LIGO Laboratory / LIGO Scientific Collaboration

LIGO- T1000023-v1 *ADVANCED LIGO* 2/2/10

Viewports Subsystem
Preliminary Design Document

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Abstract

This document will present the preliminary design for the Viewports Subsystem. The Viewports subsystem provides optical viewports for the passage of all optical beams in and out of the vacuum region(s) of the IFO. The optical beams include the following: optical lever beams, CO_2 laser beams for thermal compensation, chamber illumination beams, video camera beams, and optical beams used for interferometer sensing and control.

1 Introduction

1.1 Purpose

The purpose of this document is to present the current design status for the Viewports Subsystem.

The Viewports subsystem provides optical viewports for the passage of all optical beams in and out of the vacuum region(s) of the IFO. The optical beams include the following: optical lever beams, CO2 laser beams for thermal compensation, chamber illumination beams, video camera beams, and optical beams used for interferometer sensing and control.

1.2 Definitions

1.3 Acronyms

LIGO - Laser Interferometer Gravity Wave Observatory

IO - Input Optics

PRM, PR2, and PR3 – Power Recycling Mirrors

SRM, SR2, and SR3 – Signal Recycling Mirrors

BS - Beam Splitter

ITMx, ITMy - Input Test Mass in the interferometer ‘X’ or ‘Y’ arm

ETMx, ETMy - End Test Mass in the interferometer ‘X’ or ‘Y’ arm

AR - Antireflection mirror coating

HR – Hi-reflectance mirror coating

ppm - parts per million

ISC- Interferometer Sensing and Control

IFO - LIGO interferometer

HAM - Horizontal Access Module

BSC - Beam Splitter Chamber

TBD - To Be Determined

rms - root-mean-square

p-v, peak to valley

OPTLEV- optical lever

1.4 Applicable Documents

1.4.1 LIGO Documents

1. M950046-F LIGO Project System Safety Management Plan

2. L060068-00 ASC Vacuum Viewports
3. E960022-B LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
4. D970211-B Video Imaging Assembly ASC Alignment
5. D970212-B Illuminator Assembly ASC Alignment
6. E080501 Enhanced LIGO TCS Hazard Analysis
7. E070253-A ELI Septum Window Assembly And Installation Procedure
8. D0901109 ZnSe Protector Plate Front View
9. D0901110 ZnSe Protector Plate Back

1.4.2 Non-LIGO Documents

2 General description

Viewports are mounted to flanges in the nozzles of the vacuum chambers. The viewport material and the AR coatings on the viewport surfaces are chosen to maximize the transmissivity of the light passing through the viewport. Previous viewports from Initial LIGO and Enhanced LIGO may be re-used as appropriate.

2.1.1 Viewport Naming Convention

2.1.1.1 BSC Chamber Viewport Names

The BSC viewport names are shown in Figure 1, Figure 2, and Figure 3.

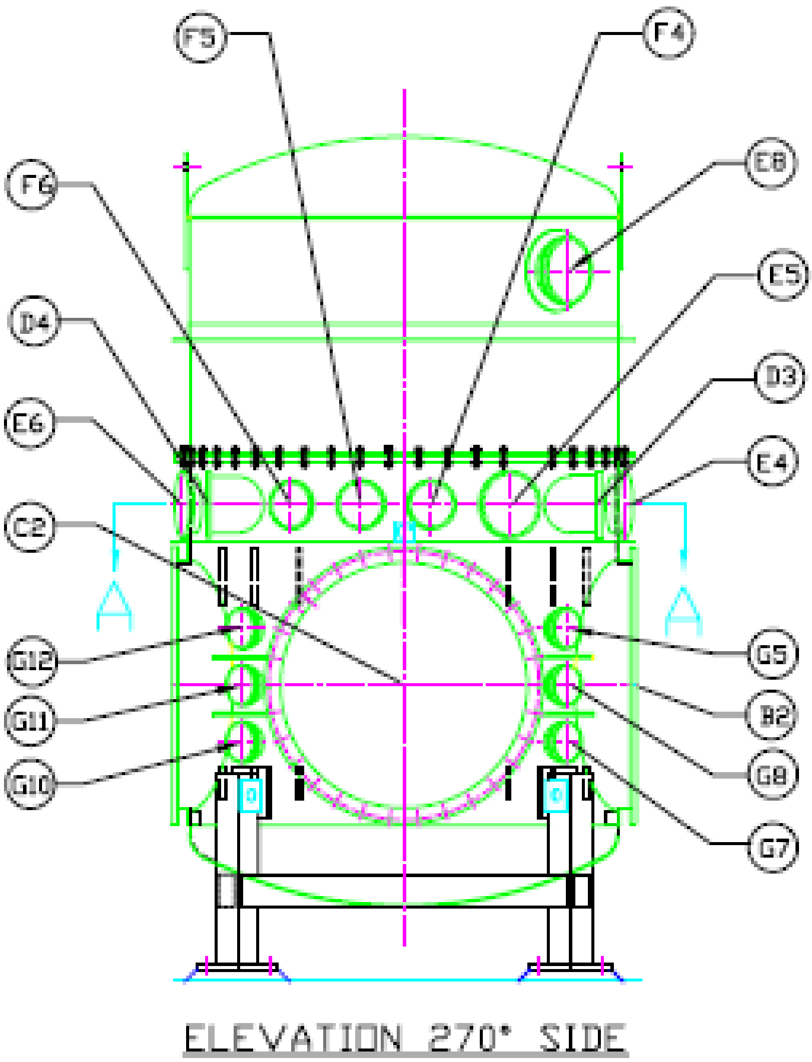

Figure 1: BSC viewport names, 270 deg elevation side

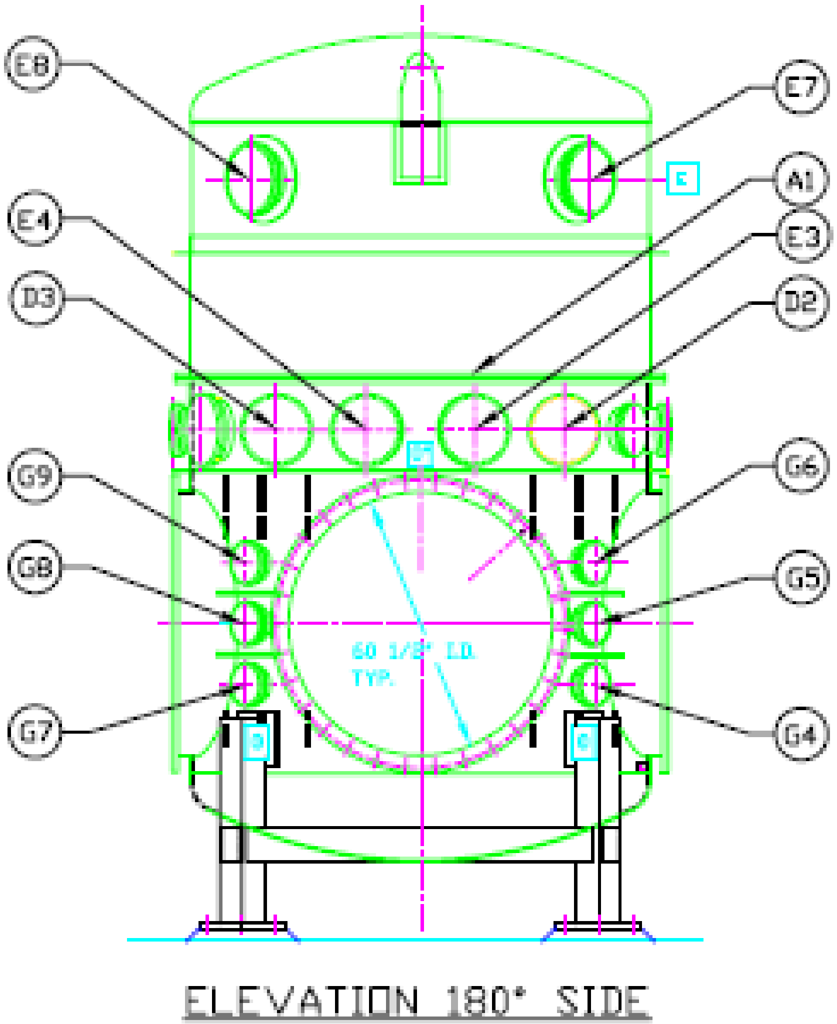

Figure 2: BSC viewport names, 180 deg elevation side

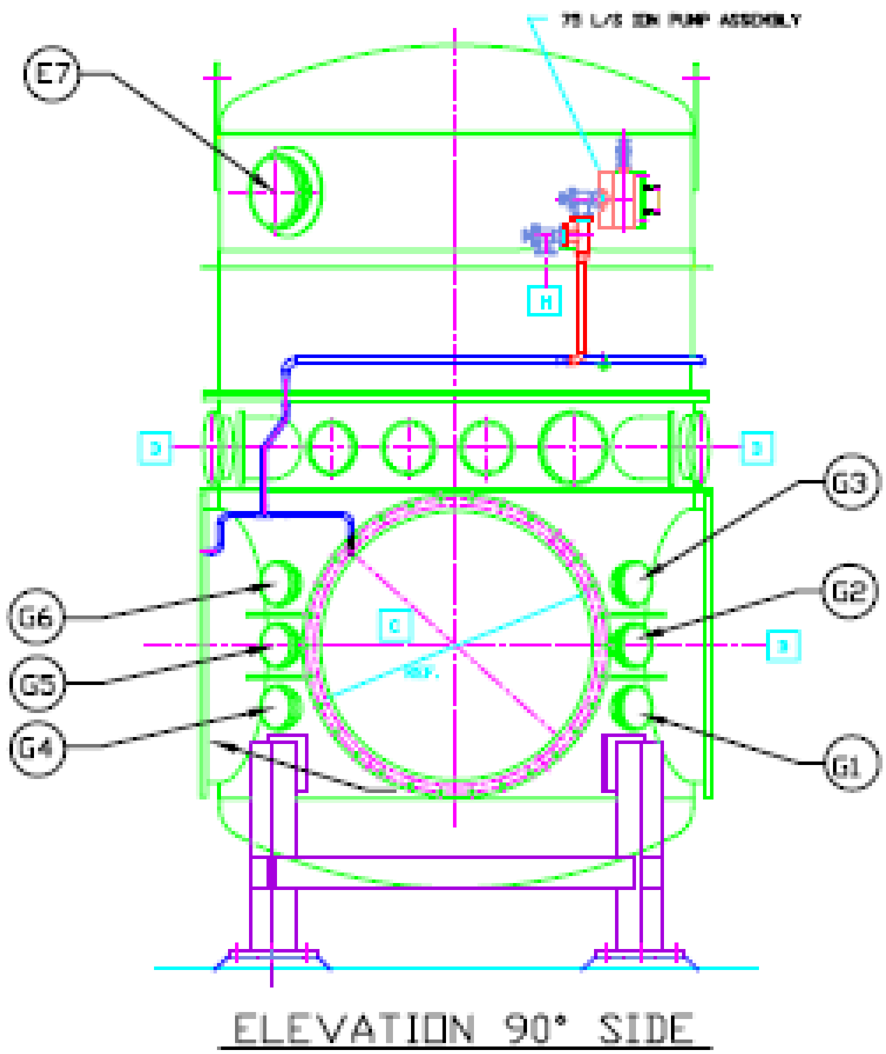

Figure 3: BSC viewport names, 90 deg elevation side

2.1.1.2 BSC Door Viewport Names

The BSC Door Viewport Names are shown in Figure 4.

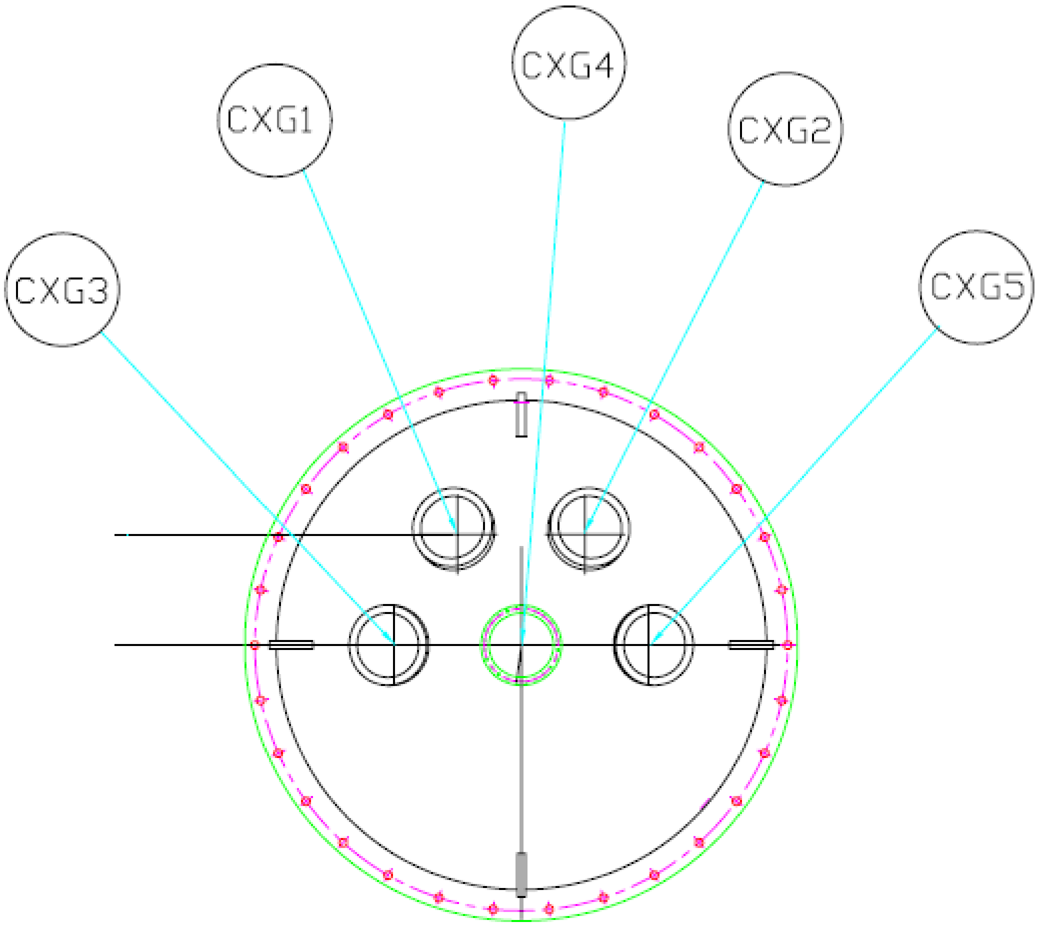

Figure 4: BSC Door Viewport Names

2.1.1.3 HAM Chamber Viewport Names

The HAM viewport names are shown in Figure 5.

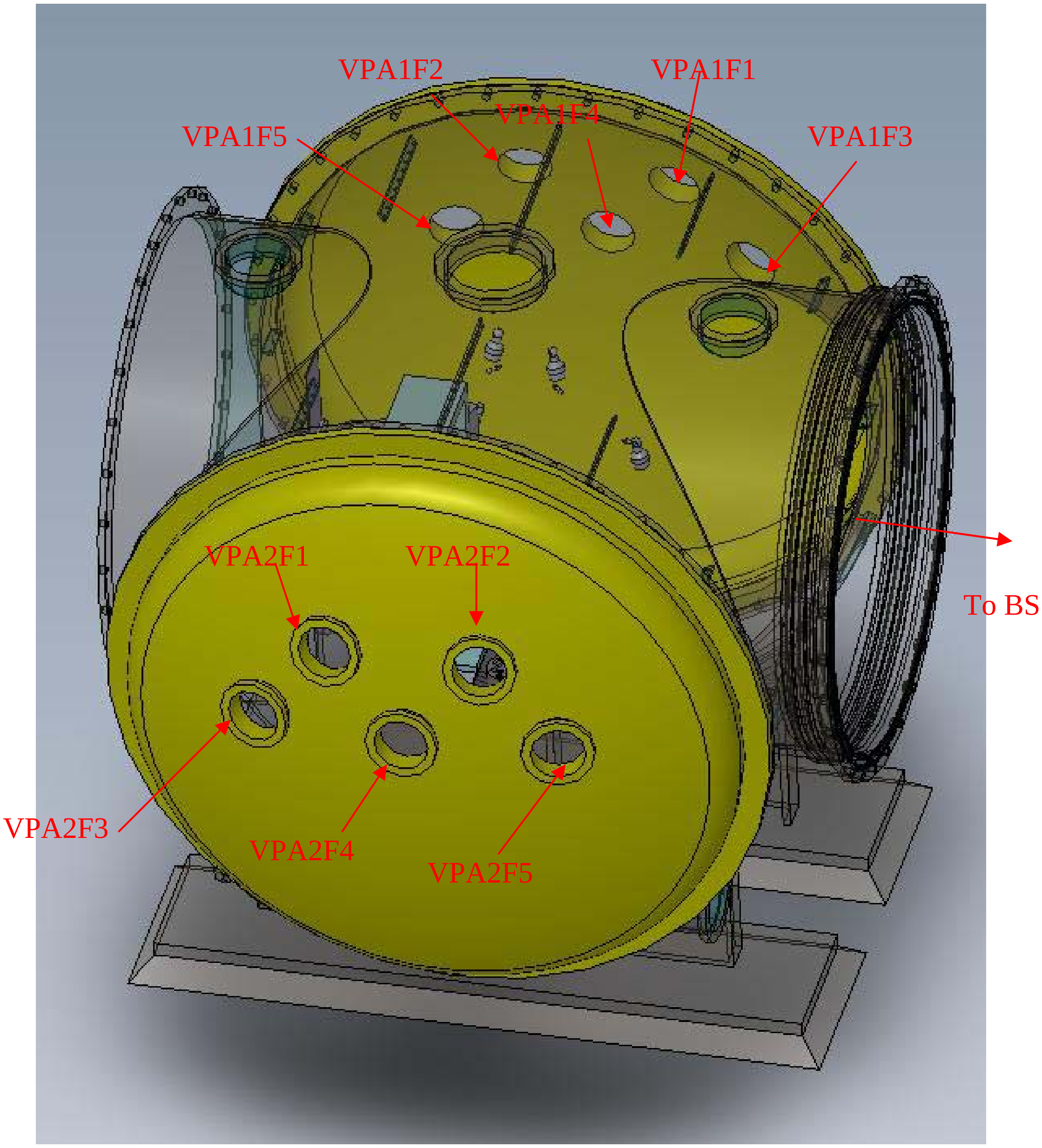

Figure 5: HAM Viewport Names

2.1.1.4 Mode Cleaner Tube Viewport Names

The Mode Cleaner Tube viewport names are shown in Figure 6. The naming convention for the Mode Cleaner Tubes are shown in Figure 7.

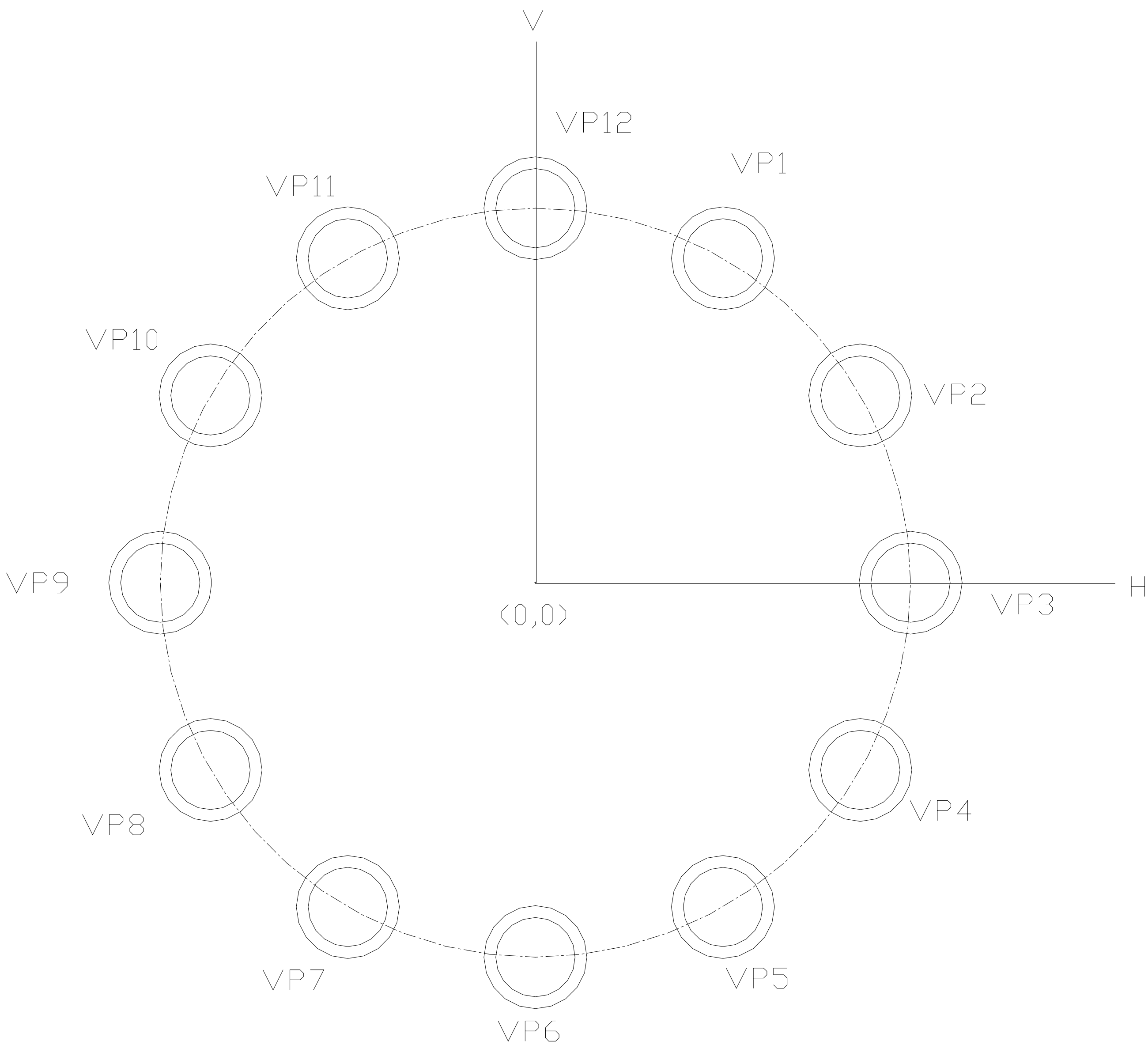

Figure 6: Mode Cleaner Tube Viewport Names

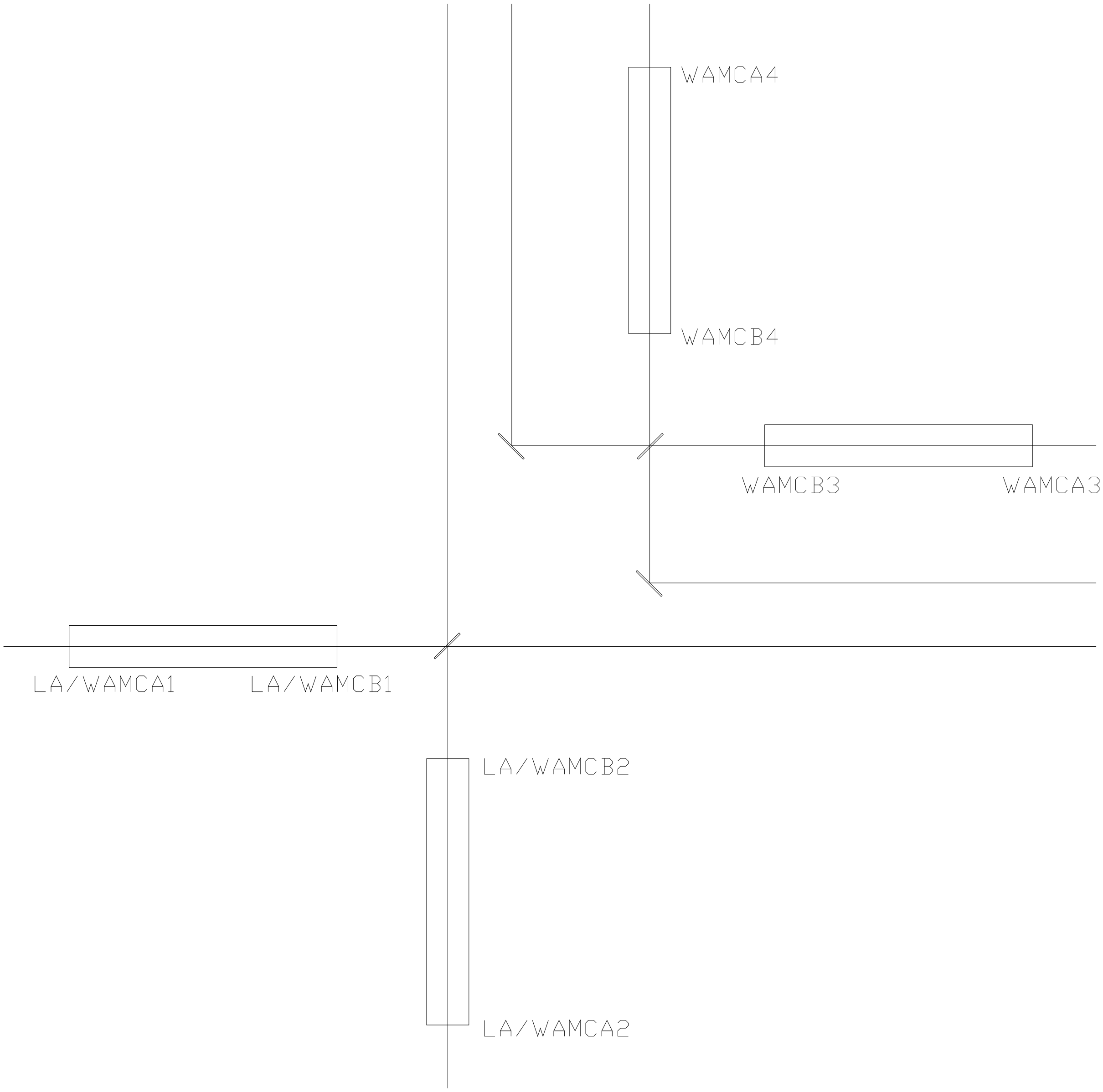

Figure 7: Mode Cleaner Tube Naming Convention

2.1.1.5 A-1 Adapter

The A-1 Adapter viewport names are shown in Figure 8.

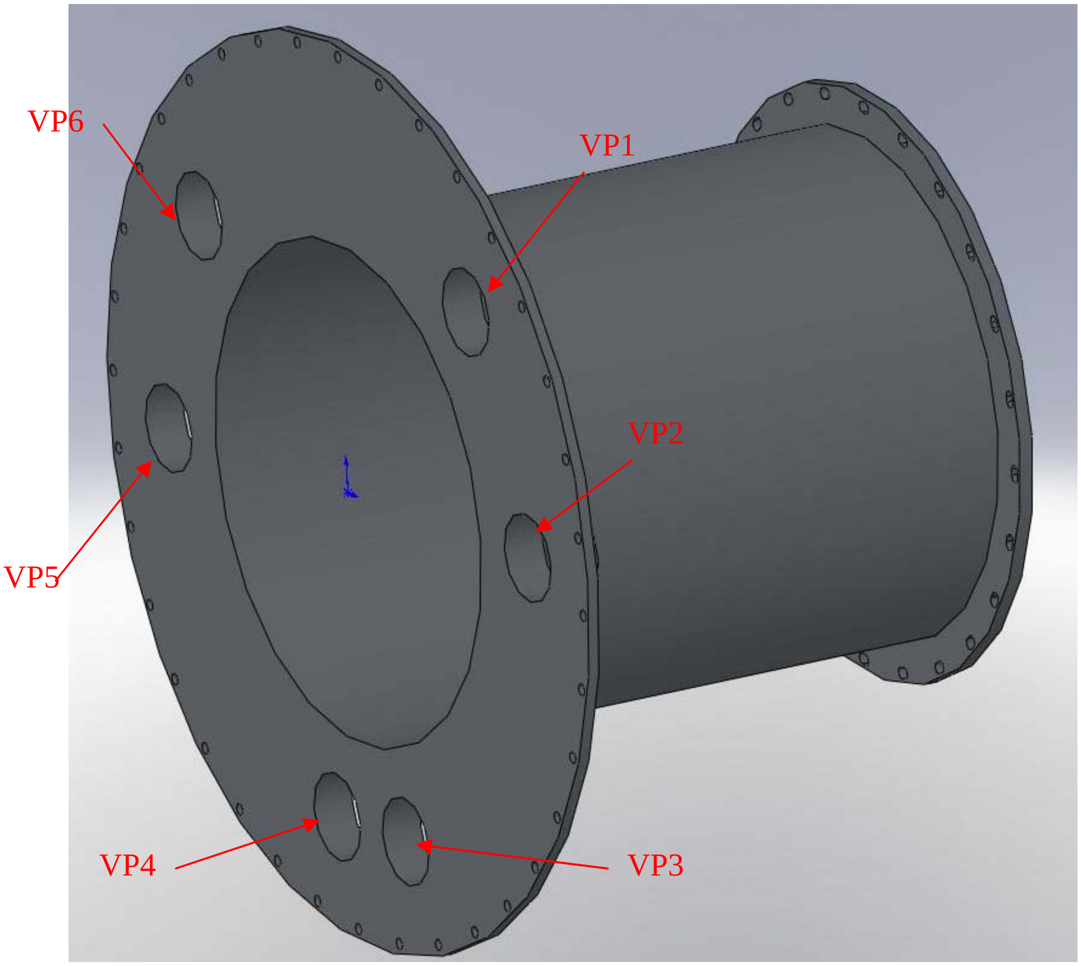

Figure 8: A-1 Adapter

2.1.1.6 D0900954 Flat Faced Flange

The H2 ETM, D0900954 Flat Faced Flange viewport names are shown in Figure 9.

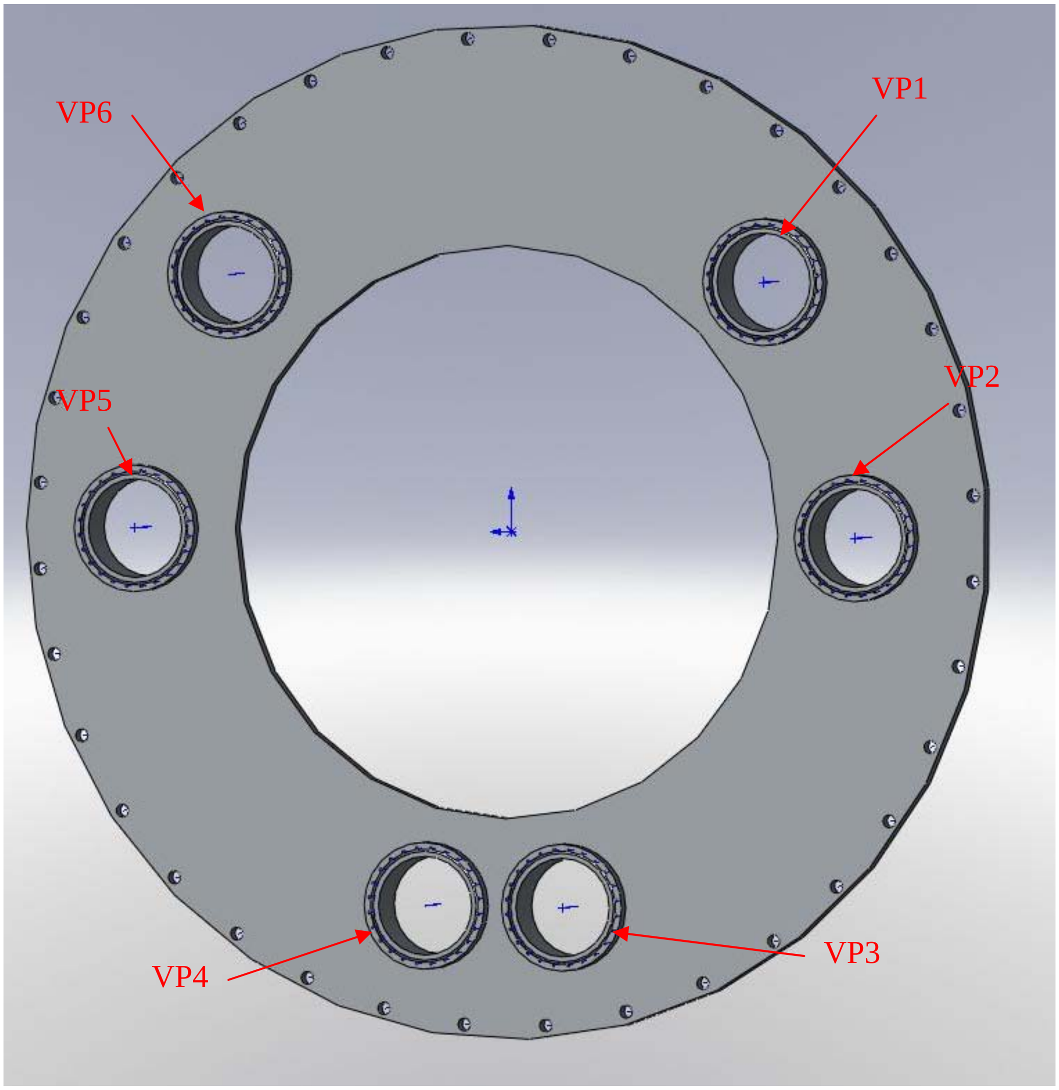

Figure 9: D0900954 Flat Faced Flange

2.1.1.7 HAM2, HAM8 Septum Plate

The HAM2, HAM8 Septum Plate viewport names are shown in Figure 10.

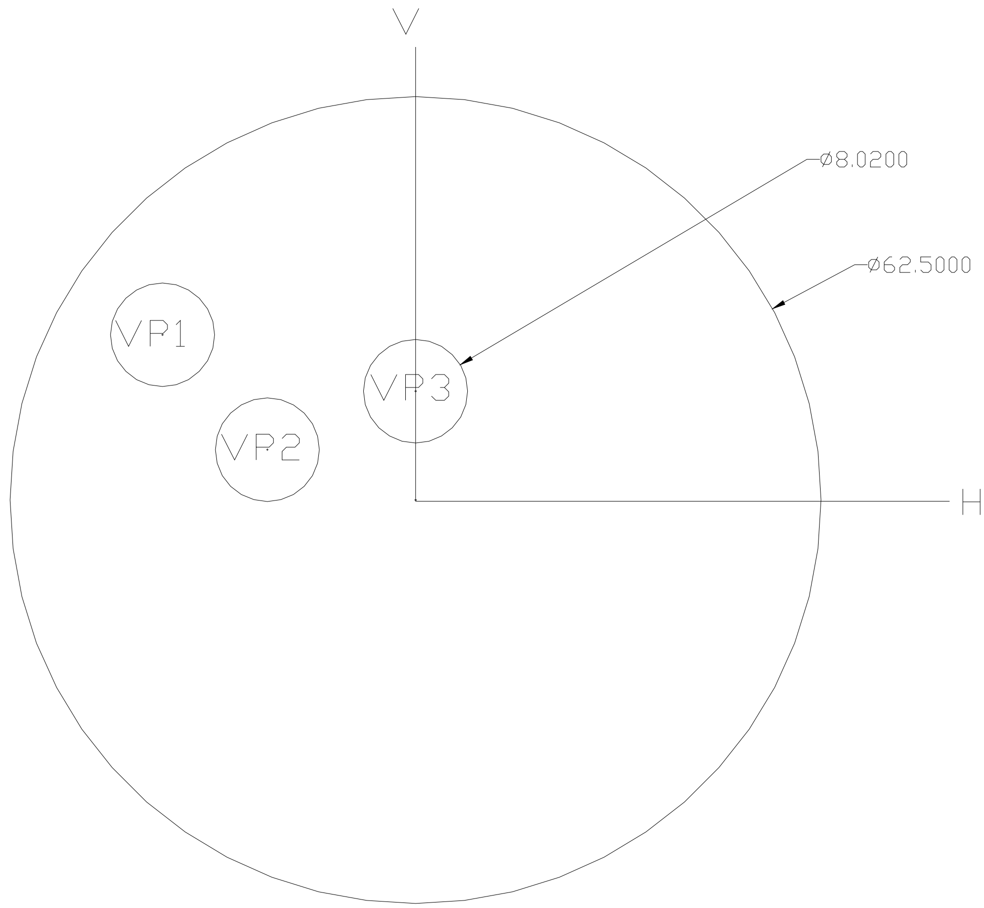

Figure 10: HAM2, HAM8 Septum Plate

2.1.1.8 HAM5, HAM11 Septum Plate

The HAM5, HAM11 Septum Plate viewport names are shown in Figure 11.

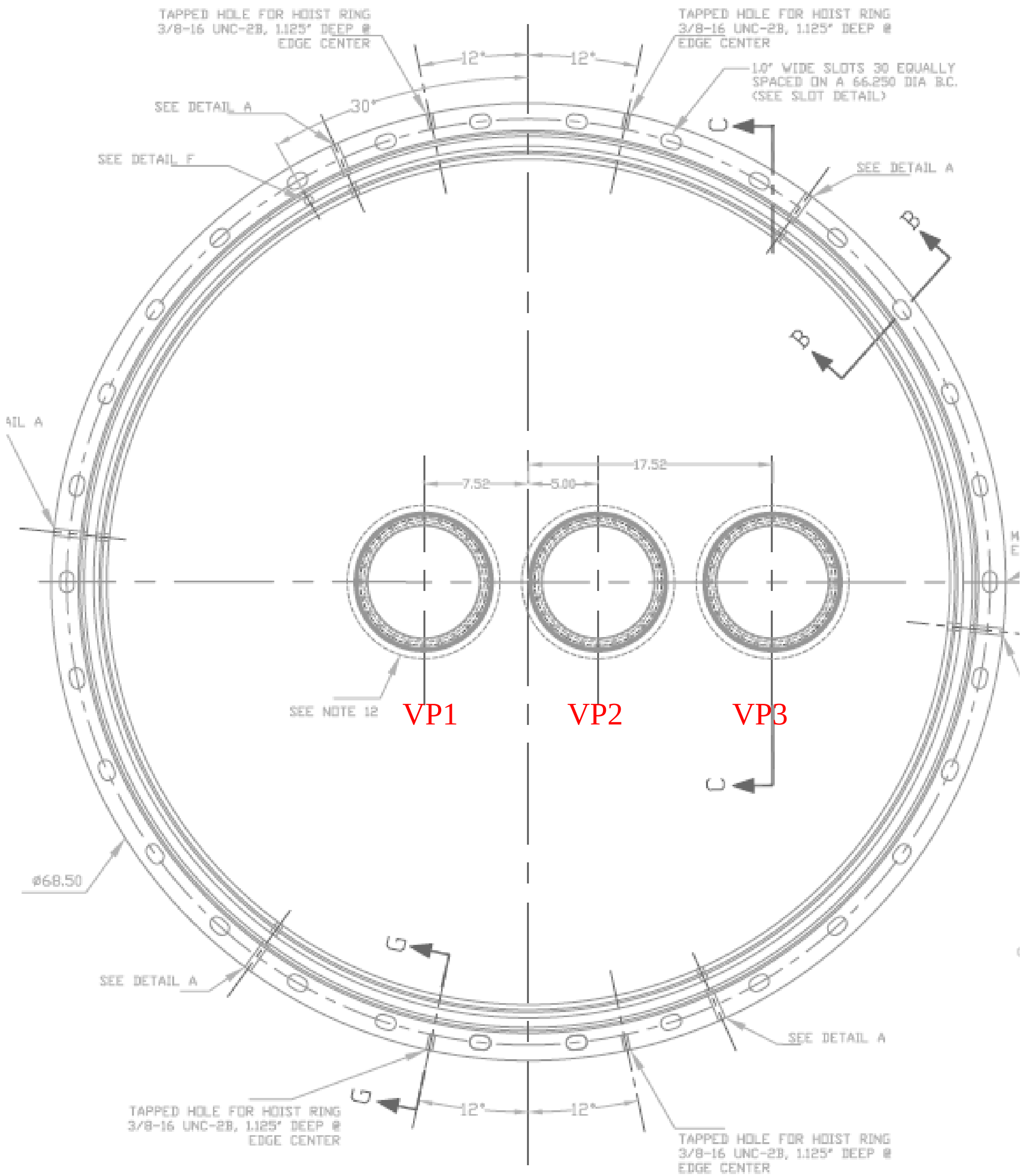

Figure 11: HAM5, HAM11 Septum Plate

2.2 General Constraints

2.2.1 Viewport Constraints

The sizes and quantities of viewports are determined by the proposed nozzles on the vacuum chambers of Advanced LIGO.

Viewports that pass high power laser beams, such as the PSL viewports, will have additional protective coverings to protect against heat-induced implosion of the viewport.

The viewport will withstand safely a 1 ATM pressure differential across both faces.

Viewports will have a sufficient wedge to avoid interference patterns wherever necessary.

3 Requirements

3.1 Video Camera Viewport

3.1.1 Optical Distortion

The video camera viewport shall have minimum optical distortion so as to enable the video camera resolution to be > 250 TV lines resolution in the horizontal and vertical directions.

3.1.2 Optical Transmissivity

The optical transmissivity of the video camera viewport shall be > 99% at the wavelengths 635 nm and 1064 nm, at normal incidence.

3.2 Chamber Illumination Viewport

3.2.1 Optical Transmissivity

The illumination viewport shall transmit a sufficient quantity of visible light to enable the video camera resolution of mirror features to be > 250 TV lines resolution in the horizontal and vertical directions.

3.3 Optical Lever Viewport

3.3.1 Optical Transmissivity

The optical transmissivity of the optical lever viewport shall be > 99% at the optical lever wavelength, TBD, and incidence angle of the optical lever beams.

3.4 Septum Plate Viewport

3.4.1 Surface Quality

The Septum Plate viewport shall have a surface micro-roughness < 0.1 nm rms over the central 140 mm diameter.

3.4.2 Wavefront Distortion

The wavefront distortion across the clear aperture shall be <1/4 wave @ 1064 nm wavelength.

3.4.3 Optical Transmissivity

The transmissivity shall be > 99% @ 1064 nm wavelength, at 5 deg incidence angle.

3.5 TCS Viewport

3.5.1 Surface Quality

The TCS Viewport shall have a surface quality of at least scratch/dig 20-10.

3.5.2 Wavefront Distortion

The wavefront distortion across the clear aperture shall be < 1/4 wave @ 10.6 micron wavelength.

3.5.3 Optical Transmissivity

The transmissivity shall be > 99% @ 10.6 micron wavelength at normal incidence

3.6 Hartmann Viewport

3.6.1 Surface Quality

The viewports shall have a surface quality of at least scratch/dig 10-5.

3.6.2 Wavefront Distortion

The wavefront distortion across the clear aperture shall be <1/4 wave at the Hartmann beam wavelength.

3.6.3 Optical Transmissivity

The transmissivity shall be > 99% at the Hartmann beam wavelength at normal incidence

3.7 Transmon Viewport

3.7.1 Surface Quality

The viewports shall have a surface quality of at least scratch/dig 10-5.

3.7.2 Wavefront Distortion

The wavefront distortion across the clear aperture shall be <1/4 wave at 532 nm wavelength.

3.7.3 Optical Transmissivity

The transmissivity shall be > 99% at 532 nm and 1964 nm wavelength at normal incidence.

4 Preliminary Design

Various types of viewports are used for providing access to optical beams into and out of the IFO.

Video camera viewports are used to provide a visible access from outside the chambers for video cameras to view the IFO optics.

Optical lever viewports are used to provide entry and exit for optical lever beams from outside the chambers to measure the tilt of the IFO suspended optics.

Illumination viewports are used to provide illumination of the vacuum chambers with an outside illumination lamp.

TCS viewports are used to provide transmission of CO_2 laser beams for heating certain core optics.

Hartmann viewports are used to provide entry and exit ports for the Hartmann wavefront sensing beams.

The Transmon viewports are used for entry and egress of the 532 nm arm length stabilization beam, the 532 nm Hartmann beam and the 1064 nm Transmon beam.

4.1 Protective Cover

All viewports will have a protective cover, similar to the one shown in Figure 12, which will cover the viewport whenever any physical activity occurs that might damage the viewport and cause a hazardous situation to nearby personnel.

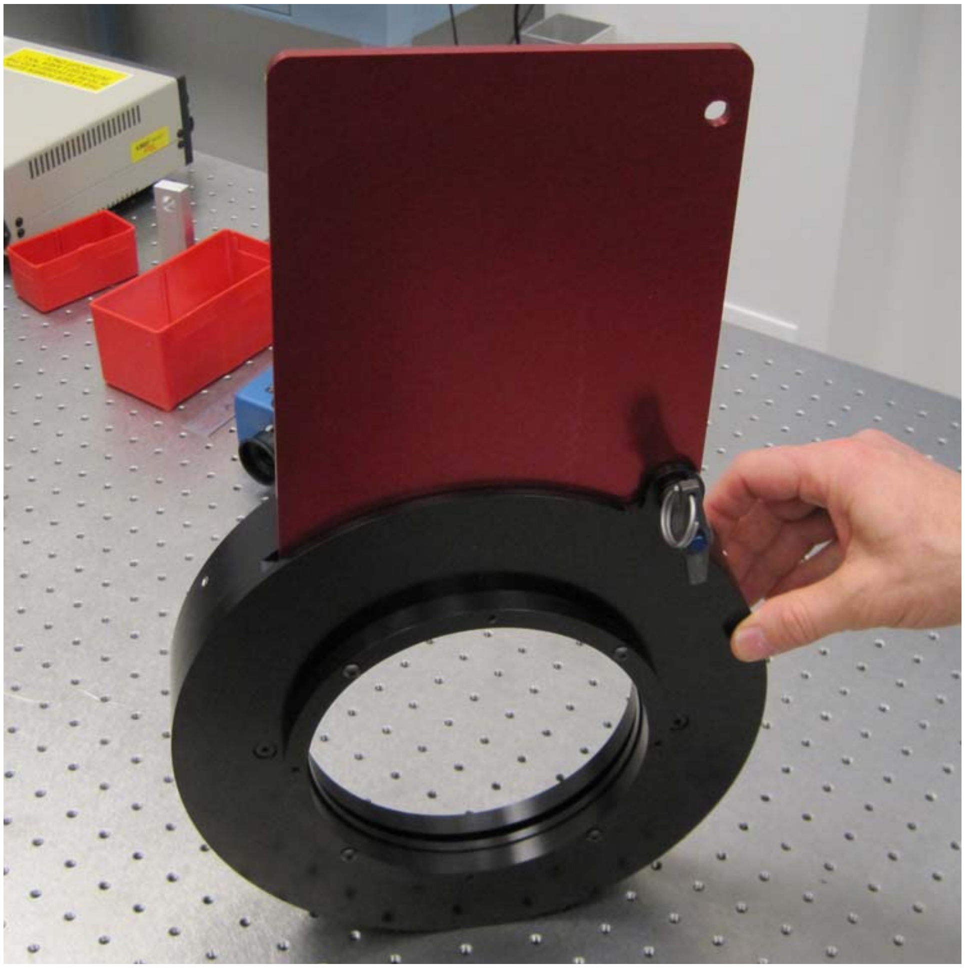

Figure 12: Viewport Protective Cover

4.2 Viewport Locations

4.2.1 Spool B-9, Adapter A-1

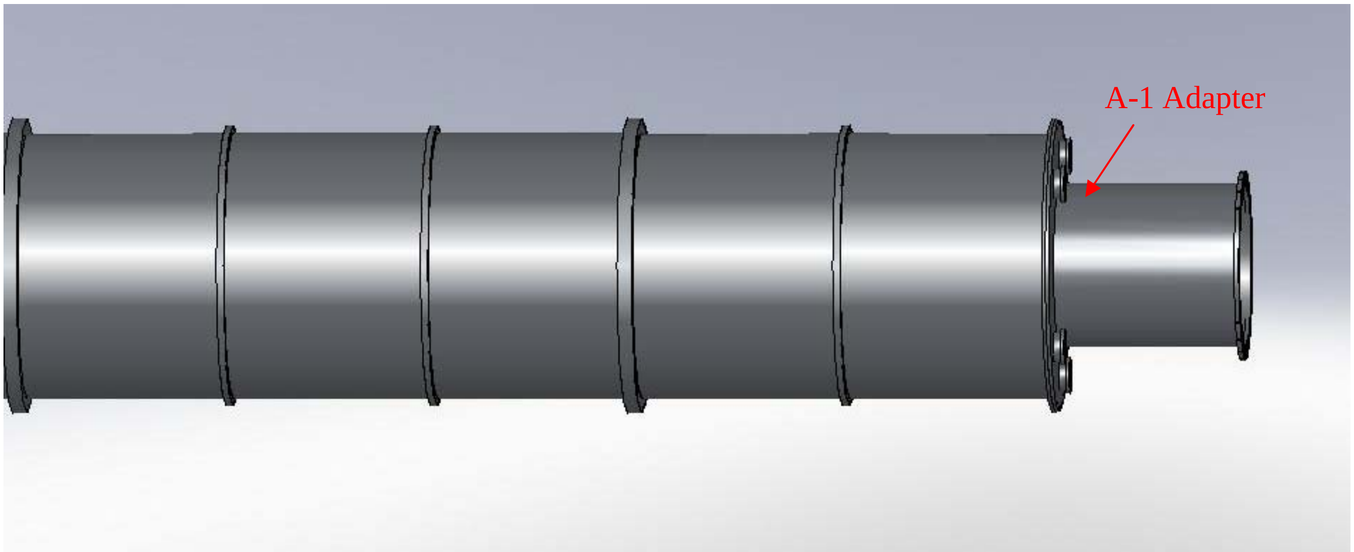

Figure 13: Spool B-9, Adapter A-1

4.2.2 H1/H2 End

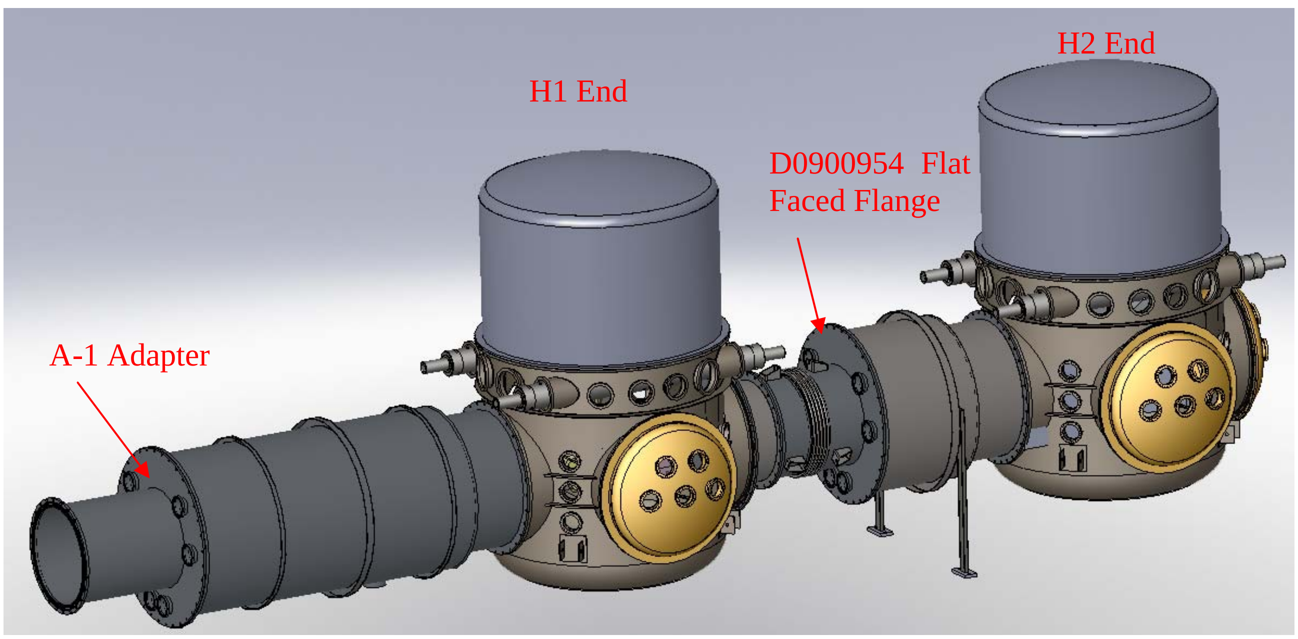

Figure 14: H1/H2 End

4.2.3 H1, L1 IFO

4.2.3.1 BSC2

The locations of the BSC2 chamber viewports are shown in Figure 15.

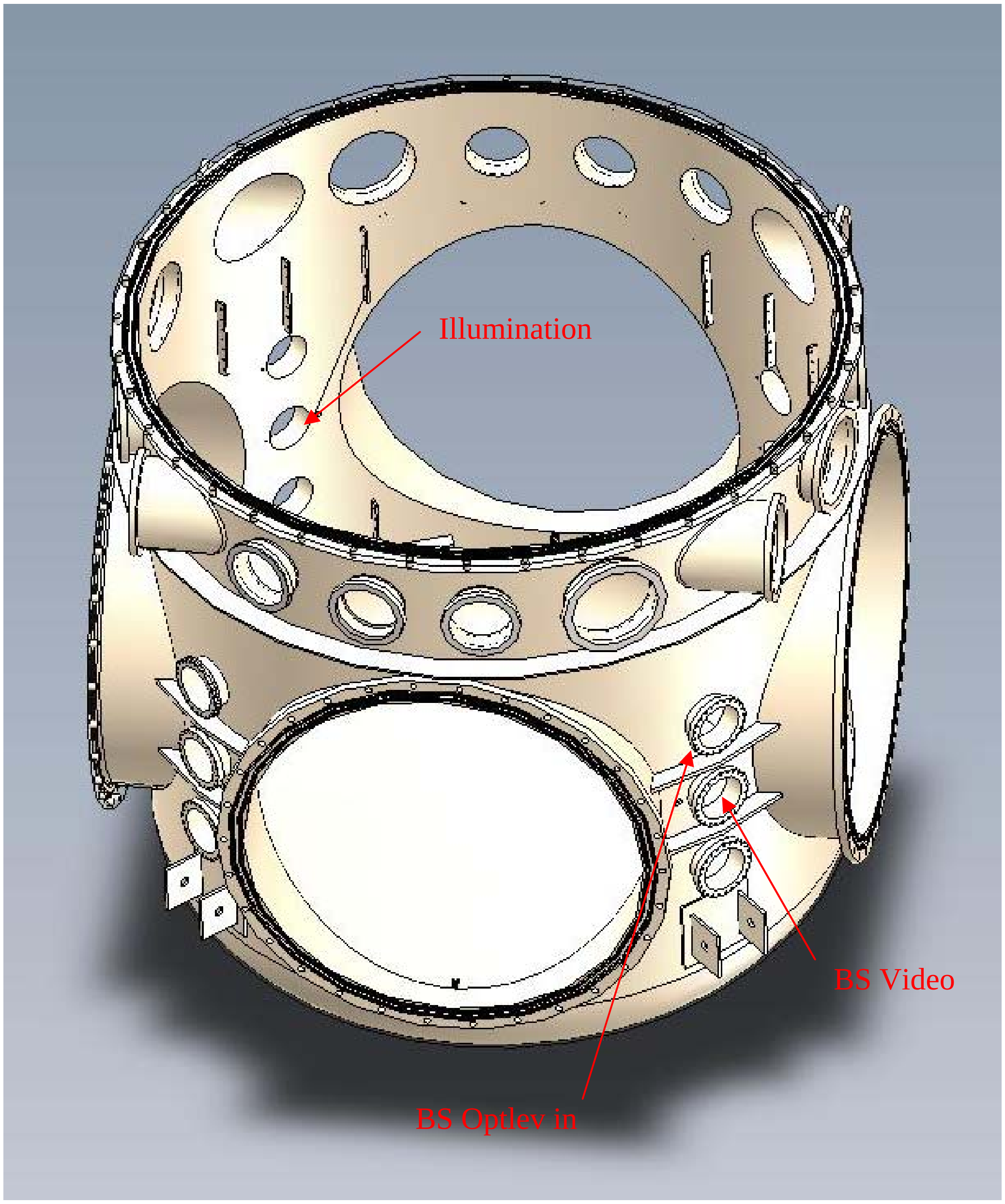

Figure 15: BSC2 Viewports

4.2.3.2 BSC1

The locations of the BSC1 chamber viewports are shown in Figure 16.

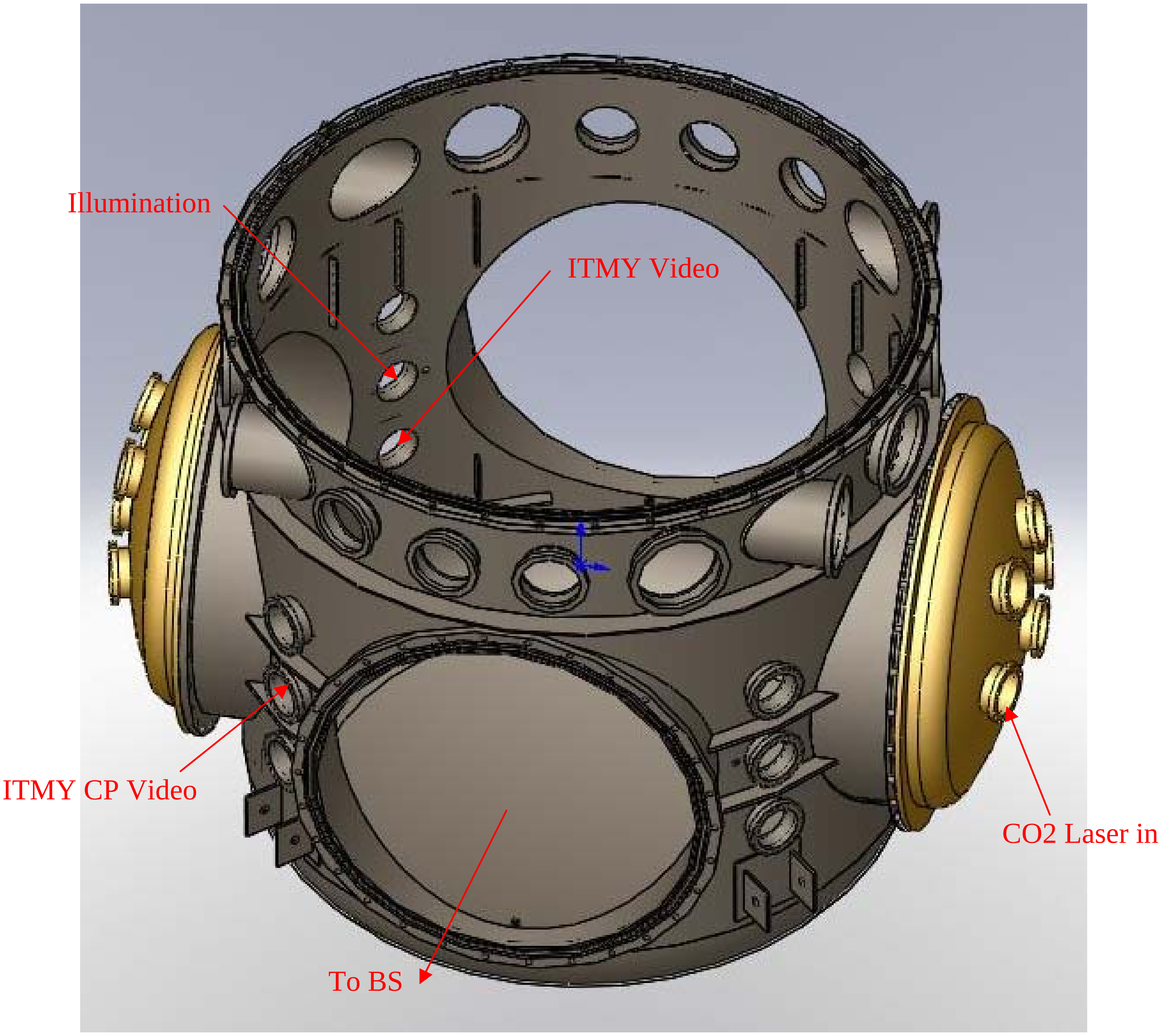

Figure 16: BSC1 Viewports

4.2.3.3 BSC3

The locations of the BSC3 chamber viewports are shown in Figure 17.

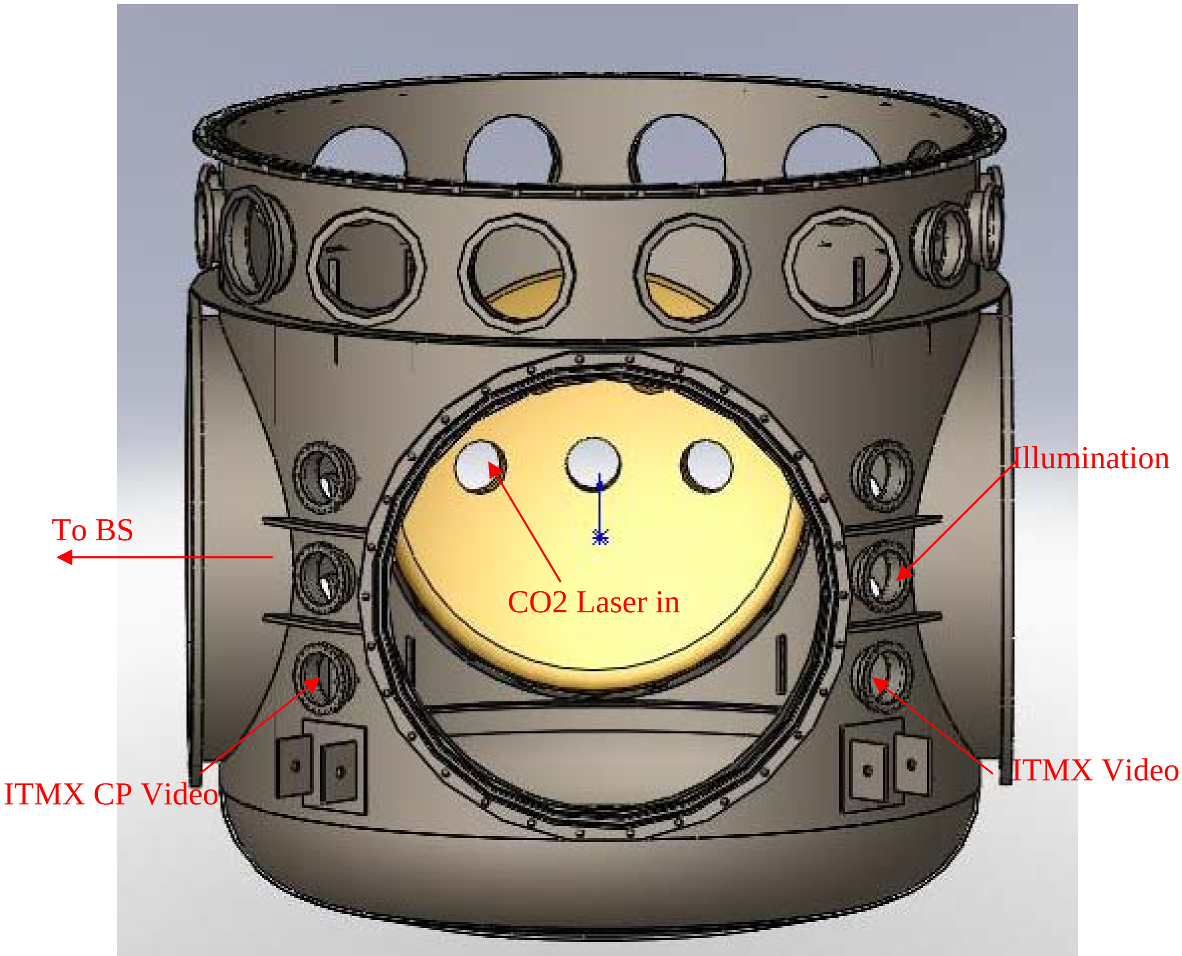

Figure 17: BSC3 Viewports

4.2.3.4 BSC9

The locations of the BSC9 chamber viewports are shown in Figure 18.

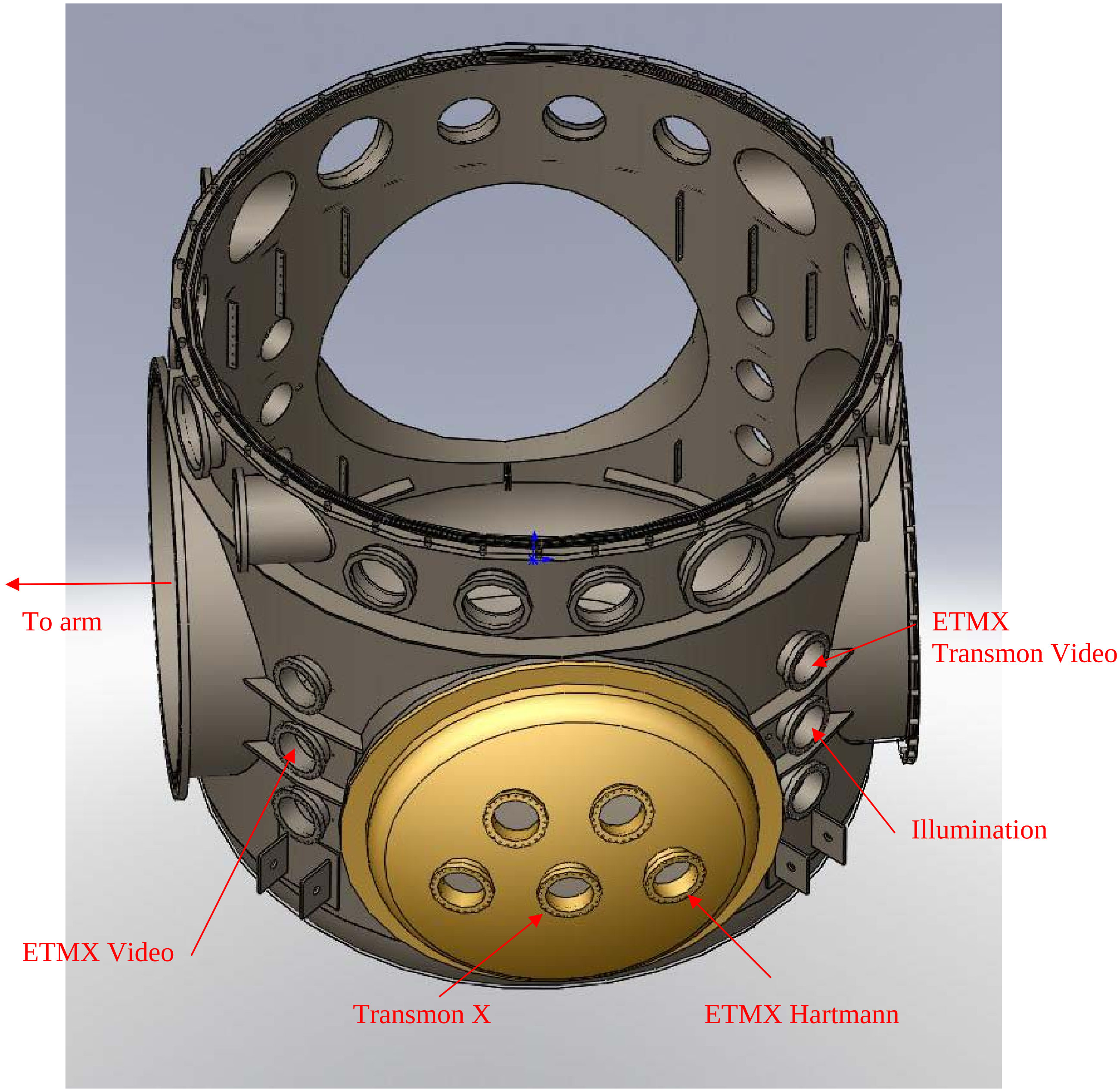

Figure 18: BSC9 Viewports

4.2.3.5 BSC10

The locations of the BSC10 chamber viewports are shown in Figure 19.

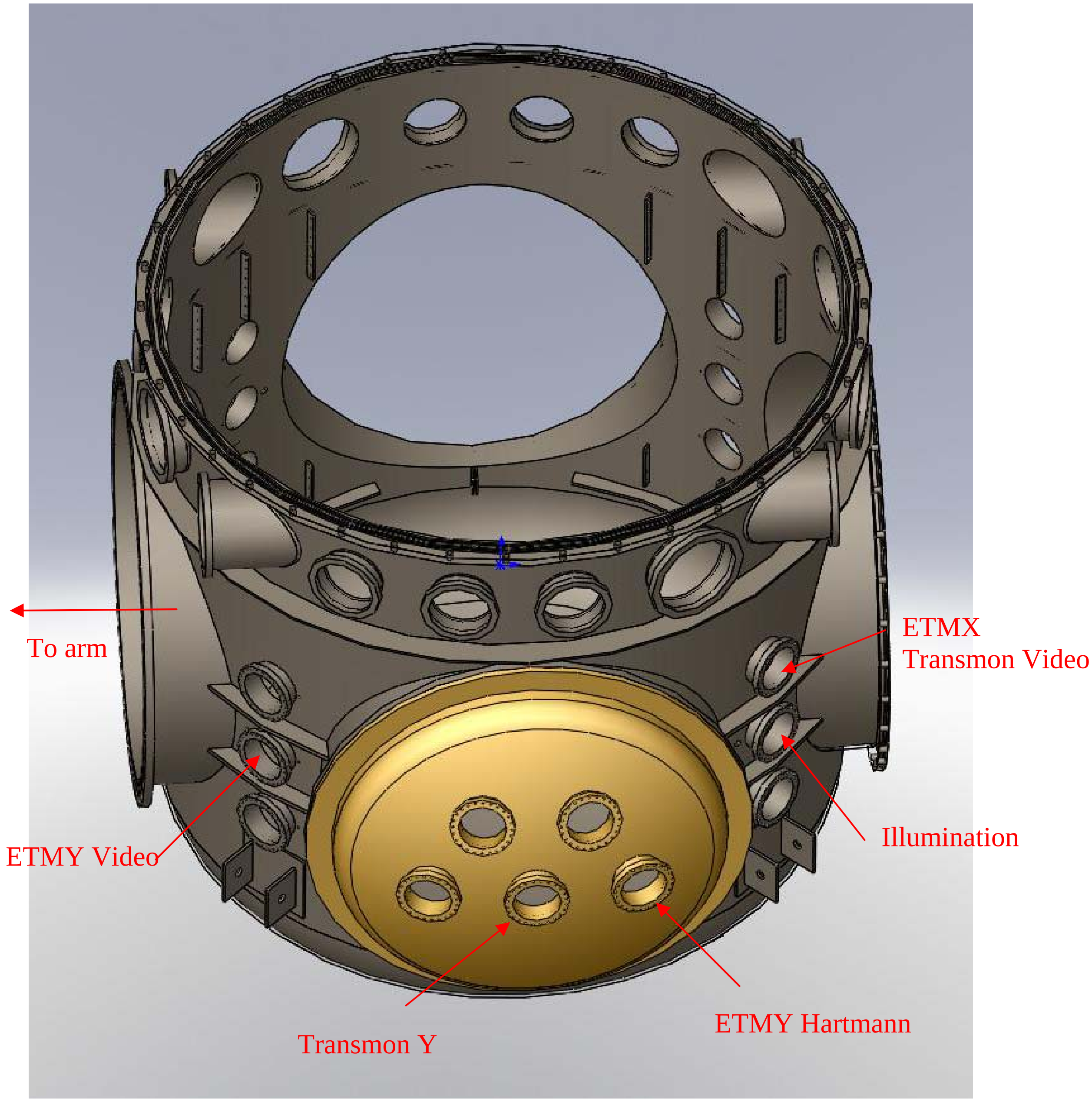

Figure 19: BSC10 Viewports

4.2.3.6 ITMX A1-A FLANGE

The locations of the ITMX A1-A FLANGE viewports are shown in Figure 20.

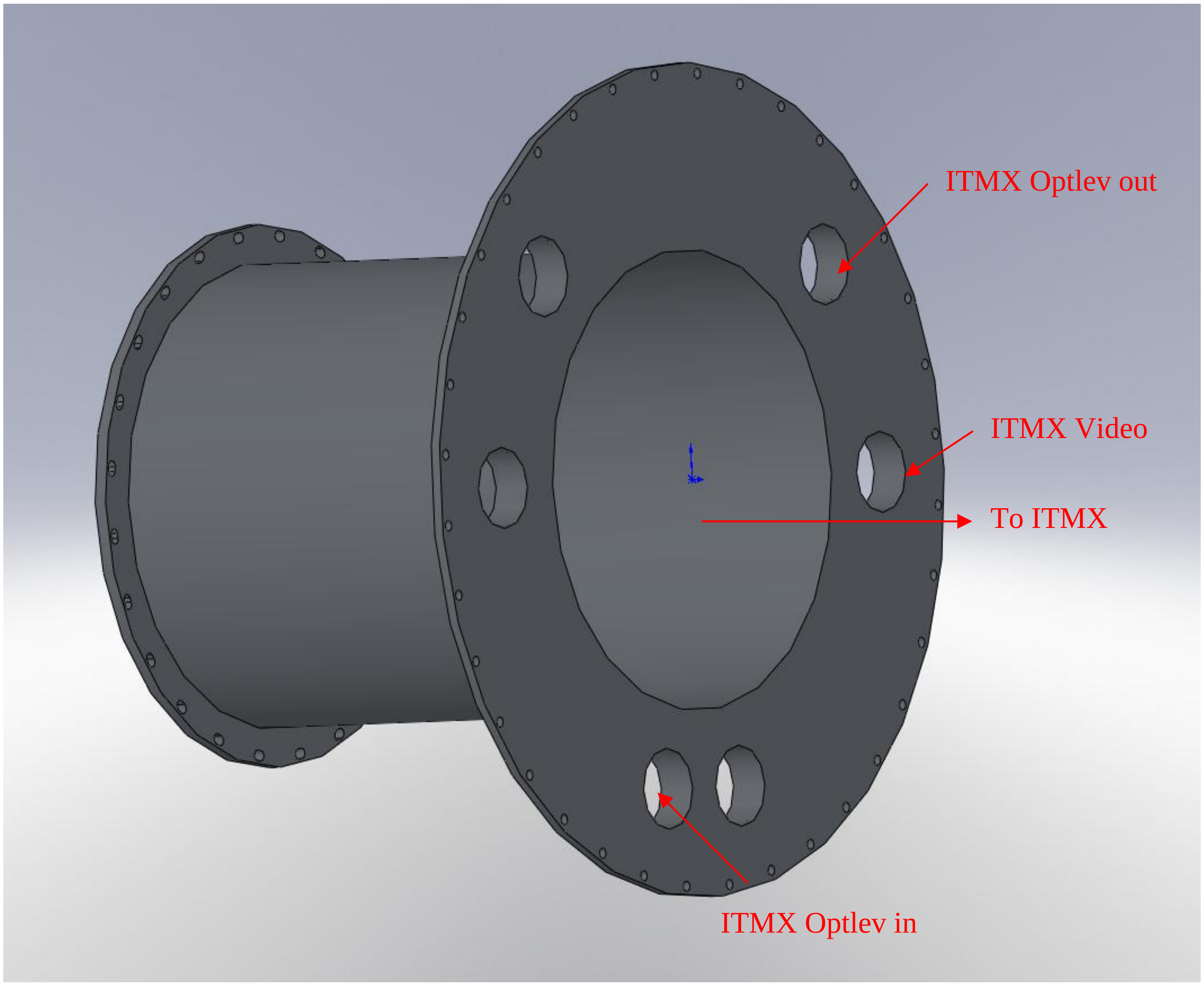

Figure 20: ITMX A1-A Adapter

4.2.3.7 ITMY A1-B FLANGE

The locations of the ITMY A1-B FLANGE viewports are shown in Figure 21.

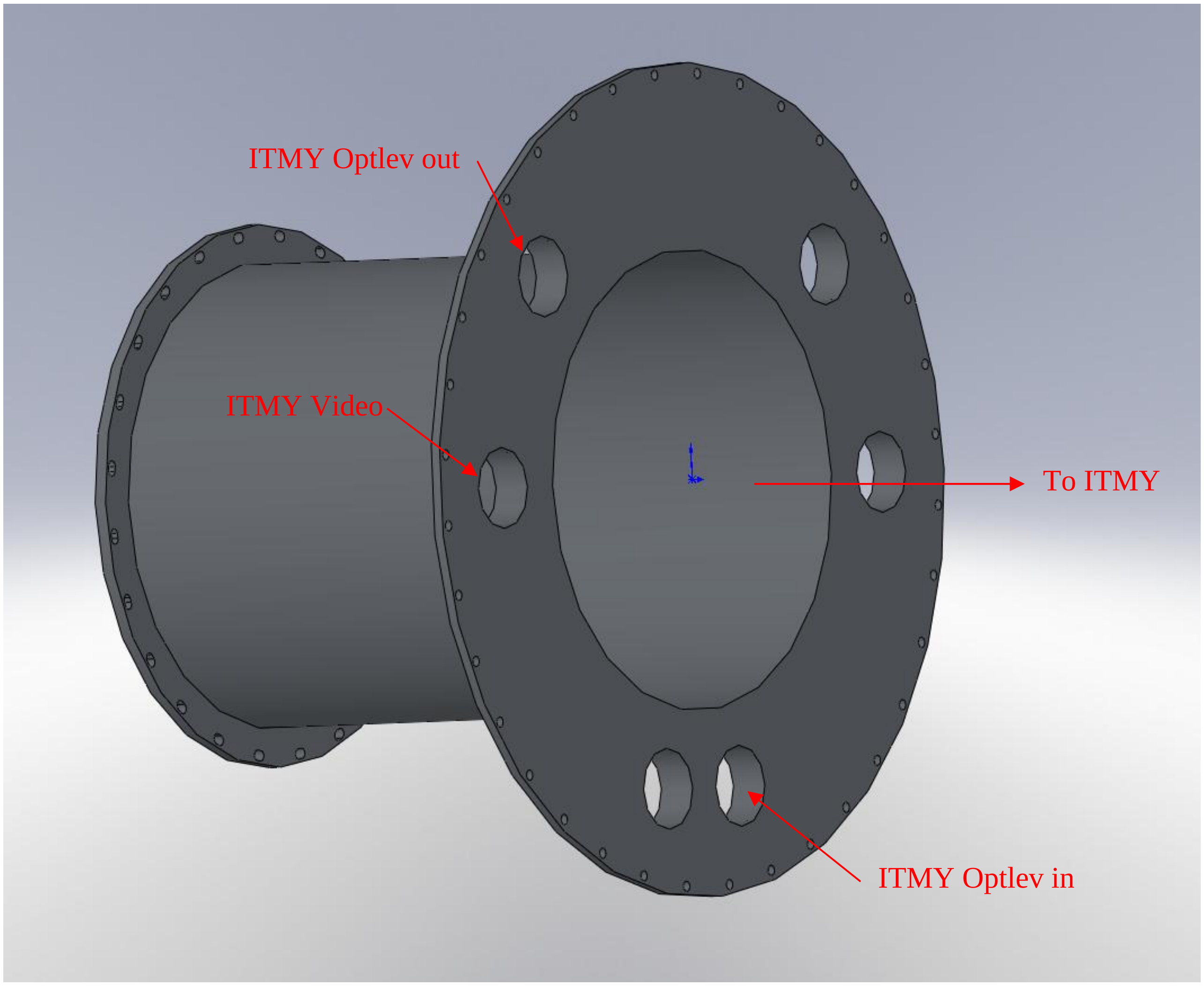

Figure 21: ITMY A1-B Adapter

4.2.3.8 ETMX A1-A FLANGE

The locations of the ETMX A1-B FLANGE viewports are shown in Figure 22.

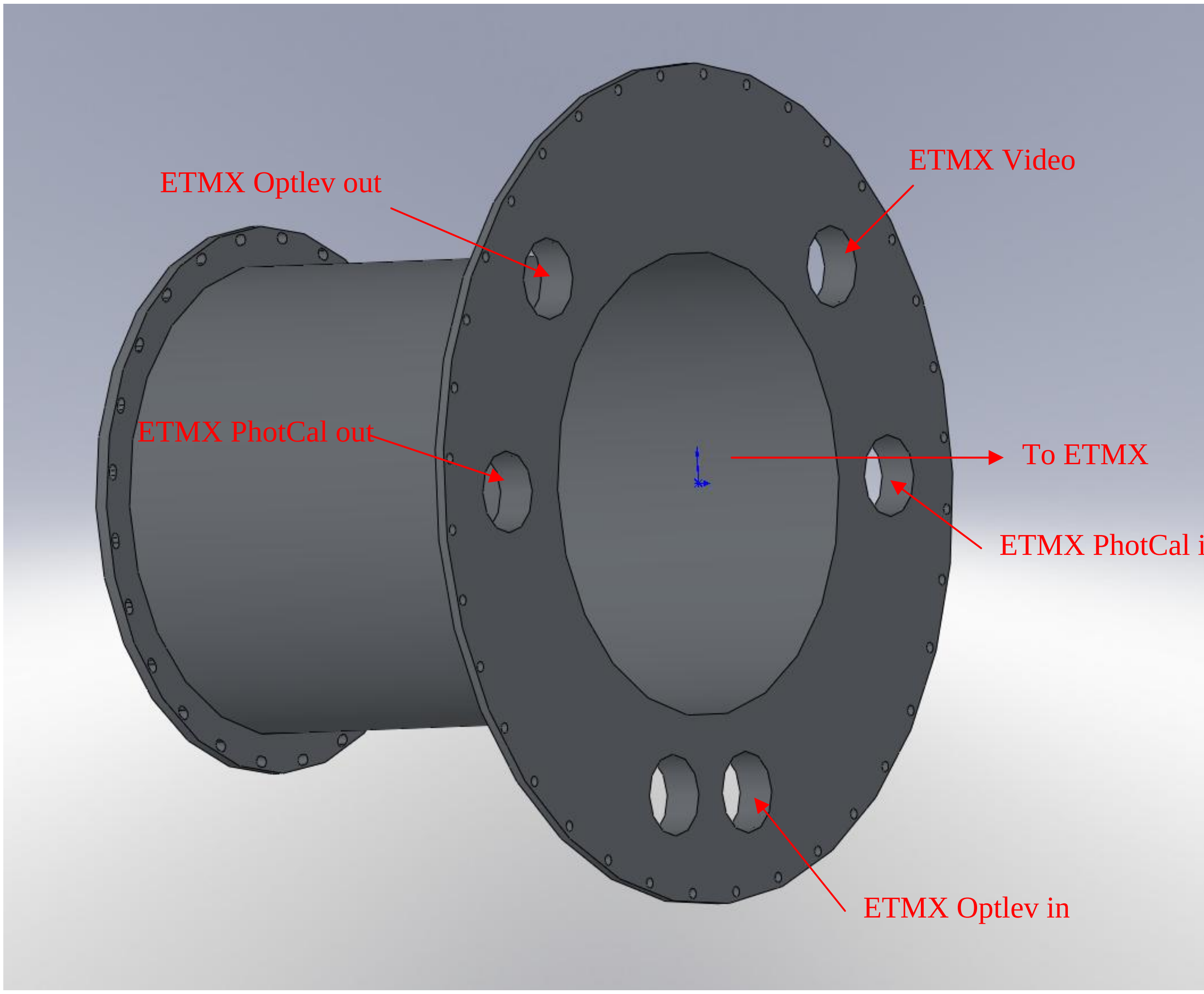

Figure 22: ETMX A1-A Adapter

4.2.3.9 ETMY A1-B FLANGE

The locations of the ETMY A1-A FLANGE viewports are shown in Figure 23.

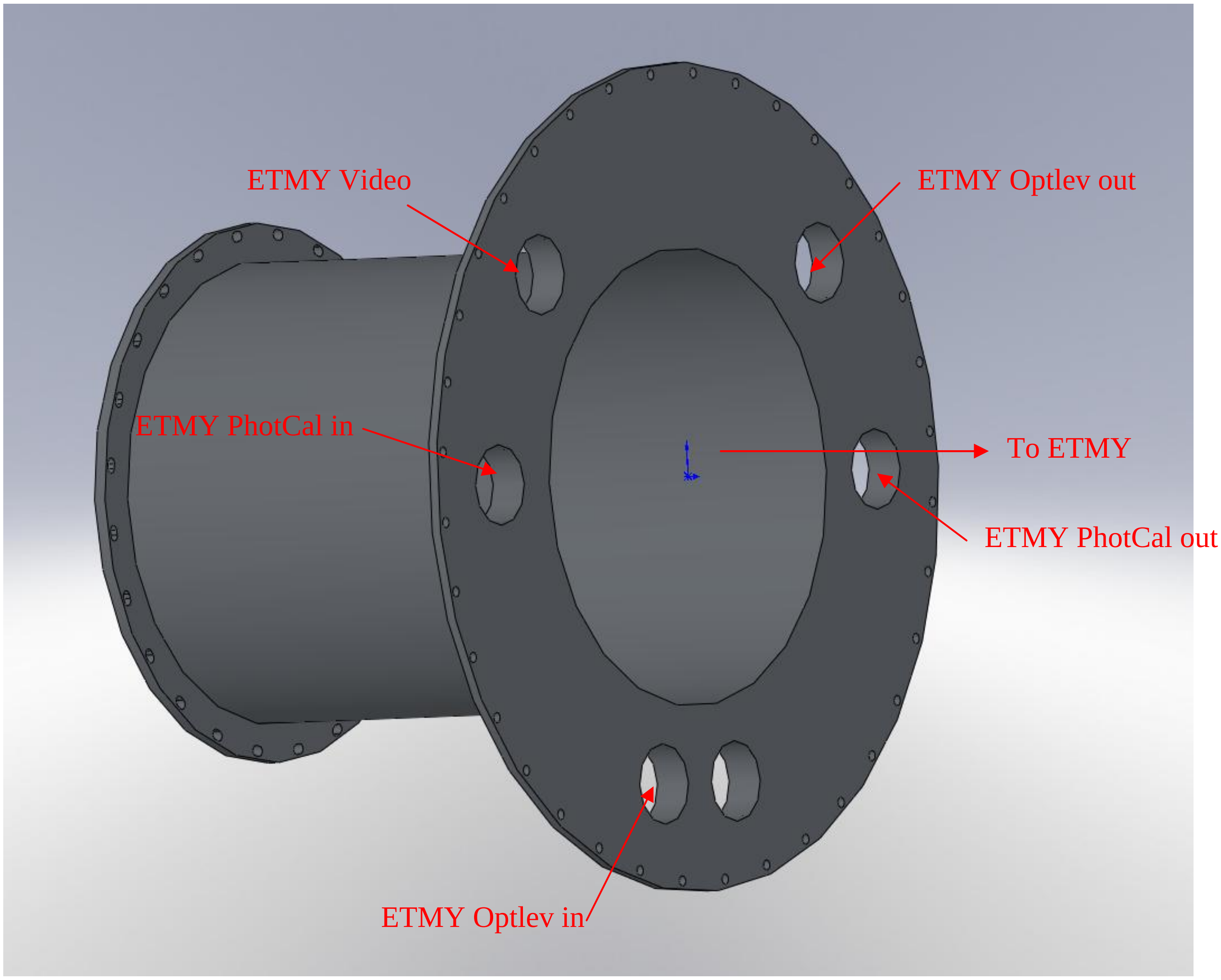

Figure 23: ETMY A1-B Adapter

4.2.3.10 HAM1

TBD

4.2.3.11 HAM2

The locations of the HAM2 viewports are shown in Figure 24.

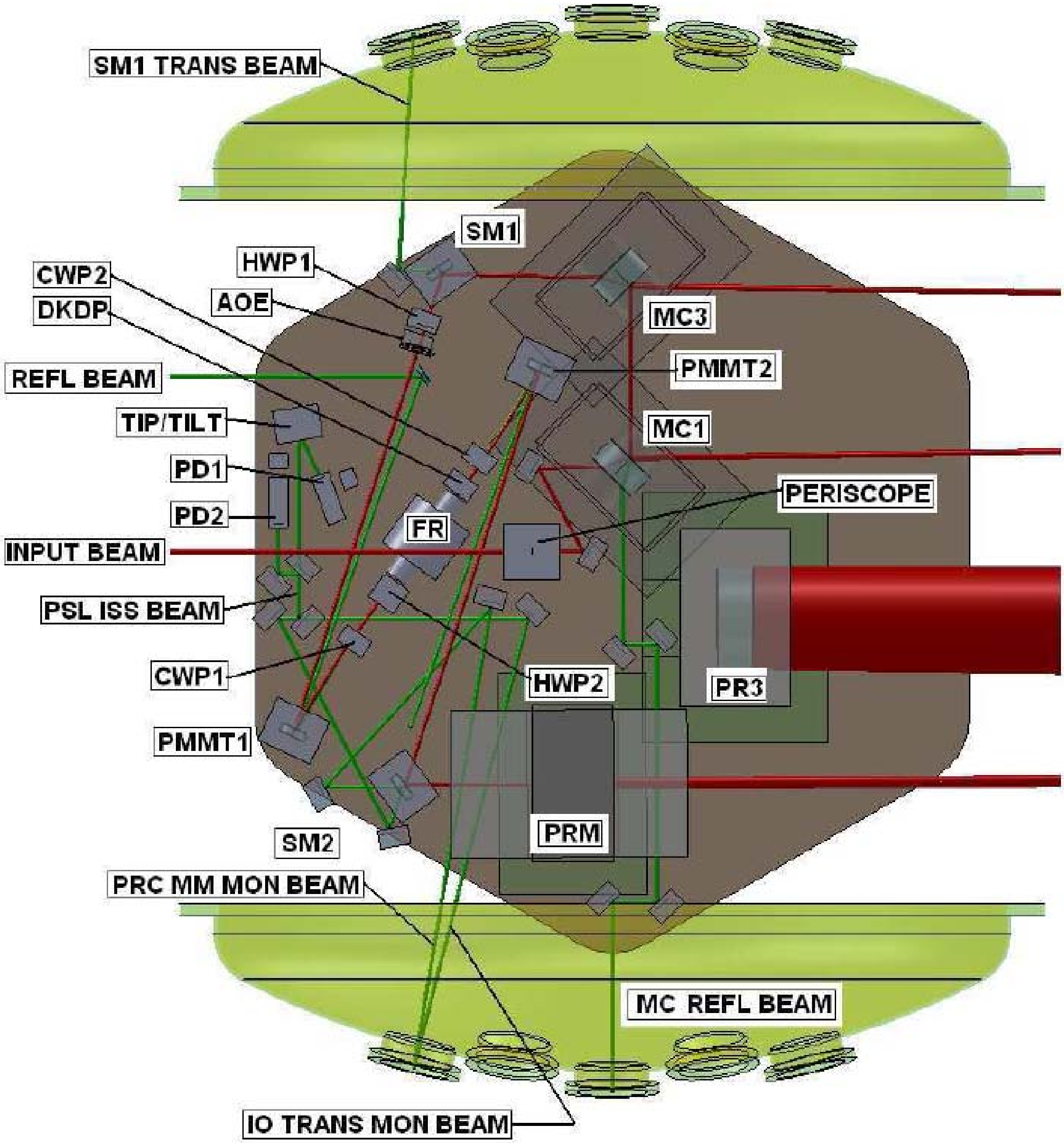

Figure 24: HAM2 Viewports

4.2.3.12 HAM3

The locations of the HAM3 viewports are shown in Figure 25.

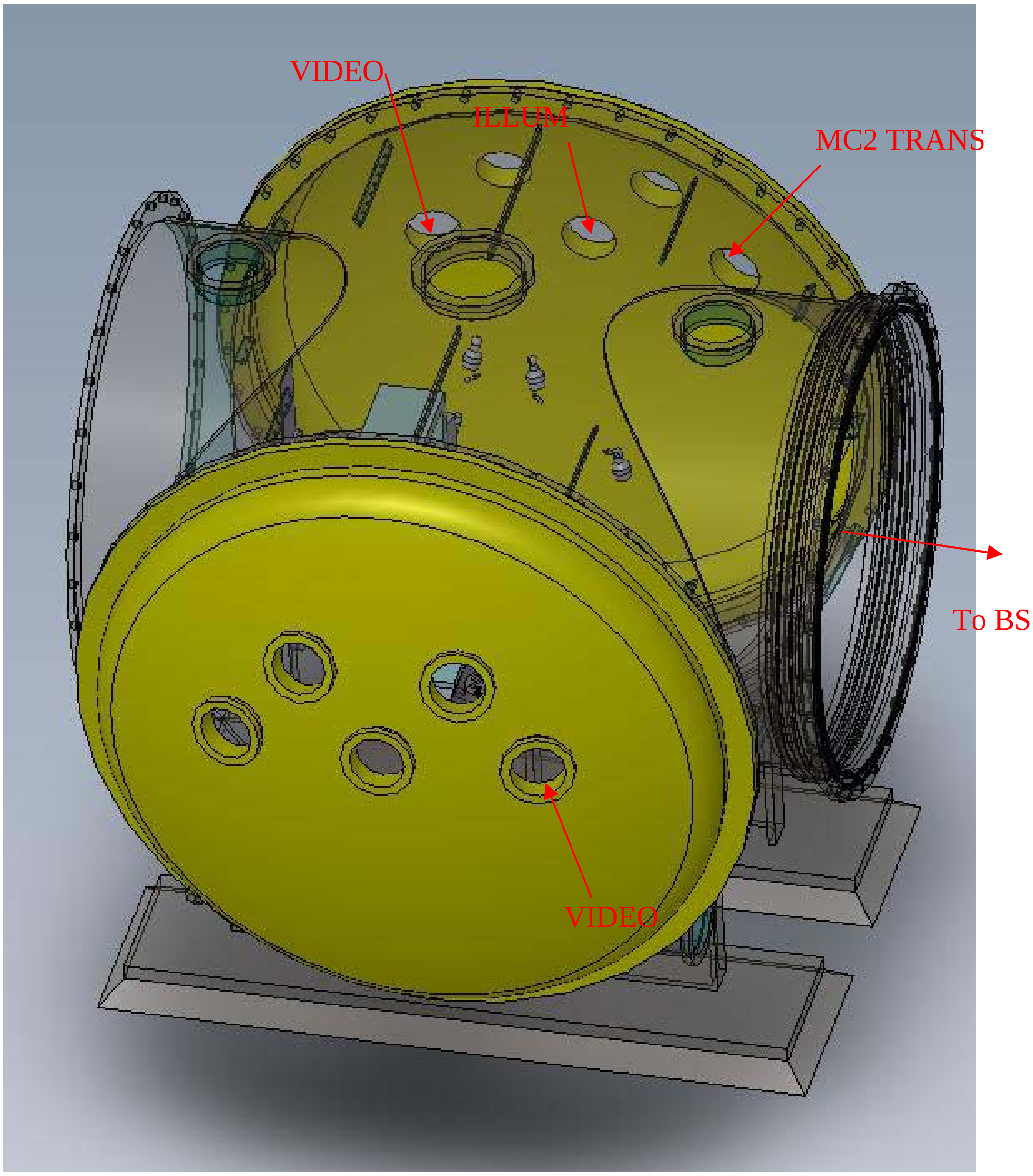

Figure 25: HAM3 Viewports

4.2.3.13 HAM4

The locations of the HAM4 viewports are shown in Figure 26.

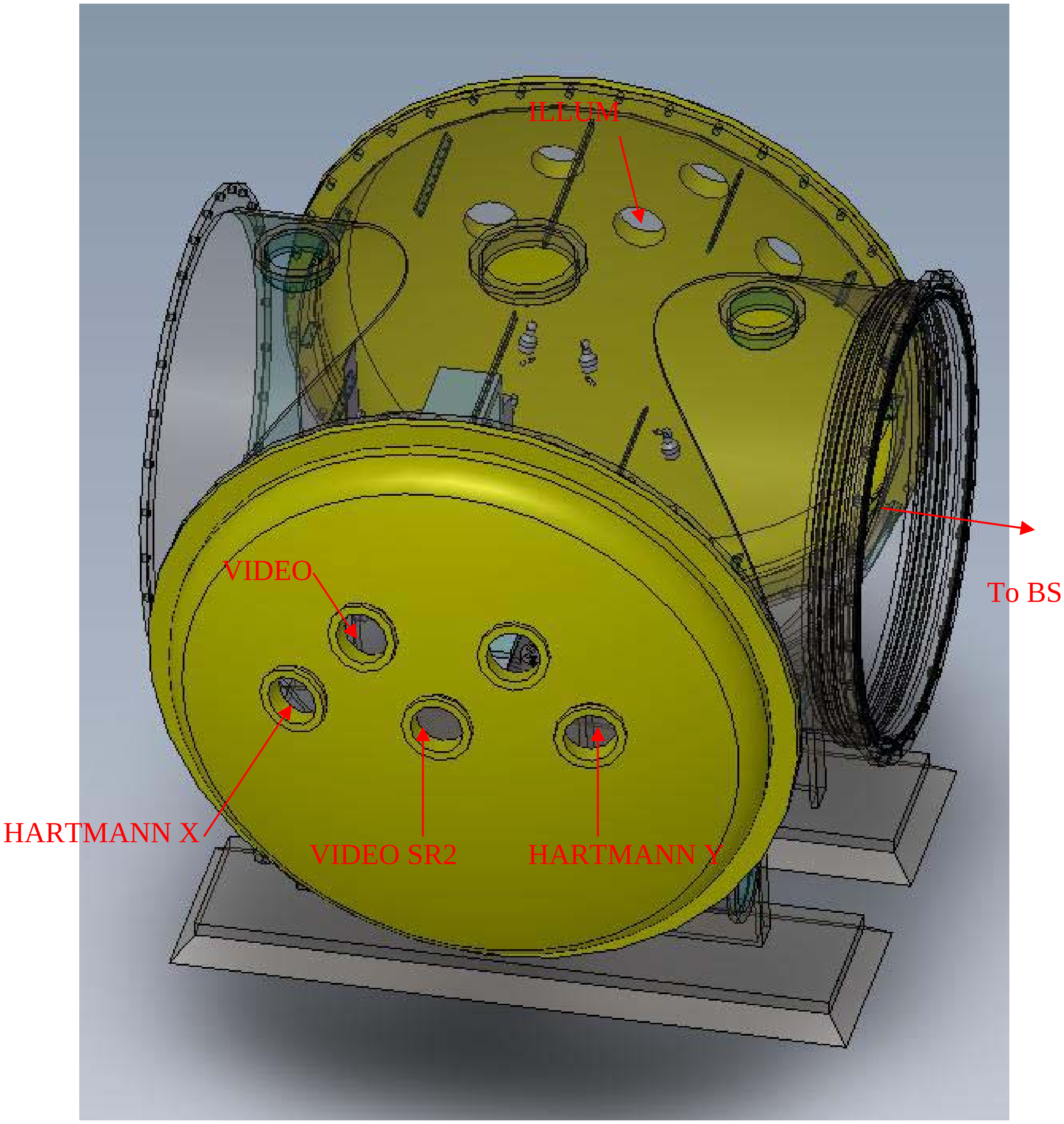

Figure 26: HAM4 Viewports

4.2.3.14 HAM5

The locations of the HAM5 viewports are shown in Figure 27.

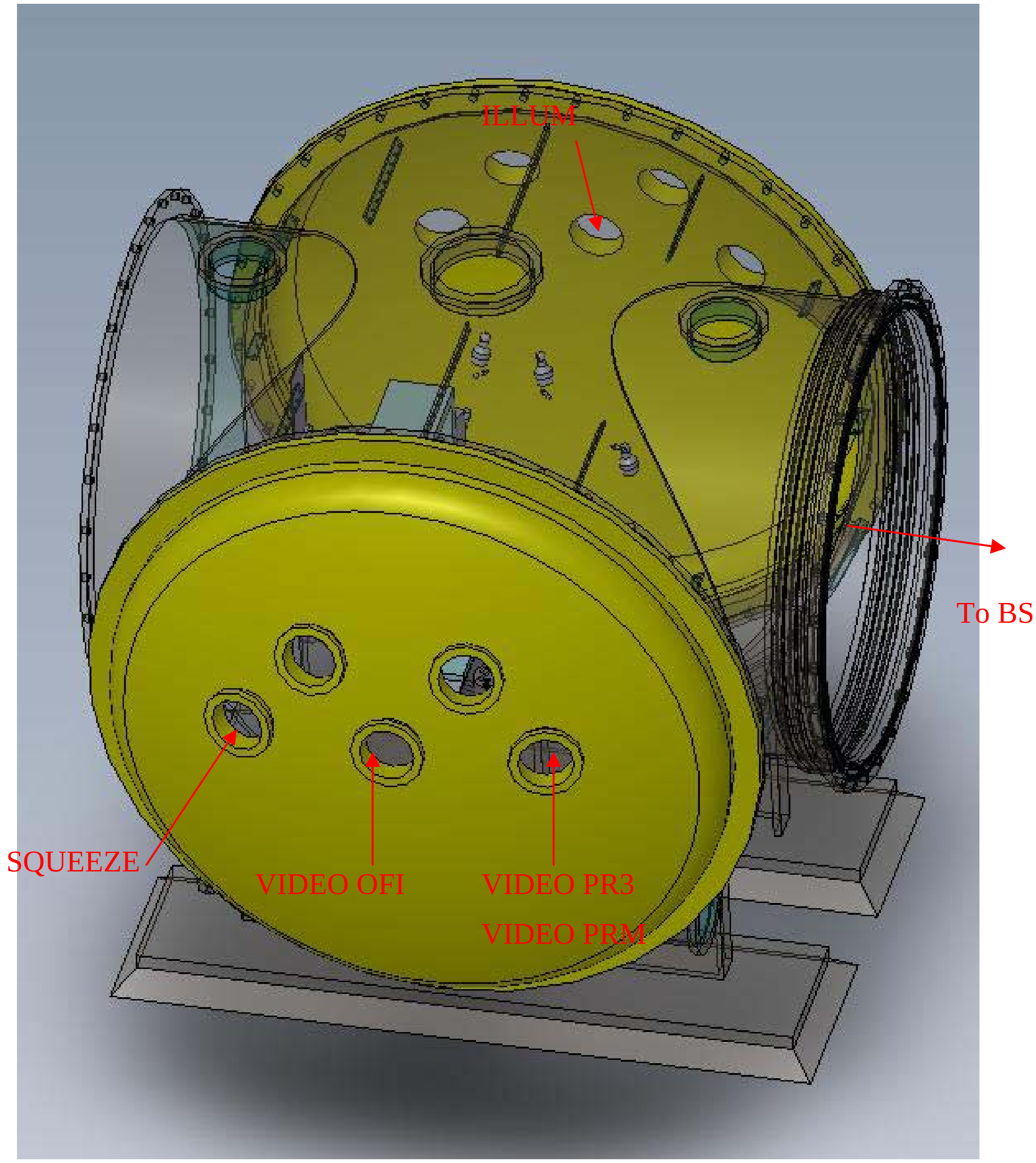

Figure 27: HAM5 Viewports

4.2.3.15 HAM6

TBD

4.2.3.16 MCA1

The locations of the MCA1 viewports are shown in Figure 28.

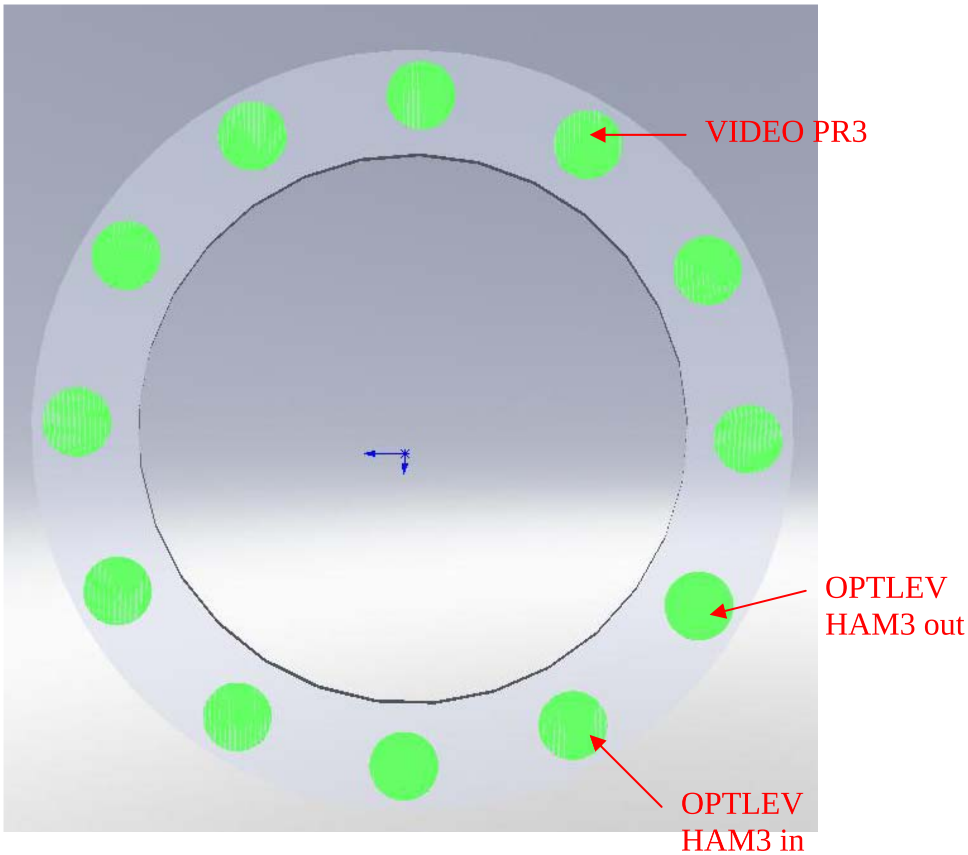

Figure 28: MCA1 Viewports

4.2.3.17 MCB1

The locations of the MCB1 viewports are shown in Figure 29.

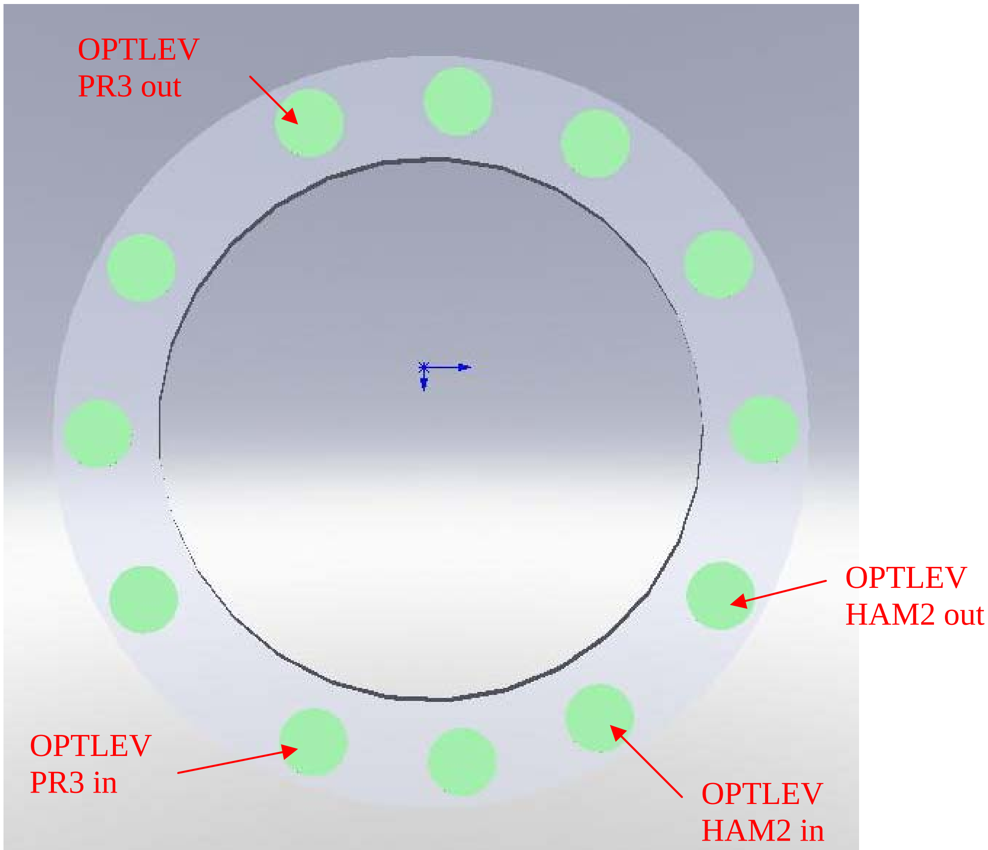

Figure 29: MCB1 Viewports

4.2.3.18 MCA2

The locations of the MCA2 viewports are shown in Figure 30.

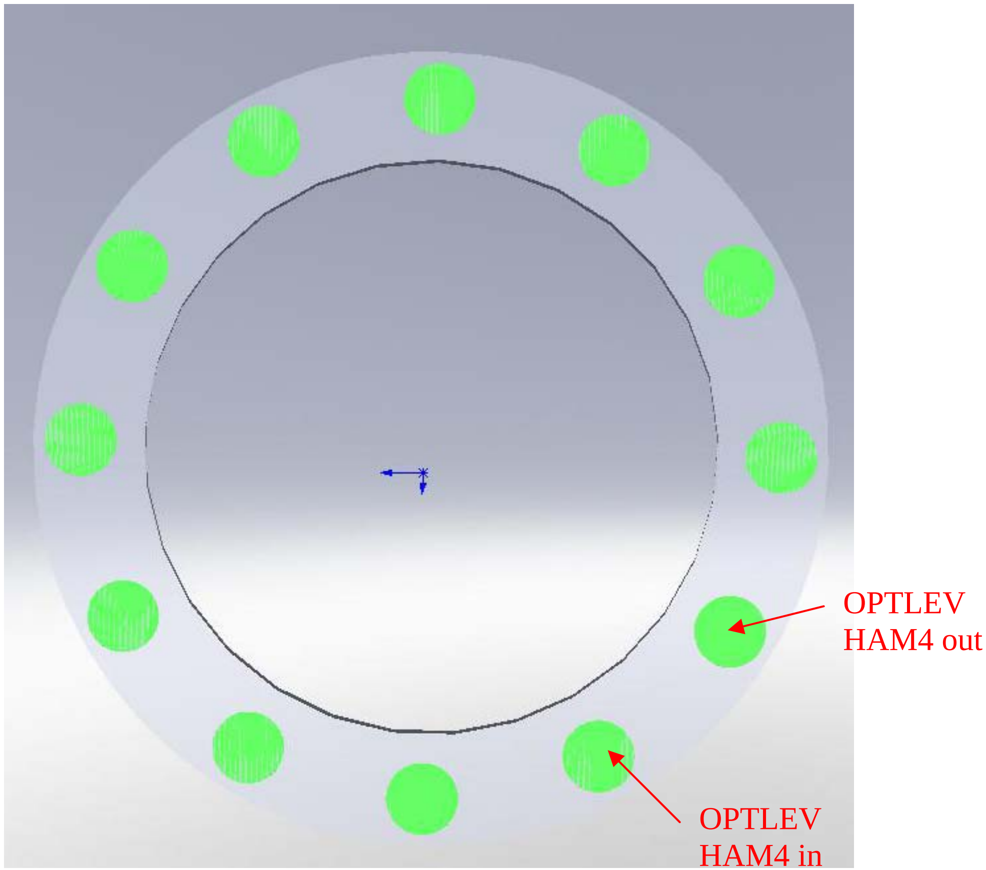

Figure 30: MCA2 Viewports

4.2.3.19 MCB2

The locations of the MCB2 viewports are shown in Figure 31.

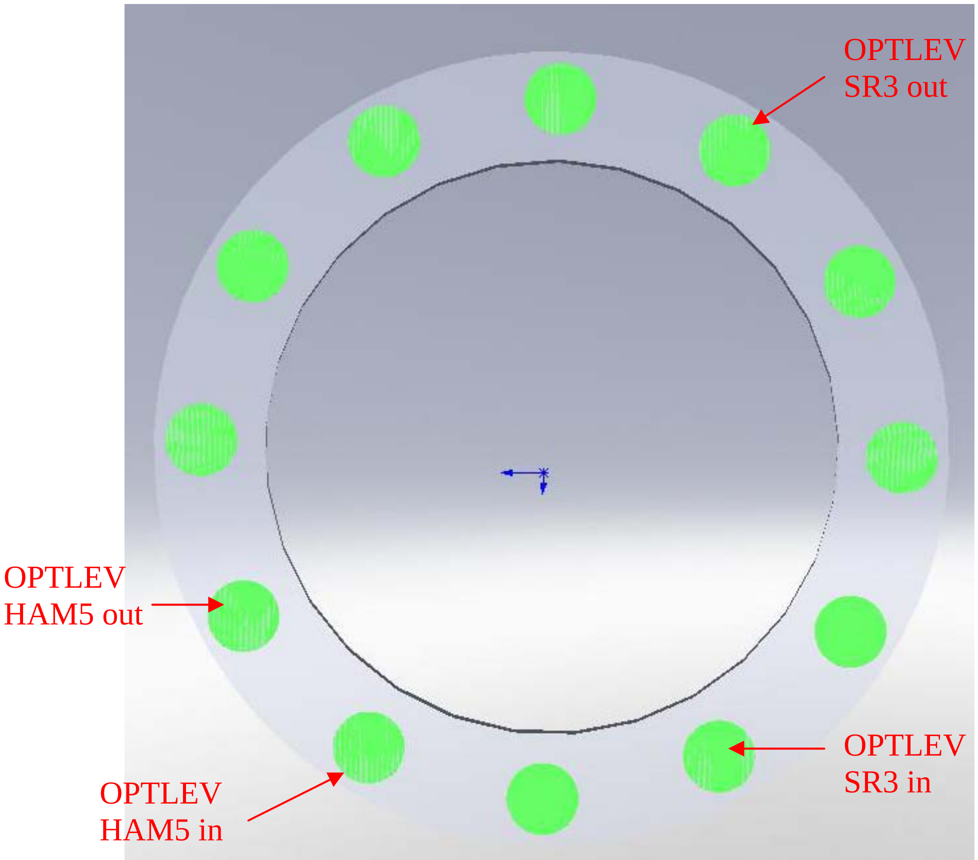

Figure 31: MCB2 Viewports

4.2.3.20 Septum In

The septum viewports between HAM1 and HAM 2 allow passage of 1) PSL input beam, 2) REFL beam, 3) POB reference beam, and 4) the Arm Length Stabilization beam.

The configuration of the septum plate will be identical to that of Enhanced LIGO. The positions of the viewports are TBD.

4.2.3.21 Septum Out

The septum viewports between HAM5 and HAM6 allow passage of the 1) Signal beam, 2) TBD beams. The septum plate and viewports that were installed in Enhanced LIGO will be re-used for aLIGO.

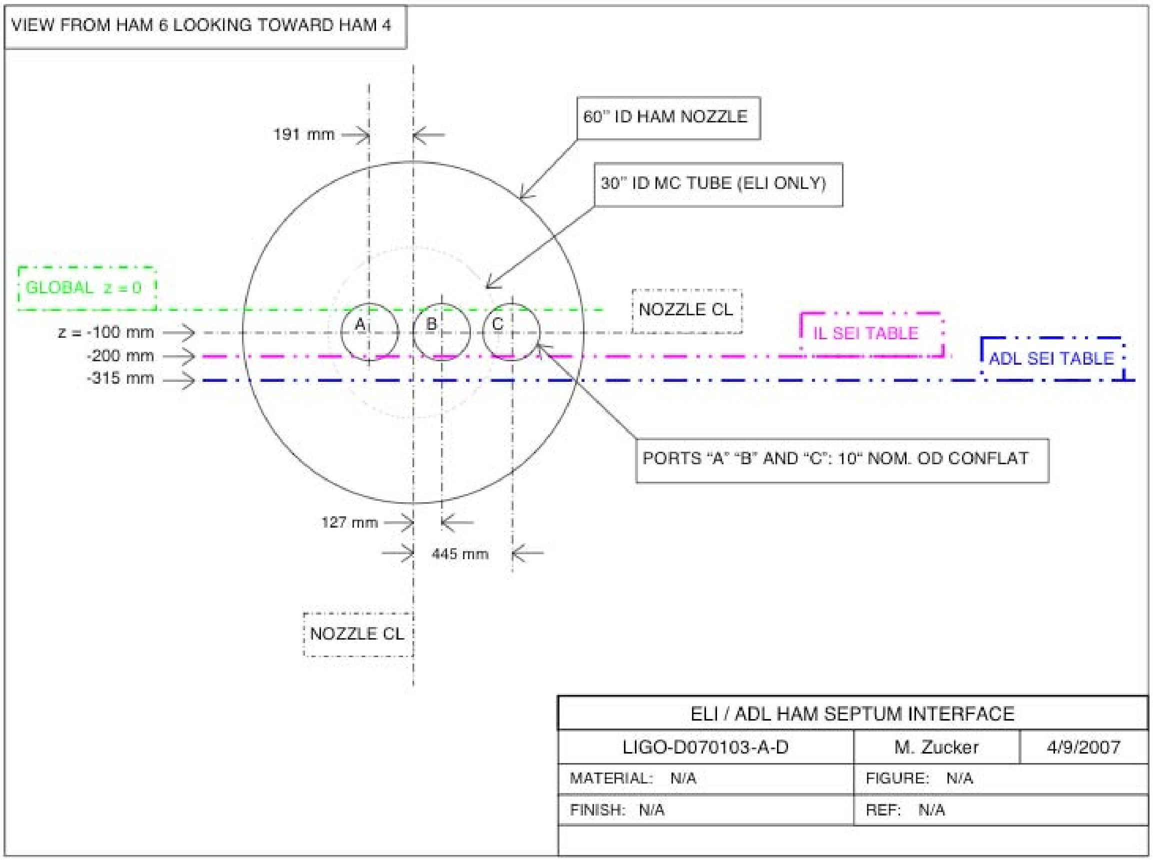

Figure 32: Septum Flange Interface Configuration

4.2.4 H2, Folded IFO

4.2.4.1 BSC4

The locations of the BSC4 viewports are shown in Figure 33.

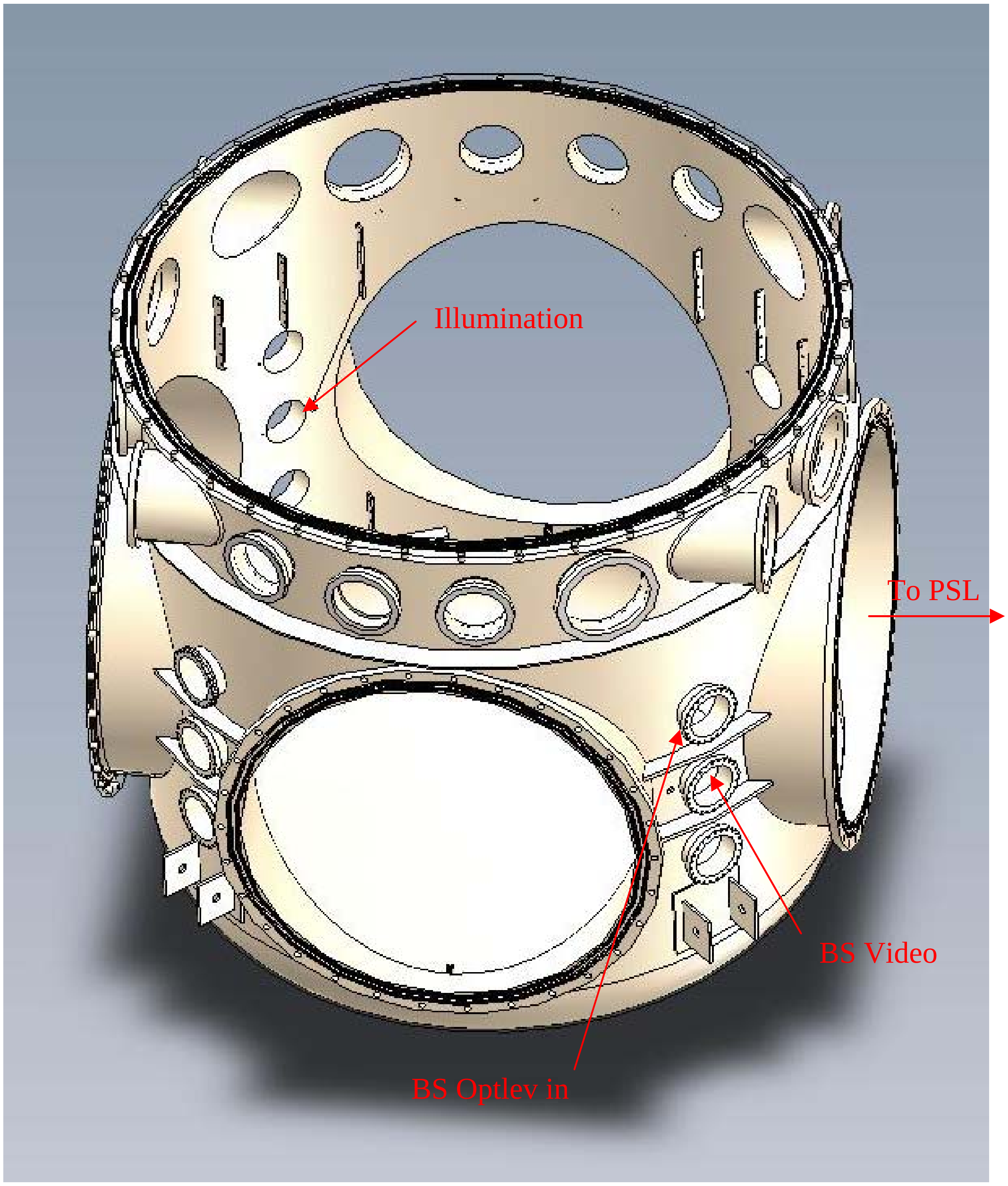

Figure 33: BSC4 Viewports

4.2.4.2 BSC7

The locations of the BSC7 viewports are shown in Figure 34.

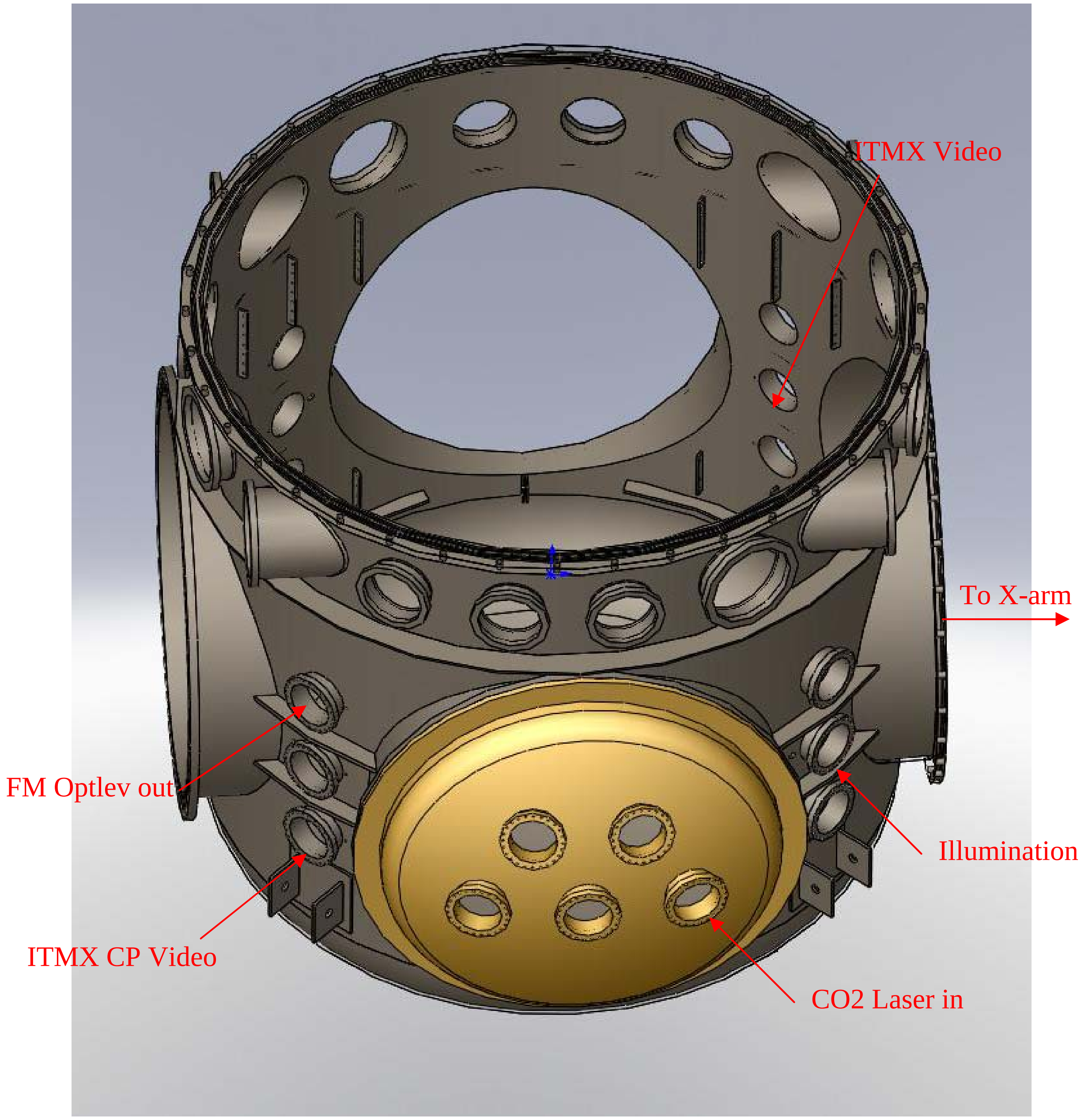

Figure 34: BSC7 Viewports

4.2.4.3 BSC7 A15 Adapter

The A15 adapter attaches to the BSC chamber, as shown in Figure 35.

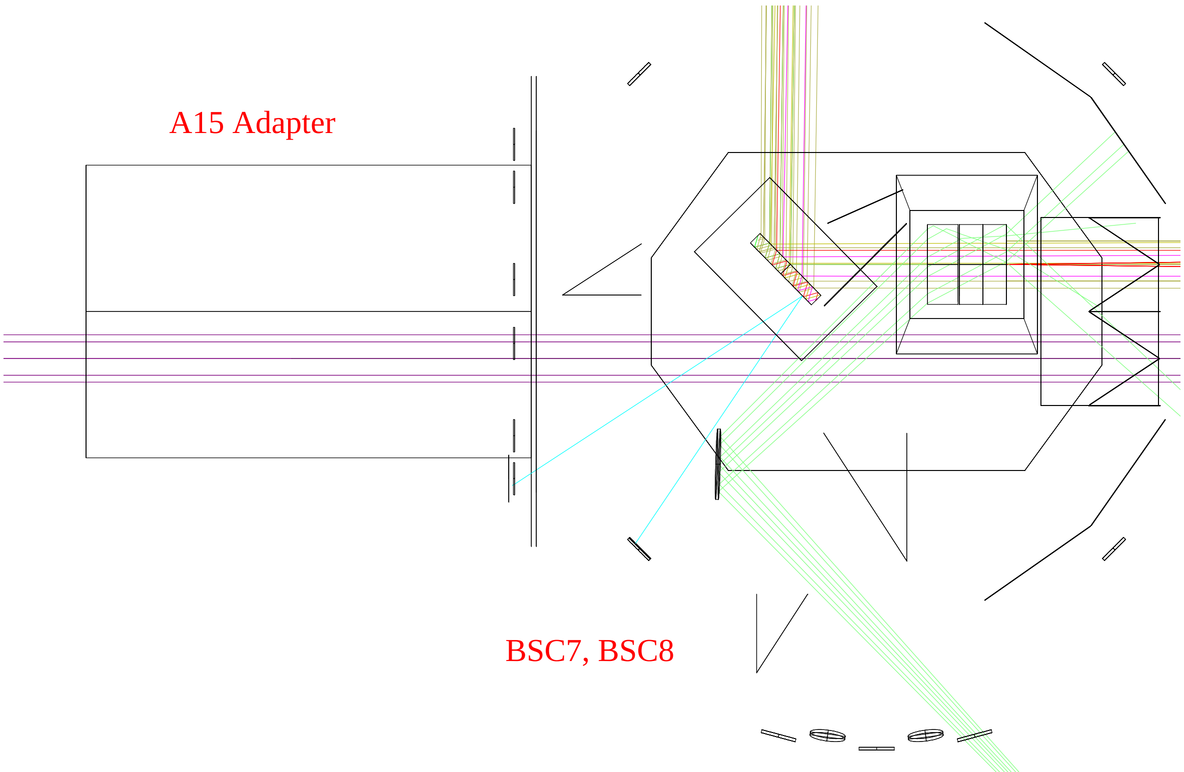

Figure 35: A15 Adapter Attaches to BSC 7 and BSC 8 Chambers

The locations of the BSC7 A15-A Adapter viewports are shown in Figure 36.

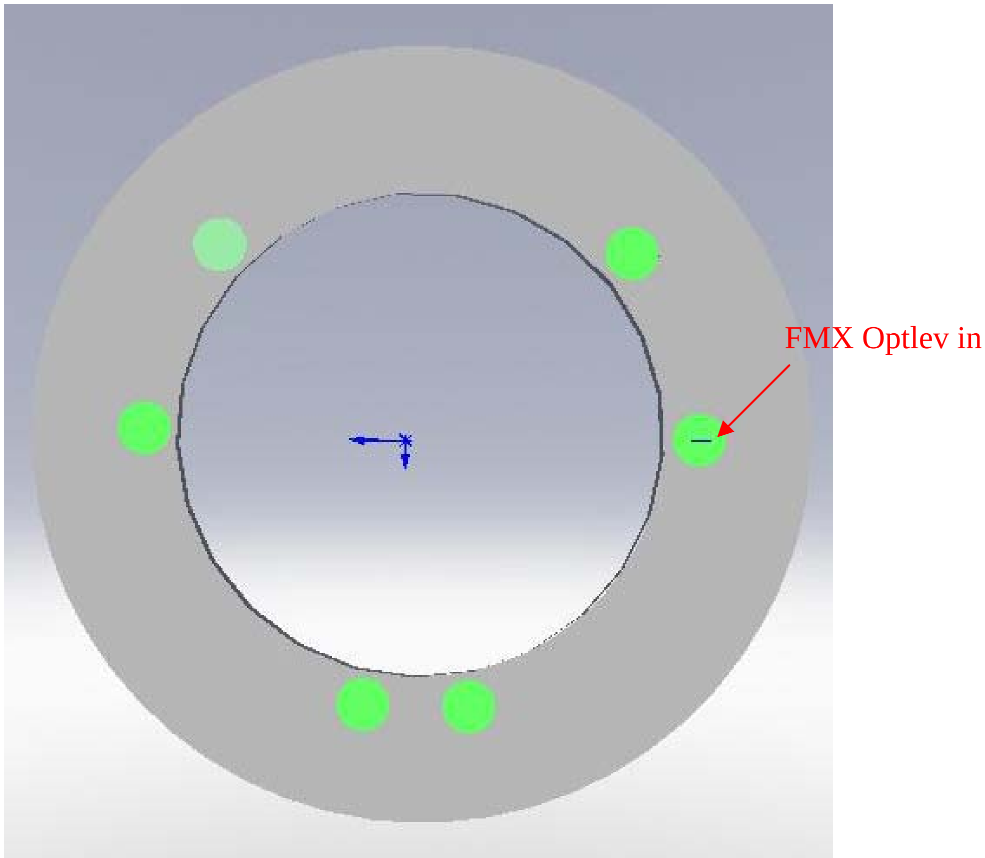

Figure 36: BSC7 A15-A Adapter

4.2.4.4 BSC8

The locations of the BSC8 viewports are shown in Figure 37.

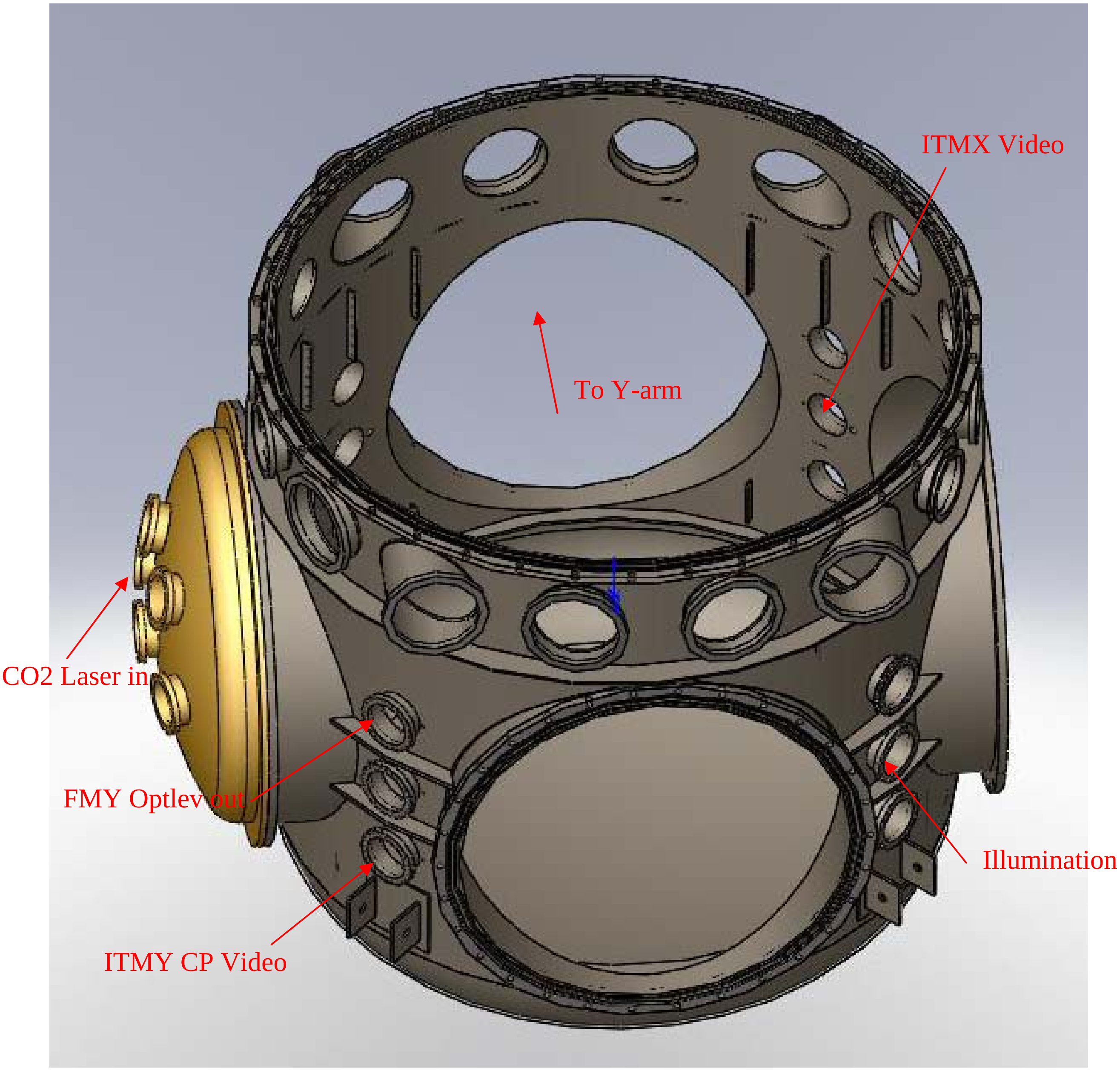

Figure 37: BSC8 Viewports

4.2.4.5 BSC8 A15-B Adapter

The locations of the BSC8 A15-B Adapter viewports are shown in Figure 38.

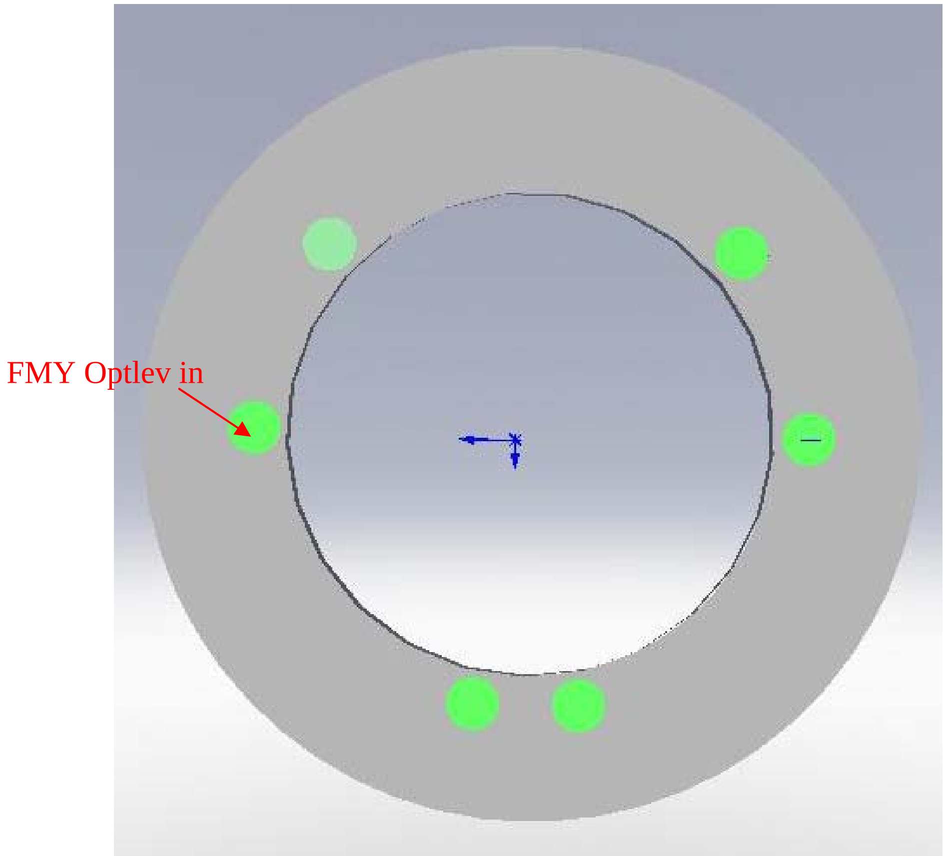

Figure 38: BSC8 A15-B Adapter

4.2.4.6 BSC5

The locations of the BSC5 viewports are shown in Figure 39.

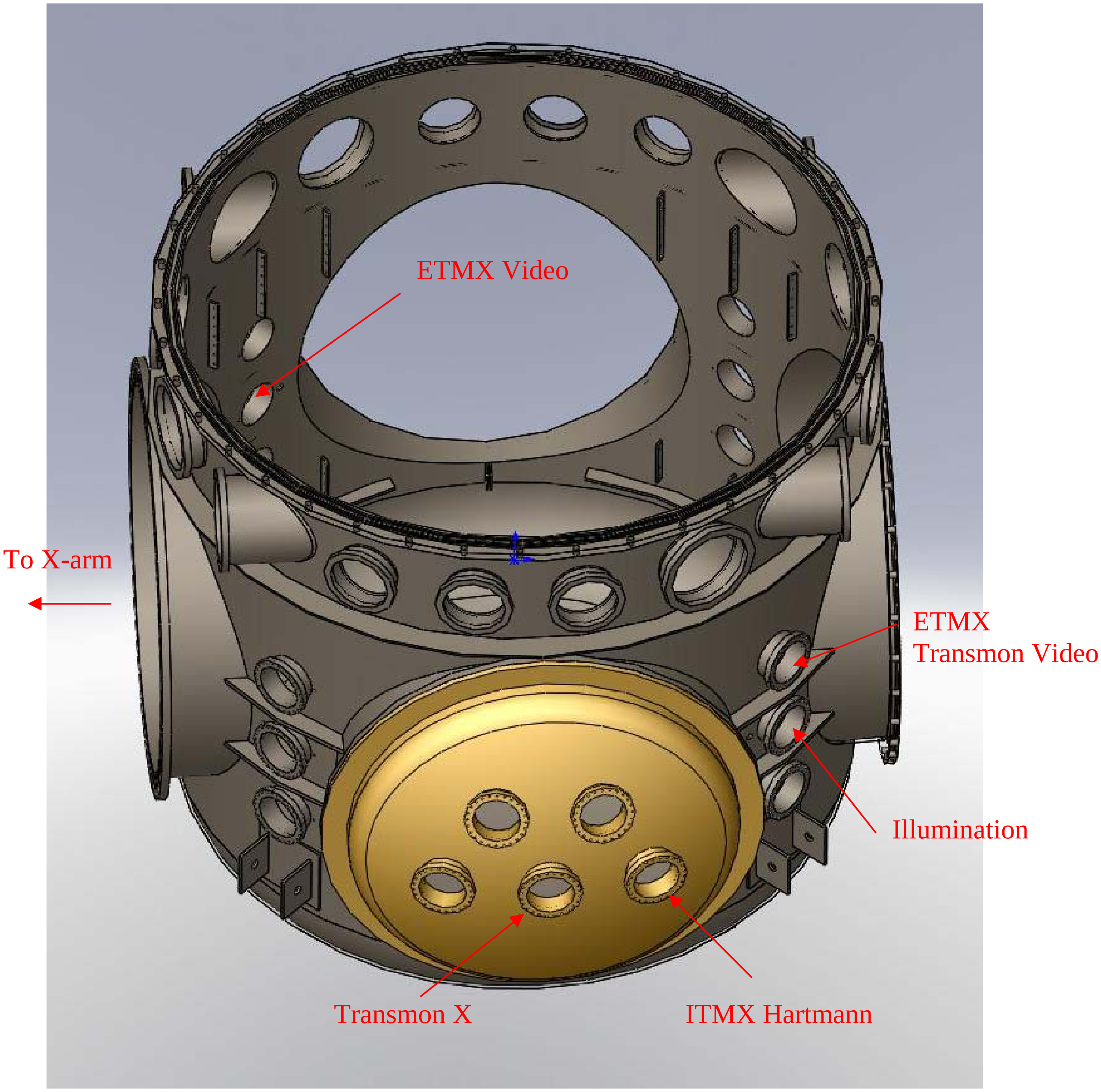

Figure 39: BSC5 Viewports

4.2.4.7 BSC6

The locations of the BSC5 viewports are shown in Figure 40.

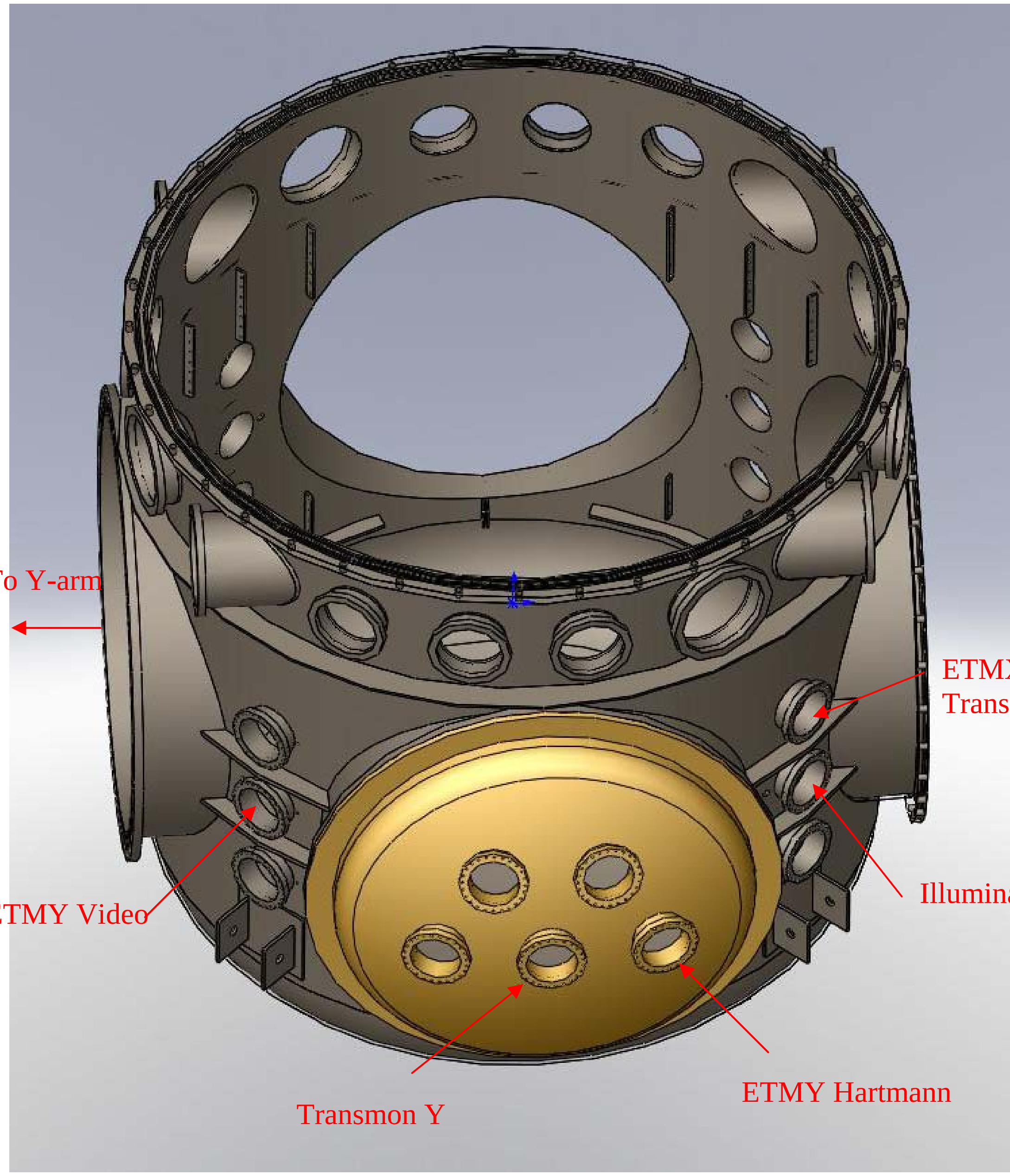

Figure 40: BSC6 Viewports

4.2.4.8 ITMX A1-A FLANGE

The locations of the ITMX A1-A FLANGE viewports are shown in Figure 41.

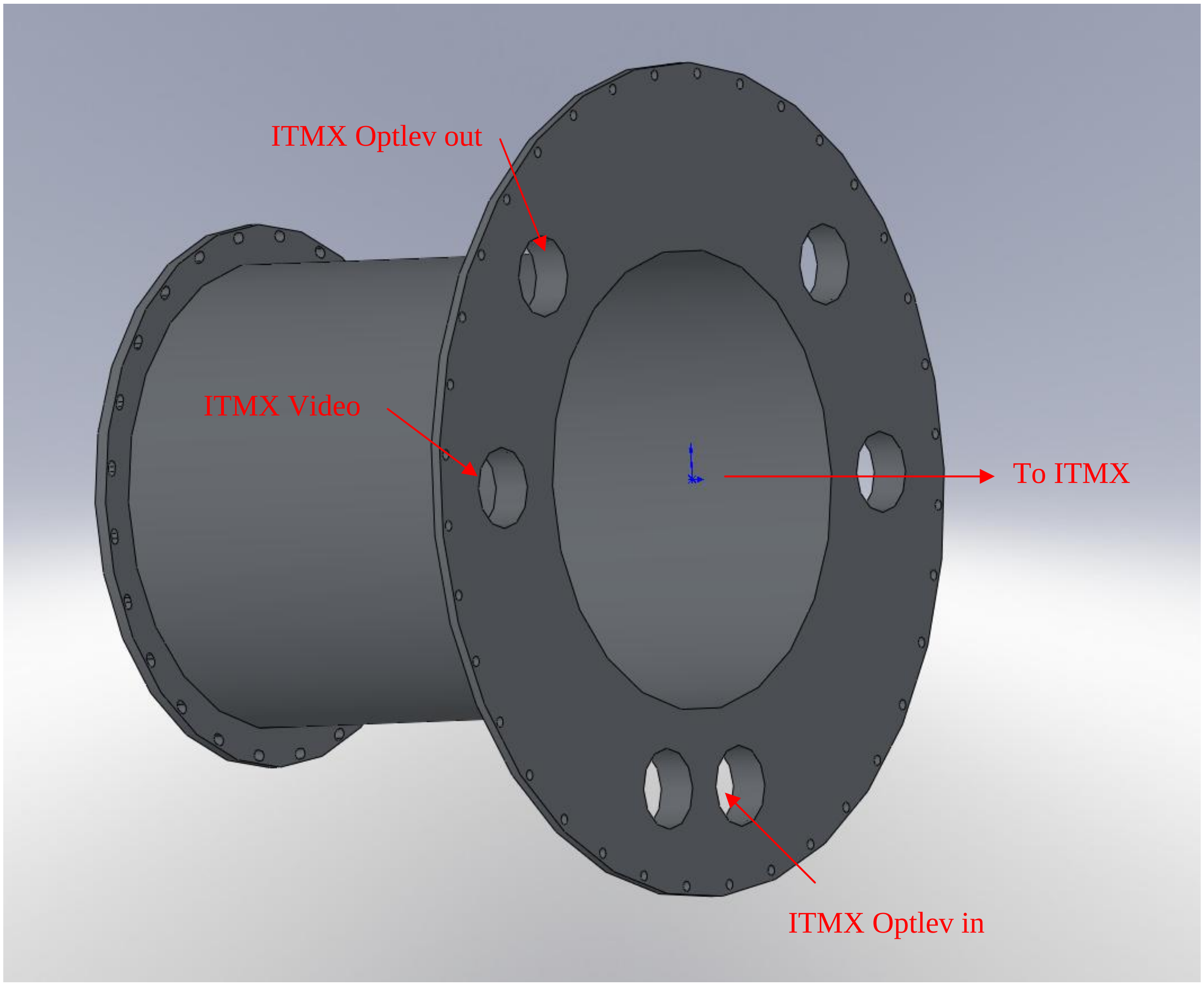

Figure 41: ITMX A1-A Adapter

4.2.4.9 ITMY A1-B FLANGE

The locations of the ITMY A1-B FLANGE viewports are shown in Figure 42.

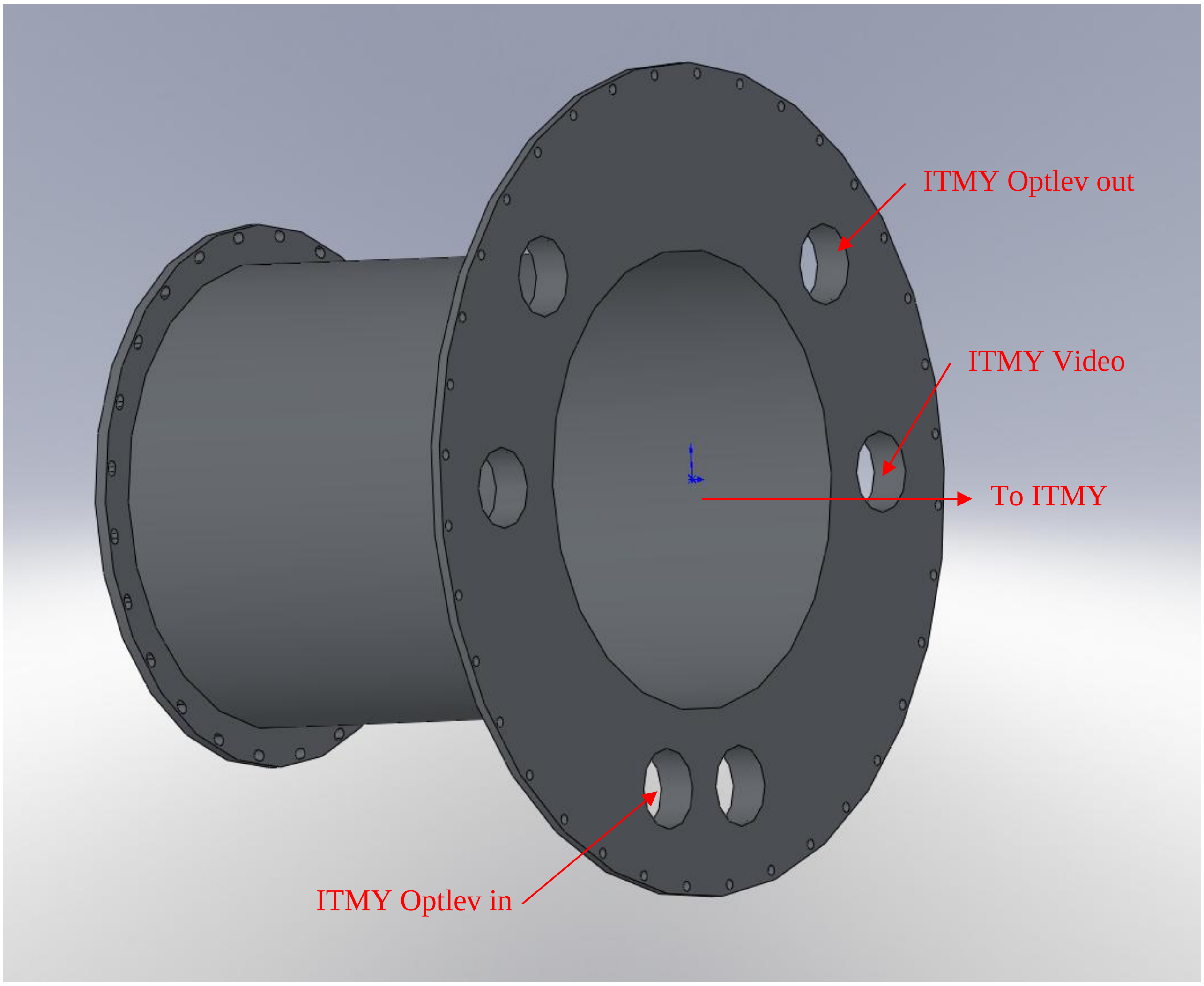

Figure 42: ITMY A1-B Adapter

4.2.4.10 ETMX D0900954 Flat Faced Flange

The locations of the ETMX D0900954 Flat Faced Flange viewports are shown in Figure 43.

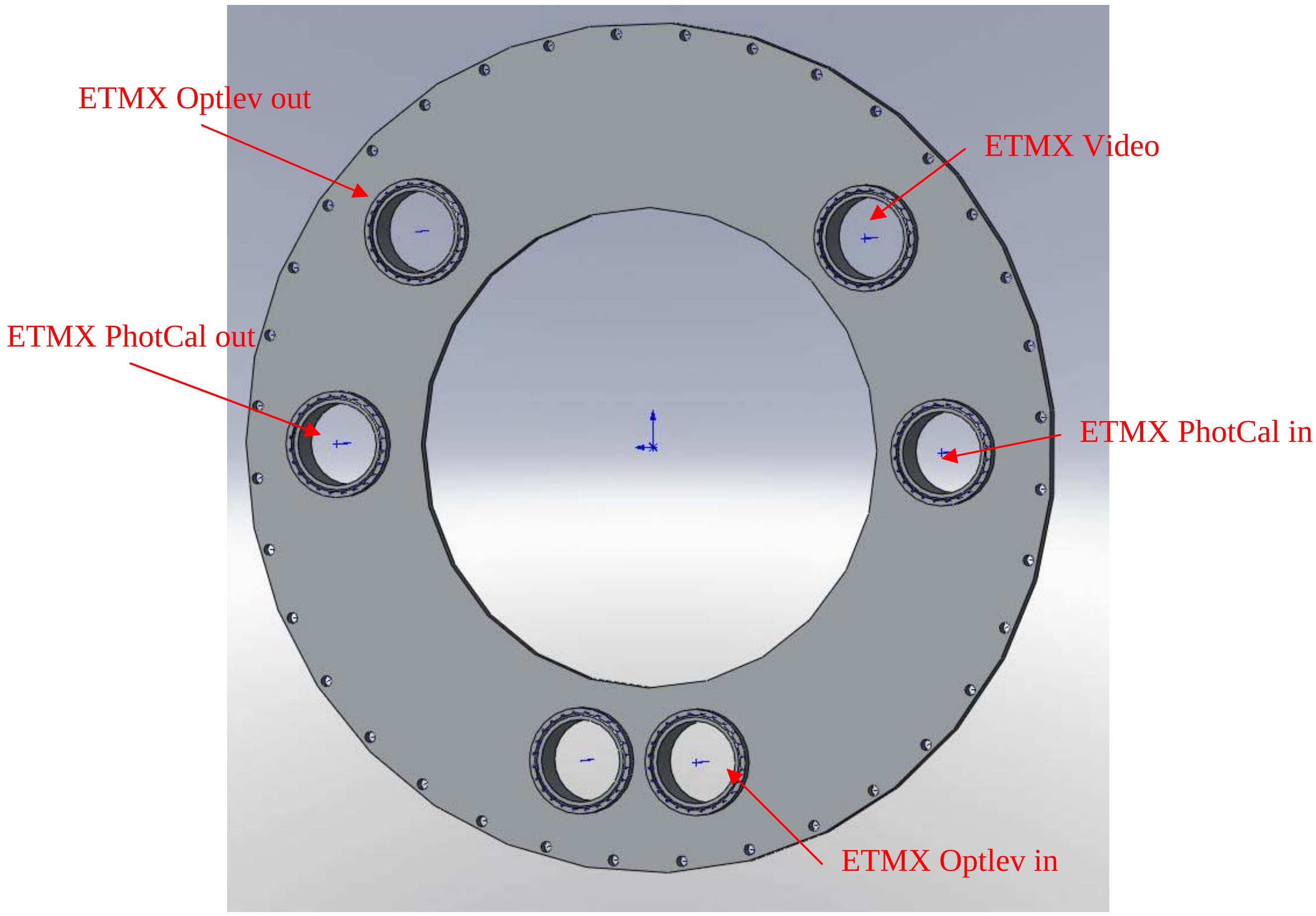

Figure 43: ETMX D0900954 Flat Faced Flange

4.2.4.11 ETMY D0900954 Flat Faced Flange

The locations of the ETMY D0900954 Flat Faced Flange viewports are shown in Figure 44.

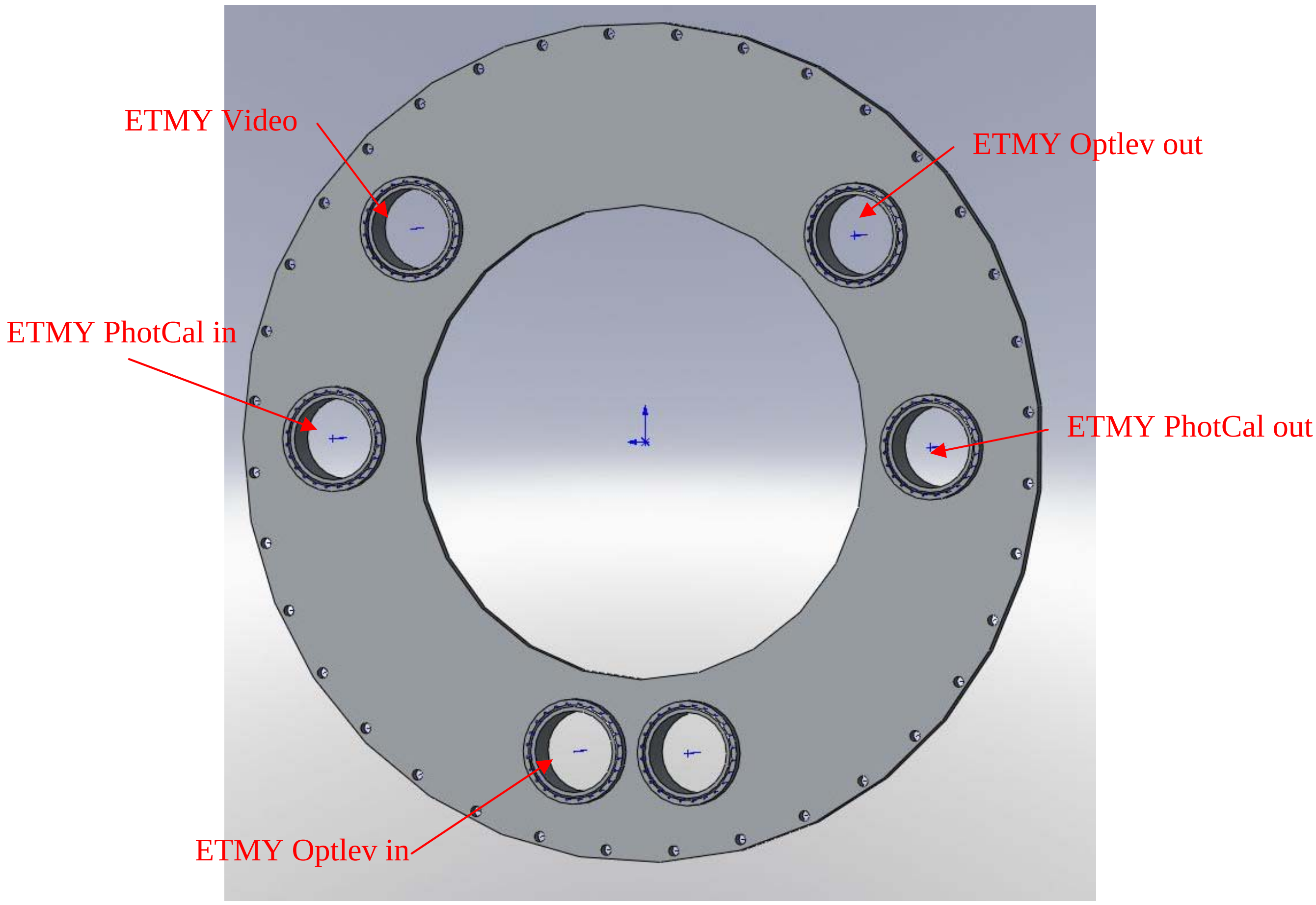

Figure 44: ETMY D0900954 Flat Faced Flange

4.2.4.12 HAM7

TBD

4.2.4.13 HAM8

The locations of the HAM8 viewports are shown in Figure 45.

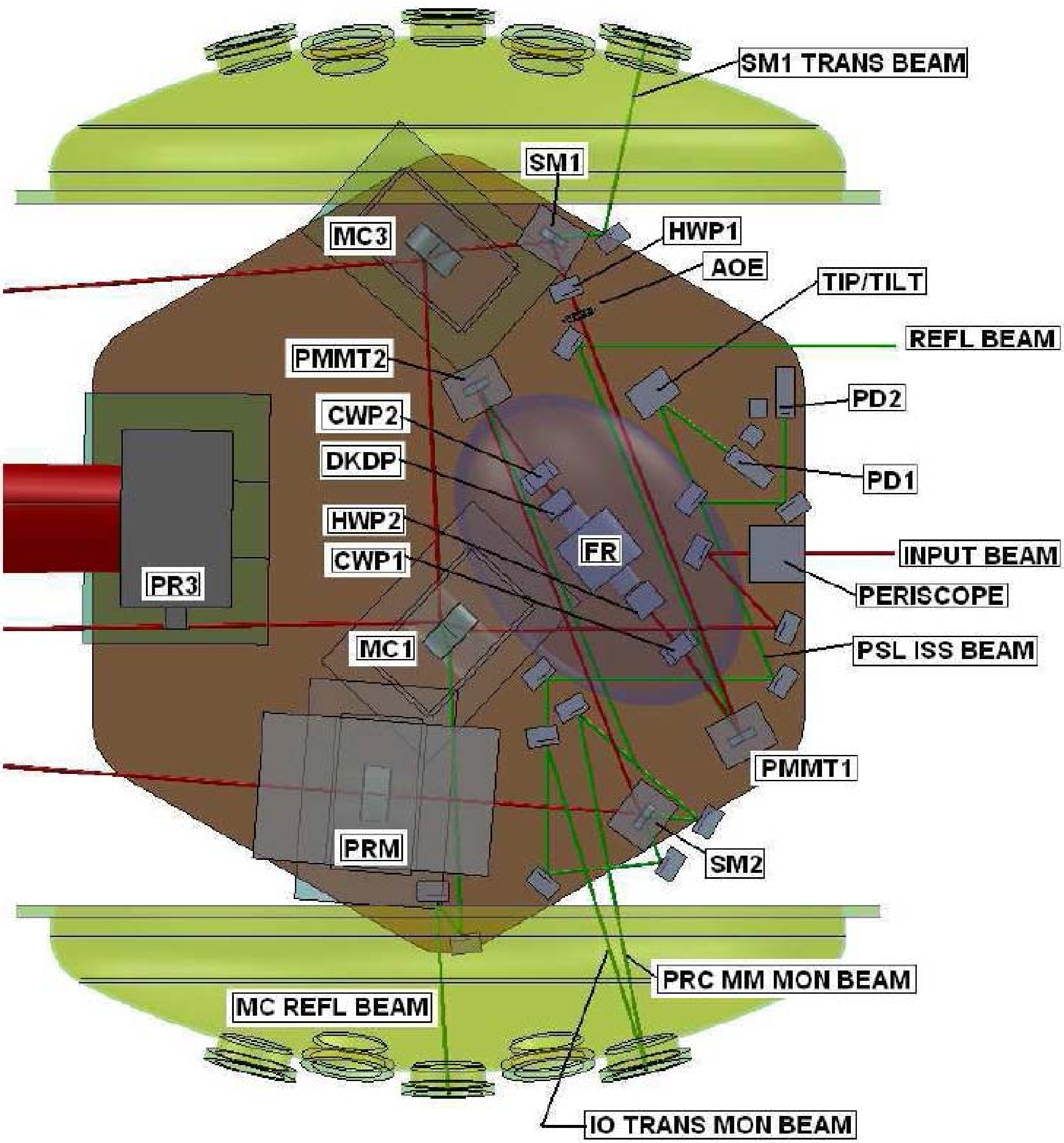

Figure 45: HAM8 Viewports

4.2.4.14 HAM9

The locations of the HAM9 viewports are shown in Figure 46.

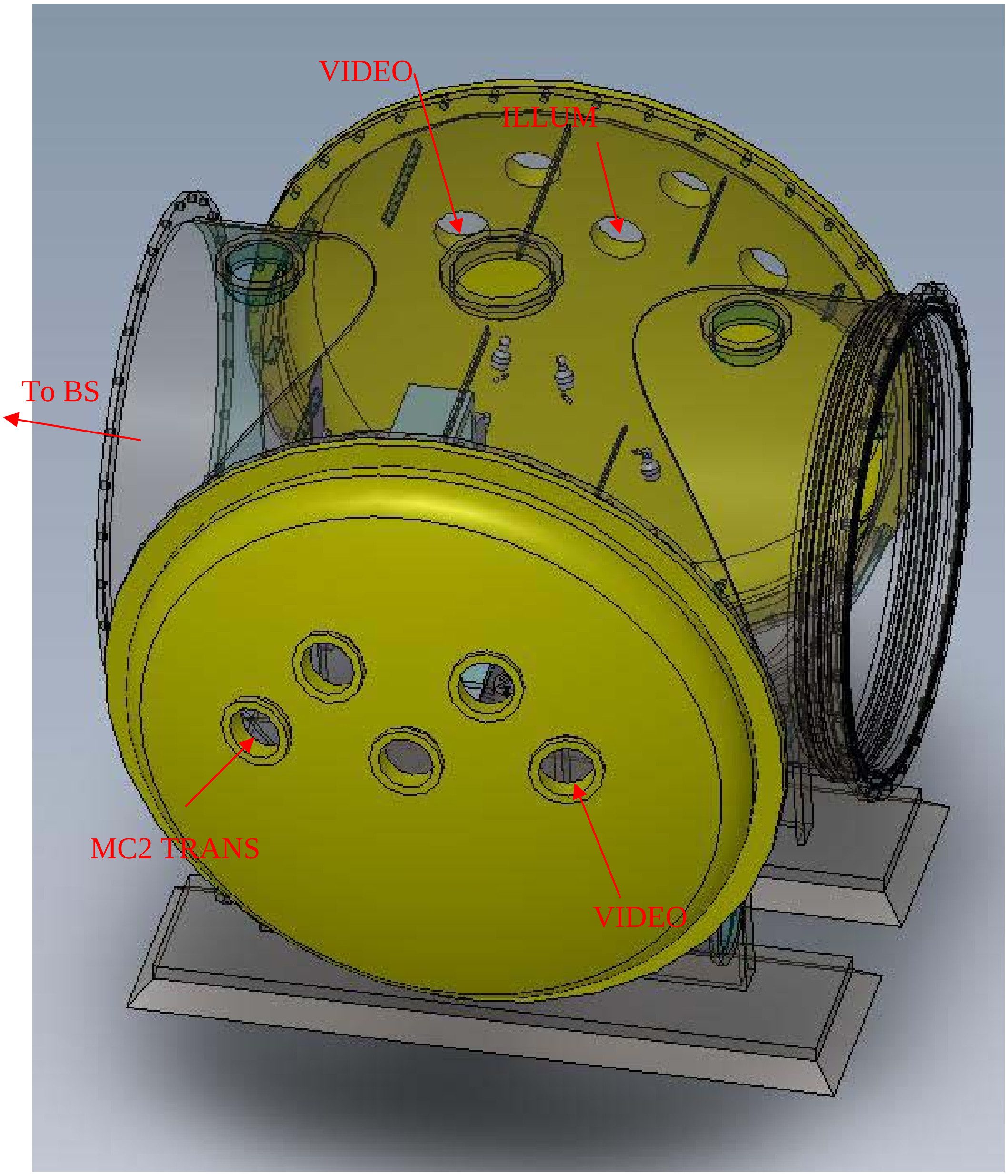

Figure 46: HAM9 Viewports

4.2.4.15 HAM10

The locations of the HAM10 viewports are shown in Figure 47.

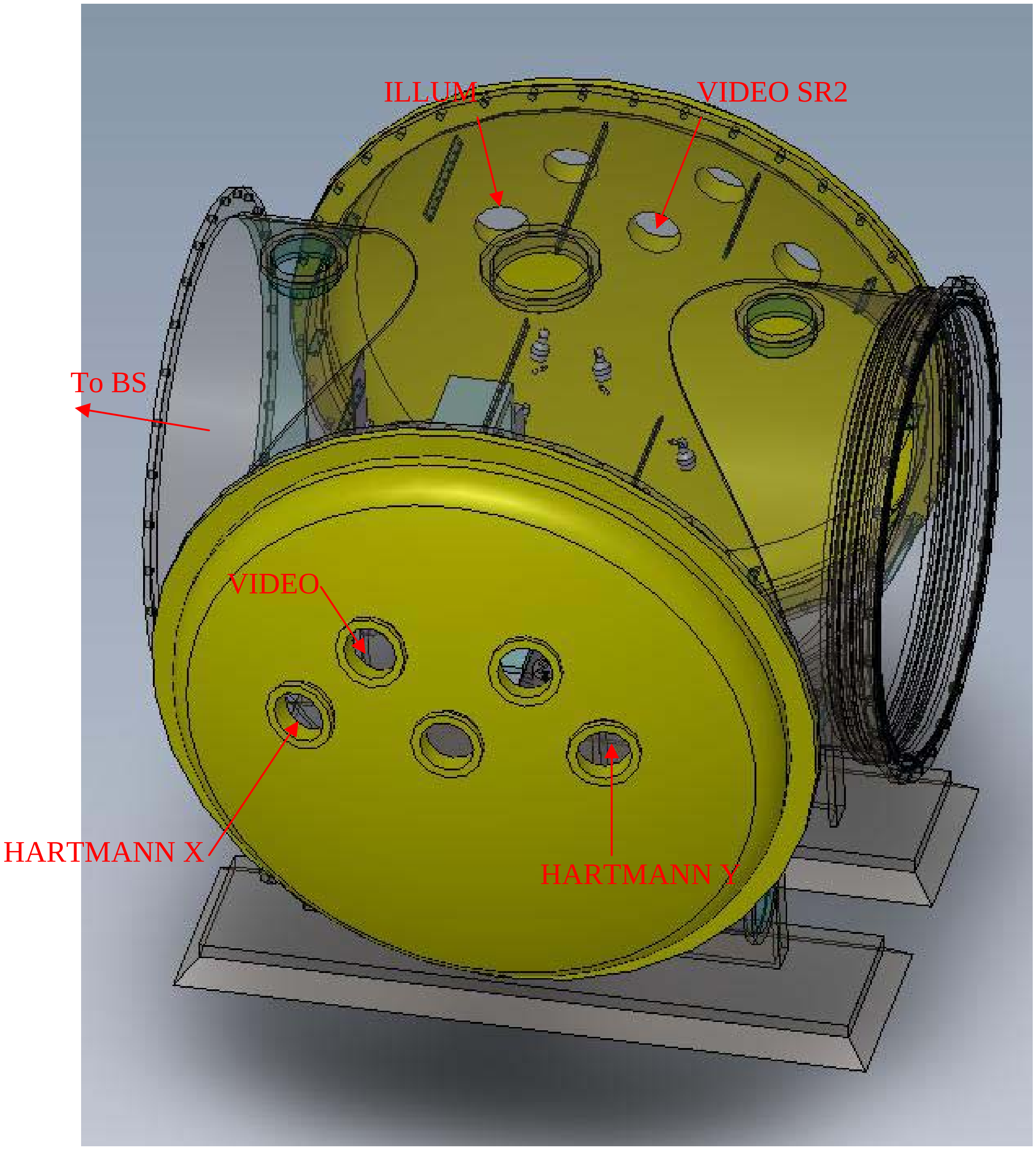

Figure 47: HAM10 Viewports

4.2.4.16 HAM11

The locations of the HAM11 viewports are shown in Figure 48.

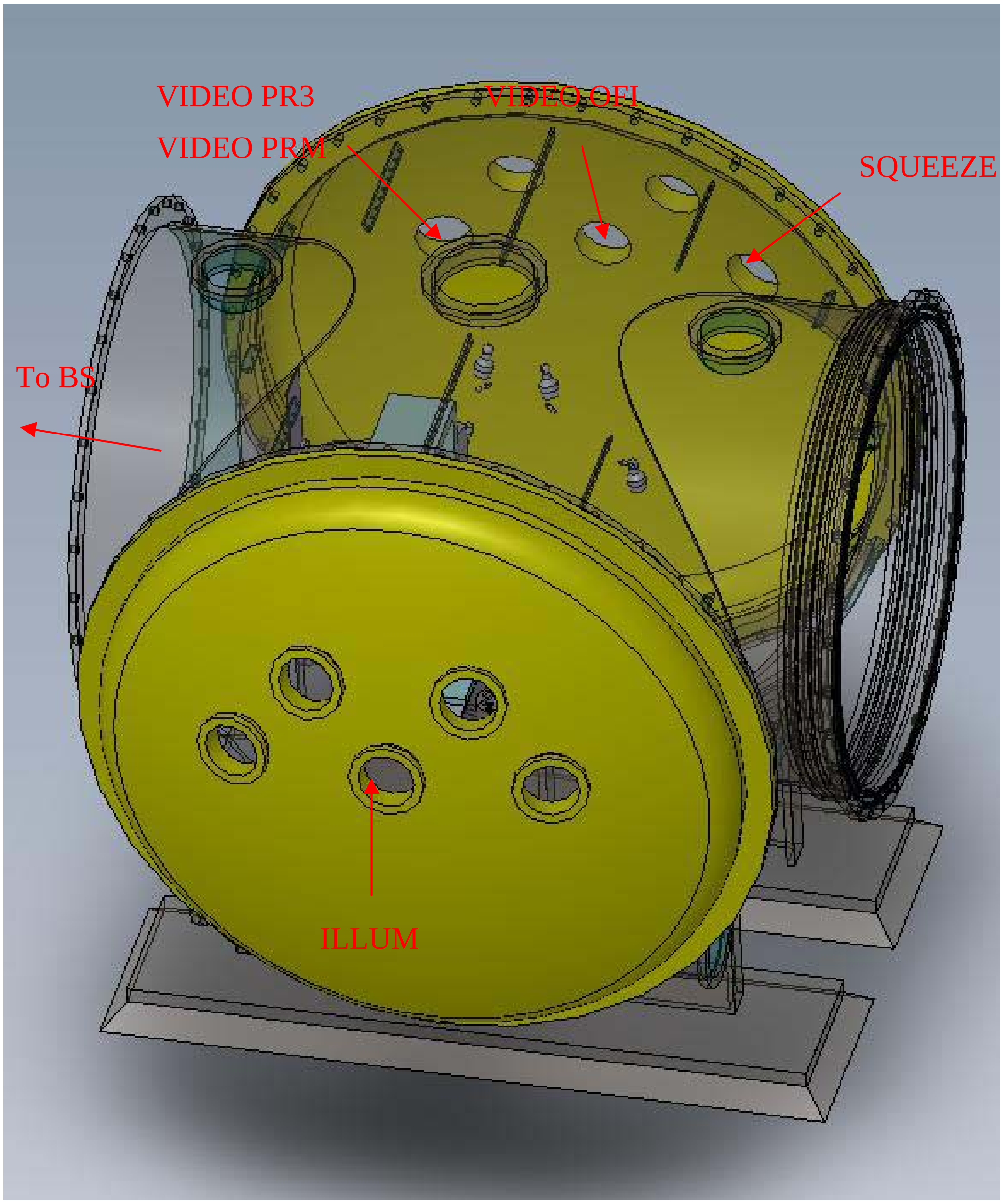

Figure 48: HAM11 Viewports

4.2.4.17 HAM12

TBD

4.2.4.18 MCA3

The locations of the MCA3 viewports are shown in Figure 49.

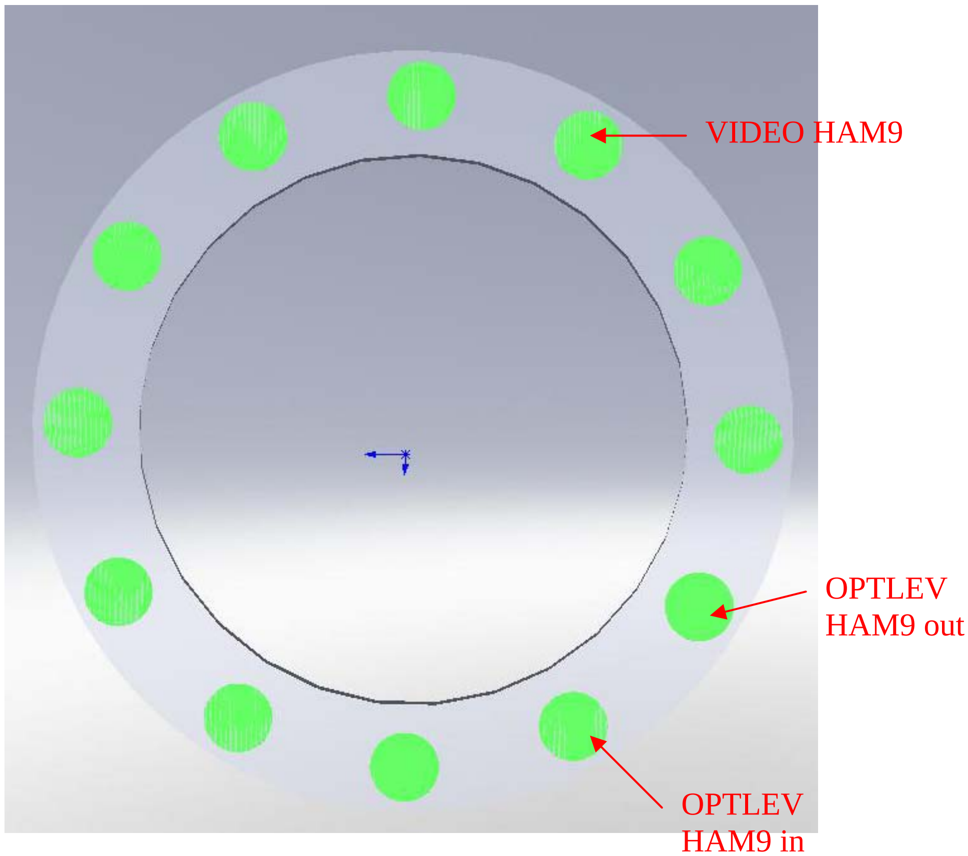

Figure 49: MCA3 Viewports

4.2.4.19 MCB3

The locations of the MCB3 viewports are shown in Figure 50.

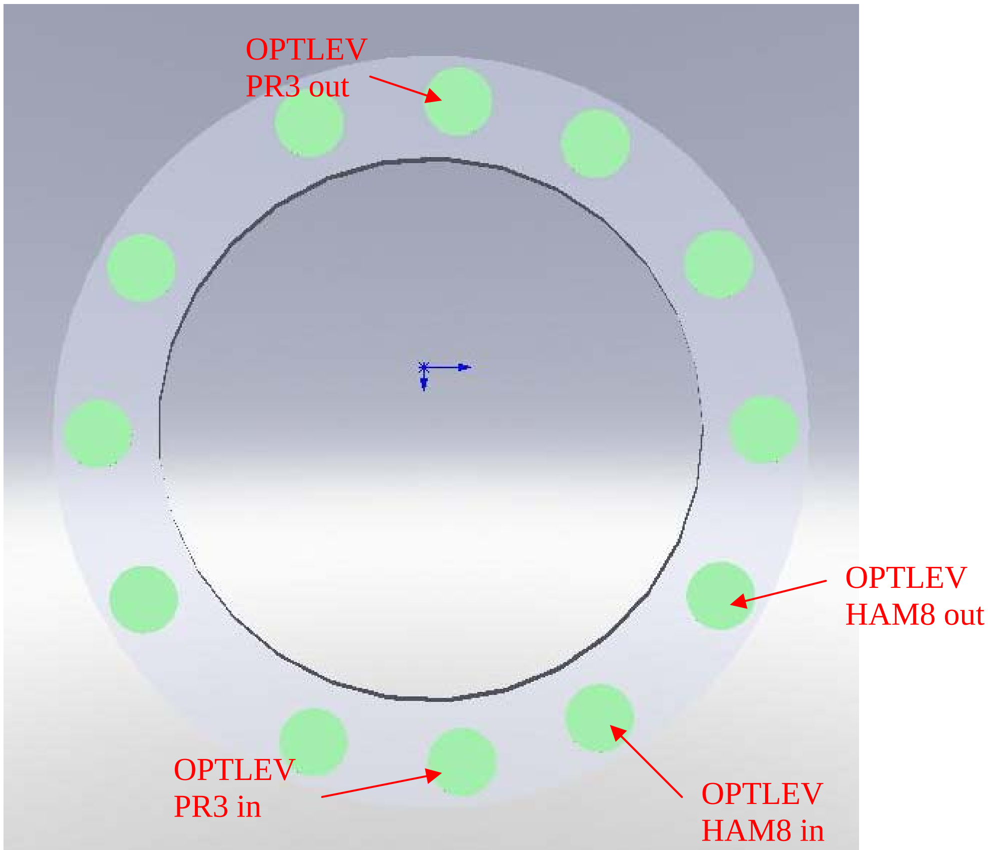

Figure 50: MCB3 Viewports

4.2.4.20 MCA4

The locations of the MCA4 viewports are shown in Figure 51.

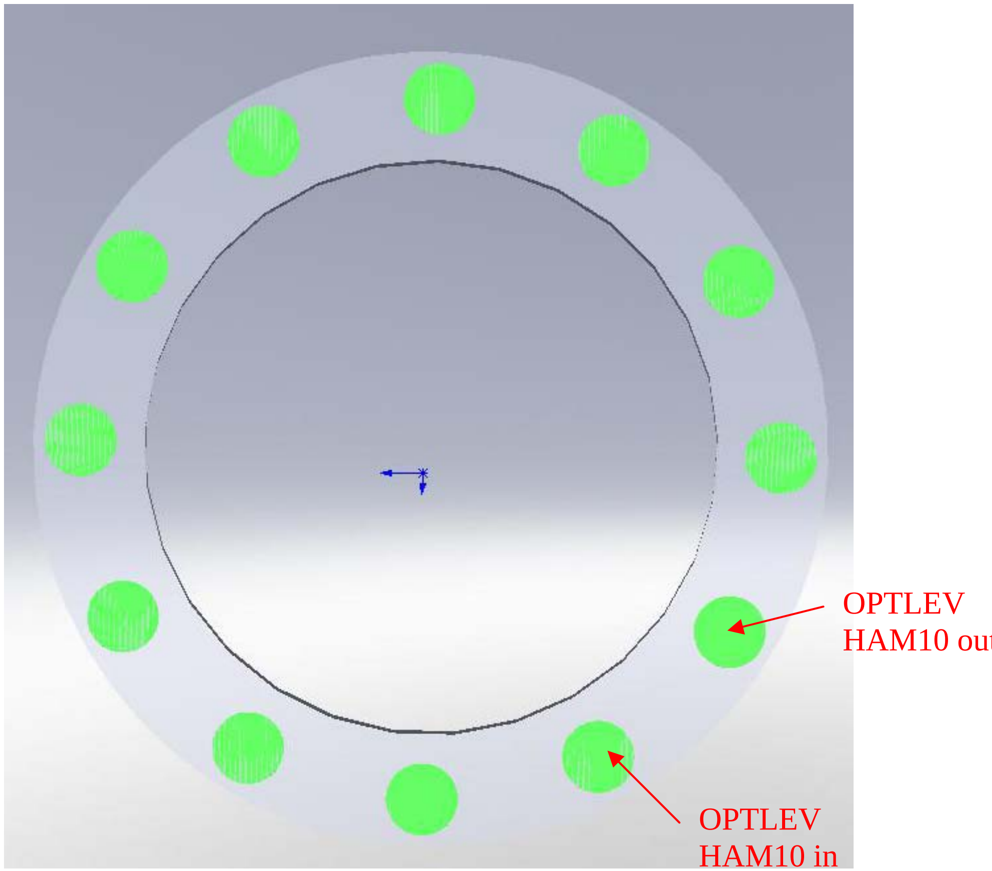

Figure 51: MCA4 Viewports

4.2.4.21 MCB4

The locations of the MCB4 viewports are shown in Figure 52.

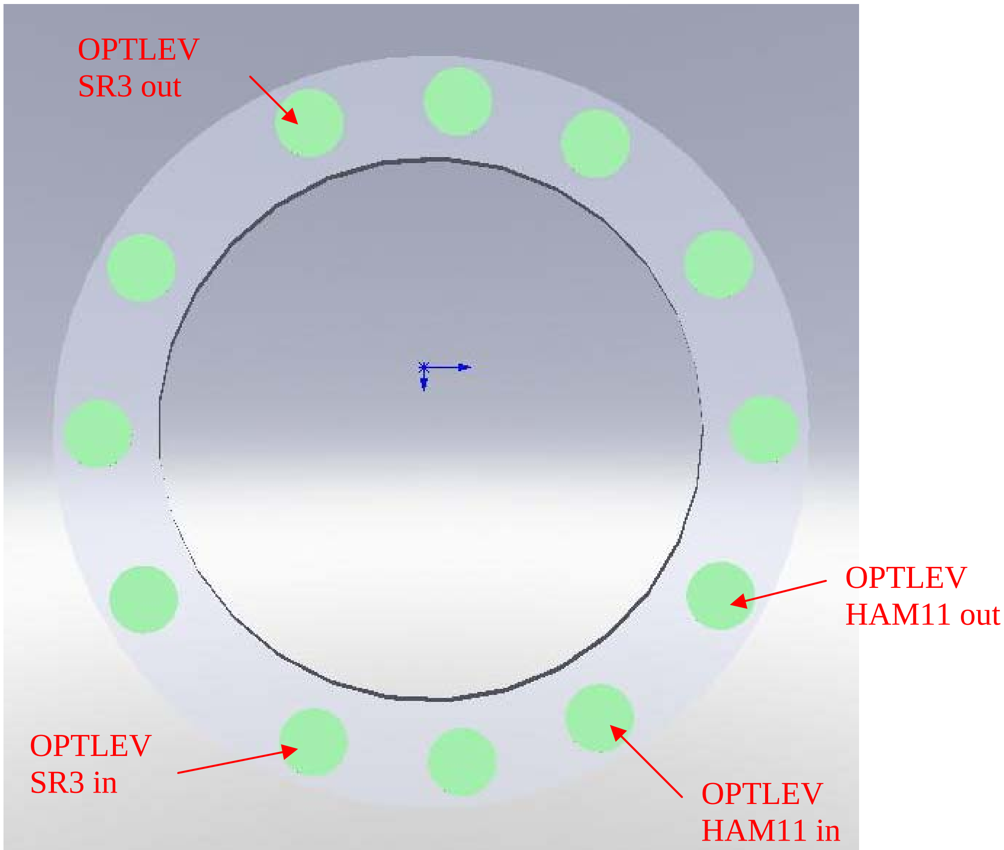

Figure 52: MCB4 Viewports

4.2.4.22 Septum In

The septum viewports between HAM7 and HAM8 allow passage of 1) PSL input beam, 2) REFL beam, 3) POB reference beam, and 4) the Arm Length Stabilization beam.

The configuration of the septum plate will be identical to that of Enhanced LIGO. The positions of the viewports are TBD.

4.2.4.23 Septum Out

The septum viewports between HAM11 and HAM12 allow passage of the 1) Signal beam, 2) TBD beams. The design of the septum plate and the positions of the viewports will be identical to that of Enhanced LIGO.

4.2.5 Summary of Viewports

The viewport descriptions for H1, H2, and L1 interferometers are presented in the following tables.

Table 1: H1 Viewports

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H1	BSC1	G2	illuminator	BSC1 CHAMBER	5.4 DIA VP800/450009
H1	BSC1	CXG3	TCS	CO2 LASER	TCS, P/N 414494
H1	BSC1	G1	VIDEO	ITMY video	5.4 DIA VP800-AR1064
H1	BSC1	G11	VIDEO	ITMY CP video	5.4 DIA VP800-AR1064
H1	BSC10	CXG4	HARTMANN	ETMY HARTMANN	5.4 DIA VP800-AR532
H1	BSC10	G8	illuminator	BSC10 CHAMBER	5.4 DIA VP800/450009
H1	BSC10	CXG5	TRANSMON	TRANSMON Y	5.4 DIA VP800-AR1064/532
H1	BSC10	G2	VIDEO	ETMY video	5.4 DIA VP800-AR1064
H1	BSC2	G2	illuminator	BSC2 CHAMBER	5.4 DIA VP800/450009
H1	BSC2	G9	OPTLEVER	BS optlev in	7.8 DIA, ISI 4.9722012
H1	BSC2	G8	VIDEO	BS video	5.4 DIA VP800-AR1064
H1	BSC3	G11	illuminator	BSC3 CHAMBER	5.4 DIA VP800/450009
H1	BSC3	CXG5	TCS	CO2 LASER	TCS, P/N 414494
H1	BSC3	G1	VIDEO	ITMX CP video	5.4 DIA VP800-AR1064
H1	BSC3	G10	VIDEO	ITMX video	5.4 DIA VP800-AR1064
H1	BSC9	CXG4	HARTMANN	ETMX HARTMANN	5.4 DIA VP800-AR532
H1	BSC9	G8	illuminator	BSC9 CHAMBER	5.4 DIA VP800/450009
H1	BSC9	CXG5	TRANSMON	TRANSMON X	5.4 DIA VP800-AR1064/532
H1	BSC9	G11	VIDEO	ETMX video	5.4 DIA VP800-AR1064
H1	BSC9	G9	VIDEO	ETMX Transmon video	5.4 DIA VP800-AR1064
H1	ETM A1-A FLANGE	VP1	OPTLEVER	ETMX optlev out	7.8 DIA, ISI 4.9722012
H1	ETM A1-A FLANGE	VP4	OPTLEVER	ETMX optlev in	6.0 in Optlev
H1	ETM A1-A FLANGE	VP2	PHOTOCAL	ETMX photon cal out	6.0 in Optlev
H1	ETM A1-A FLANGE	VP5	PHOTOCAL	ETMX photon cal in	6.0 in Optlev
H1	ETM A1-A FLANGE	VP6	VIDEO	ETMX video	5.4 DIA VP800-AR1064
H1	ETM A1-B FLANGE	VP3	OPTLEVER	ETMY optlev in	6.0 in Optlev

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H1	ETM A1-B FLANGE	VP6	OPTLEVER	ETMY optlev out	7.8 DIA, ISI 4.9722012
H1	ETM A1-B FLANGE	VP2	PHOTOCAL	ETMY photon cal in	6.0 in Optlev
H1	ETM A1-B FLANGE	VP5	PHOTOCAL	ETMY photon cal out	6.0 in Optlev
H1	ETM A1-B FLANGE	VP1	VIDEO	ETMY video	5.4 DIA VP800-AR1064
H1	HAM1	A1F4	illuminator	HAM1 CHAMBER	5.4 DIA VP800/450009
H1	HAM1	A1F5	TBD		
H1	HAM1	A2F3	TBD		
H1	HAM1	A2F4	TBD		
H1	HAM1	A2F5	TBD		
H1	HAM1	BF2	TBD		
H1	HAM1	BF3	TBD		
H1	HAM1	A1F1	VIDEO	PMMT2	5.4 DIA VP800-AR1064
H1	HAM1	BF1	VIDEO	PMMT2	5.4 DIA VP800-AR1064
H1	HAM2	A1F5	DIAGNOSTIC	SM1 TRANS BEAM	5.4 DIA VP800-AR1064
H1	HAM2	A2F3	DIAGNOSTIC	PRC MM MON BEAM	5.4 DIA VP800-AR1064
H1	HAM2	A2F3	DIAGNOSTIC	IO TRANS MON BEAM	5.4 DIA VP800-AR1064
H1	HAM2	A2F4	DIAGNOSTIC	MC REFL	5.4 DIA VP800-AR1064
H1	HAM2	A1F4	illuminator	HAM2 CHAMBER	5.4 DIA VP800/450009
H1	HAM2	A1F1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
H1	HAM2	A2F1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
H1	HAM2	A2F2	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
H1	HAM2	C1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
H1	HAM3	A1F3	DIAGNOSTIC	MC2 trans	5.4 DIA VP800-AR1064
H1	HAM3	A1F4	illuminator	HAM3 CHAMBER	5.4 DIA VP800/450009
H1	HAM3	A1F5	VIDEO	MC2	5.4 DIA VP800-AR1064
H1	HAM3	A2F5	VIDEO	PR2	5.4 DIA VP800-AR1064
H1	HAM3	A2F3			
H1	HAM3	A2F4			
H1	HAM4	A2F3	HARTMANN	ITMX RC HARTMANN	5.4 DIA VP800-AR TBD
H1	HAM4	A2F5	HARTMANN	ITMY RC HARTMANN	5.4 DIA VP800-AR TBD
H1	HAM4	A1F4	illuminator	HAM4 CHAMBER	5.4 DIA VP800/450009
H1	HAM4	A2F1	VIDEO	SR2 video	5.4 DIA VP800-AR1064

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H1	HAM4	A2F4	VIDEO	SR2 video	5.4 DIA VP800-AR1064
H1	HAM5	A1F4	illuminator	HAM5 CHAMBER	5.4 DIA VP800/450009
H1	HAM5	A2F3	Squeeze beam		5.4 DIA VP800-AR1064
H1	HAM5	A2F4	VIDEO	OFI video	5.4 DIA VP800-AR1064
H1	HAM5	A2F5	VIDEO	PR3 video	5.4 DIA VP800-AR1064
H1	HAM5	A2F5	VIDEO	PRM video	5.4 DIA VP800-AR1064
H1	HAM6	A2F4	illuminator	HAM6 CHAMBER	5.4 DIA VP800/450009
H1	HAM6	A1F3	TBD		
H1	HAM6	A1F4	TBD		
H1	HAM6	A1F5	TBD		
H1	HAM6	A2F3	TBD		
H1	HAM6	A2F5	TBD		
H1	ITM A1-A FLANGE	VP3	OPTLEVER	ITMX optlev in	6.0 in Optlev
H1	ITM A1-A FLANGE	VP6	OPTLEVER	ITMX optlev out	7.8 DIA, ISI 4.9722012
H1	ITM A1-A FLANGE	VP5	VIDEO	ITMX video	5.4 DIA VP800-AR1064
H1	ITM A1-B FLANGE	VP1	OPTLEVER	ITMY optlev out	7.8 DIA, ISI 4.9722012
H1	ITM A1-B FLANGE	VP4	OPTLEVER	ITMY optlev in	6.0 in Optlev
H1	ITM A1-B FLANGE	VP2	VIDEO	ITMY video	5.4 DIA VP800-AR1064
H1	MCA1	VP4	OPTLEVER	OPTLEV HAM3 OUT	5.4 DIA VP800-AR635
H1	MCA1	VP5	OPTLEVER	OPTLEV HAM3 IN	5.4 DIA VP800-AR635
H1	MCA1	VP1	VIDEO	PR3	5.4 DIA VP800-AR1064
H1	MCA2	VP4	OPTLEVER	OPTLEV HAM4 OUT	5.4 DIA VP800-AR635
H1	MCA2	VP5	OPTLEVER	OPTLEV HAM4 IN	5.4 DIA VP800-AR635
H1	MCB1	VP11	OPTLEVER	OPTLEV PR3 OUT	7.8 DIA, ISI 4.9722012
H1	MCB1	VP4	OPTLEVER	OPTLEV HAM2 OUT	5.4 DIA VP800-AR635
H1	MCB1	VP5	OPTLEVER	OPTLEV HAM2 IN	5.4 DIA VP800-AR635
H1	MCB1	VP7	OPTLEVER	OPTLEV PR3 IN	7.8 DIA, ISI 4.9722012
H1	MCB1	VP1	VIDEO	MC1 & MC3	5.4 DIA VP800-AR1064
H1	MCB1	VP10	VIDEO	PR3, PRM	5.4 DIA VP800-AR1064
H1	MCB2	VP1	OPTLEVER	OPTLEV SR3 OUT	7.8 DIA, ISI 4.9722012
H1	MCB2	VP5	OPTLEVER	OPTLEV SR3 IN	7.8 DIA, ISI 4.9722012
H1	MCB2	VP7	OPTLEVER	OPTLEV HAM5 IN	5.4 DIA VP800-AR635

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H1	MCB2	VP8	OPTLEVER	OPTLEV HAM5 OUT	5.4 DIA VP800-AR635
H1	SEPTUM IN	VP1	DIAGNOSTIC	GRN BEAM, POB	SEPTUM
H1	SEPTUM IN	VP2	DIAGNOSTIC	REFL	SEPTUM
H1	SEPTUM IN	VP3	PSL IN		SEPTUM
H1	SEPTUM OUT	VP3	SIGNAL OUT		SEPTUM
H1	SEPTUM OUT		TBD		
H1	SEPTUM OUT		TBD		

Table 2: H2 Viewports

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H2	BSC4	G2	illuminator		5.4 DIA VP800/450009
H2	BSC4	G9	OPTLEVER	BS optlev in	5.4 DIA VP800-AR635
H2	BSC4	G8	VIDEO	BS video	5.4 DIA VP800-AR1064
H2	BSC5	CXG5	HARTMANN	ETMX HARTMANN	5.4 DIA VP800-AR532
H2	BSC5	G8	illuminator		5.4 DIA VP800/450009
H2	BSC5	CXG4	TRANSMON	TRANSMON X	5.4 DIA VP800-AR1064/532
H2	BSC5	G2	VIDEO	ETMX video	5.4 DIA VP800-AR1064
H2	BSC5	G9	VIDEO	TRANSMON X video	5.4 DIA VP800-AR1064
H2	BSC6	CXG5	HARTMANN	ETMY HARTMANN	5.4 DIA VP800-AR532
H2	BSC6	G8	illuminator		5.4 DIA VP800/450009
H2	BSC6	CXG4	TRANSMON	TRANSMON Y	5.4 DIA VP800-AR1064/532
H2	BSC6	G11	VIDEO	ETMY video	5.4 DIA VP800-AR1064
H2	BSC6	G9	VIDEO	TRANSMON Y video	5.4 DIA VP800-AR1064
H2	BSC7	G8	illuminator		5.4 DIA VP800/450009
H2	BSC7	G12	OPTLEVER	FMX optlev out	5.4 DIA VP800-AR635
H2	BSC7	CXG5	TCS	CO2 LASER	TCS, P/N 414494

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H2	BSC7	G10	VIDEO	ITMX CP video	5.4 DIA VP800-AR1064
H2	BSC7	G5	VIDEO	ITMX	5.4 DIA VP800-AR1064
H2	BSC7 A15-A FLANGE	VP2	OPTLEVER	FMX optlev in	2.7 DIA VP300-AR635
H2	BSC8	G5	illuminator		5.4 DIA VP800/450009
H2	BSC8	G9	OPTLEVER	FMY optlev out	5.4 DIA VP800-AR635
H2	BSC8	CXG3	TCS	CO2 LASER	TCS, P/N 414494
H2	BSC8	G2	VIDEO	ITMY	5.4 DIA VP800-AR1064
H2	BSC8	G7	VIDEO	ITMY CP video	5.4 DIA VP800-AR1064
H2	BSC8 A15-B FLANGE	VP5	OPTLEVER	FMY optlev in	2.7 DIA VP300-AR635
H2	ETMX D0900954 Flat Faced Flange	VP3	OPTLEVER	ETMX optlev in	6.0 in Optlev
H2	ETMX D0900954 Flat Faced Flange	VP6	OPTLEVER	ETMX optlev out	7.8 DIA, ISI 4.9722012
H2	ETMX D0900954 Flat Faced Flange	VP2	PHOTOCAL	ETMX photon cal in	6.0 in Optlev
H2	ETMX D0900954 Flat Faced Flange	VP5	PHOTOCAL	ETMX photon cal out	6.0 in Optlev
H2	ETMX D0900954 Flat Faced Flange	VP1	VIDEO	ETMX	5.4 DIA VP800-AR1064
H2	ETMY D0900954 Flat Faced Flange	VP4	OPTLEVER	ETMY optlev in	6.0 in Optlev
H2	ETMY D0900954 Flat Faced Flange	VP1	OPTLEVER	ETMY optlev out	7.8 DIA, ISI 4.9722012
H2	ETMY D0900954 Flat Faced Flange	VP2	PHOTOCAL	ETMY photon cal out	6.0 in Optlev
H2	ETMY D0900954 Flat Faced Flange	VP5	PHOTOCAL	ETMY photon cal in	6.0 in Optlev
H2	ETMY D0900954 Flat Faced Flange	VP6	VIDEO	ETMY	5.4 DIA VP800-AR1064
H2	HAM10	A1F3	HARTMANN	ITMX RC HARTMANN	5.4 DIA VP800-AR TBD
H2	HAM10	A1F5	HARTMANN	ITMY RC HARTMANN	5.4 DIA VP800-AR TBD
H2	HAM10	A2F4	illuminator		5.4 DIA VP800/450009
H2	HAM10	A1F1	VIDEO		5.4 DIA VP800-AR1064
H2	HAM10	A2F4	VIDEO	SR2	5.4 DIA VP800-AR1064
H2	HAM10	A1F3			
H2	HAM11	A1F4	illuminator		5.4 DIA VP800/450009
H2	HAM11	A2F3	Squeeze beam		5.4 DIA VP800-AR1064
H2	HAM11	A2F4	VIDEO	OFI	5.4 DIA VP800-AR1064
H2	HAM11	A2F5	VIDEO	PR3	5.4 DIA VP800-AR1064
H2	HAM11	A2F5	VIDEO	PRM	5.4 DIA VP800-AR1064
H2	HAM11	A1F3			
H2	HAM12	A1F4	illuminator		5.4 DIA VP800/450009
H2	HAM12	A1F3			
H2	HAM12	A1F5			

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H2	HAM12	A2F3			
H2	HAM12	A2F4			
H2	HAM12	A2F5			
H2	HAM7	A2F5	illuminator		5.4 DIA VP800/450009
H2	HAM7	B1	VIDEO		5.4 DIA VP800-AR1064
H2	HAM7	A1F3			
H2	HAM7	A1F4			
H2	HAM7	A1F5			
H2	HAM7	A2F3			
H2	HAM7	A2F4			
H2	HAM8	A1F4	DIAGNOSTIC	MC REFL	5.4 DIA VP800-AR1064
H2	HAM8	A1F5	DIAGNOSTIC	PRC MM MON BEAM	5.4 DIA VP800-AR1064
H2	HAM8	A1F5	DIAGNOSTIC	IO TRANS MON BEAM	5.4 DIA VP800-AR1064
H2	HAM8	A2F3	DIAGNOSTIC	SMS1 TRANS BEAM	5.4 DIA VP800-AR1064
H2	HAM8	A2F1	illuminator		5.4 DIA VP800/450009
H2	HAM8	A1F1	VIDEO		5.4 DIA VP800-AR1064
H2	HAM8	A1F2	VIDEO		5.4 DIA VP800-AR1064
H2	HAM8	A2F1	VIDEO		5.4 DIA VP800-AR1064
H2	HAM8	A2F2	VIDEO		5.4 DIA VP800-AR1064
H2	HAM8	C1	VIDEO		5.4 DIA VP800-AR1064
H2	HAM9	A1F3	DIAGNOSTIC	MC2 trans out	5.4 DIA VP800-AR1064
H2	HAM9	A2F4	illuminator		5.4 DIA VP800/450009
H2	HAM9	A1F5	VIDEO	MC2	5.4 DIA VP800-AR1064
H2	HAM9	A2F5	VIDEO	PR2	5.4 DIA VP800-AR1064
H2	HAM9	A1F4			
H2	HAM9	A2F3			
H2	ITMX A1-A FLANGE	VP1	OPTLEVER	ITMX optlev in	6.0 in Optlev
H2	ITMX A1-A FLANGE	VP4	OPTLEVER	ITMX optlev out	7.8 DIA, ISI 4.9722012
H2	ITMX A1-A FLANGE	VP2	VIDEO	ITMX	5.4 DIA VP800-AR1064
H2	ITMY A1-B FLANGE	VP3	OPTLEVER	ITMY optlev in	6.0 in Optlev
H2	ITMY A1-B FLANGE	VP6	OPTLEVER	ITMY optlev out	7.8 DIA, ISI 4.9722012
H2	ITMY A1-B FLANGE	VP5	VIDEO	ITMY	5.4 DIA VP800-AR1064
H2	MCA3	VP4	OPTLEVER	OPTLEV HAM9 OUT	5.4 DIA VP800-AR635
H2	MCA3	VP5	OPTLEVER	OPTLEV HAM9 IN	5.4 DIA VP800-AR635

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
H2	MCA3	VP1	VIDEO	HAM9	5.4 DIA VP800-AR1064
H2	MCA4	VP4	OPTLEVER	OPTLEV HAM10 OUT	5.4 DIA VP800-AR635
H2	MCA4	VP5	OPTLEVER	OPTLEV HAM10 IN	5.4 DIA VP800-AR635
H2	MCB3	VP4	OPTLEVER	OPTLEV HAM8 OUT	5.4 DIA VP800-AR635
H2	MCB3	VP5	OPTLEVER	OPTLEV HAM8 IN	5.4 DIA VP800-AR635
H2	MCB3	VP12	OPTLEVER	OPTLEV PR3 OUT	7.8 DIA, ISI 4.9722012
H2	MCB3	VP6	OPTLEVER	OPTLEV PR3 IN	7.8 DIA, ISI 4.9722012
H2	MCB4	VP4	OPTLEVER	OPTLEV HAM11 OUT	5.4 DIA VP800-AR635
H2	MCB4	VP5	OPTLEVER	OPTLEV HAM11 IN	5.4 DIA VP800-AR635
H2	MCB4	VP8	OPTLEVER	OPTLEV HAM5 OUT	5.4 DIA VP800-AR635
H2	MCB4	VP11	OPTLEVER	OPTLEV SR3 OUT	7.8 DIA, ISI 4.9722012
H2	MCB4	VP7	OPTLEVER	OPTLEV SR3 IN	7.8 DIA, ISI 4.9722012
H2	MCB4	VP1	VIDEO	HAM11	5.4 DIA VP800-AR1064
H2	SEPTUM IN	VP1	DIAGNOSTIC	GRN BEAM, POB	SEPTUM
H2	SEPTUM IN	VP2	DIAGNOSTIC	REFL	SEPTUM
H2	SEPTUM IN	VP3	PSL IN		SEPTUM
H2	SEPTUM OUT	VP3	SIGNAL OUT		SEPTUM
H2	SEPTUM OUT	VP1			
H2	SEPTUM OUT	VP2			

Table 3: L1 Viewports

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
L1	BSC1	G2	illuminator	BSC1 CHAMBER	5.4 DIA VP800/450009
L1	BSC1	CXG3	TCS	CO2 LASER	TCS, P/N 414494
L1	BSC1	G1	VIDEO	ITMY video	5.4 DIA VP800-AR1064
L1	BSC1	G11	VIDEO	ITMY CP video	5.4 DIA VP800-AR1064
L1	BSC10	CXG4	HARTMANN	ETMX HARTMANN	5.4 DIA VP800-AR1064
L1	BSC10	G8	illuminator	BSC10 CHAMBER	5.4 DIA VP800/450009

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
L1	BSC10	CXG5	TRANSMON	TRANSMON Y	5.4 DIA VP800-AR1064
L1	BSC10	G2	VIDEO	ETMY video	5.4 DIA VP800-AR1064
L1	BSC2	G2	illuminator	BSC2 CHAMBER	5.4 DIA VP800/450009
L1	BSC2	G9	OPTLEVER	BS optlev in	7.8 DIA, ISI 4.9722012
L1	BSC2	G8	VIDEO	BS video	5.4 DIA VP800-AR1064
L1	BSC3	G11	illuminator	BSC3 CHAMBER	5.4 DIA VP800/450009
L1	BSC3	CXG5	TCS	CO2 LASER	TCS, P/N 414494
L1	BSC3	G1	VIDEO	ITMX CP video	5.4 DIA VP800-AR1064
L1	BSC3	G10	VIDEO	ITMX video	5.4 DIA VP800-AR1064
L1	BSC9	CXG4	HARTMANN	ETMX HARTMANN	5.4 DIA VP800-AR1064
L1	BSC9	G8	illuminator	BSC9 CHAMBER	5.4 DIA VP800/450009
L1	BSC9	CXG5	TRANSMON	TRANSMON X	5.4 DIA VP800-AR1064
L1	BSC9	G11	VIDEO	ETMX video	5.4 DIA VP800-AR1064
L1	BSC9	G9	VIDEO	ETMX Transmon video	5.4 DIA VP800-AR1064
L1	ETM A1-A FLANGE	VP1	OPTLEVER	ETMX optlev out	7.8 DIA, ISI 4.9722012
L1	ETM A1-A FLANGE	VP4	OPTLEVER	ETMX optlev in	6.0 in Optlev
L1	ETM A1-A FLANGE	VP2	PHOTOCAL	ETMX photon cal out	6.0 in Optlev
L1	ETM A1-A FLANGE	VP5	PHOTOCAL	ETMX photon cal in	6.0 in Optlev
L1	ETM A1-A FLANGE	VP6	VIDEO	ETMX video	5.4 DIA VP800-AR1064
L1	ETM A1-B FLANGE	VP3	OPTLEVER	ETMY optlev in	6.0 in Optlev
L1	ETM A1-B FLANGE	VP6	OPTLEVER	ETMY optlev out	7.8 DIA, ISI 4.9722012
L1	ETM A1-B FLANGE	VP2	PHOTOCAL	ETMY photon cal in	6.0 in Optlev
L1	ETM A1-B FLANGE	VP5	PHOTOCAL	ETMY photon cal out	6.0 in Optlev
L1	ETM A1-B FLANGE	VP1	VIDEO	ETMY video	5.4 DIA VP800-AR1064
L1	HAM1	A1F4	illuminator	HAM1 CHAMBER	5.4 DIA VP800/450009
L1	HAM1	A1F5	TBD		
L1	HAM1	A2F3	TBD		
L1	HAM1	A2F4	TBD		
L1	HAM1	A2F5	TBD		
L1	HAM1	BF2	TBD		
L1	HAM1	BF3	TBD		
L1	HAM1	A1F1	VIDEO	PMMT2	5.4 DIA VP800-AR1064
L1	HAM1	BF1	VIDEO	PMMT2	5.4 DIA VP800-AR1064
L1	HAM2	A1F5	DIAGNOSTIC	SM1 TRANS BEAM	5.4 DIA VP800-AR1064

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
L1	HAM2	A2F3	DIAGNOSTIC	PRC MM MON BEAM	5.4 DIA VP800-AR1064
L1	HAM2	A2F3	DIAGNOSTIC	IO TRANS MON BEAM	5.4 DIA VP800-AR1064
L1	HAM2	A2F4	DIAGNOSTIC	MC REFL	5.4 DIA VP800-AR1064
L1	HAM2	A1F4	illuminator	HAM2 CHAMBER	5.4 DIA VP800/450009
L1	HAM2	A1F1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
L1	HAM2	A2F1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
L1	HAM2	A2F2	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
L1	HAM2	C1	VIDEO	HAM2 TABLE	5.4 DIA VP800-AR1064
L1	HAM3	A1F3	DIAGNOSTIC	MC2 trans	5.4 DIA VP800-AR1064
L1	HAM3	A1F4	illuminator	HAM3 CHAMBER	5.4 DIA VP800/450009
L1	HAM3	A1F5	VIDEO	MC2	5.4 DIA VP800-AR1064
L1	HAM3	A2F5	VIDEO	PR2	5.4 DIA VP800-AR1064
L1	HAM3	A2F3			
L1	HAM3	A2F4			
L1	HAM4	A2F3	HARTMANN	ITMX RC HARTMANN	5.4 DIA VP800-AR1064
L1	HAM4	A2F5	HARTMANN	ITMY RC HARTMANN	5.4 DIA VP800-AR1064
L1	HAM4	A1F4	illuminator	HAM4 CHAMBER	5.4 DIA VP800/450009
L1	HAM4	A2F1	VIDEO	SR2 video	5.4 DIA VP800-AR1064
L1	HAM4	A2F4	VIDEO	SR2 video	5.4 DIA VP800-AR1064
L1	HAM5	A1F4	illuminator	HAM5 CHAMBER	5.4 DIA VP800/450009
L1	HAM5	A2F3	Squeeze beam		5.4 DIA VP800-AR1064
L1	HAM5	A2F4	VIDEO	OFI video	5.4 DIA VP800-AR1064
L1	HAM5	A2F5	VIDEO	PR3 video	5.4 DIA VP800-AR1064
L1	HAM5	A2F5	VIDEO	PRM video	5.4 DIA VP800-AR1064
L1	HAM6	A2F4	illuminator	HAM6 CHAMBER	5.4 DIA VP800/450009
L1	HAM6	A1F3	TBD		
L1	HAM6	A1F4	TBD		
L1	HAM6	A1F5	TBD		
L1	HAM6	A2F3	TBD		
L1	HAM6	A2F5	TBD		
L1	ITM A1-A FLANGE	VP3	OPTLEVER	ITMX optlev in	6.0 in Optlev
L1	ITM A1-A FLANGE	VP6	OPTLEVER	ITMX optlev out	7.8 DIA, ISI 4.9722012
L1	ITM A1-A FLANGE	VP5	VIDEO	ITMX video	5.4 DIA VP800-AR1064
L1	ITM A1-B FLANGE	VP1	OPTLEVER	ITMY optlev out	7.8 DIA, ISI 4.9722012

IFO	CHAMBER	VIEWPORT	DESCRIPTION		VIEWPORT P/N
L1	ITM A1-B FLANGE	VP4	OPTLEVER	ITMY optlev in	6.0 in Optlev
L1	ITM A1-B FLANGE	VP2	VIDEO	ITMY video	5.4 DIA VP800-AR1064
L1	MCA1	VP4	OPTLEVER	OPTLEV HAM3 OUT	5.4 DIA VP800-AR635
L1	MCA1	VP5	OPTLEVER	OPTLEV HAM3 IN	5.4 DIA VP800-AR635
L1	MCA1	VP1	VIDEO	PR3	5.4 DIA VP800-AR1064
L1	MCA2	VP4	OPTLEVER	OPTLEV HAM4 OUT	5.4 DIA VP800-AR635
L1	MCA2	VP5	OPTLEVER	OPTLEV HAM4 IN	5.4 DIA VP800-AR635
L1	MCB1	VP11	OPTLEVER	OPTLEV PR3 OUT	7.8 DIA, ISI 4.9722012
L1	MCB1	VP4	OPTLEVER	OPTLEV HAM2 OUT	5.4 DIA VP800-AR635
L1	MCB1	VP5	OPTLEVER	OPTLEV HAM2 IN	5.4 DIA VP800-AR635
L1	MCB1	VP7	OPTLEVER	OPTLEV PR3 IN	7.8 DIA, ISI 4.9722012
L1	MCB1	VP1	VIDEO	MC1 & MC3	5.4 DIA VP800-AR1064
L1	MCB1	VP10	VIDEO	PR3, PRM	5.4 DIA VP800-AR1064
L1	MCB2	VP1	OPTLEVER	OPTLEV SR3 OUT	7.8 DIA, ISI 4.9722012
L1	MCB2	VP5	OPTLEVER	OPTLEV SR3 IN	7.8 DIA, ISI 4.9722012
L1	MCB2	VP7	OPTLEVER	OPTLEV HAM5 IN	5.4 DIA VP800-AR635
L1	MCB2	VP8	OPTLEVER	OPTLEV HAM5 OUT	5.4 DIA VP800-AR635
L1	SEPTUM IN	VP1	DIAGNOSTIC	GRN BEAM, POB	SEPTUM
L1	SEPTUM IN	VP2	DIAGNOSTIC	REFL	SEPTUM
L1	SEPTUM IN	VP3	PSL IN		SEPTUM
L1	SEPTUM OUT	VP3	SIGNAL OUT		SEPTUM
L1	SEPTUM OUT		TBD		
L1	SEPTUM OUT		TBD		

4.3 Viewport System Characteristics

4.3.1 Viewport Performance Characteristics

The viewports will have antireflection coatings to provide high transmissivity at the appropriate wavelengths. The optical quality of the viewports will not significantly degrade the resolution of the video cameras and of the TCS heating pattern. The Septum plate viewports will have low scattering and reflection losses @ 1064 nm wavelength.

4.3.2 Viewport Physical Characteristics

4.3.2.1 Video Camera Viewport

The video camera viewport will be the same as was used for Initial LIGO (see D970211-B Video Imaging Assembly ASC Alignment), MDC VP-800, 5.4 in clear viewing diameter, zero-length 10.0 in diameter flange, Kovar-sealed viewport, made of Corning 7056 glass.

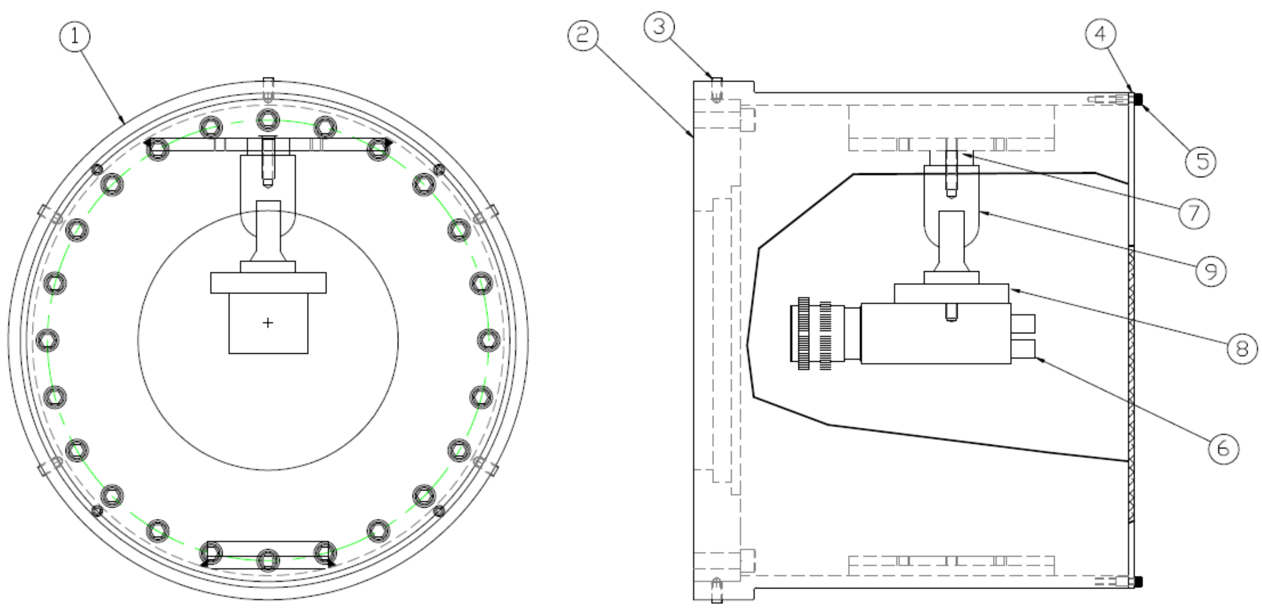

Figure 53: Video Imaging Assembly ASC Alignment

The experience of Initial LIGO showed that these video camera viewports maintained the resolution of the video cameras > 250 TV lines vertical and horizontal. This resolution was adequate for measuring the beam centroid with respect to the rim of the COC mirrors to a precision < 1 mm.

The viewport will be AR coated for minimum reflection @ 1064 nm (specified R<0.25% per surface at normal incidence).

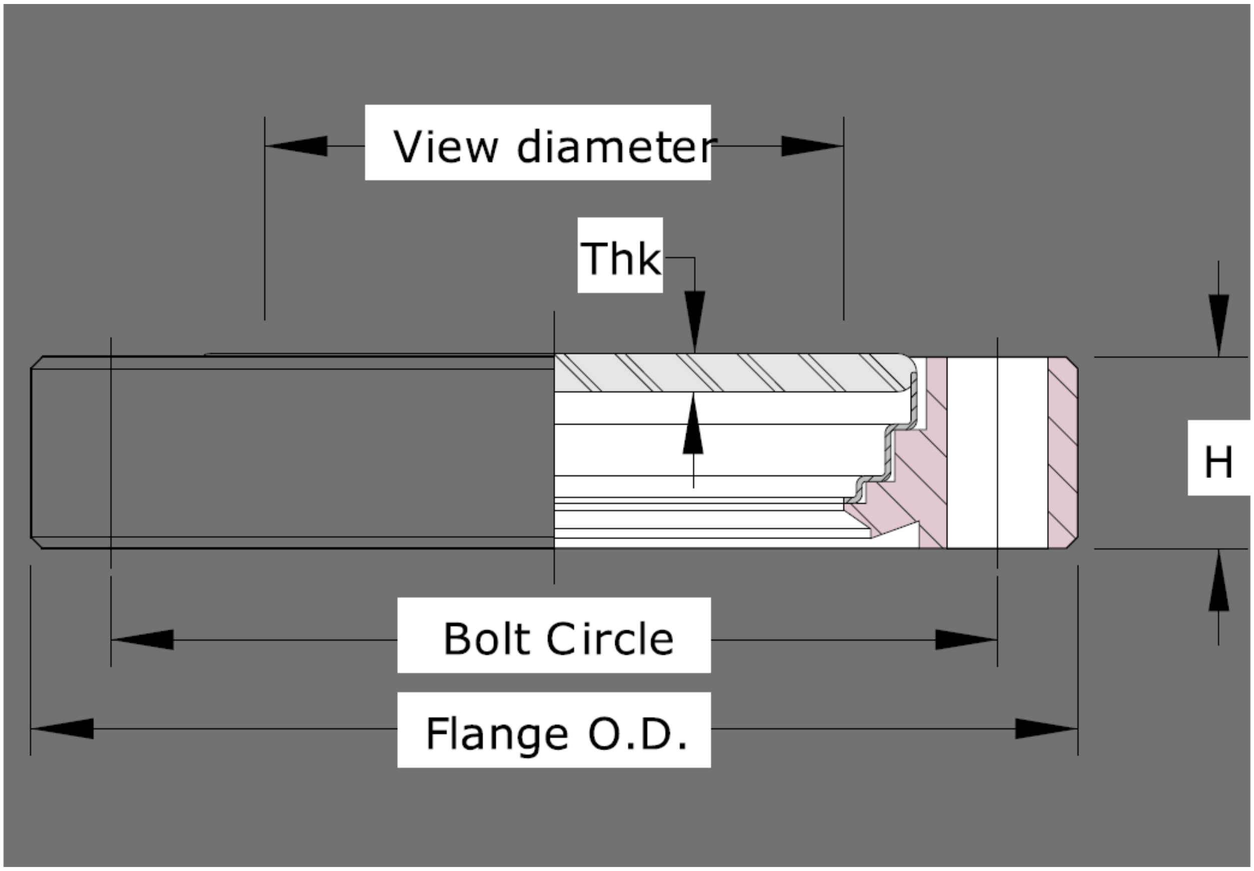

Figure 54: MDC series VPxxx Kovar-sealed viewport

4.3.2.2 Illuminator Viewport

The chamber illuminator assemblies from Initial LIGO will be re-used for aLIGO. (See D970212-B Illuminator Assembly ASC Alignment).

The illuminator viewport will be the same as the camera viewport, without any AR coating.

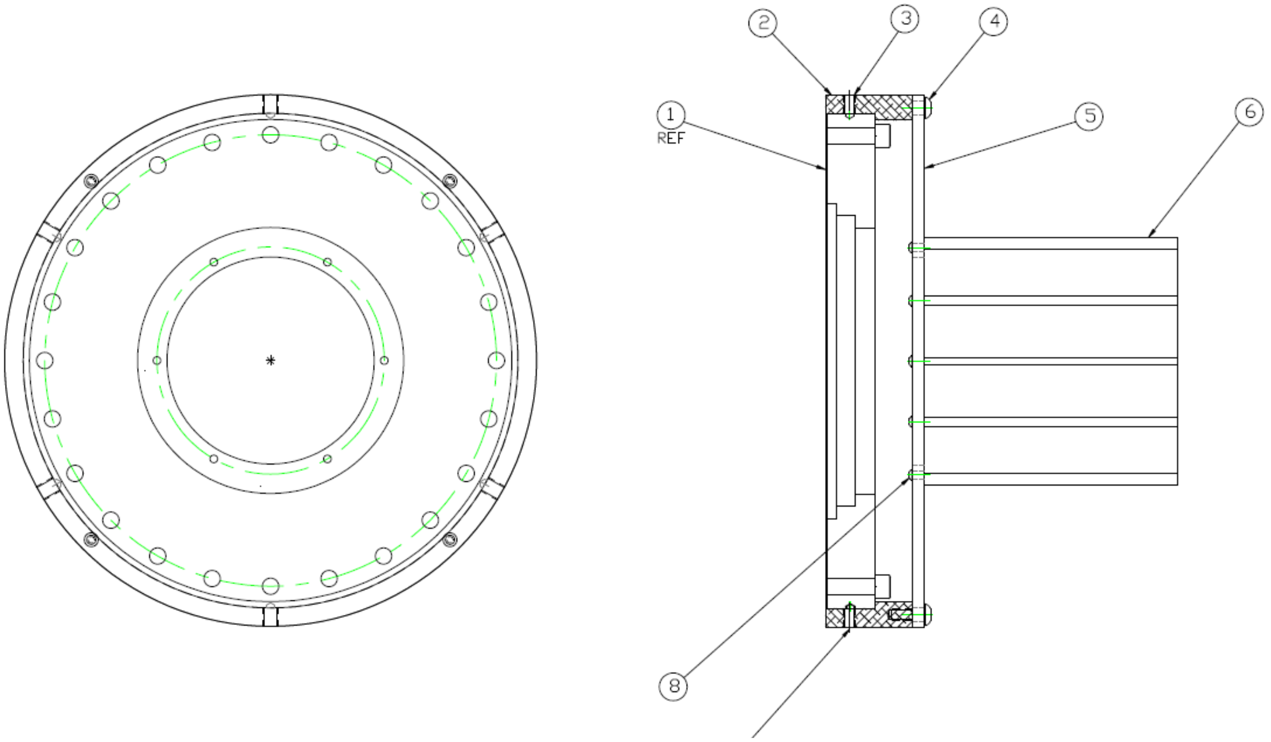

Figure 55: Illuminator Assembly

4.3.2.3 Optical Lever Viewport

The 2.7 in and 5.4 in viewing diameter viewports will be of the MDC series VPxxx Kovar-sealed, viewport designed for vacuum sealing, made of Corning 7056 glass.

The 7.8 diameter viewports will be fused silica viewports made by Insulator Seal, P/N ISI 4.9722012 designed for vacuum sealing, shown in Figure 56.

The 6.0 in viewing diameter viewports will be fused silica viewports, sealed with o-rings into conflat flange adapters similar to the septum viewports, as shown in Figure 57

The surface finish will be the same as specified in E070069 for enhanced LIGO.

All Optical Lever viewports will have an AR coating @ TBD nm wavelength, normal incidence with a specified total reflectivity < 0.5%.

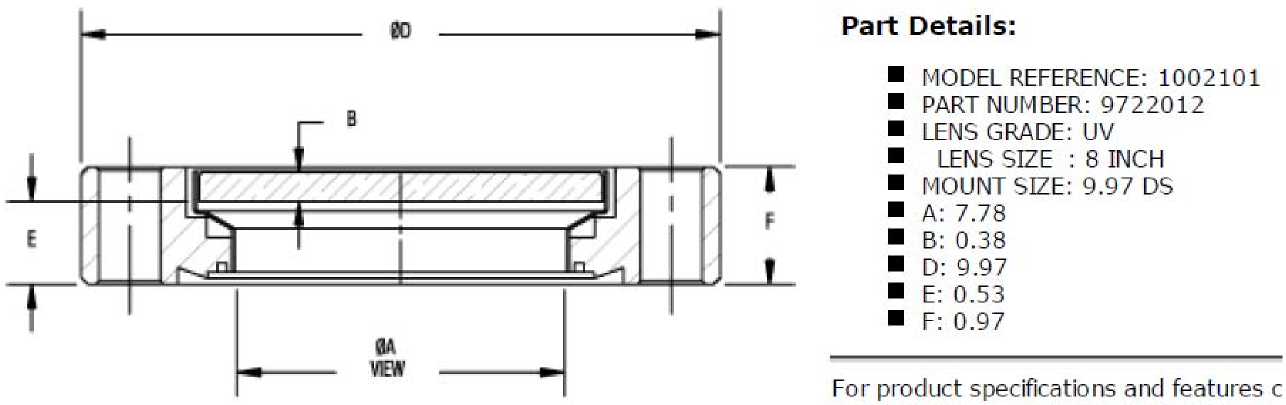

Figure 56: 7.8 Diameter Viewport

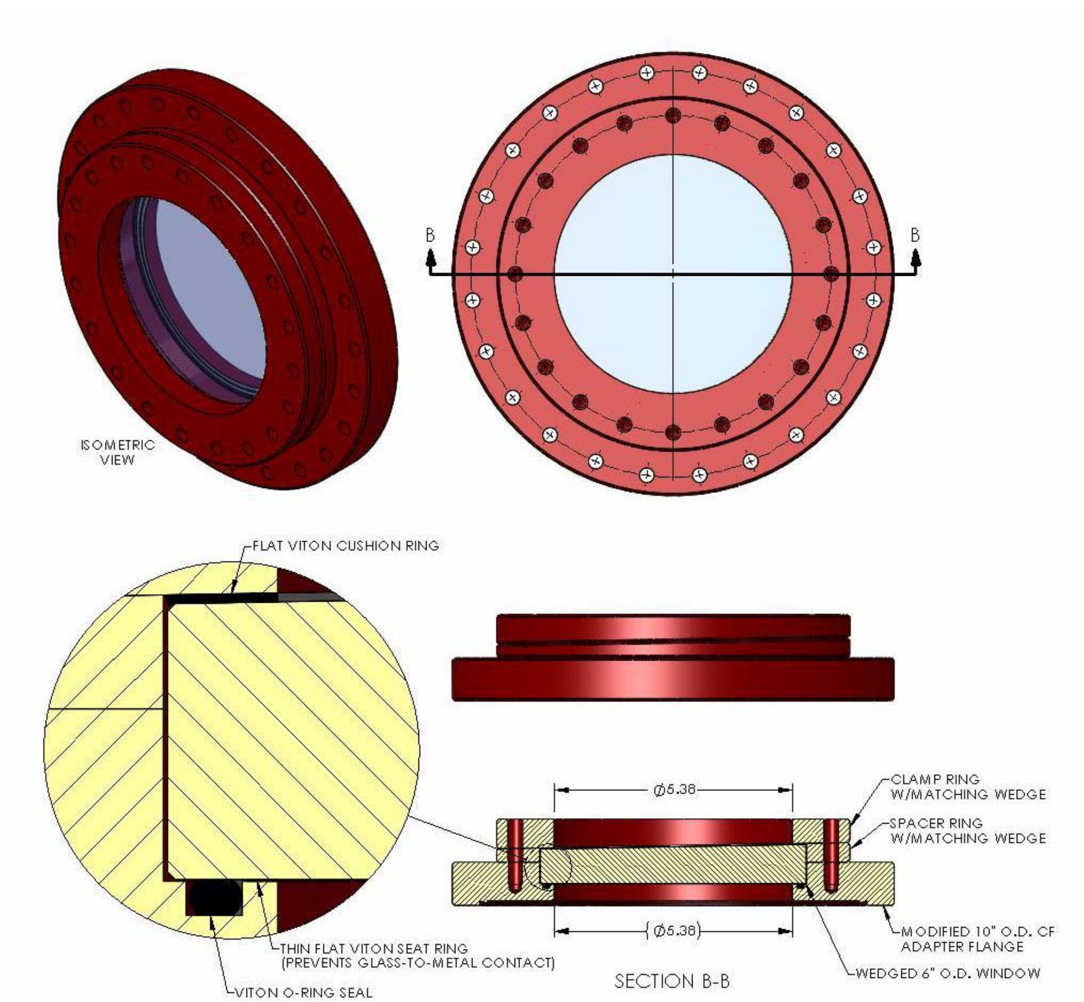

Figure 57: 6.0 in Optical Lever Viewport

4.3.2.4 Septum Viewport

The septum viewports will have a viewing diameter of 6.0 in, and will be made from fused silica, sealed with o-rings into conflat flange adapters as shown in Figure 58.

The polishing for the Septum viewport substrate, shown in Figure 59, is specified in LIGO E070069.

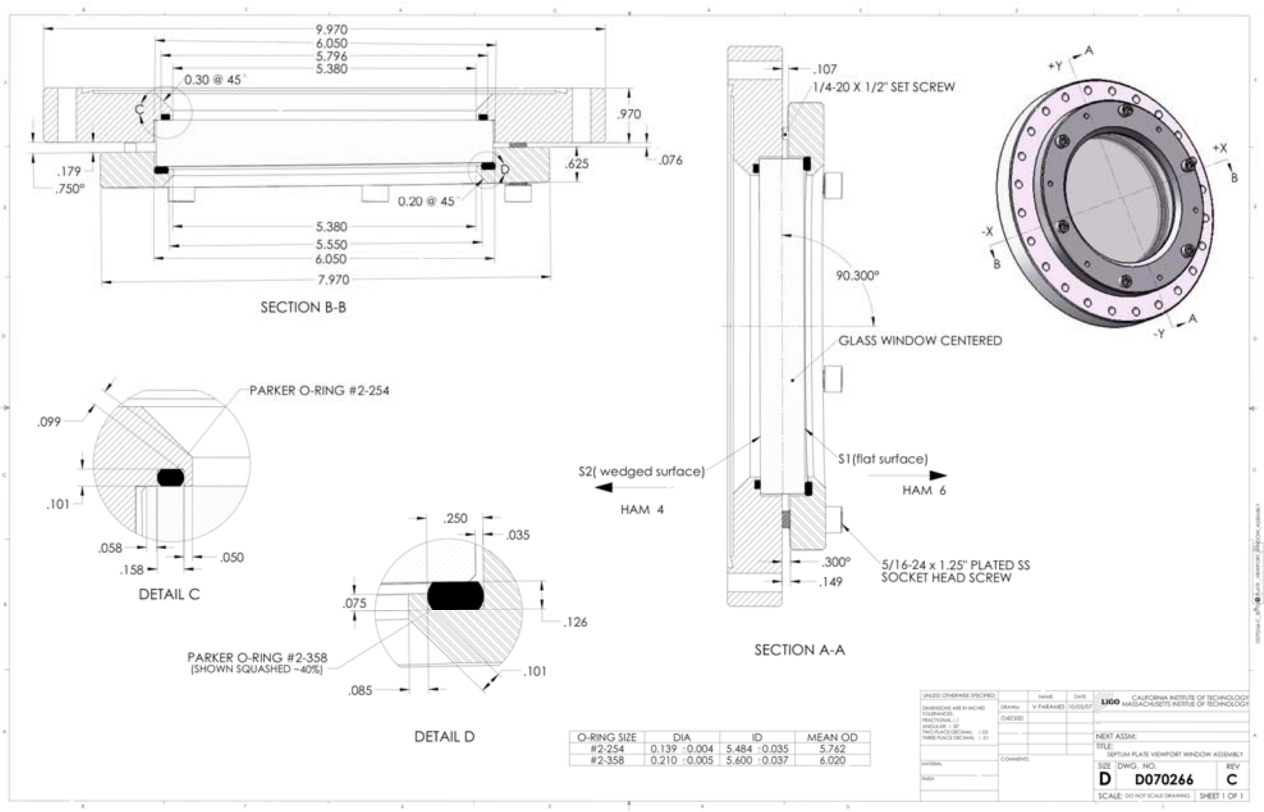

Figure 58: Septum Window Flange Assembly

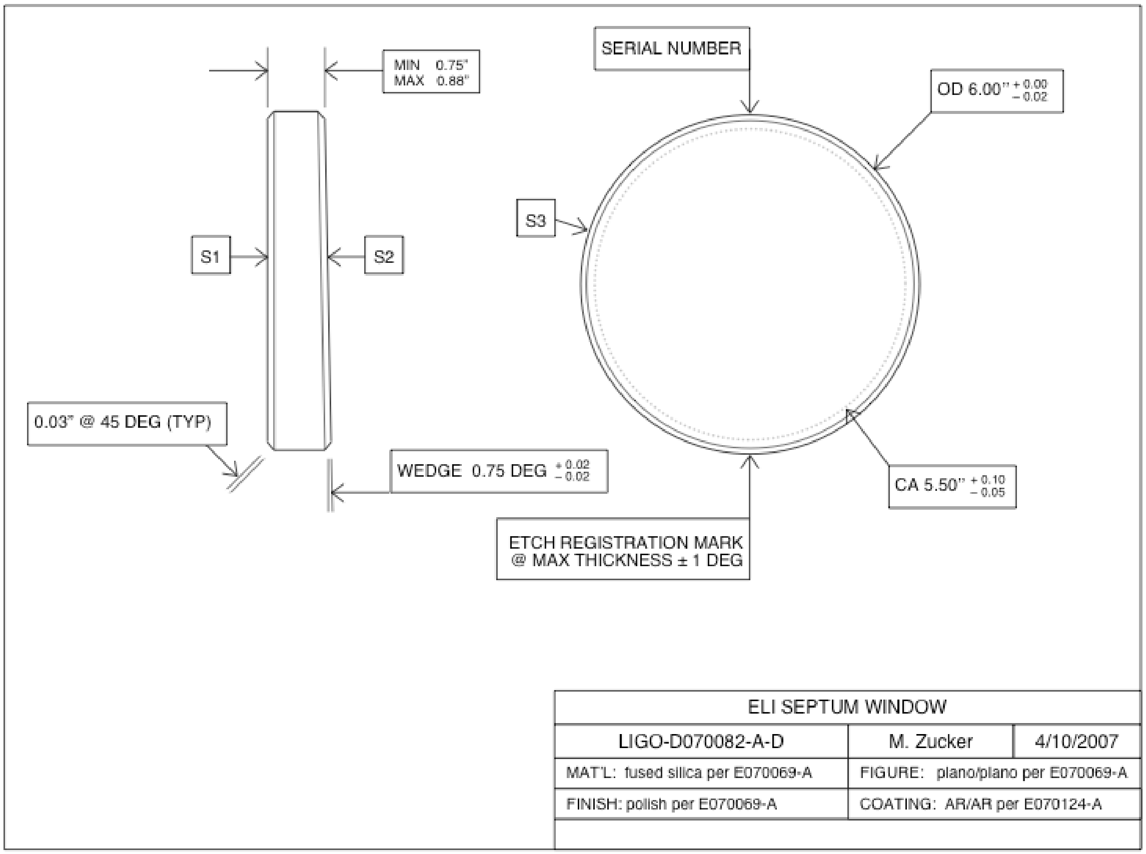

Figure 59: Septum Window

4.3.2.5 TCS Viewport

The TCS viewport will be the same as was used in Initial LIGO for vacuum sealing—P/N 414494 manufactured by II-VI Infrared from ZnSe, 3.0 in diameter by 0.5 in thick. It will be mounted inside a vacuum conflat adapter flange and sealed with o-rings.

The ZnSe viewport has an AR coating, with a typical transmissivity @ 10.6 microns wavelength at normal incidence >99.5%, and >90% @ 635 nm.

The windows will be optical quality with a maximum wavefront distortion of 1 wave @ 633nm wavelength, with a surface polish quality of 20-10 scratch-dig.

4.3.2.5.1 Zn Se Viewport Safety Viewport

A second Zn Se safety viewport will be placed in front of the TCS viewport, with an airtight seal to avoid organic particulates from touching the incident surface of the TCS Viewport. The safety viewport will avoid the creation of hot spots on the TCS viewport caused by particulate absorption of the CO2 laser beam. (Ref: E080501 Enhanced LIGO TCS Hazard Analysis.)

4.3.2.6 Hartmann Viewport

The Hartmann viewport will be the 5.4 in viewing diameter MDC series VP800 Kovar-sealed, viewport designed for vacuum sealing, made of Corning 7056 glass.

The wavelength for the AR coating is TBD.

4.3.2.7 Transmon Viewport

The Transmon viewport will be the 5.4 in viewing diameter MDC series VP800 Kovar-sealed, viewport designed for vacuum sealing, made of Corning 7056 glass.

AR coatings will be provided at the two wavelengths, 1064 nm and 532 nm.

4.3.3 Viewport Interface Definitions

4.3.3.1 Interfaces to other LIGO detector subsystems

The viewports are mounted to vacuum flanges that mount to the existing nozzles on the HAM and BSC chambers, and to the viewport adapters that are attached to the various manifolds and vacuum tubes between vacuum chambers.

4.3.3.1.1 Septum Plate Installation

The septum window assembly and installation procedure is described in E070253.

4.3.3.1.2 Stay Clear Zones

The optical path of the light beams passing from the optical lever transmitters and receivers, and to the video cameras will be enclosed by a suitable means to define the stay clear zone.

4.3.4 Viewport Reliability

4.3.4.1 Mean Time before Failure

Viewports are durable optical components that have an essentially unlimited lifetime.

4.3.4.2 Viewports Maintainability

The viewports will be handled and maintained using the E960022-B LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures cleaning procedures and protocols. The viewports will be replaced if they fail.

4.3.4.3 Viewports Environmental Conditions

4.3.4.3.1 Natural Environment

4.3.4.3.1.1 Temperature and Humidity

The viewports are designed to function with vacuum conditions on the inside surface, and with the humidity and temperature controlled environment of the enclosed LIGO LVEA on the outer surface.

Table 4 Environmental Performance Characteristics

Operating	Non-operating (storage)	Transport
+20C to +25C, 20-70% RH, non- condensing	0C to +60C, 10-90% RH, non-condensing	0C to +60C, 10-90% RH, non- condensing

4.3.4.3.1.2 Atmospheric Pressure

The viewports are designed to function with a differential pressure between faces of one atmospheric pressure.

4.3.5 Viewport Transportability

All items will be transportable by commercial carrier without degradation in performance. As necessary, provisions will be made for measuring and controlling environmental conditions (temperature and accelerations) during transport and handling. Special shipping containers, shipping and handling mechanical restraints, and shock isolation will be utilized to prevent damage. All containers shall be movable by forklift.

4.4 Viewport Design and Construction

4.4.1 Materials and Processes

The in-vacuum materials and processes used in the fabrication of the viewports will be compatible with the LIGO approved materials list.

4.4.1.1 Materials

A list of currently approved materials for use inside the LIGO vacuum envelope can be found in E960022-B LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures. All materials used inside the vacuum chamber will comply with LIGO-E960022-00-D.

4.4.1.2 Processes

4.4.1.2.1.1 Cleaning

All materials used inside the vacuum chambers will be cleaned in accordance with Specification Guidance for Seismic Component Cleaning, Baking, and Shipping Preparation (LIGO-L970061-00-D).

4.4.1.3 Component Naming

All components will be identified using the LIGO naming convention. This will include identification (part or drawing number, revision number, serial number) physically stamped on all components, in all drawings and in all related documentation. The flange edges of the glass-to-metal sealed viewports will be marked to indicate the AR coating.

4.4.2 Workmanship

All components will be manufactured according to good commercial practice.

4.4.3 Interchangeability

Viewports with like dimensions and like coatings will be interchangeable.

4.4.4 Safety

This item will meet all applicable NSF and other Federal safety regulations, plus those applicable State, Local and LIGO safety requirements.

4.4.5 Human Engineering

Protective covers will be provided to protect personnel from the hazards of viewport implosion.

4.5 Assembly and Maintenance

TBD

4.6 Documentation

4.6.1 Specifications

Manufacturer's specifications for standard MDC VP-xxx series viewports, and Insulator Seal 9722012 series viewports, as well as special specifications published by LIGO for custom viewports, will apply.

4.6.2 Design Documents

Same as 4.6.1

4.6.3 Engineering Drawings and Associated Lists

Same as 4.6.1

4.6.4 Technical Manuals and Procedures

Not applicable.

4.6.5 Documentation Numbering

All documents will be numbered and identified in accordance with the LIGO documentation control numbering system LIGO document TBD

4.6.6 Test Plans and Procedures

A test plan and procedure will be developed for testing those viewports that use an o-ring for vacuum sealing to assure that the vacuum leak rate is acceptable.

4.7 Logistics

4.7.1 Spare Parts

TBD

4.7.2 Special Test Equipment

TBD

4.8 Precedence

4.9 Qualification

5 Quality Assurance Provisions

This section includes all the examinations and tests to be performed for ascertaining that the viewports conform to the requirements in section 3.

5.1 General

5.1.1 Responsibility for Tests

AOS will conduct tests to verify the as-delivered performance specifications of the viewports.

5.1.2 Special Tests

5.1.2.1 Engineering Tests

TBD

5.1.2.2 Reliability Testing

5.1.2.2.1 Viewports

The reliability of the viewports that will be used in aLIGO was evaluated during Initial LIGO. Therefore, no further reliability testing will be conducted.

5.1.3 Configuration Management

Configuration control of specifications and designs will be in accordance with the LIGO Detector Implementation Plan.

5.2 Quality conformance inspections

Design and performance requirements identified in this specification and referenced specifications shall be verified by inspection, analysis, demonstration, similarity, test or a combination thereof per the Verification Matrix, Appendix 1 (See example in Appendix). Verification method selection shall be specified by individual specifications, and documented by appropriate test and evaluation plans and procedures. Verification of compliance to the requirements of this and subsequent specifications may be accomplished by the following methods or combination of methods:

5.2.1 Inspections

Manufactured parts with LIGO identification numbers or marks will be inspected to determine conformity with the procurement specification.

A witness sample will be acceptable proof of the properties of anti-reflection coatings applied to viewports

5.2.2 Demonstration

A demonstration of the visual quality of the video camera image of the optics in the chamber will be acceptable as verification of the resolution characteristics of the video camera and the acceptable intensity level of the illumination lamp.

5.2.3 Test

TBD

6 Safety

6.1 Hazard Analysis

A hazard analysis for the TCS viewports is presented in

6.2 Working Covers

Protective covers for all viewports will be provided to protect personnel from possible implosion hazards of the viewports and to avoid eye damage from errant optical beams exiting through the viewport.

7 Preparation for Delivery

Packaging and marking of equipment for delivery will be in accordance with the Packaging and Marking procedures specified herein.

7.1 Preparation

- Vacuum preparation procedures as outlined in E960022-B LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures will be followed for all components intended for use in vacuum. After wrapping vacuum parts as specified in this document, an additional, protective outer wrapping and provisions for lifting shall be provided.
- Electronic components will be wrapped according to standard procedures for such parts.

7.2 Packaging

Procedures for packaging will ensure cleaning, drying, and preservation methods adequate to prevent deterioration, appropriate protective wrapping, adequate package cushioning, and proper containers. Proper protection will be provided for shipping loads and environmental stress during transportation, hauling and storage. The shipping crates used for large items will use for guidance military specification MIL-C-104B, Crates, Wood; Lumber and Plywood Sheathed, Nailed and Bolted. Passive shock witness gauges will accompany the crates during all transits.

For the viewports, the shipping preparation will include double bagging with Ameristat 1.5TM plastic film (heat sealed seams as practical, with the exception of the inner bag, or tied off, or taped with care taken to insure that the tape does not touch the cleaned part). The bag will be purged with dry nitrogen before sealing.

7.3 Marking

Appropriate identification of the product, both on packages and shipping containers; all markings necessary for delivery and for storage, if applicable; all markings required by regulations, statutes, and common carriers; and all markings necessary for safety and safe delivery will be provided.

Identification of the material will be maintained through all manufacturing processes. Each component will be uniquely identified. The identification will enable the complete history of each component to be maintained (in association with Documentation “travelers”). A record for the optical lever support structures will indicate all weld repairs and fabrication abnormalities.

The specification for marking the viewports will state that marking fluids, die stamps and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of 0.005" is acceptable for marking on surfaces that are not hidden from view. Engraving and stamping are also permitted.

8 Notes

Appendix A Quality Conformance Inspections

Appendix A contains a table that lists the requirements and the method of testing requirements. TBD

Table 5 Quality Conformance Inspections

Paragraph	Title	I	A	D	S	T
	Performance Characteristics					
	Controls Performance					
	Timing Performance‘					