LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
–LIGO–
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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LIGO Hanford Observatory 2k IFO PSL Test Report

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Distribution of this draft:
Detector

This is an internal working note
of the LIGO Project.

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1 General Constraints

1.1 Reliability

No report on the reliability of the PSL is available at this time.

1.2 Availability

1.2.1 Start-up Times

The cold start-up time for the PSL to lock the system was not measured. The warm start-up time was measured, in a worst case scenario, to be $\sim$ 11 minutes. The warm start-up was performed without the aid of the automatic lock acquisition software and was done whilst explaining how to lock the PSL servos.

Ultimate level of performance could not be achieved, as it takes a number of hours for the 126 MOPA Laser to “warm up”.

1.2.2 Endurance

Figure 1 shows the endurance of the PSL. Other data exists that suggests that the PSL remains locked and functional for periods greater than 40 hours on a regular basis. The EPICS archiver, AR, regularly logs the performance of the PSL. The data logs of which, can readily be scrutinized.

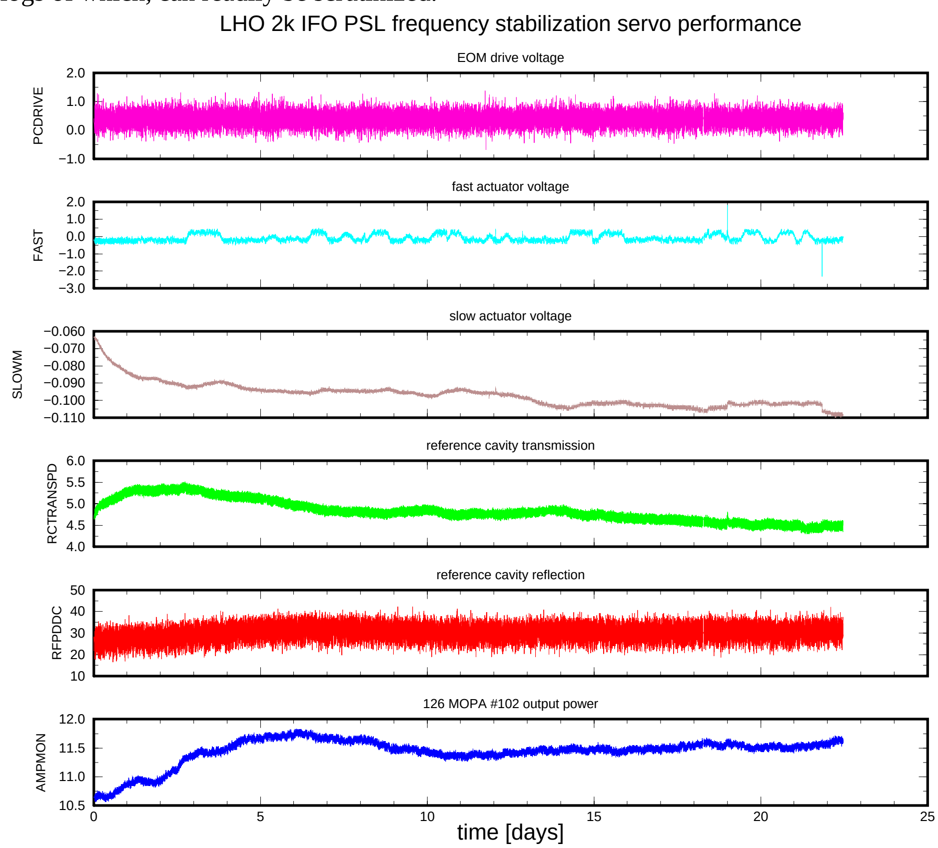

Figure 1: The performance of the PSL as monitored for a period of $\sim$ 25 days.

1.2.3 Remote Control Functions

During installation of the LHO 2k IFO PSL, the PSL was operated from two offices within the OSB. Subsequently the laser has been monitored, at various times, from Caltech.

2 Requirements

2.1 PSL TEM_{00} Output Power

The nominal **PSL** output power shall be greater than or equal to 8.5 W in a circular TEM_{00} mode.

When installation was completed, the stabilized output power of the LHO 2k IFO PSL was measured to be 8 W. This was measured with the site's Gentec TPM–300 laser power monitor and PS–330WB surface absorbing calorimeter.

Rick Savage measured the power after every optical element in the PSL optical train. This was measured approximately two months after the installation of the PSL.

2.2 PSL Non-TEM_{00} Output Power

The total output power in all modes except the circular TEM_{00} mode shall be less than or equal to 500 mW.

The PSL non-TEM_{00} output power was not measured.

2.3 PSL TEM_{00} Output Power Variations

The low-frequency variations in the PSL output power shall be less than 1 % peak-to-peak over any 24-hour period.

2.4 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 $\delta P(f) \,/\, P < 10^{-6}\ 1 \,/\, \sqrt{\text{Hz}}$ for $100\,\text{Hz} < f < 10\,\text{kHz}$ and rising as $f^{-3/2}$ for $40\,\text{Hz} < f < 100\,\text{Hz}$.

Figure 2 shows the relative intensity noise as measured by both an in-the-loop and outside-the-loop photodetector. The outside-the-loop measurement shows that the PSL is within specification for frequencies greater than 700 Hz.

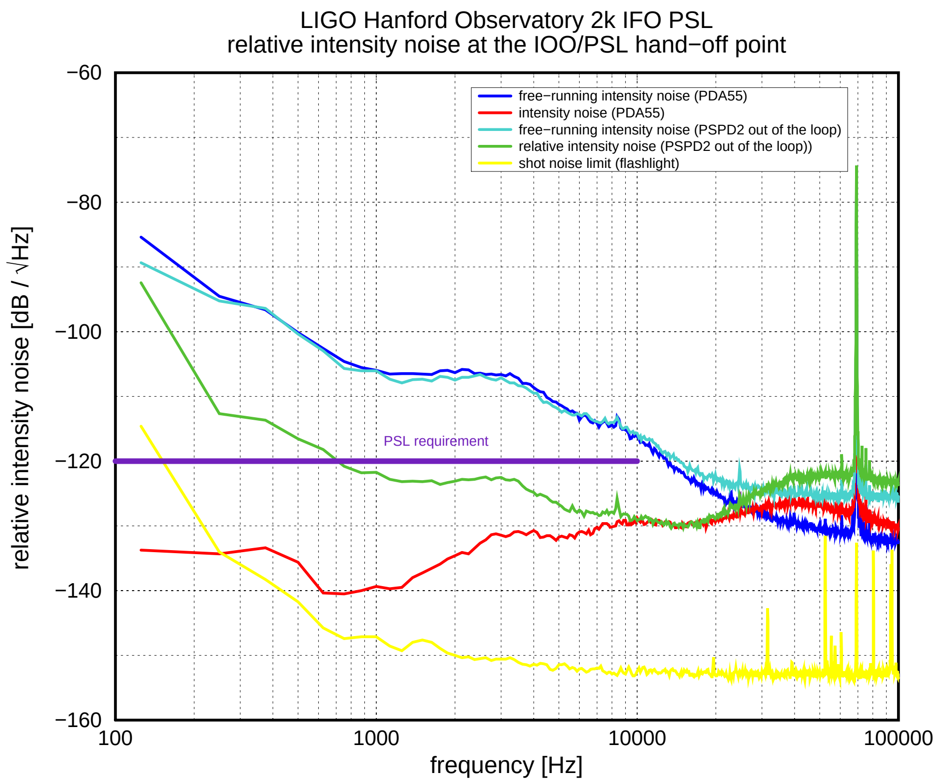

Figure 2: The relative intensity noise spectrum of the PSL, as measured by both an in-the-loop and outside-the-loop photodetector, measured near the input to IOO.

2.5 Fractional Light Power Fluctuations at COC Input

The amplitude spectral density of the fractional light power fluctuations at the input to the **COC** shall be $\delta P(f)\,/\,P < 10^{-7}\ 1\,/\sqrt{\mathrm{Hz}}$ for 100 Hz ¡ f ¡ 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.

The relative intensity noise at the COC input was not measured at the time of installation.

2.6 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).

P. King needs to go through Peter Csatorday's measurements of the high frequency relative intensity noise measurements. Already it is known that the PSL is above the shot-noise limit at the modulation frequencies because the pre-modecleaner does not provide sufficient filtering — the bandwidth of the pre-modecleaner is too large.

The other issue to resolve is why the apparent measured bandwidth appears to be 3.3 MHz rather than the expected 1.6 MHz.

2.7 Frequency Fluctuations

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	$< 0.1 \times (100\,\text{Hz} / f)^{2.5}\ \text{Hz} / \sqrt{\text{Hz}}$
100 Hz to 1 kHz	$< 0.1 \times (100\,\text{Hz} / f)\ \text{Hz} / \sqrt{\text{Hz}}$
1 kHz to 10 kHz	$< 1.0 \times 10^{-2}\ \text{Hz} / \sqrt{\text{Hz}}$

Table 1: Allowed PSL output beam frequency fluctuations.

Figure 3 shows the measured in-the-loop frequency noise measurement. The in-the-loop measurement shows that the PSL stabilized frequency noise is consistent with its design requirements.

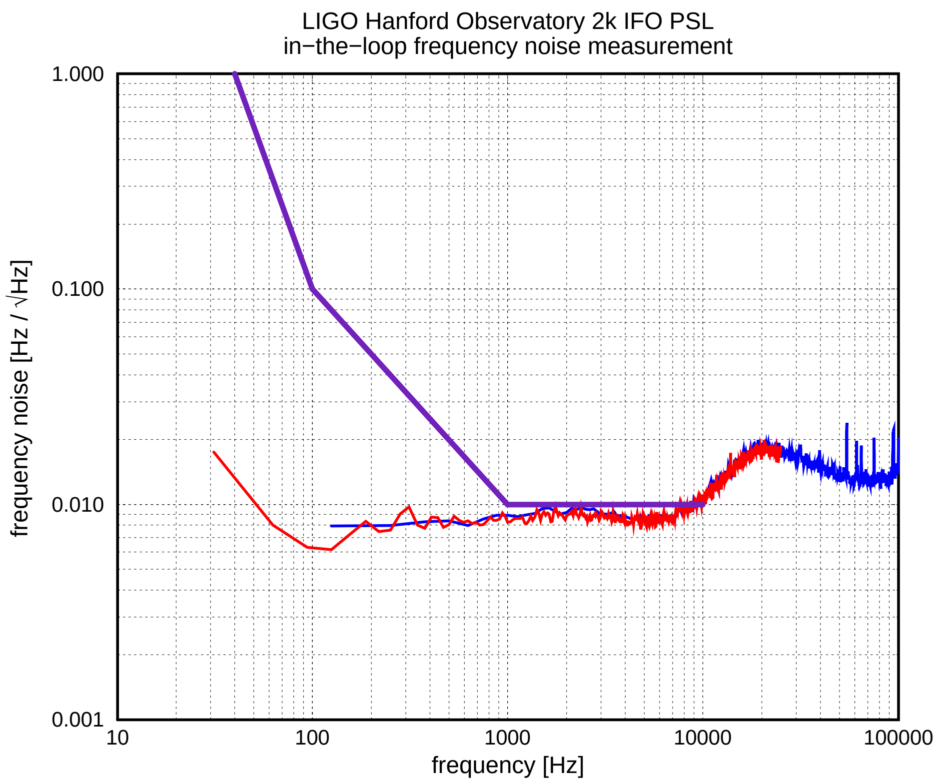

Figure 3: The frequency noise spectrum of the PSL, as measured inside-the-loop with the error signal from the frequency stabilization servo.

2.8 PSL Output Beam Relative Pointing Angle Fluctuations

The relative pointing angle fluctuations of the PSL output beam, $\delta\theta / (\theta_d / 2)$, at the interface with **IOO** shall be as specified in Table 2, below. $\theta_d / 2$, the divergence half angle, is given by $\theta_d / 2 = \lambda / (\pi \times w_0)$, where w_0 is the spot size at the beam waist.

Frequency Range	Allowed Relative Pointing Angle Fluctuations
DC to 40 Hz	< 0.1 peak-to-peak (**TBD** by **IOO**)
40 Hz to 150 Hz	$< 2 \times 10^{-6} \times (150\,/\,f)^2\ 1\,/\,\sqrt{\mathrm{Hz}}$ (from **SYS**)
¿ 150 Hz	$< 2 \times 10^{-6} 1\,/\,\sqrt{\mathrm{Hz}}$

Table 2: Allowed PSL output beam relative pointing angle fluctuations.

The output beam relative pointing angle fluctuations were not measured.

2.9 PSL Output Beam Relative Displacement Fluctuations

The relative displacement fluctuations of the PSL output beam, $\delta x\,/\,w_0)$, at the interface with **IOO** shall be as specified in Table 3, below.

Frequency Range	Allowed Relative Displacement Fluctuations
DC to 40 Hz	< 0.1 peak-to-peak (**TBD** by **IOO**)
40 Hz to 150 Hz	$< 1.3 \times 10^{-5} \times (150\,/\,f)^2\ 1\,/\,\sqrt{\mathrm{Hz}}$ (from **SYS**)
¿ 150 Hz	$< 1.3 \times 10^{-5} 1\,/\,\sqrt{\mathrm{Hz}}$

Table 3: Allowed PSL output beam relative displacement fluctuations.

The output beam relative displacement fluctuations were not measured.

2.10 Output Polarization Ratio

The polarization ratio of the PSL output beam at the input to the **IOO** shall be greater than 100:1.

The output polarization ratio was not measured during installation because a rotatable polarizer was placed at the input to IOO by IOO.

2.11 Output Beam Polarization Direction

The electric field (polarization direction) of the PSL output beam at the input to the **IOO** shall be oriented normal to the surface of the shared **IOO** / PSL optical table within ± 1 degree.

The output beam polarization direction was not measured because a half waveplate, allowing rotation of the polarization to any angle, was placed in the output of the PSL. This waveplate could be rotated by IOO to suit their polarization alignment needs.

2.12 Output Beam Polarization Angle Fluctuations

The amplitude spectral density of fluctuations in the polarization angle of the PSL output beam with respect to the plane of the shared PSL / **IOO** optical table shall be less than **TBD** by **IOO / SYS** radians / $\sqrt{\mathrm{Hz}}$.

The output beam polarization angle fluctuations were not measured.

2.13 Allowed Scattered Light Level

TBD by **COS / SYS**.

The allowed scattered light level was not measured.

3 Interfaces External to LIGO Detector Subsystems

3.1 Mechanical Interfaces

3.1.1 Optical Table Vibration Isolators

The IOO / PSL optical table is supported by six rigid legs. Each leg sits on a metal pad. Under each pad is a small rubber pad. All six legs sit on the LVEA floor.

The position of the IOO / PSL optical table is given in drawing **LIGO–D980260–C**.

The exact position of the optical table is known by Hugh Radkins. I have the data sheet too but don't know the numbers off the top of my head.

3.1.2 Laser Cooling Water Chiller Unit

The 2k IFO PSL water chiller is situated in the interstitial wall space close to the 2k IFO PSL laser area enclosure.

3.2 Electrical Interfaces

3.2.1 Power for the Lightwave 10-W Laser

Electrical power for the Lightwave 10-W Laser is drawn from CDS power, 103–CDSAC–01, circuit 4.

3.2.2 Power for the Lightwave 10-W Laser Cooling Water Chiller Unit

Electrical power for the Lightwave 10-W Laser cooling water chiller is drawn from facilities power, VEAC–03A, circuit 13.

3.2.3 Power for the Optical Table Enclosure

The shelves inside the optical table enclosure are provided with CDS power from 103–CDSAC–01, circuit 6. The PSL electronics rack, designated 2X7, draws power from 103–CDSAC–01, circuit 23.

3.3 Stay Clear Zones

3.3.1 IOO / PSL Optical Table

A stay clear zone of 36 in. width minimum shall be maintained on all sides of the IOO / PSL optical table enclosure, except for the side facing the closest HAM chamber. This stay clear zone provides space for the optical table enclosure as well as access to the table and PSL electronics rack for maintenance and repairs.

3.3.2 Laser Cooling Water Chiller Unit

A stay clear zone of 36 in. minimum is required in front of the water chiller to facilitate maintenance and repairs.

4 Reliability

Currently no 126 MOPA Laser has accumulated 5000 hours of run time.

Experience obtained at Caltech, suggests that the laser can be replaced and the optical train alignment tweaked in under 72 hours.

5 Maintainability

6 Environmental Conditions

6.1 Natural Environment

Doug Cook has the data about the dust conditions inside the IOO/PSL optical table enclosure during the time of installation.

No records of the temperature, humidity and atmospheric pressure were kept during the installation phase of the PSL by the PSL group. The PSL will rely on PEM to provide this information.

6.1.1 Temperature and Humidity

6.1.2 Atmospheric Pressure

6.1.3 Seismic Disturbance

6.2 Induced Environment

6.2.1 Electromagnetic Radiation

6.2.2 Acoustic

6.2.3 Mechanical Vibration

7 Transportability

8 Design and Construction

8.1 Materials and Processes

8.2 Component Naming

8.3 Workmanship

8.4 Interchangeability

Interchangeability was not demonstrated at the site. However it has been demonstrated at Caltech, where three 10-W lasers have been deployed. No change in the control electronics was found to be necessary. The only changes required minor adjustments to the optics.

8.5 Safety

The aspect of safety is managed by the site management. All aspects of the PSL conform with the requirements, otherwise the PSL would not be allowed to be operated. With the exception of the use of beam tubes, care has been taken so that every stray beam from the PSL is safely dumped.

8.6 Human Engineering

9 Documentation

9.1 Specifications

9.2 Design Documents

9.3 Engineering Drawings and Associated Lists

9.4 Technical Manuals and Procedures

9.4.1 Procedures

9.4.2 Manuals

10 Logistics