LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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OSEM
Interface Control Document

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This is an internal working note
of the Advanced LIGO Project, prepared by members of the UK team.

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1 Introduction

The purpose of this document is to capture the interface definition for the advanced LIGO system. The nature of all Interface Control Documents (ICD) is to describe the design implementation of the requirements in the specifications (requirements and design descriptions) as they relate to interfaces. During the design phases of the program the ICD is a 'living' document; It must be actively maintained and controlled. Once the ICD has achieved a reasonable level of completion (at least for sections related to a few subsystems), it will be released with a Document Change Notice (DCN) which is signed by the leaders/managers for all subsystems involved. This places the ICD under configuration control. For each subsequent revision, a DCN is required. This DCN is initiated by the systems engineering group and signed by all the leaders/managers of the effected subsystems. The DCN lists the changes and the reasons for the changes. The DCN also indicates if the changes effects cost, schedule or performance. It is the responsibility of the systems engineering group to arrange for appropriate review or approval by a Material Review Board (MRB), Technical Review Board (TRB) or the Configuration Control Board (CCB) as required in the process of reviewing the DCN.

The advanced LIGO system is divided into subsystems as listed in Table 1. Of all the possible pair wise interactions, less than half have interface definition, as indicated in Table 1.

Table 1: Subsystem interface matrix

LIGO.4. WBS	Subsystems			FAC	SEI	SUS UK	SUS US	PSL	IO	COC	AOS PhDr	AOS ATC	AOS COS	ISC	DAQ	SUP	LDAS	INS	SYS
1	Facilities		FAC		✓	✓	✓	✓		✓					✓		✓		
2	Seismic Isolation		SEI			✓	✓					✓	✓	✓	✓	✓		✓	✓
3A	Suspensions (SUS)	UK Scope	UK				✓			✓	✓	✓	✓	✓	✓	✓		✓	✓
3B		US Scope	US						✓	✓			✓	✓	✓	✓		✓	✓
4	Pre-Stabilizaed Laser		PSL						✓					✓	✓				
5	Input Optics		IO										✓	✓	✓				✓
6	Core Optics Components		COC																✓
7A	Auxiliary Optics (AOS)	Photon Drive	PhDr											✓	✓				✓
7B		Active Thermal Compensation	ATC											✓	✓				✓
7C		Core Optics Support	COS											✓					✓
8	Interferometer Sensing & Control		ISC												✓				
9	Data Acquisition		DAQ														✓		
10	Support Equipment		SUP																
12	LIGO Data Analysis System		LDAS																✓
13	Installation		INS																
14.5	Systems Engineering		SYS																

Note: The cells in Table 1 should eventually cite the section in which the interface is defined.

The Suspension subsystem is further divided into the United Kingdom (UK) team's scope and the United States (US) team's scope. In this way the interfaces between elements common to the overall assemblies produced by both teams are effectively captured in this ICD.

The Auxiliary Optics Subsystem (AOS) is also divided into its principal subsystem elements, due to the considerably different nature of these various elements, and the likelihood that different groups will address the design of each element.

1.1 Applicability of the System Interface Matrix to the OSEM

The OSEM represents a constituent part of the Suspension subsystem, and as such will interface to a subset of the subsystems (as detailed in table 1) to which the Suspension interfaces. This subset is listed below, and is used as the basis for this document.

i) Suspension (SUS)

ii) Seismic Isolation (SEI)

iii) Support Equipment (SUP)

2 Applicable Documents

Ref No	Document Title	ID Number
	Existing Hybrid OSEM documentation	
1	Hybrid OSEM Test specification	E030084-02-D
2	Hybrid OSEM Manufacturing Specification	E030094-01-D
3	Hybrid OSEM Assy Drawing	D030105 Rev 2
	LIGO Design Guidelines	
4	LIGO Laboratory Electronics EMC Requirements	E020986-01-D
5	LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures	E960022-B-E
6	LIGO Vacuum Compatible Materials List	E960050-B-E
7	Peter Fritschel Talk: Global Control issues for Adv LIGO Quad Suspensions	G010086-00-0
	AdvLIGO Documents	
8	Measurement of LIGO Hybrid OSEM Sensitivity	T040106-01-K
9	Input to OSEM Selection Review	T040110-01-K
10	AdvLIGO OSEM Manufacturing Specification	Exxxxxx
11	AdvLIGO OSEM Test Specification	Exxxxxx
	AdvLIGO Drawings	
12	AdvLIGO OSEM Top Level Assy Drawing	Dxxxxxx
13	AdvLIGO OSEM Interface Drawing	Dxxxxxx
14	AdvLIGO OSEM Flex Rigid PCB Schematic	Dxxxxxx
15	AdvLIGO OSEM Flex Rigid PCB BOM	Dxxxxxx
16	AdvLIGO OSEM Flex Rigid PCB Fabrication Drawing	Dxxxxxx

Table 2-1

Note: ICD INFORMATION: The drawings listed in table 2-1 contain interface information. Revisions must be coordinated with a revision to E03xxxx and with LIGO systems engineering

3 OSEM to Suspension (SUS) Interfaces

3.1 Physical Interface

Mounting interface details will be identical to those of the Hybrid OSEM, and as detailed in applicable document [13].

Further details may be found in applicable document [12].

3.2 Mass Properties

The Mass of the OSEM (with sensors fitted) and mounting plates are given below:-

Part	Mass (Kg)
OSEM	TBC
Mounting Plate	TBC

Table 3.2-1

The Centre of Mass of the OSEM is given below. The Reference Point for the measurement is the central axis of the OSEM at the front surface:-

Dimension	Value (mm)
X	TBC
Y	TBC
Z	TBC

Table 3.2-2

3.3 Actuator Properties

The actuator will be wound to the following specification:-

Number of Turns:-	400TBC (See note 1)
Winding sense:-	Clockwise with respect to the back face of the OSEM
Nominal Winding Tension:-	TBD
Wire Type:-	32QML (Supplied by MWS Industries)
Winding Inductance:-	3.1±0.2mH TBC (Measured at 1KHz)
Winding Capacitance:-	TBD ± TBD pF
Winding Resistance:-	16±1Ω TBC
Coil Inner Diameter:-	TBC (Former Diameter)
Coil Length:-	4±0.25mmTBC
Maximum Current:-	150mA
Isolation:-	
Actuator Coil to the OSEM Body:	250MΩ

Note 1: It is clear that some OSEM locations will require a lower actuation force than the 'nominal' value. It is envisaged that this will be accommodated either by presetting the drive electronics gain or changing the size of the magnet, rather than the producing multiple build variants with different numbers of turns.

3.4 Restriction on Usage of Magnetic Materials

The use of magnetic materials in the construction of the OSEM shall be restricted to ensure that the residual actuation force (with actuator coil unbiased and actuator magnet positioned on the OSEM axis in line with the front face) is less than 5mN.

3.5 Optical Sensor Properties

The optical Sensor shall have the following properties:-

Minimum sensing range:-	0.35mm (pk to pk) (See AD [9])
Target Sensing Range:-	0.7mm (pk to pk)
Worst Case Sensitivity	3×10^{-10} m/√Hz in range 1 to 10 Hz TBC (In conjunction with the sensor electronics)
Emitter Type	Optek OP232
Max continuous Forward Current:	100mA
Nominal Forward Current:	35mA
Detector Type	TBD
Maximum Bias:	TBD

Nominal Photodiode bias:	0V
Sensor Temperature Coefficient	1.5%/K
Current transfer ratio	>0.05% TBC (with flag fully retracted from the field of view)

Isolation:-

Sensor IR emitter circuit to the OSEM body:	250MΩ
Sensor IR detector circuit to the OSEM body:	250MΩ

3.5.1 Degradation of Sensor Output with Time

Degradation of the sensor output with can be attributed to the degradation of the Emitters optical output power with time. In order to minimize the risk of premature OSEM failure due to such effects, the Emitter batch used for the final deliverable product will be subject to a Lot Acceptance Test on 20 pieces TBC selected at random. The format of the test is TBD.

3.6 Thermal Considerations

The OSEM shall function under the following environmental conditions:- (TBC) (RODA?)

Operational temperature:-	22^0C (nominal ambient)
Seasonal variation:-	$\pm 2^0$C (between sites)

In-situ, bake-out shall occur at the following temperatures:- (TBC) (RODA?)

Non-operational:-	$20\text{-}30^0$C above ambient

The Maximum dissipation from the OSEM shall be as follows-

Item	Maximum Dissipated Power	Notes
Coil	360mW TBC	At 150mA continuous forward current
IR Emitter	50mW	At 35mA continuous forward current

Table 3.6-1

Note: The Detector diode dissipation is considered negligible

3.7 Flag Properties

The Flag shall have the following dimensions:-

Length:	TBC
Shape:	Flat edge cylinder
Diameter:	3mm TBC

4 OSEM to Suspension (SUS) and Seismic Isolation (SEI) Interfaces

4.1 OSEM Connector Details and Pin Allocation

Electrical Connection to the OSEM is via a Glenair Micro D male 9 way connector Part Number MWDM2L9PCBRP.110 (TBC) mounted on the rear face of the device. The pin allocations are as shown below and are applicable to the connector at the OSEM and at the Seismic Isolation Bridge:-

Pin Number	Signal Name	Description
2	ST	Start of Coil winding
3		Not Connected
4	LED-A	IR Emitter Anode
5	PD-A	Photodiode Anode
6	FN	End of Coil winding
7		Not Connected
8	LED-K	IR Emitter Cathode
9	PD-K	Photodiode Cathode

Table 4.1-1

4.2 OSEM Cable Harness (Pigtail)

Cable Harnessing shall comply with the requirements of Applicable Document [4] where appropriate.

Each cable harness shall have the following properties:-

Connector Mating to OSEM:	9 way Female Micro D, Pin out as Table 3.2-1
	Part Number MWDM2L9SSx-MC216 (TBC)
Connector Mating to SEI Bridge:	9 way Male Micro D, Pin out as Table 3.2-1
	Part Number MWDM2L9PSx (TBC)
Backshell:	None
Cable type:	CZ1104 Clear Teflon Coated Copper Wire TBC
Outer braided shield:	None due to stiffness requirement.

4.3 OSEM Cable Harness (Pigtail) Lengths

Cables will be manufactured to suit the locations of OSEMs within the suspension stacks of the 6 TBC different suspension designs:

Details below are TBD pending completion of suspension designs and cable routing proposals. It is expected that there will be no more than 8 different cable lengths.

Cable clamping details and locations to be agreed with SUS design team.

4.3.1 IMC Triple Suspensions

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	6	Hybrid	TBD	TBD
Penultimate Mass	4	LIGO1	TBD	TBD
Bottom Mass	4	LIGO1	TBD	TBD

Table 4.3.1-1

4.3.2 OMC Triple Suspensions

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	6	Hybrid	TBD	TBD
Penultimate Mass	TBC	TBC	TBD	TBD
Bottom Mass	TBC	TBC	TBD	TBD

4.3.3 RM Triple Suspension

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	6	Hybrid	TBD	TBD
Penultimate Mass	4	LIGO1	TBD	TBD
Bottom Mass	4	LIGO1	TBD	TBD

Table 4.3.2-1

4.3.4 ITM Quad Suspension

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	12	Hybrid	TBD	TBD
Intermediate Mass	4	Hybrid	TBD	TBD
Penultimate Mass	4	Hybrid	TBD Note	TBD

Table 4.3.3-1

Note: Cable length will be split by in–line micro D connector to allow suspension to be assembled in 2 sections.

4.3.5 FM Quad Suspension

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	12	Hybrid	TBD	TBD
Intermediate Mass	4	Hybrid	TBD	TBD

Table 4.3.4-1

4.3.6 BS Quad Suspension

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	12	Hybrid	TBD	TBD
Intermediate Mass	4	Hybrid	TBD	TBD

Table 4.3.5-1

4.3.7 ETM Quad Suspension

OSEM Location	Qty	OSEM Type	Cable Length	Cable Drawing
Top Mass	12	Hybrid	TBD	TBD
Intermediate Mass	4	Hybrid	TBD	TBD
Penultimate Mass	4	Hybrid	TBD Note	TBD

Table 4.3.6-1

Note: Cable length will be split by in–line micro D connector to allow suspension to be assembled in 2 sections.

5 Materials

The following table lists all materials used in the OSEM manufacture, including connectors, electronic components and cable harness (pigtail).

Item	Material	Where Used	Vacuum Review Board Approval Status
1	Beryllium Copper (ASTM-B194)	Male Connector	Approved
2	Phos Bronze (ASTM 139)	Female Connector	Approved
3	Gold (ASTM-B488)	Connector pin/socket Plating	Approved
4	Aluminium (Alloy 6062)	Connector Body, Coil Former, Mounting Plates	Approved
5	Electroless Nickel (ASTM B733-90,SC2,Type 1, Class J (MIL-C-26074)	Connector Body Finish	Approved
6	LCP (MIL-M-24519)	Connector Insulators and Inserts	
7	Hysol Epoxy #4215 (Black)	Connector Encapsulant	
8	Stainless Steel (300 per SAE-AMS-QQ-S-763)	Connector Jackscrews and Posts	Approved
9	Copper Wire (32QML)	Coil Winding	
10	Copper Wire (CZ1104)	Pigtail	Approved (initial LIGO)
10	Kapton	Flex Rigid PCB	
11	PEEK 450G	Coil Winding post Mounting Block	
12	FR4	Flex-Rigid PCB	
13	Kovar	Emitter and Detector Can TBC	
13	TBC	TBC	

Table 5-1

6 Manufacture and Cleaning

Parts will be manufactured and cleaned in accordance with ALIGO OSEM Manufacturing Specification Exxxxxxx TBC. All machining fluids used in manufacture of subassemblies shall be water soluble and free of sulfur (sic), chlorine and silicone.

Note: Finished item cleanliness will be such that the devices are acceptable for use/testing in a Laboratory environment. It is envisaged that final UHV cleaning will be conducted at the LIGO sites.

6.1 Finished Item Packaging for Storage and Shipping

Packaging for storage and shipping shall comply with the requirements of Applicable Document [5] that are relevant to the state of cleanliness.

6.2 Handling

Finished parts should only be handled in a Clean, static safe working environment, using standard static safe handling precautions and clean item handling procedures.

7 OSEM to Support Equipment (SUP) Interfaces

7.1 Automatic Test Equipment

Due to the volume of devices to be manufactured, finished product setup and test will be assisted by a PC based Automated test system. The system will measure and record the following parameters:-

i) Actuator Winding Inductance

ii) Actuator Winding Self Capacitance

iii) Actuator Winding Resistance

iv) Actuator Winding isolation to OSEM body

v) Sensor Current Transfer Ratio

vi) Sensor Emitter isolation to OSEM body

vii) Sensor Detector isolation to OSEM body

Test results will be provided with the finished product.

8 Quality Assurance

8.1 Requirements Verification Matrix

A Verification Matrix will be added once the content of the document is agreed