



LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T1200380-v1

LIGO

31 July 2012

ISC Single Channel WFS RFPD Test Procedure:

Richard Abbott

Distribution of this document:
LIGO Scientific Collaboration

This is an internal working note
of the LIGO Laboratory.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW22-295
185 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 159
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

<http://www.ligo.caltech.edu/>

1 Introduction

This document describes the testing of the single channel RFPD photodetector used in the aLIGO ISC or IO subsystems. A summary of the characteristics of this detector are available in [T1100402](#). The schematics for this detector can be found in [D1200066](#). A list of ISC detectors (RF & DC) can be found in [T1000264](#).

This procedure relies upon a familiarity with the complex nature of this circuit and the techniques of network analysis, modulated laser light sources, and shot noise limited sensitivity measurements. Minimal instructions are included in this procedure to avoid lengthy and complex tutorials.

All final data results are recorded in [T1200381](#)

This procedure is broken into the following sections:

- ***Serial number*** – Unique identification of the unit is recorded in the form of the serial number if the internal circuit board and associated schematic details
- ***DC checks*** – Current draw into the detector and verification of all internally regulated voltages
- ***DC path transimpedance*** – A measurement of the DC transimpedance of the DC path of the RFPD.
- ***Notch tuning*** – Adjustment of RF notch frequencies
- ***Notch rejection ratios*** – Measurement of RF notch depths
- ***RF transimpedance*** – A white-light based measurement of the RF transimpedance
- ***Shot noise limited input sensitivity*** – Verification that the RF noise performance is within design limits

2 Product Perspective

As shown in Figure 1, the ASC RFPD is mounted in a metal housing with all connections on the top surface. There are 4 SMA connectors for the RF outputs. Power and the DC outputs are on the 15-pin D-sub connector.

Figure 1



3 D-Connector Pinout

15 pin D Pin	Function
1	Q1 Readout Positive
9	Q1 Readout Negative
2	Q2 Readout Positive
10	Q2 Readout Negative
3	Q3 Readout Positive
11	Q3 Readout Negative
4	Q4 Readout Positive
12	Q4 Readout Negative
5	No Connect
13	No Connect
6	DC Power Positive
14	Ground
7	DC Power Negative
15	Ground
8	No Connect

4 Serial Number Data

Record the serial number and relevant schematic D-number/revision in [T1200381](#)

5 DC Checks

Record the total circuit board quiescent current draw and regulated voltages in [T1200381](#). Use caution in believing the digital readouts of laboratory triple output power supplies. Their meters are not highly accurate. When in doubt, use a multimeter on the appropriate scale in series with the supply to be measured.

6 DC Readout Path

Using a handheld current calibrator, inject 1mA DC into the anode circuit of the RFPD through a 100 Ω resistor. By observation of the DC voltages present at each differential DC readout

terminal-pair on the 15 pin D-connector, calculate the transimpedance of the DC readout chain for each quadrant, Z_{dc} by:

$$Z_{dc} = \frac{V_{out}}{0.001A}$$

Record each result in [T1200381](#).

7 Notch Tuning

The LSC photodetector circuit has series resonant RF notches that are tuned to allow amplification of some frequencies, while providing rejection at other frequencies. The notches are tuned by means of surface mounted RF trimmer capacitors on the photodetector PCB. Table 1 shows which capacitor to tune for each notch frequency. Due to the fact that there is no electrical monitor of the anode of each quadrant, the fundamental frequency notch must be adjusted by using a FET probe right on the anode of the quadrant under test. The 2ω notch is visible at the SMA output connector for each quadrant under test.

Using a laser capable of RF AM modulation, and an RF network analyzer, perform a frequency sweep from the photodiode to the FET probe for the fundamental frequency, and each RF output connector on the top surface of the photodetector housing for the 2ω notch.

Table 1, Notch Adjustment Frequencies

Notch Frequency	Adjustment Capacitor
Fundamental Frequency	C8
2ω Notch	C12

After adjusting each notch, record into [T1200381](#) the achieved 2ω tuning frequency as indicated. Be sure to note the DC photocurrent for each quadrant when it is illuminated by the laser light source. This data allows for normalization if so desired later on.

8 Notch Rejection Ratios

With the series resonant portions of the circuit tuned to the appropriate frequencies, a measurement can be performed to establish the ratio of the gain at the desired readout frequencies to the gain at the undesired frequencies corresponding to the rejection notches.

Using a laser capable of RF, AM modulation and an RF network analyzer, perform a frequency sweep from the photodiode to each SMA output connector on the top surface of the photodetector housing. Use the delta marker function to record the difference between each notch and the relevant RF operating frequency. Be sure to note the DC photocurrent for each quadrant when it is illuminated by the laser light source. This data allows for normalization if so desired later on. Record the results in [T1200381](#).

9 RF Transimpedance Measurement

Illuminate the photodiode with white light (as generated by a shot noise limited source such as an incandescent bulb) to generate between 5 mA and 10 mA of photocurrent. At each SMA connector, use an RF spectrum analyzer to measure the RF power spectral density at the readout frequency associated with each output. A low noise RF pre-amplifier (gain ~20dB) is useful to boost the signal to a comfortable level. Be sure the measurement is not electronically noise limited by careful attention to signal levels.

Convert the RF power spectral density to an rms voltage power spectral density assuming 50 Ω and note it at a few different photocurrents in the suggested range for use in calculating an average later. With each photocurrent, I_{dc} and each voltage spectral density, V_{rms} calculate the transimpedance, Z

$$Z = \frac{V_{rms}}{\sqrt{3.2 \times 10^{-19} I_{dc}}}$$

Average the calculation of Z and enter the average transimpedances in the appropriate spots on [T1200381](#).

10 Shot Noise Limited Sensitivity

The shot noise limited sensitivity will characterize the minimum useful optical signal level below which the photodetector will be limited by electronics noise. An RF spectrum analyzer and a low noise RF amplifier will be used to measure the noise voltages at each SMA RF output connector. Setup the measurement by connecting the preamplifier of known gain to the output of interest. With the photodiode completely dark, use an RF spectrum analyzer to measure the output of the preamplifier at the operating RF frequency. Be careful to verify the test setup is not limited by preamplifier noise or spectrum analyzer noise.

Note the dark RF noise level on the RF spectrum analyzer. Use a variable white light source to gradually increase the photocurrent until a 3 dB increase in RF noise is observed at the frequency of operation. Note the DC photocurrent level I_{dc} , in amperes corresponding to this RF level. Convert the RF noise level to a voltage spectral density V_{rms} , and calculate the shot noise limited sensitivity $Ilim_{rf}$ by using the RF transimpedance Z (as calculated earlier in section 9), for each quadrant.

$$Ilim_{rf} = \left[\frac{V_{rms}}{Z} \right]^2 \times \frac{1}{3.2 \times 10^{-19}}$$

Record the resulting shot noise limited sensitivity in [T1200381](#).