LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Input Optics CDS Design Requirements Document

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1 INTRODUCTION

1.1. Purpose

The purpose of this technical note is to describe and document the design requirements for the LIGO Input Optics Electronics hardware and software.

1.2. Scope

This document covers the design and performance requirements for all electronics hardware and software to be used for the control and monitoring of the LIGO Input Optics

1.3. Definitions

1.4. Acronyms

- ASC- Alignment Sensing and Control
- CDS- Control and Data System
- DAQ- Data Acquisition Subsystem
- FM- Folding Mirror
- GDS- Global Diagnostics Subsystem
- GW- Gravity Wave
- IFO- Interferometer
- IOO- Input Optics Subsystem
- LED- Light Emitting Diode
- LIGO- Laser Interferometer Gravitational-wave Observatory
- LOS- Large Optics Suspension
- LSC- Length Sensing and Control
- MC- Mode Cleaner
- MMT- Mode-Matching Telescope
- MTBF- Mean Time Between Failure
- MTTR- Mean Time To Repair
- N/A- Not Applicable
- PD- Photodiode/detector
- PIT- Pitch of optic being controlled
- PSL- Pre-Stabilized Laser Subsystem
- RFAM- Radio Frequency Amplitude Modulation
- RFPD- Radio Frequency Photodiode/detector
- SOS- Small Optics Suspension

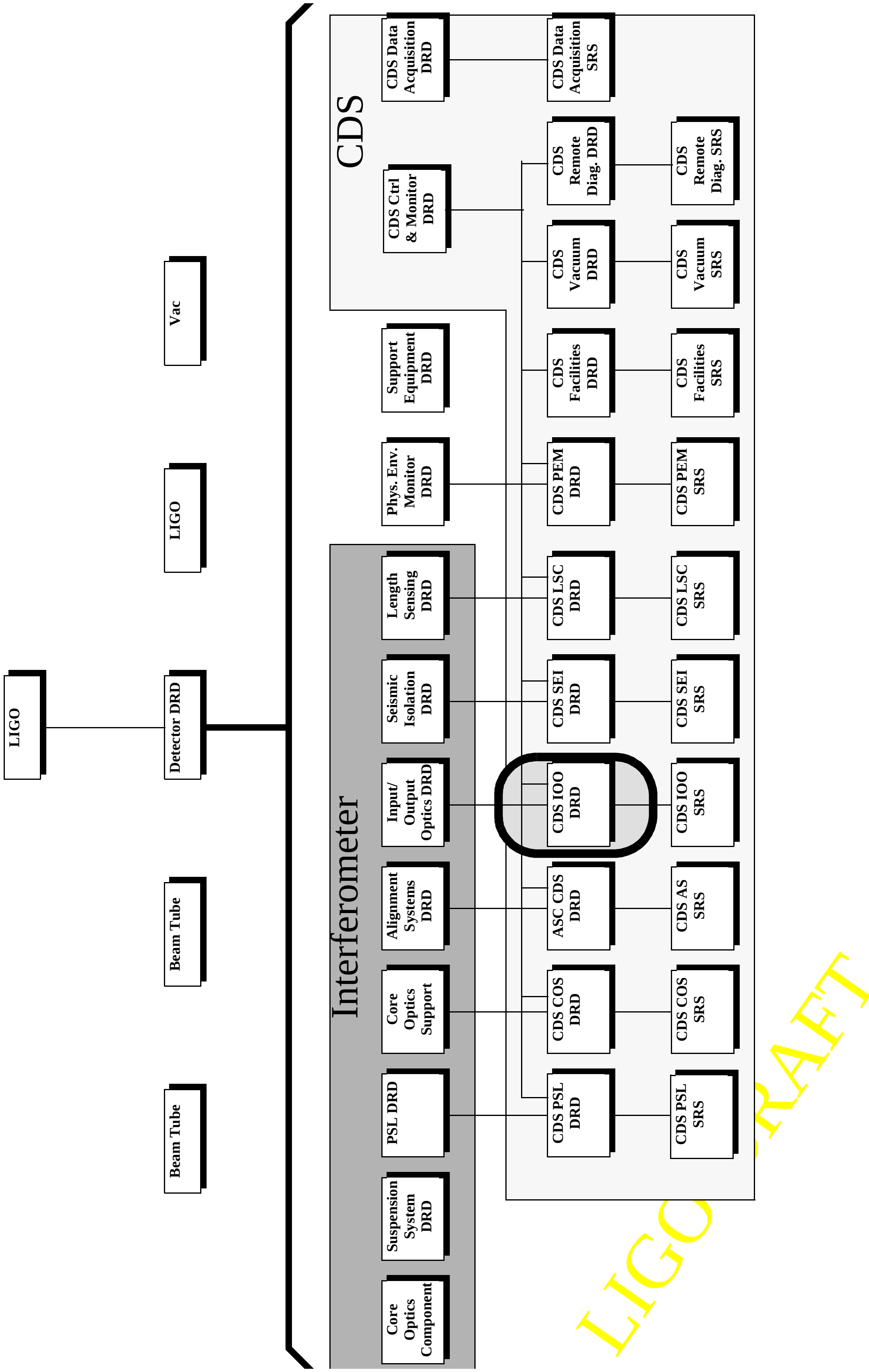
- SUS- Suspension Subsystem
- TBD- To Be Determined
- WFS- Wavefront Sensor
- YAW- Yaw of optic being controlled

1.5. Applicable Documents

- *Input Optics Final Design*- LIGO T980009
- *Mode Cleaner Length/Frequency Control Design*- LIGO T970218
- *ASC CDS Conceptual Design*- LIGO T970062

2 GENERAL DESCRIPTION

2.1. Specification Tree


LIGO
Detector DRD
Vac
LIGO
Beam Tube
Beam Tube
Interferometer
Core Optics Component
Suspension System DRD
PSL DRD
Core Optics Support
Alignment Systems DRD
Input/ Output Optics DRD
Seismic Isolation DRD
Length Sensing DRD
Phys. Env. Monitor DRD
Support Equipment DRD
CDS
CDS Ctrl & Monitor DRD
CDS Data Acquisition DRD
CDS Data Acquisition SRS
CDS Remote Diag. DRD
CDS Remote Diag. SRS
CDS Vacuum DRD
CDS Vacuum SRS
CDS Facilities DRD
CDS Facilities SRS
CDS PEM DRD
CDS PEM SRS
CDS LSC DRD
CDS LSC SRS
CDS SEI DRD
CDS SEI SRS
CDS IOO DRD
CDS IOO SRS
ASC CDS DRD
CDS AS SRS
CDS COS DRD
CDS COS SRS
CDS PSL DRD
CDS PSL SRS

2.2. Product Perspective

The IOO CDS portion of the LIGO detector provides all electronics hardware and software necessary to control and monitor each of the IOO systems. The IOO systems are:

- Suspended Optic Controllers
- Mode Cleaner Alignment Controls
- Mode Cleaner Length Control
- Mirror Fine Actuator Control
- Cameras
- Optical Levers
- Mode Matching Wavefront Sensing
- Analyzer Cavity Monitoring
- RF Photodiode Monitoring

2.3. Product Functions

The IOO CDS provides all electronics hardware and software for the IOO suspended optics, mode cleaner alignment controls, mode cleaner length controls, mirror fine actuator controls, cameras, optical levers, mode matching wavefront sensing, analyzer cavity monitoring and RF spectrum analyzer monitoring. The function of each of these systems is:

- Suspended Optic Controllers- Large and Small Optic (LOS, SOS) Controllers identical to those used in the interferometer provide for local damping and control of each of the suspended optics in the IOO.
- Mode Cleaner Alignment Control- A wavefront sensing system identical to that used in the interferometer provides for control of the pitch and yaw degrees of freedom for each of the optics in the mode cleaner.
- Mode Cleaner Length Control- A length sensing and control system similar to that used in the interferometer provides for mode cleaner length control.
- Mirror and Lens Fine Actuator Control- Pico motors will be used to provide control for many of the focussing elements and mirrors external to the vacuum chamber.
- Cameras- The cameras are used to provide “live” displays to the operator of the beam position on some of the optics and views of the beam spot at certain points on the optical tables.
- Optical Levers- The optical levers provide for the monitoring of the pitch and yaw degrees of freedom for some of the suspended optical components, but are also designed to have the capability of providing the local pitch and yaw signals for orientation damping.
- Mode Matching Wavefront Sensing- Bulls Eye sensors will be used to monitor and measure the mode matching of the input beam to the interferometer. These sensors will use demodulator electronics identical to those used by the alignment systems.
- Analyzer Cavity Monitoring- Commercial optical spectrum analyzers will be used in two places in the IOO. Controls and monitoring for these cavities will be provided.
- RF Photodiode Monitoring- RF photodiodes on the PSL table and IOT7 will be used to monitor RFAM and IOO output noise in the GW band, respectively.

2.4. General Constraints

- Rack locations- IOO controls electronics hardware shall be located in rack 2X7 and 1X3 for the 2 Km and 4 Km IFOs, respectively.

2.5. Assumptions and Dependencies

- Pico Motors and controllers- It is assumed that a multi-axis, multi-device pico motor controller such as the New Focus model 8732 will be used. This controller and similar devices have an RS-232 connection that can be used by CDS for remote control.
- Analyzer Cavity and Controller- It is assumed that the analyzer cavity and controller will have some sort of analog interface which will allow CDS to monitor both the cavity sweep voltage and cavity output simultaneously. It is also assumed that there is a mechanism for turning the cavity sweep on and off and adjusting the sweep rate remotely.
- Bull's Eye Sensor- It is assumed that existing WFS demodulator electronics, ADCs and processors will be sufficient for use with the Bull's Eye sensors.
- Cameras- It is assumed that there are no image processing requirements for camera images. In addition it is assumed that there are no remote controls, such as pointing and zooming associated with the cameras.

3 REQUIREMENTS

3.1. Characteristics

3.1.1. Performance Characteristics

3.1.1.1 Suspended Optic Controllers

Suspension controllers and suspension electronics shall be provided that meet the requirements in the table below.

Table 1: IOO Suspension Controller Noise and Dynamic Range Requirements

Optic	*Type of Controller*	*Dynamic Range Length and Angle*	*Noise*
MMT1, MMT2	SOS	500 um p-p >5 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MC1, MC2, MC3	SOS	27 um p-p 1.5 mrad p-p	$3.8x10^{-18}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
FM1, FM2 (2Km IFO only)	SOS	500 um p-p > 5 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz
MMT3	LOS	40 um p-p 1 mrad p-p	$5x10^{-16}\left(\frac{f}{40}\right)^{-2}(m/(\sqrt{Hz}))$ f > 40 Hz

3.1.1.2 Mode Cleaner Alignment Control

IOO CDS shall provide all wavefront sensor electronics and controls necessary to maintain mode cleaner alignment to better than 2 x 10^{-5} rad. Wavefront sensor photodiode heads, demodulator boards and VME electronics shall be similar to those used for IFO ASC systems. Mode cleaner alignment sensing and actuation points are shown in figure TBD. IFO ASC systems are described in document T970062-00, ASC CDS Conceptual Design. The modulation frequencies for the 2 Km and 4 Km IFOs shall be as shown in the table below.

The mirrors used for mode cleaner alignment control (PM2 and TM5) are actuated using Physik Instruments SI-330 PZT actuated mirrors and controller. In the optical configuration used for the

Table 2: IOO ASC Modulation Frequencies

IFO	*WFS Modulation Frequency*
2 Km	26.7 MHz
4 Km	33.3 MHz

input optics, a 0-10 volt input to the controller provides a 0 to 0.16mrad angular movement of each mirror.

3.1.1.3 Mode Cleaner Length Control

Mode cleaner length shall be controlled such that it does not deviate from the perfectly resonant length by more than $10^{-13} m_{rms}$. More detailed requirements are described in LIGO document T970218-01-D, Mode Cleaner Length/Frequency Control Design.

3.1.1.4 Mirror and Lens Fine Actuator Control

At this time there are no pico motor actuated mirrors or devices on the PSL table. There are TBD motorized mirrors on ISC7 and two motorized mirrors on IOT7 in the WFS optical path. These mirrors are New Focus model 8852 with a New Focus model 8732 multi-axis driver. CDS shall provide all hardware and software necessary to control and monitor these mirrors.

3.1.1.5 Cameras

3.1.1.5.1 Camera Make and Model

Cameras are Sony model XC-73 CCD cameras.

3.1.1.5.2 Camera Locations

The locations of the cameras for the IOO are TBD. The cameras in the IOO will be used by the operator to view the surface of optics to determine beam centering and to view beams on optical tables IOT7 and ISCT7 for the 2 Km IFO and IOT1 and ISCT1 for the 4 Km IFOs.

3.1.1.5.3 Image Processing Requirements

The are no on-line image processing requirements. CDS shall provide a means for the operator to view the output of each CCD in real time (30 frames per second). In addition the operator will be able to snapshot the image and store the snapshot for future display or analysis.

3.1.1.5.4 Chamber Illumination Lamps

Chamber illumination lamps are Waldmann model HGKW-70-24V. CDS shall provide a means for the operator to turn the lamps on and off remotely.

3.1.1.6 Optical Levers

A block diagram of a nominal optical lever configuration is shown in the figure below.

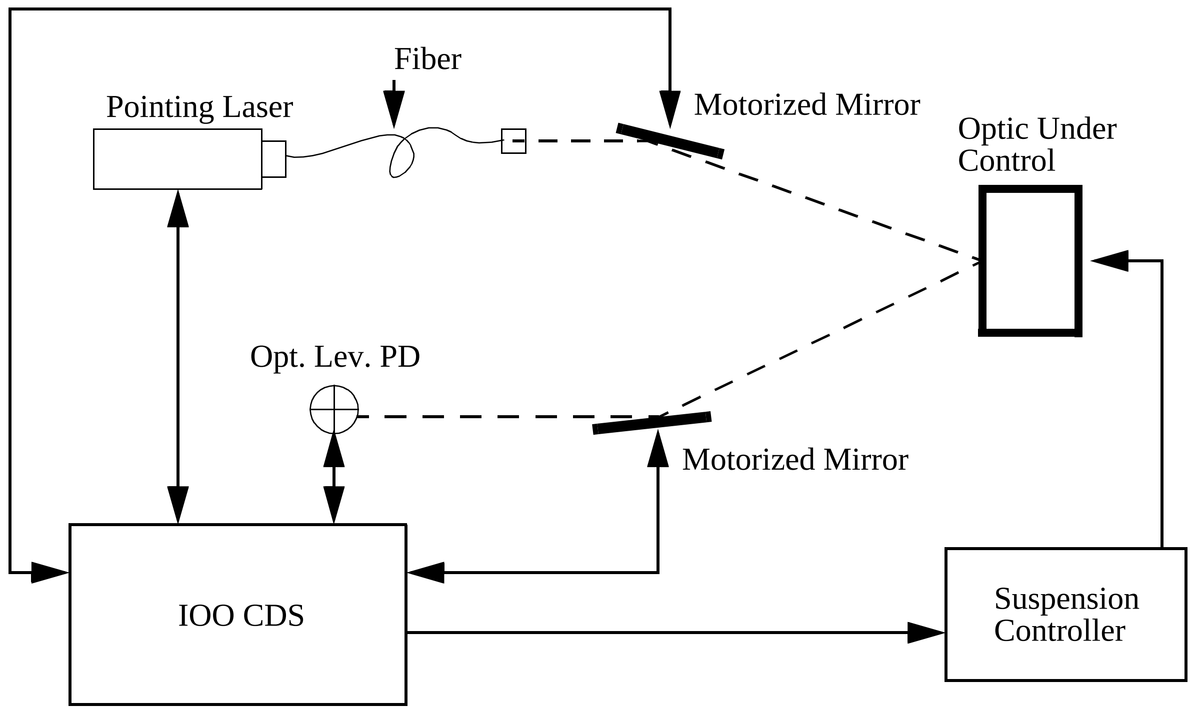


Figure 1: Optical Lever Block Diagram

3.1.1.6.1 Placement of sensors

Optical levers are located on the following optics:

- Mode Matching Telescope 3 (MMT3)

3.1.1.6.2 Pointing Laser Controls

3.1.1.6.2.1 Laser Make and Model

The laser diode to be used for the optical levers is a Blue Sky Research Model FBC019 that operates from 5 Volts DC input power.

3.1.1.6.2.2 Intensity stabilization

Nominal intensity stabilization is provided by the laser vendor, and there is no requirement for further stabilization.

3.1.1.6.2.3 Laser Control and Monitoring

IOO CDS shall provide all electronics hardware and software required to control and monitor the pointing laser, typically including monitoring of ON/OFF status, power, diode current, TEC current and temperature, depending on the features provided on the laser unit.

3.1.1.6.3 Motorized Mirror Controls

IOO CDS shall provide all electronics hardware and software necessary to control the steering mirrors used to direct the output beam into the vacuum port to the optic and from the vacuum port to the optical lever quadrant photodiode. These mirrors are New Focus model 8852 pico motor actuated mirrors controlled via a New Focus model 8732 multi-axis driver.

3.1.1.6.4 Receiver Electronics and Processing Requirements

A block diagram of the optical lever electronics and processing is shown in the figure below.

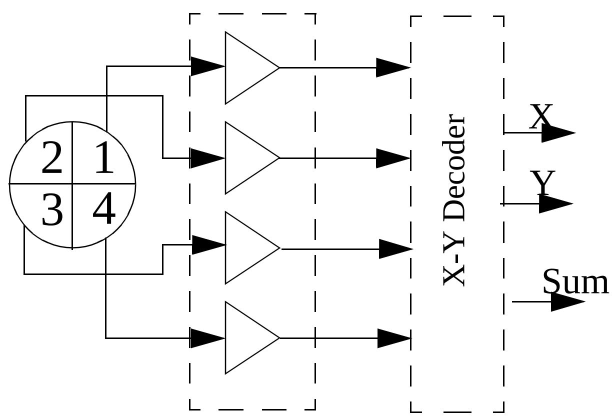


Figure 2: Optical Lever Receiver Electronics Block Diagram

3.1.1.6.4.1 Photodiode Electronics

3.1.1.6.4.1.1 Photodiode Make and Model

The photodiodes used for the optical levers are Centronics model QD100.

3.1.1.6.4.1.2 Transimpedance Gain/Frequency Response

The nominal transimpedance of each channel of the quad photodiode amplifier shall be 1000 ohms. The frequency response shall be greater than 1 KHz.

3.1.1.6.4.1.3 Input/Output Referred Noise

The input referred noise of the amplifier shall be less than $6\times10^{-12}\frac{\mathrm{A}}{\sqrt{\mathrm{Hz}}}$ for frequencies greater than 40 Hz.

3.1.1.6.4.1.4 Offset Drift

The offset drift shall be less than one part in 10K over the operating temperature range.

3.1.1.6.4.2 Transfer Function and Processing Requirements

3.1.1.6.4.2.1 X and Y Position Calculation

The Optical Lever Electronics shall calculate the position of the beam on the quad using the following equations:

$$Y_{Position} = \frac{K_{Top}(Top - Top_{offset}) - K_{Bottom}(Bot - Bot_{offset})}{Sum}$$

$$X_{Position} = \frac{K_{Left}(Left - Left_{offset}) - K_{Right}(Right - Right_{offset})}{Sum}$$

$$Sum = (K_{Top}Top) + (K_{Bot}Bot) + (K_{Left}Left) + (K_{Right}Right) - \sum_{Top}^{Right} offsets$$

where the offsets for each channel are obtained during a calibration procedure in which the beam to quad photodiode is blocked and the offset voltage for each channel is measured and stored for use in the calculations listed above. The gain constants are obtained during a calibration procedure in which the quad photodiode is uniformly illuminated and the output of each channel is measured. The relative gain for each channel is then calculated once the offsets are subtracted.

In addition, the position calculation shall be translated into angle for each optical lever.

3.1.1.6.4.2.2 Frequency Response of Position Calculation

The position calculation shall be updated at a rate greater than 3 times per second.

3.1.1.7 Mode Matching Wavefront Sensing

The mode matching bulls eye sensors are described in LIGO document T980009-00, "Input Optics Final Design". Each sensor consists of a four segment photodetector with three outer segments and one center segment. The sensors will use wavefront sensing photodetector electronics and demodulator boards identical to those used by the alignment system. CDS shall provide all hardware and software necessary for control and monitoring of the sensors.

The algorithm used to convert the sensor information into modal information is TBD. The update rate for the sensors shall be 256 Hz.

3.1.1.8 Analyzer Cavity Monitoring

Commercial analyzer cavities will be located on the PSL table and IOT7. CDS shall provide all necessary hardware and software to allow the operator to view cavity output versus cavity sweep voltage.

The design shall include a provision for operator control of beam blocks at the entrance to the cavity.

3.1.1.9 RF Photodiode Monitoring

RF photodetectors will be located on the PSL table and IOT7/IOT1 as shown in figure TBD. CDS shall provide all hardware and software necessary to allow the operator to monitor these photodetectors.

The RFPD on the PSL table will be used to monitor RFAM at the resonant sideband modulation frequency (29.486 MHz and 24.493 MHz for 2K and 4K IFOs, respectively). A tuned circuit and diode detector shall be used for this monitor. The sample rate shall be 1 Hz. The fractional sensitivity of the monitor shall be better than 10e-6.

The RFPD on IOT7/IOT1 will be used to monitor noise in the GW band. The I and Q components at the LSC resonant sideband frequency (29.486 MHz and 24.493 MHz for 2K and 4K IFOs, respectively) will be monitored by the DAQ system. The sample rate shall be 16384 samples per second. The measurement shall be shot noise limited.

3.1.2. Interface Definitions

3.1.2.1 Interfaces to other LIGO detector subsystems

3.1.2.1.1 Mechanical Interfaces

Table 3: IOO CDS Detector Mechanical Interfaces

IOO CDS Component	*Other System or Subsystem*	*Characteristics*

3.1.2.1.2 Electrical Interfaces

Table 4: IOO CDS Detector Electrical Interfaces

IOO CDS Component	*Other System or Subsystem*	*Characteristics*
Rack 1X3	AC Power	115VAC, 20 amp
Rack 2X7	AC Power	115VAC, 20 amp

3.1.2.1.3 Optical Interfaces

Table 5: IOO CDS Detector Optical Interfaces

IOO CDS Component	*Other System or Subsystem*	*Characteristics*
N/A		

3.1.2.1.4 Stay Clear Zones

TBD

3.1.2.1.5 Interfaces to LIGO DAQ and GDS Systems

The following signals/inputs shall be provided to the DAQ and GDS systems.

Table 6: DAQ and GDS Signals

Signal	*Type*	*Sample Rate*
All Suspension Local PD read backs	Output to DAQ	2048
All SUS coil currents	Output DAQ	2048
Sum Coil currents	Output to DAQ	16384

Table 6: DAQ and GDS Signals

Signal	*Type*	*Sample Rate*
All MC ASC demodulated PD signals I & Q	Output to DAQ	IOO ASC sample freq.
All MC ASC output signals	Output to DAQ	IOO ASC sample freq
All MC ASC PD DC outputs	Output to DAQ	1
All MC LSC demodulated PD signals I & Q	Output to DAQ	16384
MC LSC output signal (MC length)	Output to DAQ	256
MC LSC output signal (PSL freq)	Output to DAQ	16384
MC LSC PD DC output	Output to DAQ	1
MC LSC PD Temp.	Output to DAQ	1
Bull's Eye Sensor demodulated PD signals	Output to DAQ	256
RFAM PD	Output to DAQ	1
Noise Monitor RFPD demodulated signals I & Q	Output to DAQ	16384
MC Misalign/shift test input	Input from GDS	IOO ASC sample freq
MC ASC PD Test Inputs	Input from GDS	IOO ASC sample freq
MC LSC Test input at error summing junction	Input from GDS	16384
MC LSC Test input before feedback split MC/laser	Input from GDS	16384

3.1.2.2 Interfaces external to LIGO detector subsystems

3.1.2.2.1 Mechanical Interfaces

Table 7: IOO CDS Detector Mechanical Interfaces

IOO CDS Component	*Other System or Subsystem*	*Port*
WA 2 Km MC mirror 1 cabling	Vacuum Chamber	Port WH7D4
WA 2 Km MC mirror 2 cabling	Vacuum Chamber	Port WH8D1
WA 2 Km MC mirror 3 cabling	Vacuum Chamber	Port WH7D4
WA 2 Km MMT1 cabling	Vacuum Chamber	Port WH7D1
WA 2 Km MMT2 cabling	Vacuum Chamber	Port WH8D1
WA 2 Km MMT3 cabling	Vacuum Chamber	Port WH7D6
WA 2 Km SM1 cabling	Vacuum Chamber	Port WH7D6/
WA 2 Km SM2 cabling	Vacuum Chamber	Port WH7D1
WA/LA 4 Km MC mirror 1 cabling	Vacuum Chamber	Port WH1D4/ LH1D4
WA/LA 4 Km MC mirror 2 cabling	Vacuum Chamber	Port WH2D1/ LH2D1
WA/LA 4 Km MC mirror 3 cabling	Vacuum Chamber	Port WH1D4/ LH1D4
WA/LA 4 Km MMT1 cabling	Vacuum Chamber	Port WH1D1/ LH1D1
WA/LA 4 Km MMT2 cabling	Vacuum Chamber	Port WH2D1/ LH2D1
WA/LA 4 Km MMT3 cabling	Vacuum Chamber	Port WH1D6/ LH1D6

All mechanical interfaces to the vacuum chamber shall be 25 pin D connectors mounted in pairs to 4.5” conflat flanges. These 4.5” conflat flanges are then mounted in groups of three to the 12” conflat flanges on each vacuum chamber port. The 4.5” conflat flanges with 2 each 25 pin D connectors are MDC part number 63002-1000.

3.1.2.2.2 Electrical Interfaces

N/A

3.1.2.2.3 Stay Clear Zones

N/A

3.1.3. Reliability

Mean Time Between Failures (MTBF), Availability: TBD

3.1.4. Maintainability

Mean Time To Repair (MTTR); Qualitative requirements for accessibility, modular construction, test points, etc.: TBD

3.1.5. Environmental Conditions

3.1.5.1 Natural Environment

3.1.5.1.1 Temperature and Humidity

Table 8: Environmental Performance Characteristics

Operating	*Non-operating (storage)*	*Transport*
+0 C to +50 C, 0-90%RH	-40 C to +70 C, 0-90% RH	-40 C to +70 C, 0-90% RH

3.1.5.1.2 Atmospheric Pressure

The IOO CDS design must accommodate atmospheric pressure change from a maximum of 15.2 psia to a minimum of 14.2 psia.

3.1.5.1.3 Seismic Disturbance

N/A

3.1.5.2 Induced Environment

3.1.5.2.1 Electromagnetic Radiation

The IOO CDS shall not degrade due to electromagnetic emissions as specified by IEEE C95.1-1991.

The IOO electronics shall not produce electromagnetic emissions beyond those specified in TBD.

3.1.5.2.2 Acoustic

IOO electronics shall be designed to produce the lowest levels of acoustic noise as possible and practical. In any event, IOO electronic components shall not produce acoustic noise levels greater than those specified in TBD.

3.1.5.2.3 Mechanical Vibration

IOO electronics shall not produce mechanical vibrations greater than those specified in TBD.

3.1.6. Transportability

All items shall be transportable by commercial carrier without degradation in performance. As necessary, provisions shall 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 shall be utilized to prevent damage. All containers shall be movable for forklift. All items over 100 lbs. which must be moved into place within LIGO buildings shall have appropriate lifting eyes and mechanical strength to be lifted by cranes.

3.2. Design and Construction

3.2.1. Materials and Processes

3.2.1.1 Finishes

- Ambient Environment: Surface-to-surface contact between dissimilar metals shall be controlled in accordance with the best available practices for corrosion prevention and control.
- *External surfaces: External surfaces requiring protection shall be painted purple or otherwise protected in a manner to be approved.*

3.2.1.2 Materials

TBD

3.2.1.3 Processes

TBD

3.2.2. Component Naming

All components shall identified using the LIGO Detector Naming Convention (document TBD). This shall include identification physically on components, in all drawings and in all related documentation.

3.2.3. Workmanship

All details of workmanship shall be of the highest grade appropriate to the methods and level of fabrication and consistent with the requirements specified herein. There shall be no evidence of poor workmanship that would make the components unsuitable for the purpose intended. All electronic circuits and wiring shall be consistent with good engineering practice and fabricated to best commercial standards.

3.2.4. Interchangeability

The IOO electronics shall be designed to maximize interchangeability and replaceability of mating components. Using the Line Replaceable Unit (LRU) concept, the designs shall be such that mating assemblies may be exchanged without selection for fit or performance and without modification to the section, the unit being replaced or adjacent equipment. Mature performance proven, standard, commercially available equipment shall not be modified unless it impacts safety.

3.2.5. Safety

This item shall meet all applicable NSF and other Federal safety regulations, plus those applicable State, Local and LIGO safety requirements. A hazard/risk analysis shall be conducted in accordance with guidelines set forth in the LIGO Project System Safety Management Plan LIGO-M950046-F, section 3.3.2.

3.2.6. Human Engineering

N/A

3.3. Documentation

3.3.1. Specifications

TBD

3.3.2. Design Documents

TBD

3.3.3. Engineering Drawings and Associated Lists

Any drawings to be provided and any standard formats that they must comply with, such as shall use LIGO drawing numbering system, be drawn using LIGO Drawing Preparation Standards, etc.

3.3.4. Technical Manuals and Procedures

3.3.4.1 Procedures

Procedures shall be provided for, at minimum,

- *Initial installation and setup of equipment*
- *Normal operation of equipment*
- *Normal and/or preventative maintenance*
- *Troubleshooting guide for any anticipated potential malfunctions*

3.3.4.2 Manuals

TBD

3.3.5. Documentation Numbering

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

3.3.6. Test Plans and Procedures

All test plans and procedures shall be developed in accordance with the LIGO Test Plan Guidelines, LIGO document TBD.

3.4. Logistics

The design shall include a list of all recommended spare parts and special test equipment required.

3.5. Precedence

TBD

3.6. Qualification

TBD

4 QUALITY ASSURANCE PROVISIONS

4.1. General

4.1.1. Responsibility for Tests

TBD

4.1.2. Special Tests

4.1.2.1 Engineering Tests

TBD.

4.1.2.2 Reliability Testing

Reliability evaluation/development tests shall be conducted on items with limited reliability history that will have a significant impact upon the operational availability of the system.

4.1.3. Configuration Management

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

4.2. 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:*

4.2.1. Inspections

Inspection shall be used to determine conformity with requirements that are neither functional nor qualitative; for example, identification marks.

4.2.2. Analysis

Analysis may be used for determination of qualitative and quantitative properties and performance of an item by study, calculation and modeling.

4.2.3. Demonstration

Demonstration may be used for determination of qualitative properties and performance of an item and is accomplished by observation. Verification of an item by this method would be accomplished by using the item for the designated design purpose and would require no special test for final proof of performance.

4.2.4. Similarity

Similarity analysis may be used in lieu of tests when a determination can be made that an item is similar or identical in design to another item that has been previously certified to equivalent or more stringent criteria. Qualification by similarity is subject to Detector management approval.

4.2.5. Test

Test may be used for the determination of quantitative properties and performance of an item by technical means, such as, the use of external resources, such as voltmeters, recorders, and any test equipment necessary for measuring performance. Test equipment used shall be calibrated to the manufacture's specifications and shall have a calibration sticker showing the current calibration status.

5 PREPARATION FOR DELIVERY

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

5.1. Preparation

Equipment shall be appropriately prepared. For example, vacuum components shall be prepared to prevent contamination.

5.2. Packaging

Procedures for packaging shall ensure cleaning, drying, and preservation methods adequate to prevent deterioration, appropriate protective wrapping, adequate package cushioning, and proper containers. Proper protection shall be provided for shipping loads and environmental stress during transportation, hauling and storage.

5.3. 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 shall be provided.

6 NOTES

APPENDIX 1 QUALITY CONFORMANCE VERIFICATION MATRIX

Table 9: Quality Conformance Inspections

Paragraph	*Title*	*I*	*A*	*D*	*S*	*T*

APPENDIX 2 IOO CDS BLOCK DIAGRAM