LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Document Type	DCC Number	
Test procedure	LIGO- E050204-00-C	9 August, 2005
LSC RFPD Compensation of Photocurrent Detuning Effect		
Richard Abbott, Mike Zucker	Richard Abbott Digitally signed by Richard Abbott DN: CN = Richard Abbott, C = US, O = LIGO Reason: I attest to the accuracy and integrity of this document Date: 2005.08.16 11:32:29 -07'00'	

Distribution of this draft: NSF reviewers, LIGO scientists
This is an internal working note of the LIGO Laboratory

California Institute of Technology
LIGO Project – MS 18-33
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

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

Date _______________
Tech _______________
RFPD Serial Number_______________

1 Overview

This procedure supersedes the bias compensation portion of procedure T010121 for LSC RF Photodetector D980454 revisions D and later. This revision to the design incorporates a potentiometer (R11) in conjunction with a fixed resistor (R24) that set the amount of feed-forward compensation that is applied to the photodiode element (D5) bias. The term “feed-forward” is used here to differentiate from true feedback. To first order, there is no feedback occurring, as a change in bias voltage does not cause a direct change in photocurrent.

As the amount of photocurrent in the photodetector element D5 changes with varying light levels, a change can occur in the voltage drop across the diode depletion region, which, in an identical fashion to a Varactor Diode, will cause a change in diode capacitance. Simply maintaining a constant bias voltage across the entire diode as the photocurrent varies is not sufficient to avoid this effect, as the total diode resistance is the sum of several resistances - point contact resistance, depletion region resistance, bulk semiconductor resistance etc.

An external bias compensation voltage must be derived from the magnitude of the photocurrent. The amount of bias compensation must maintain a constant voltage across the depletion region of the photodetector. Adjusting R11 varies the voltage gain in the bias compensation path. R24 is a fixed resistor chosen to be the statistically best resistance to bracket the required adjustment range.

This procedure uses two independent lasers. The first laser (Biasing Laser) is used to establish the desired photocurrent. The second smaller laser (Modulating Laser) is used to sweep the frequency response of the photodetector under test while at the desired photocurrent. Comparisons can be made between high and low photocurrent modes by observing the phase of the frequency sweep at the point of resonance in both states. With R11 properly adjusted, minimal phase difference occurs between the extremes of photocurrent.

This procedure uses relatively high power laser light. All applicable safety procedures for the operation of NPRO lasers, or any other laser light source must be consulted and adhered to prior to commencement of this procedure. See local laser safety officer for detailed instruction.

This procedure assumes a working knowledge of lasers and optics as well as experience in operating the associated test equipment.

2 Necessary test equipment

- ❑ RF Network analyzer
- ❑ Lab supply to power photodetector
- ❑ Hand-held volt meter
- ❑ NPRO or equivalent laser to produce ~100mW of light at λ = 1064 nm wavelength
- ❑ Fiber laser or equivalent at 950 nm < λ < 1150 nm wavelength that can be AM modulated to sweep over the desired frequency span
- ❑ Laser power meter capable of accurate readings of laser light at 1mW to 100mW of optical power
- ❑ ¼ wave plate and polarizing beam splitter cube to set the laser bias level between low and high photocurrent states

3 Procedure

- ❑ On a suitable optical table, mount the two lasers and the RFPD under test allowing enough spacing to measure power incident on the RFPD using the optical power meter. Apply DC power to the RFPD under test.
- ❑ Setup optical components to provide 100mW of optical power incident on the RFPD under test. ***Ensure*** the Biasing Laser spot size is greater than **200 microns**. The back

cover of the RFPD will have to be removed for access to the adjustment potentiometer, R11.

- ❑ Verify that the wave plate can be adjusted to provide 1mW to 100mW by measurement with the optical power meter. Note the range of detected voltages produced at the SMA connector for the RFPD DC monitor.

- ❑ Set the wave plate such that 5mW +/- 2mW of optical power from Biasing Laser is incident on the RFPD under test. Note the detected RFPD DC value and optical power.

  RFPD DC Voltage _______ VDC. Optical Power ________mW

- ❑ Setup the Modulating Laser and network analyzer to sweep the resonant peak of the RFPD under test. Measure magnitude and phase of the peak with sufficient resolution to observe 0.1dB, 0.1-degree phase changes. Record the RF magnitude and phase at this low power state.

  RF Magnitude __________dB RF Phase (~5mW) ________ Degrees

- ❑ Record the RFPD DC voltage with only the Modulating Laser on. Typically around 1mA of photocurrent from the Modulating Laser is appropriate for good measurement resolution.

  RFPD DC Voltage _______VDC

- ❑ Move the wave plate until 40mW +/- 5mW of optical power from the Biasing Laser is incident on the RFPD under test. Note the detected RFPD DC value as this is used to return to this wave plate setting later.

  RFPD DC Voltage _______VDC

- ❑ Move the wave plate until 100mW +/- 10mW of optical power is incident on the RFPD under test. Note the detected RFPD DC value and optical power

  RFPD DC Voltage _______VDC Optical Power _______mW

- ❑ Set R11 to the middle of its adjustment range. With the biasing laser providing 100mW bias to the RFPD under test, observe the phase as measured on the network analyzer and compare the value to the value obtained at the ~5mW optical power setting. Apply an external voltage to the "Vc Adjust" node of the RFPD and vary it until the measured phase value is equal to the previously recorded value within +/- 1dB, +/- 1.5-degrees of phase.

- ❑ Still with ~100mW of light on the diode, measure the bias voltage at TP2, $V_{bias\text{-}high}$ and the voltage across R1, V_{R1}. Remove the voltage from the "Vc Adjust" input, block all the light into the photodetector and measure TP2, $V_{bias\text{-}low}$ again.

  $V_{bias\text{-}high}$ _________VDC V_{R1} (~100mW)______VDC $V_{bias\text{-}low}$ _______VDC

- ❑ The requisite feed-forward gain, A_{fwd}, is calculated by:

  $$A_{fwd} = [V_{bias\text{-}high} - V_{bias\text{-}low}] / V_{R1} =$$ _____________

- ❑ R_{total}, the value of R24 plus R11 (assuming R23 = 2.67k ohms), is calculated by:

  $$R_{total} = 2670 / A_{fwd}$$ __________Ohms

- ❑ Assuming that R11 is in the middle of its range (500 ohms total), the exact value for R24 is given by:

  $R24 = R_{total} - 250 =$ __________ Ohms

  Value actually installed based on closest available part:

  R24 = __________ Ohms

If this R_{total} is outside the adjustment range achievable with the installed value of R24 and the adjustment potentiometer, R11, then R24 must be replaced with an appropriate value. A note must be made on the associated traveler for the RFPD under test.

- ❑ After resolving the issue with R24, restore the RFPD under test to have the ~100mW Biasing Laser input and sweep the resonance peak. Make any necessary adjustments to R11 to restore the phase to the ~5mW, previously recorded phase value ensuring that there is no external "Vc Adjust" input. Record the final RF Magnitude and phase.

  RF Magnitude ___________dB RF Phase _________ Degrees

- ❑ Measure the RF phase at the 40mW light level to obtain an intermediate check of the compensation at mid power. Less than +/- 1dB, +/- 1.5-degree changes are acceptable

  RF Magnitude ___________dB RF Phase (~40mW) _________ Degrees