

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
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Technical Note

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**Photon Calibrator Procedure for  
Measuring Responsivity Ratios of  
Power Calibration Standards**

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# 1 Introduction

This procedure is used for measuring respective responses of two power calibration standards through Keithley 2100 digital multimeter / Keithley 2182 Nanovoltmeter:

-Working Standard (WSH, WSL, WSS, WSK, WSV) /GS;

## 1.1 Abbreviations

GS - Gold Standard

WSH - Working Standard Hanford (similarly WSL, Working Standard Livingston)

Dev - generalized device identifier (e.g. WS1, GS, CS)

Instr - instrument (Keithley 2100 Multimeter, Keithley 2182 Nanovoltmeter)

Resp - response

Meas - measurement

Refl - reflection

Tran - transmission

Bg - background

VI - LabView program which connects to instruments, reads measurements, and saves them into CSV files

# 2 Procedure

## 2.1 Pressurized Air Setup

*Warning: Pressurized air canisters can be dangerous if mishandled. If you have no prior experience working with these canisters, or feel in any way unsure about handling these canisters, please ask for help from a Pcal member*

- Turn the valve directly on top of the canister counter-clockwise. The pressure should rise to  $\sim 50$  psi, adjust the center knob to reach that point if it is off by a significant amount.

## 2.2 Hardware and Laser Setup

Turning on Tx Module:

- If the laser is not already on, turn the key in the Tx module. The “Laser On” light should turn on. The laser will take a few minutes to power up.

Preparation of power measurement standards

- Make sure that calibration standards are assembled and electronic equipment is connected according to Calibration Standard System Description document (T070210); applies for both device 1 (WS, WS2, WS3, CS, or other) and device 2 (GS or other)
- Place devices on front and back sliders if not already attached, making sure to secure them to their mounts with a washer and screw. Remove input port covers (the standards can be in either front/back configuration to start)

### 2.3 Instrument Settings for Gold Standard and Working Standards

Keysight power supply/blue box:

- If not already on, turn on both Keysight power supplies and check that their V1 and V2 voltages are set to 15 V.
- Connect the power supply to the back of the blue box (side without BNC port) and check that green LED's on the back are lit up.
- Switch on blue box, check that green LED's on the front and on the Standard are lit up

Keithley 2100 digital multimeter:

- Set digital multimeter input to REAR
- Make sure there is a USB cable connected from the back of the multimeter to the USB interface.
- As of right now, the Labview program will always attempt to take temperature sensor measurements:
  - For devices with temperature sensors (all but GS, WSK), connect a DB9 breakout board to the back of the blue box, attach clip leads to pins 1 (+) and 6 (-), and plug the output into an unused multimeter with a BNC-to-banana adapter.
  - For devices without temperature sensors installed (or measurements in which you don't want to take a temperature measurement), short the input on an unused multimeter.
  - Make sure the four multimeters have USB cables connected to them, and make sure the multimeter is using that input.

## 2.4 Software Settings

Startup:

- If the Labview file is not open on the PCal computer already, you can click the Labview icon in the toolbar and search 'pcal\_calibration\_auto.vi'.
- To begin the program, click the continuous run button (cycling arrow icon on the upper left).

First tab:

- On the leftmost tab, the VM's being used for voltage measurements are assigned. Select the Keithley Multimeters being used from the drop-down panel (instruments ID's correspond to the serial numbers printed on the front of each multimeter). Instrument 1 will correspond to the Standard you want in the numerator for your responsivity ratio, instrument 2 to the denominator.
- For instruments 1 and 2, pick the following settings on the "Instrument \_\_: Keithley 2100 Config" panel:
  - NPLC: 1
  - Auto Range: Auto
  - Digital Filter: Off

Second Tab:

- On the middle tab, the VM's being used for temperature measurements are assigned. Since the program will always try to take temperature measurements, VM's have to be assigned or the Keithley driver will return an error. Similarly, assigning two to the same multimeter will return an error.

NOTE: The button saying whether or not to take a temperature measurement has not been configured, and will not do anything.

## 2.5 Background Measurement

[At the present moment, the background measurement and main measurement need to be taken separately]

- Close the shutter on the Tx module.
- On the third tab, set "Number of Measurements" to take (typically 5), set "Duration" to 0:05, and set "Trigger Interval" to 1000 ms. Set the slider move time to 5 seconds. Set the "Background Measurement" switch to on. Set the configuration switch, based on which devices are on the front and back sliders if you are facing the laser.

- If the standards have been powered on by blue boxes for more than 1 hour, set “Warmed Up” to Yes. If not, the program will wait 1 hour after you click start to begin the measurement. Set Background to On, and denote whether or not you are taking a background measurement before or after the main measurement.
- Press “Start” at the bottom of the second tab. If you need to stop the measurement, click the stop sign next to the continuous run button.

## 2.6 Main Measurement

- Open the shutter on the Tx module
- On the third tab, set “Number of Measurements” to take (typically 100), set “Duration” to 0:05, and set “Trigger Interval” to 1000 ms. Set the slider move time to 5 seconds. Set the “Background Measurement” switch to off. There are two positions per measurement and a five second delay for the spheres to switch places, so the total measurement time will be  $2 * \# \text{ of measurements} * (\text{measurement period} + \text{slider period})$ .
- Add your name to the appropriate section and a note detailing the specifics of this experiment to the notes sections. These will be saved in the “summary.txt” file.
- Follow the warming up procedure from the previous section. Set Background to Off.
- Start the measurement.

## 2.7 Temperature Dependence Measurements

Temperature dependence measurements require some extra setup time, as the standard being tested needs time to warm up in the oven.

- Turn on oven to the right of the lab computer and set the temperature (generally we’ve set it to 30C). Place the Working Standard (still plugged in to the blue box) into the oven and let it come up to equilibrium (generally wait a few hours).
- Open the shutter on the Tx module
- On the third tab, set “Number of Measurements” to take (typically enough to last about 3 hours), set “Duration” to 0:05, and set “Trigger Interval” to 1000 ms. Set the slider move time to 5 seconds.
- Add your name and notes to the appropriate section and set the “Measurement Type” switch to “Experimental”. Set “Background Measurement” switch to off.
- Move the Working Standard from the oven to the slider, secure it in place, make sure the DB9 connecting to the blue box doesn’t droop too much, and start the measurement.

## 3 Analyzing the Data

### 3.1 Combining Background and Main Measurements

- Go to `pcal.svn/PhotonCalibrator/measurements/LabData/[Device1_Device2]` and find the two measurements just taken
- Inside the background measurement directory should be a folder called Summary. Go into Summary and move the directory Background into the first level of the main measurement directory
- Delete the background measurement directory

### 3.2 Averaged Data Analysis

NOTE: Directions for in-lab analysis script and other Pcal scripts are also given in DCC Document T1900758. Scripts should be run with python3.

- In the same measurement directory, go to `scripts/python/WS_GS` and enter command:  
`python analyze.py calc_set directory_stamp`  
 where the directory stamp corresponds to the date denoted name of the measurement directory (e.g. “t2019-07-08T160729”).
- Check that the ratio timeseries’ have a low standard deviation, and that there is no significant trend in the final ratio values (and look at the average values listed in the legend as a sanity check). If the data looks acceptable, remove the “t” in front of the directory name. If it is not acceptable, investigate and replace the “t” with an “x”.
- Add the measurement to the svn by going into the device directory (e.g. ’“WSH\_GS”’) and typing:  
`svn add [meas. directory]`  
`svn commit -m "[relevant message]"`

### 3.3 Generating Responsivity Ratio Trends

- In the measurement directory, go to `scripts/pcaltoolbox` and type in:  
`python pcalPublishReport.py`
- This should generate a pdf that shows the Working Standard/Gold Standard trends and the weighted mean of their relative responsivities. Check this document (located in that directory under the name “pcal\_powercal\_trends.pdf”) to see how the most recent measurement compares to previous values.
- Add this to the svn as well by typing:  
`svn add pcal_powercal_trends.pdf`  
`svn commit -m "[relevant message]"`

## 4 Cleaning Up Post-Measurement

- Close Tx module shutter
- Replace input port covers on integrating spheres
- Turn off air to sliders and close air canister valve.
- Replace wall of plexiglass enclosure.