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# (Infrared) Pre-stabilized Laser (PSL) Electronics Design Requirements

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## Abstract

This technical note describes the design requirements for the LIGO Infrared Pre-Stabilized Laser (PSL) electronics. As the design and construction of the 10 watt laser was done by an outside vendor, a large portion of the document is comprised of constraints to the design requirements imposed by “life support” needs of the 10 watt laser.


# 1 INTRODUCTION

## 1.1. Purpose

The purpose of this technical note is to describe and document the design requirements for the LIGO Infrared Pre-Stabilized Laser (PSL) electronics

## 1.2. Scope

This document covers the design and performance requirements for all electronics hardware and software to be used for the LIGO Infrared Pre-Stabilized Laser (PSL) electronics.

## 1.3. Definitions

Infrared Pre-Stabilized Laser- In the context of this document the Infrared Pre-Stabilized Laser refers to the electronics designed and specified by the CDS including such things as servo electronics, control and monitoring, alarms and interfaces to other systems.

## 1.4. Acronyms

- ASC- Alignment Sensing and Control
- CDS- Control and Data System
- EMI- Electro Magnetic Interference
- FSS- Frequency Stabilization Servo
- IOO- Input Output Optics
- ISS- Intensity Stabilization Servo
- LCM- Laser Control And Monitoring
- LED- Light Emitting Diode
- LIGO- Laser Interferometer Gravitational-wave Observatory
- LSC- Length Sensing and Control
- LVEA- LIGO Vacuum Equipment Area
- MOPA- Master Oscillator Power Amplifier
- MTBF- Mean Time Between Failure
- MTTR- Mean Time To Repair

- PD- Photodiode
- PSL- Pre-Stabilized Laser
- PSS- Personnel Safety System
- SYS- Detector System Engineering
- TEC- Thermo Electric Cooler (Peltier Device)
- TBD- To Be Determined
- VCO- Voltage Controlled Oscillator

## 1.5. Applicable Documents

### 1.5.1. LIGO Documents

- *Detector Subsystems Requirements*, LIGO-E960112-06-D
- *Frequency Stabilization: Servo Configuration & Subsystem Interface Specification,* LIGO-T970088-00-D
- *Frequency Stabilization in LIGO,* LIGO-T960164-00-D
- *Prestabilized Laser Design Requirements,* LIGO-T950030-03-D
- *Vibration and Acoustic Requirements for the Laser and Vacuum Equipment Area (LVEA) and Vacuum Equipment Areas (VEA) for the LIGO Facilities,* LIGO-T950113-05-0.
- *LIGO 10-W Laser Specifications*, LIGO-E970055-01-D.
- *Science Requirements Document*, LIGO-E950018-00.
- *LIGO EMI Control Plan And Procedures,* LIGO-E960036-A-E.
- *Prestabilized Laser Design Requirements,* LIGO-T950030-03-D.
- *LIGO Naming Conventions,* LIGO E950111-A-E
- *LIGO Laser Safety Program, LIGO-M960001-A-P*

### 1.5.2. Non-LIGO Documents

- *Diode-Pumped Non-Planar Ring Laser Model 126 Users Manual*, Lightwave Electronics Corp. Mountain View, CA.
- *Lightwave Specification for LIGO 10W Laser Amplifier Electronics*, Document number:D-0226X1.DOC, Current revision date 6-9-97.

# 2 GENERAL DESCRIPTION

## 2.1. Product Perspective

The PSL electronics described in this document specify the servo electronics, controls, monitors, and specialized functions that form the Infrared Pre-Stabilized Laser for LIGO. Figure 1: Laser Frequency Control - Global configuration and subsystem interfaces, shows the relative position of the PSL to other systems. Figure 2: PSL Electrical Controls shows a high level view of the PSL main features.

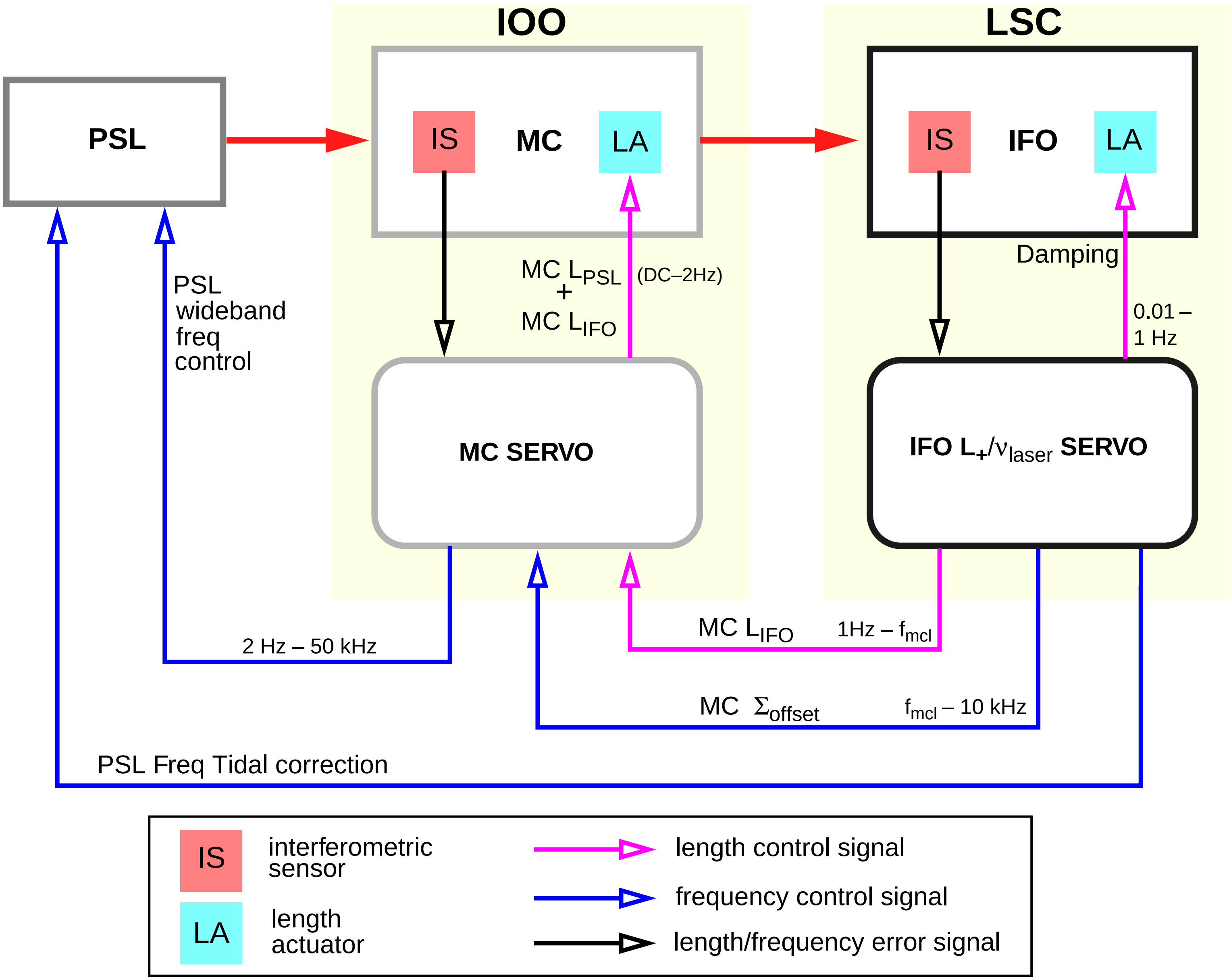


**Figure 1: Laser Frequency Control - Global configuration and subsystem interfaces**

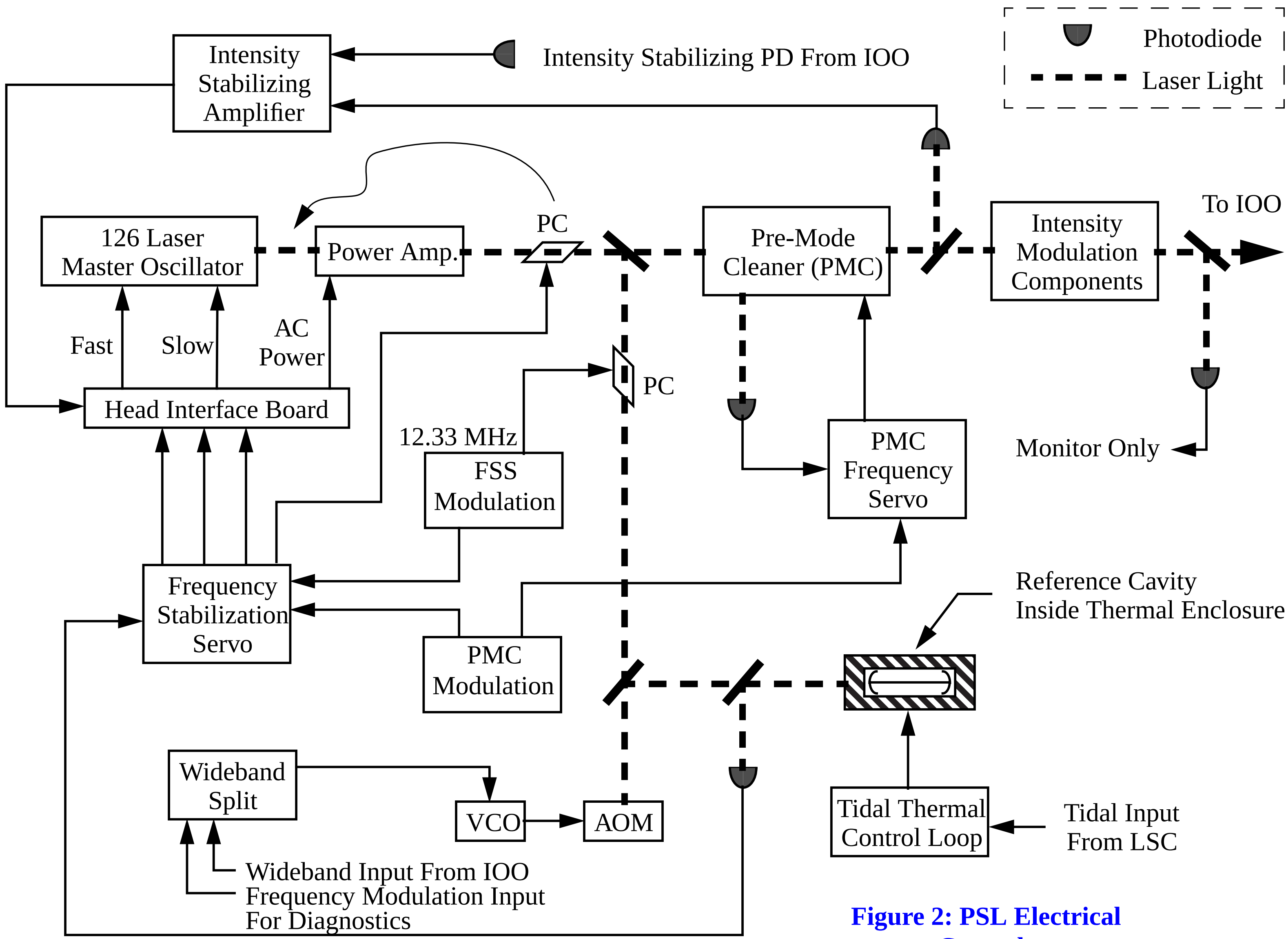


**Figure 2: PSL Electrical Controls**

## 2.2. Product Functions

The PSL electronics can be separated into several functional components: the Frequency Stabilization Servo loop, Intensity Stabilization loop, Laser Control and Monitoring, Personnel Safety System, Diagnostic Modes and Pre-mode Cleaner. The function of each is described below.

### 2.2.1. Frequency Stabilization Servo (FSS)

The function of the FSS is to suppress the free running frequency noise of the LIGO 10 W laser to the level required and to provide the necessary control and monitoring points for interfacing with the LIGO EPICS computerized control system. The FSS is also required for interfacing with the IOO for further frequency noise suppression.

### 2.2.2. Intensity Stabilization Servo (ISS)

The function of the ISS is to suppress the free running relative intensity noise of the LIGO 10 W laser to the level required and to provide the necessary control and monitoring points for interfacing to the LIGO EPICS computerized control system.

### 2.2.3. Laser Control And Monitoring (LCM)

The function of the LCM is to provide the control and data interface for the LIGO 10 W laser system and all other PSL subsystems.

### 2.2.4. Personnel Safety System (PSS)

The function of the Personnel Safety System is to ensure that persons working in the vicinity of the laser are not inadvertently exposed to laser emissions and that the Infrared Pre-Stabilized Laser system is in conformance with the LIGO Laser Safety standards.

### 2.2.5. Diagnostic Modes

The diagnostic modes support routine tests required of the PSL to ensure correct settings and alignment. Depending on how often the diagnostic is required to be performed, the diagnostic may or may not be fully controllable remotely.

### 2.2.6. Pre-mode Cleaner

The pre-mode cleaner is required to reduce the intensity noise fluctuations in order to meet the Shot-noise-limited Power Fluctuation specification at frequencies above 24.5 MHz and 29.5 MHz (the modulation frequencies for 4 km and 2 km interferometers, respectively). A servo will be required to lock the pre-mode cleaner to the incoming PSL light.

## 2.3. General Constraints

### 2.3.1. Equipment Locations

The electronics for the PSL shall be located in a 19 inch rack. The location of the racks for PSL electronics is defined in LVEA_WA_CDS_p.dwg

### 2.3.2. Reliability

LIGO must operate continuously, therefore this subsystem must be designed with high reliability and low mean time to repair. The PSL subsystem incorporates several feedback control loops that enable the frequency and power of the laser radiation to be stabilized to very low fluctuation levels. Those control loops must acquire lock quickly and reliably via a computer-automated sequence and maintain lock for long periods of time.

### 2.3.3. Frequency Servo System Constants

#### 2.3.3.1 Reference Cavity

- Bandwidth: 74 kHz
- Finesse: 10,000
- Length: 203.2 +/-0.3 mm
- Free Spectral Range: 738 MHz

#### 2.3.3.2 Actuator Constants

- Slow actuator: 4 GHz/ volt
- Fast Actuator: 4 MHz/ volt
- Pockels Cell: 0.015 rad/ volt

### 2.3.4. Intensity Servo System Constants

#### 2.3.4.1 Location of IOO/PSL Interface for Mode Cleaner Output Beam Sample for Power Stabilization.

The **IOO** output beam sample for power stabilization shall be delivered outside the vacuum vessel to the (**TBD-IOO/SYS**) optical table at the location (**TBD-IOO/SYS**)

#### 2.3.4.2 Power Level of IOO Output Beam Sample for Power Stabilization.

The power contained in the **IOO** output beam sample for power stabilization shall be greater than 25 mW (**TBD** PSL/S**YS**).

#### 2.3.4.3 Intensity Servo AC Power Adjust Actuator

Power Adjust Actuator Gain: 1 watt/ 100 volts

## 2.3.5. Laser Control and Monitoring Constants

### 2.3.5.1 Laser Power Supply Physical Parameters

- Width: 19 in rack mount chassis with holes for slides.
- Height: 3U (5.25 in)
- Depth: <16 in

### 2.3.5.2 Figure 3: Laser Power Supply Front Panel

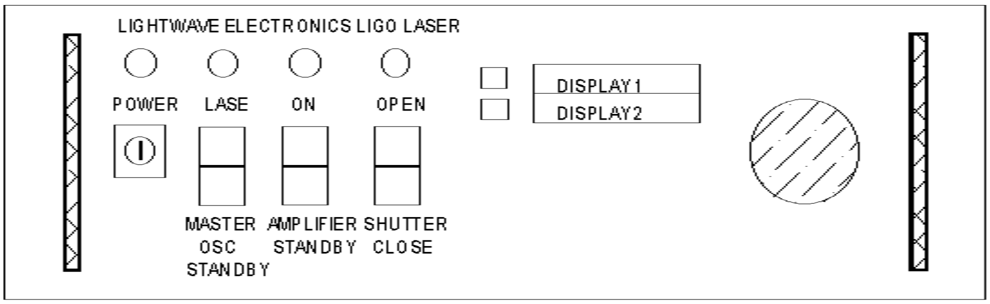


**Figure 3: Laser Power Supply Front Panel**

#### *2.3.5.2.1 Controls*

- AC Power Switch - Key lock switch, removable only when off
- Shutter Open/Closed - Rocker
- Amplifier Standby - Rocker, standby position will override external input
- Master Oscillator Standby - Rocker, standby position will override external input
- Display 1 Push Button - Momentary, selects display function
- Display 2 Push Button - Momentary, selects display function
- Dial - Changes control parameter

#### *2.3.5.2.2 Status*

- Power On LED - AC power on indicator
- Amplifier On LED - On indicates amplifier could be on
- Master Oscillator Lase LED - On indicates Master Oscillator could be on
- Shutter LED - On indicates shutter is open
- Display - Two 8 character yellow LED displays

#### *2.3.5.2.3 System Interface Cable*

The system interface will provide discrete data signals, analog and digital to the LIGO computer system. These signals are on a 2 x 32 PCB right angle back mounted connector (64 pin Thomas & Betts 609-640ES or equivalent), see Figure 4: Laser Electrical Interconnect Diagram.

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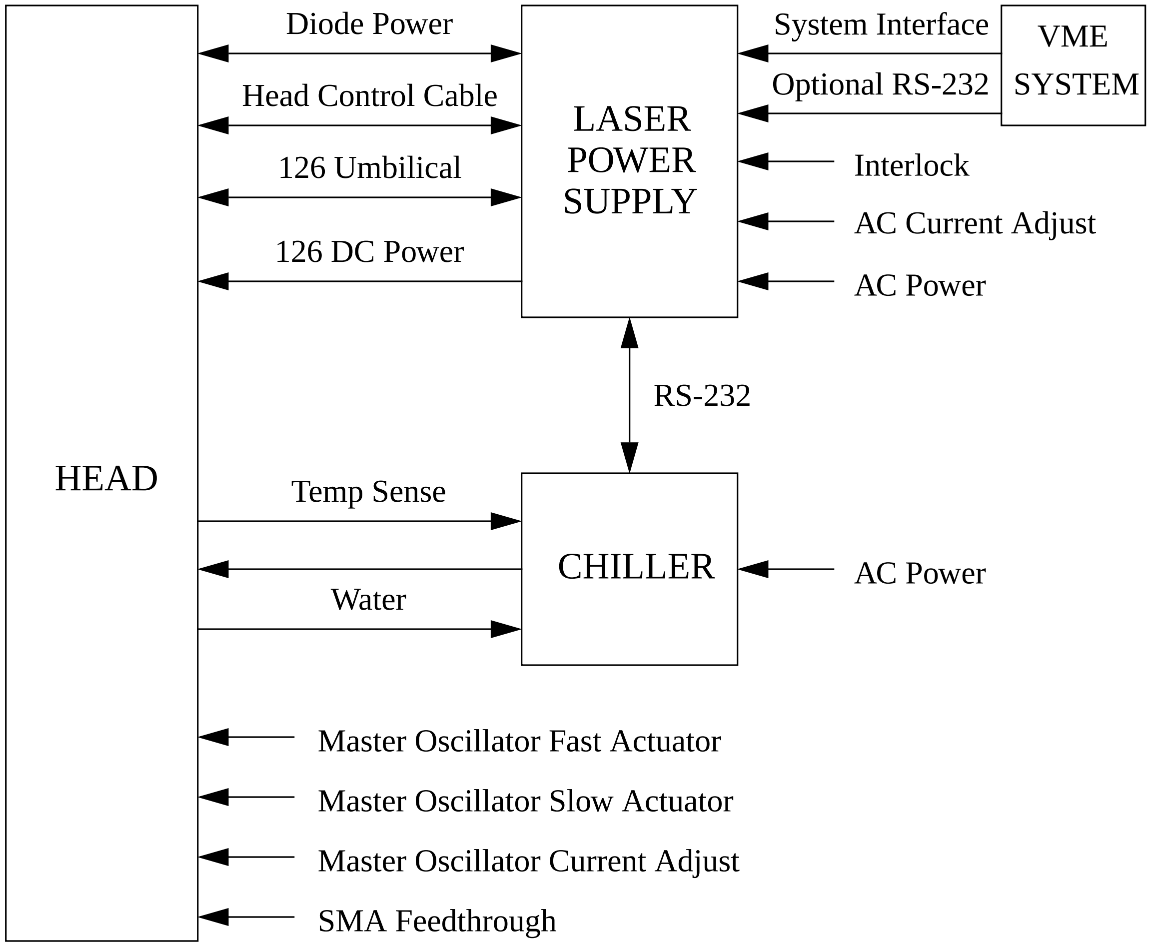


**Figure 4: Laser Electrical Interconnect Diagram**

*2.3.5.2.3.1 Head Signals - Analog.* ***These next three signals have a separate sensor analog ground which is tied to amplifier ground at the amplifier. Do not externally connect to ground.***

1. Amplifier Power Monitor: 8V nominal for full power output Z = 1k
2. Oscillator Power Monitor: 8V nominal for full power output Z = 1k
3. Diode Monitor Signals (8): 0 to 10V, Current to voltage conversion on head sensor PCB output Z = 1k

*2.3.5.2.3.2 Model 126 Laser Analog Signals*

1. 126 Slow Actuator: Control Slow Frequency (Laser Temperature) 4GHz/V, three poles at 0.2 Hz Z in = >10 kohms. On the head interface board, there will be the option to disconnect this signal from the mass term 64 conductor cable if it should be necessary for noise reasons.
2. 126 +5V: Status indicates DC power is on at the 126. +5V indicates DC power on. Z out = 100 ohms.

3. Dtmp: Status diode temperature, reads +5V at a temperature of 10 deg. C and -5V at a temperature of 35 deg. C Zout = 10 kohm
4. Ltmp: Status laser temperature, measured crystal temperature at 10 deg C/ Volt Zout = 10 kohm.
5. Dmon: Status diode monitor, uncalibrated negative voltage used to monitor the power of the laser diode pump, Zout = 10 kohm.
6. Lmon: Status laser monitor, uncalibrated indication of laser power before being launched into the fiber. Zout = 10 kohm
7. 126 Current Monitor: 126 Diode current monitor @ 1V/A. Zout = 10 kohm.
8. 126 DTEC: Diode TEC voltage, positive voltage indicates cooling while a negative voltage indicates heating. This voltage should never exceed +4.5 Volts or -2.5 Volts. Zout = 10 kohms.
9. 126 LTEC: Status laser crystal applied TEC voltage, positive voltage indicates cooling while a negative voltage indicates heating. This voltage should never exceed +3.9V or -2.5V. Zout = 10 kohms.
10. 126 Current Adjust: Control current adjust, +2V to -10V produces a +2% to -10% change in diode current. Zin = 10 kohms.

**The above signals each have a separate analog ground which is tied to head power ground at the 126 head. Do not externally connect to ground.**

11. PZT+: Paired with PZT- and passed through to 126 head. On the head interface board, there will be the option to disconnect this signal from the mass term 64 conductor cable if it should be necessary for noise reasons. Provides frequency tuning with a gain of 4 MHz/V.

#### *2.3.5.2.3.3 Amplifier Analog Signals - Status*

1. Amplifier Diode Current Monitor: +5V to 2.5V for 0 to 40A. Zout = 1 kohm.
2. Head Temperature Monitor: 0 to 5V for 5 to 30 deg. C Zout = 1 kohm.
3. Temperature Set Point: 0 to 5V for 5 to 30 deg. C (0.1 deg. C resolution) Zout = 1 kohm.

***The three signals in the above section each have a separate sensor analog ground which is tied to amplifier ground at the amplifier. Do not externally connect to ground.***

#### *2.3.5.2.3.4 System status signals, Digital.*

These signals are opto-isolated, open FET, common return line. This return line is shared with the amplifier digital control signals and may be tied to source ground. Signals will be floating with power supply off. Rated to 60V, <100 mA.

1. Fault Status: Either fault or OK, high indicates there is a fault. This is a combined fault status bit. The exact cause of the fault is available on the front panel.
2. Interlock: Either open or closed. High indicates the interlock chain could be open.
3. Shutter: Either open or closed. High indicates shutter could be open.
4. 126_lase: Either On or Standby. High indicates 126 could be lasing. The 126_lase line is a bidirectional pin which allows the user to put the laser into a Standby Mode condition, or indicates the laser’s current status as outlined below.

<u>As a control line</u>, the laser can be turned off by pulling this line low with a TTL signal or a switch to ground. During this time the 126 temperature control circuits will remain operational permit-

ting fast warm-up time. The mode when this line is low is referred to as “Standby Mode”. With the 126_lase line high, the laser will resume operation in about 2 seconds.

As a status line the 126_lase line indicates:

- Laser On: The voltage will be approximately 4.3V with a source impedance of 1 kohm.
- 15 Second Power-Up Delay: The signal will alternate between 0 and 5V at a 1 Hz rate, with a 10 kohm source impedance.
- Fault: A laser head temperature, diode temperature, or voltage level fault causes the lase line to alternate between o and 5V at a 5 Hz rate with a 10 kohm output impedance. After a temperature fault condition is removed, there will be a 15 second power-on delay.

5. Amplifier: Either On or Standby. High indicates amplifier could be on.

##### *2.3.5.2.3.5 Control Signals, Digital*

These are opto-isolated, 6 mA minimum, 10 mA maximum input current required. Common return line. This return line is shared with the amp digital control signals and may be tied to source ground.

1. 126 Noise Suppression: Must supply current to enable noise eater.
2. 126 Standby/Lase: Must supply current to lase.
3. Shutter Close/Open: Must supply current to open shutter.
4. Amp Standby/On: Must supply current to enable.

##### *2.3.5.2.3.6 Control Signals, Analog*

1. Amplifier DC Current Adjust - Differential input at amplifier, +/- 10V in yields +/- 2.5A of current change to the amplifier diodes. 10 kohm input impedance with 2 poles at about 1 Hz.

#### *2.3.5.2.4 Amplifier AC Current Adjust*

This input has a separate 2 pin lemo connector on the back panel of the rack mount amplifier power supply.

1. Gain: +10 to -10V input yields +0.1 to -0.1A current change.
2. Input Impedance: 10 kohm
3. Frequency Response: First pole > 25 kHz, additional poles > 100 kHz.
4. Connector type: LEMO EPL.OS.302.HLN, 2 pin female right angle receptacle.

#### *2.3.5.2.5 Safety Interlock*

A separate 2 pin 0.156 inch spacing connector, male pins. Must be shorted together to enable lasing. One pin tied to power supply ground, the other pulled to +5V with 360 ohm impedance. **Do not ground outside power supply.**

#### *2.3.5.2.6 RS-232 Interface.*

The amplifier will have a RS-232 port available for communication with the VME computer or for separate control and diagnostics.

##### *2.3.5.2.7 Head Control Cable*

25 wire data and control cable with DB-25 connectors on each end. This is supplied with the deliverables from Lightwave. LIGO has only to connect it to the appropriate connectors.

1. Diode Monitor Signals (8): These signals are passed through to System Interface.
2. 126 Laser & Amplifier Power Monitors: These signals are passed through to System Interface and input to an analog to digital converter internal to the Lightwave electronics.
3. Miscellaneous Control and Status: Power to head, shutter control and status, EEPROM, etc.

##### *2.3.5.2.8 Diode Power Cable*

Four 8 AWG highflex wires for diode current. Can be up to 50 feet in length.

##### *2.3.5.2.9 Master Oscillator Interface*

1. DC Power: Identical to the Lightwave DC power connectors of the 126 Analog Power Supply. This is a supplied connection requiring no construction on the part of LIGO. The pinout is available in the 126 users manual.
2. Control: 15 pin D connector cable as per 126 laser. On the Head Interface Board, there will be the option of disconnecting the Fast, Slow and Current Adjust signals from the cable.

##### *2.3.5.2.10 Chiller Interface*

The chiller will be controlled via its RS-232 port from the power supply. The target temperature will be stored in EEPROM in the head.

1. RS-232 Connector: DB-9, male connector mounted on the back of the supply
2. Temperature Sensor Connector: DB-9, male connector mounted on the Head Interface PCB.

##### *2.3.5.2.11 Amplifier AC Power*

1. Voltage: 85 to 260 VAC, universal input.
2. Power: < 2000 watts.

##### *2.3.5.2.12 Chiller AC Power*

1. Voltage: 120 VAC or 240 VAC, selectable internal to power supply.
2. Power: <2000 watts.
3. Connector: 20 amp rated connector. Type 5-20P.

## 2.3.6. Pre-mode Cleaner System Constants

### 2.3.6.1 PMC Cavity constants

1. Cavity Bandwidth: 3.2 MHz
2. Cavity Free Spectral Range: 714 MHz
3. PMC Temperature Coefficient of Frequency (approximate): 10e-6

### 2.3.6.2 Modulation

1. Modulation Frequency: TBD
2. Modulation Sideband Amplitude: 50 mW

3. Modulating Pockels Cell Gain: 0.015 rad/volt.

#### 2.3.6.3 Actuators and Detectors

1. PMC Frequency Detector Gain: 1 volt/ 120 kHz
2. PMC Actuator Displacement: 5E-6 m/kV
3. PMC Actuator Resonances: > 4.5 kHz
4. PMC Actuator Capacitance: 90 nF +/- 20%

#### 2.3.6.4 PMC Free Running Noise Estimate

The noise spectrum is of the PMC is yet to be accurately measured, although a preliminary measurement has been made.

## 2.4. Assumptions and Dependencies

**2.4.1.** The vibration and acoustic levels in the Laser and Vacuum Equipment Areas (LVEA) at the LIGO observatories are assumed to meet the requirements given in *Vibration and Acoustic Requirements for the Laser and Vacuum Equipment Area (LVEA) and Vacuum Equipment Areas (VEA) for the LIGO Facilities*, LIGO-T950113-05-0.

**2.4.2.** The temperature and pressure in the LVEA are assumed to meet the design conditions given in the Civil Construction Facilities *Design Configuration Control Document, Final Issue, July3, 1996*, LIGO-C960703-0. Specifically, a design temperature of 72°±3.5°F and pressure of 0.15 in. Hg above ambient.

**2.4.3.** The LIGO 10-W laser meets the specifications given in *LIGO 10-W Laser Specifications*, LIGO-E970055-01-D.

**2.4.4.** Neighboring systems in the LVEA conform to the standards put forth in *LIGO EMI-*

*Control Plan And Procedures*, LIGO-E960036-A-E

# 3 REQUIREMENTS

## 3.1. Characteristics

### 3.1.1. Performance Characteristics

#### 3.1.1.1 Frequency Stabilization Servo Electronics

##### *3.1.1.1.1 Frequency Fluctuations*

The PSL FSS shall suppress the amplitude spectral density of the frequency fluctuations at the input to the **IOO** shall be as specified in Table 1, below.

| *Frequency Range* | *Allowed Frequency Fluctuations* |
|---|---|
| 40 Hz to 100 Hz | $< 0.1 \times (100\ \text{Hz} / f)^{2.5}\ \text{Hz}/\sqrt{\text{Hz}}$ **(**from **SYS)** |
| 100 Hz to 1 kHz | $< 0.1 \times (100\ \text{Hz} / f)\ \text{Hz}/\sqrt{\text{Hz}}$ **(**from **SYS)** |
| 1 kHz to 10 kHz | $< 1.0 \times 10^{-2}\ \text{Hz}/\sqrt{\text{Hz}}$ **(**from **SYS**) |

**Table 1: Allowed PSL Output Beam Frequency Fluctuations**

##### *3.1.1.1.2 PSL Wideband Frequency Control Input*

PSL shall provide a wideband frequency control input for frequency correction signals from the **IOO** mode cleaner servo[1]. The interface parameters for the PSL Wideband Frequency Control Input are specified in Table 2.

| *Parameter* | *Specification* |
|---|---|
| 1. Signal Type | Analog |
| 2. Signal Coupling | DC |
| 3. Signal Range | $\pm 15\text{V}$ |
| 4. Sensitivity | 330 kHz/V (by PSL) |

**Table 2: Interface specifications for the PSL Wideband Frequency Control Input**

1. Refer to LIGO-T970088-00-D, *Frequency Stabilization: Servo Configuration & Subsystem Interface Specification*

| *Parameter* | *Specification* |
|---|---|
| 5. Frequency response DC to 100 kHz | Flat within 2 dB |
| 6. Frequency response: $f > 100$ kHz: | < ($f$/100kHz) x (average response below 100 kHz) |
| 7. Phase | Phase lag at 100 kHz, $\phi < 20°$ |

**Table 2: Interface specifications for the PSL Wideband Frequency Control Input**

#### *3.1.1.1.3 PSL Tidal Correction Frequency Control Input*

The PSL shall provide a very slow input to be used by the LSC to make the laser frequency track the common mode length changes of the interferometer's arms on tidal time scales. The interface parameters for the PSL Tidal Correction Frequency Control Input are specified in Table 3.

| *Parameter* | *Specification* |
|---|---|
| 1. Signal Type | Analog |
| 2. Signal Coupling | DC |
| 3. Signal Range | $\pm 15$V |
| 4. Sensitivity | **2** MHz/V (by PSL/**SYS**) |
| 5. Frequency Response | Step response time constant < 1 hour |
| 6. Control Range | $\pm 30$ MHz |

**Table 3: Interface Specifications for the PSL Tidal Correction Frequency Control Input**

### 3.1.1.2 Intensity Stabilization Servo Electronics

#### *3.1.1.2.1 Fractional Light Power Fluctuations at IOO Input*

The amplitude spectral density of the fractional light power fluctuations at the input to the **IOO** shall be $\delta P(f) / P < 10^{-6}\ 1/\sqrt{\mathrm{Hz}}$ for $100\ \mathrm{Hz} < f < 10\ \mathrm{kHz}$ and rising as $f^{-3/2}$ for $40\ \mathrm{Hz} < f < 100\ \mathrm{Hz}$.

#### *3.1.1.2.2 Fractional Light Power Fluctuations at COC Input*

The amplitude spectral density of the fractional light power fluctuations at the input to the COC (recycling mirror) shall be $\delta P(f) / P < 10^{-7} / \sqrt{\mathrm{Hz}}$ for $100\ \mathrm{Hz} < f < 7\ \mathrm{kHz}$ rising to $\delta P(f) / P < 2 \cdot 10^{-7} / \sqrt{\mathrm{Hz}}$ at 10 kHz and rising as $f^{-3/2}$ for $40\ \mathrm{Hz} < f < 100\ \mathrm{Hz}$. for both the carrier and for the sidebands used for GW detection.

#### 3.1.1.2.3 Shot Noise Limited Power Fluctuations

The amplitude spectral density of relative power fluctuations in the output beam of the laser, measured at the input to the **IOO**, at frequencies above 24.5 MHz and 29.5 MHz (the modulation frequencies of the sidebands used for gravity wave detection for the 4-km and 2-km interferometers, respectively) shall be less than 1.005 times the shot noise limit for 600 mW of laser power. (This is the expected power level at the dark port of the interferometer).

### 3.1.1.3 Laser Control And Monitoring Requirements

The control and monitoring of inputs and outputs associated with the LIGO 10 watt Laser will be accomplished using standard off the shelf VME cards to the extent possible. The sample rate for analog and binary inputs will be consistent with the data to be measured. All items described in section 2.3.5.2.3 of this document (System Interface Cable) will be part of the Control and Monitoring, as well as all servo error points and actuator inputs as outlined in the LIGO IR PSL CDS Conceptual Design Document, LIGO T970114-00-C.

The data monitored by the VME based control and monitoring system needs to be specified according to data type. Data should be specified according to the following types: data to be data logged, operator viewed data on control screens and data to be input to the data acquisition system.

### 3.1.1.4 Personnel Safety System Requirements

In conformance with the need to have two redundant means of ensuring personnel safety the LIGO 10 W IR PSL shall require all persons in the LVEA to wear laser safety glasses appropriate for the laser wavelength and class in conformance with *LIGO Laser Safety Program LIGO-M960001-A-P*. In addition to safety glasses the second protective measure will consist of an interlocked enclosure around the optical table to completely contain the laser radiation. The interlock associated with the enclosure shall have a keyswitch to allow local bypass of the interlock for controlled access to the laser table. Access to the laser while it is lasing and general laser operation must be carefully outlined by an approved LIGO operational safety procedure. Access to the laser enclosure shall be controlled. Only designated and authorized laser personnel shall have access to the laser table enclosure. Placards on each entrance way shall be in place to inform personnel of the laser hazard and to reinforce the requirement to wear safety glasses.

### 3.1.1.5 Diagnostic Modes

#### *3.1.1.5.1 Internal Diagnostics*

The LIGO IR PSL shall have sufficient built in test features to verify proper operation and provide routine monitoring of important signals including but not limited to actuators, servo error points, test inputs, test outputs and photodiode levels.

### 3.1.1.6 Pre-mode Cleaner (PMC) Requirements

#### *3.1.1.6.1 PMC Noise Suppression*

The PMC free running noise characteristics are assumed to be similar in shape to that of the free running frequency noise of the Lightwave Model 126 Laser. The PMC servo shall suppress the PMC noise as outlined in Table 4

**Table 4: PMC Noise Requirements**

| *Frequency (Hz)* | *Free Running PMC Noise* | *PSL Required Frequency Noise (Hz/ rtHz)* | *PMC Required Frequency Noise (Hz/ rtHz)* |
|---|---|---|---|
| DC | 600 MHz | 1/10 Line-width of reference cavity | 1/100 of 1/2 Line-width of PMC cavity 16.5 kHz |
| 40 | 4000 Hz | 1 | 4.1e4 |
| 100 | 200 Hz | 0.1 | 1.65e3 |
| 1k | 20 Hz | 0.01 | 16.5 |
| 10k | 2 | 0.01 | 1.65 |

##### *3.1.1.6.2 PMC Dynamic Range For Frequency Adjustment*

To accommodate diurnal temperature variations and alignment of the PMC the PMC length shall be continuously electronically tunable over at least one free spectral range (714 MHz). During alignment the PMC frequency will be modulated up to 100 Hz.

## 3.1.2. Physical Characteristics

### 3.1.2.1 Electronic Equipment Housings

To the extent possible and reasonable the following shall be applied to the PSL electronics.

- All equipment shall be housed in standard 19 inch racks.
- Standard 6U VME enclosures with VME, dummy or split backplanes shall be used, as appropriate, for custom and commercial modules.
- Custom electronics modules shall be 6U VME format and shall follow the design standards imposed by the LIGO CDS group.

### 3.1.2.2 Cabling and Connections

All cabling and connection of electronics modules and devices shall be in accordance with standard LIGO CDS grounding and shielding policies.

## 3.1.3. Interface Definitions

### 3.1.3.1 Interfaces to other LIGO subsystems

#### *3.1.3.1.1 Electrical Interfaces*

The following table summarizes the electrical interfaces to other LIGO subsystems.

**Table 5: LIGO Electrical System Interfaces**

| *Interface* | *System* |
|---|---|
| Tidal Frequency Correction Actuator | IOO |
| Wideband Frequency Correction Actuator | IOO |

#### *3.1.3.1.2 Optical Interfaces*

The laser light from the IR PSL is fed to the 12m Mode-cleaner.

#### *3.1.3.1.3 Stay Clear Zones*

A 2 foot stay clear zone is required around the PSL racks

### 3.1.3.2 Interfaces external to LIGO subsystems

#### *3.1.3.2.1 Electrical Interfaces*

The following table summarizes the electrical interfaces to systems external to the LIGO detector.

**Table 6: Electrical Interfaces to non-Detector Subsystems**

| *Interface* | *System* | *Characteristics* |
|---|---|---|
| Rack AC Power | AC Power System | Voltage: 115 VAC, +TBD, -TBD<br>Current: 16 A max.<br>Frequency: 60 Hz |

## 3.1.4. Environmental Conditions

The PSL electronics shall meet all performance requirements when exposed to all specified natural and induced environments.

### 3.1.4.1 Natural Environment

#### *3.1.4.1.1 Temperature and Humidity*

#### *3.1.4.1.2 Electromagnetic Radiation*

The PSL electronics shall not produce electromagnetic emissions greater than those limits imposed by the LIGO EMI Standards, nor shall the PSL be degraded by other systems in conformance with the same standards.

**Table 7: 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 |

##### *3.1.4.1.3 Acoustic*

PSL electronics and associated control components shall be designed to produce the lowest levels of acoustic noise as possible and practical. In any event, acoustic noise levels greater than 35 dBA measured 1 foot from the device will not be produced.

## 3.2. Design and Construction

### 3.2.1. Component Naming

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

### 3.2.2. 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, modules and wiring shall be consistent with good engineering practice and fabricated to the best commercial standards.

### 3.2.3. Safety

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