo} := \sqrt{2} \cdot P_{maniflat} \cdot \left( \alpha_{TM} \cdot \frac{\lambda^2}{\pi \cdot L_{maniflat}^{\ 2}} \cdot BRDF_{oxiunpolish} \cdot \cos\left(\theta_{maniflat}\right) \right)$$

$$P_{maniflatifo} = 8.001 \times 10^{-21}$$

Displacement noise @ 100 Hz

$$DN_{maniflat} := TF_{itmhr} \cdot \left(\frac{P_{maniflatifo}}{P_{psl}}\right)^{0.5} \cdot x_{manifold} \cdot 2 \cdot k$$

$$DN_{maniflat} = 8.315 \times 10^{-24}$$

## 4.7 Scattered Light Displacement Noise Summary

The summary of the scattered light displacement noise is shown in Figure 28 and Figure 29.

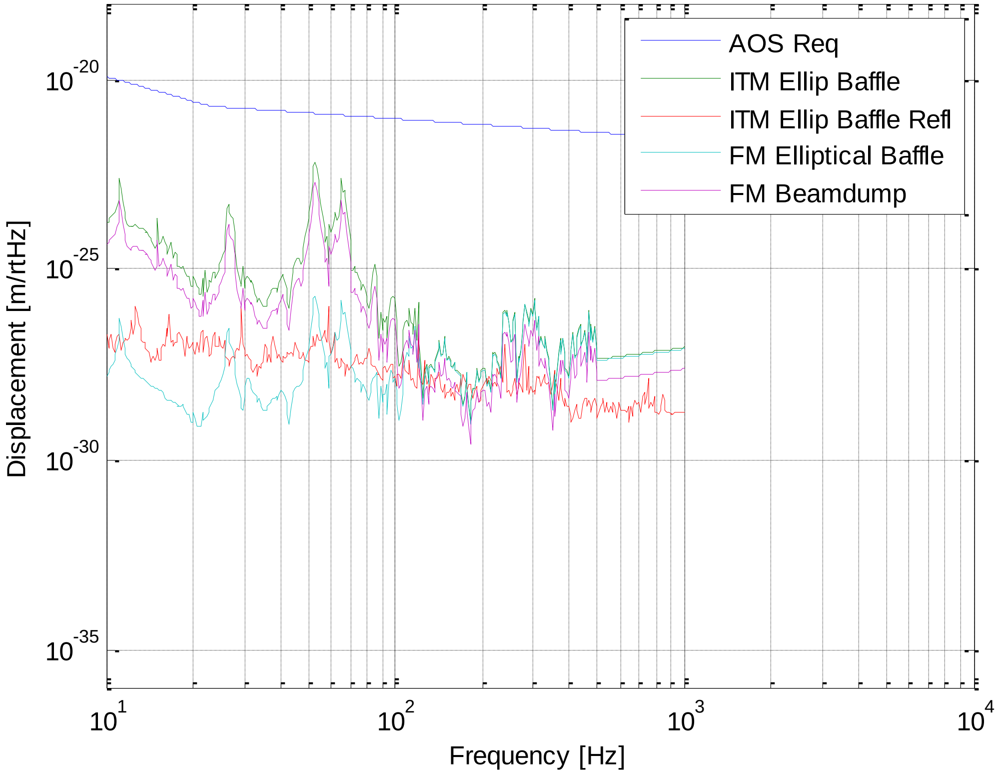


**Figure 28: Scattered Light Displacement Noise: ITM Elliptical Baffle, FM Elliptical Baffle, FM Beam Dump**

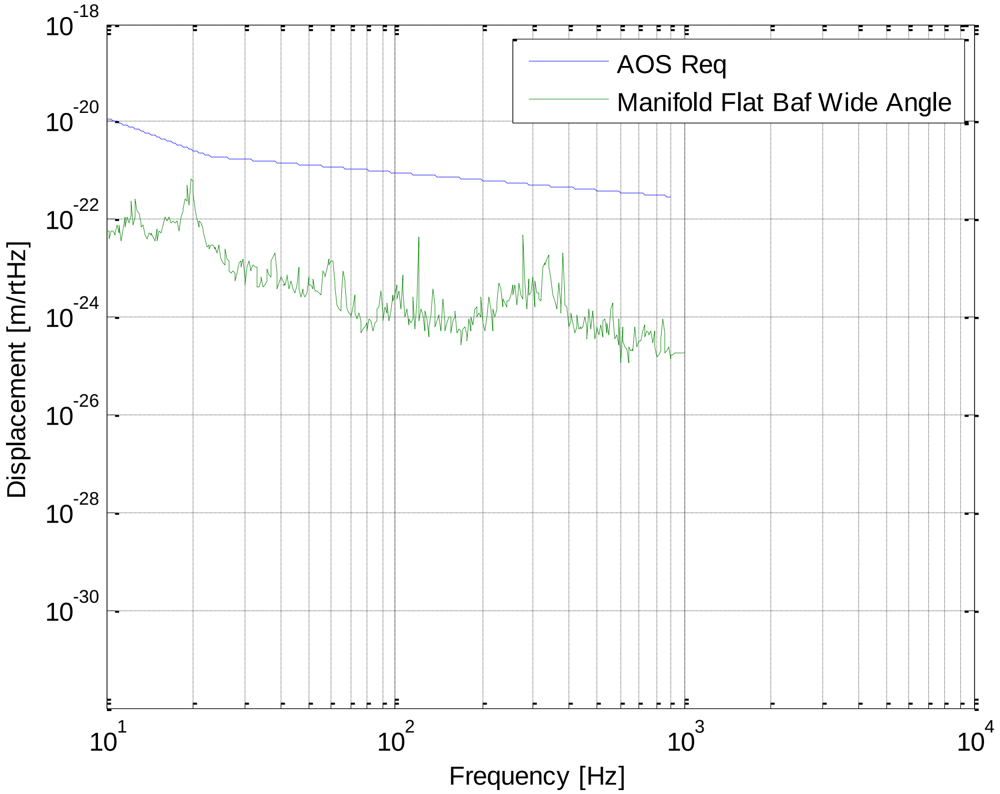


**Figure 29: Scattered Light Displacement Noise: Manifold Flat Baffle, Wide Angle Scatter**

# 5 INTERFACE CONTROL DOCUMENT

The mechanical and optical interfaces of the ITM Elliptical Baffle, the FM Elliptical Baffle, the FM Beam dump, and Manifold Flat Baffle are described in TBD E110XXX-v1AOS SLC ITM Ellip Baf, FM Elliptical Baffle, FM BD, and Manifold Flat Baffle Interface Control Doc.