Summary Requirements for Advanced LIGO ASC/LSC Photo-detectors

LIGO-T070110-00-C
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1. **Overview and Background –** Requirements are being gathered to guide the design and prototype efforts for the Advanced LIGO ASC and LSC photo-detectors. This document serves as a repository for the growing body of information on this topic, and will be refined as new decisions are made.

2. **Requirements common to ASC and LSC photo-detectors**
   - 2.1. **Construction**
     - 2.1.1. Photodetector assemblies, including the diode elements and associated electronics will reside inside the vacuum envelope, and must be constructed in a manner compatible with an ultra-high vacuum environment.
     - 2.1.2. It is desirable to be able to open the hermetic package used to house the electronics
     - 2.1.3. No specific size constraint exists yet.
   - 2.2. **Thermal:** In-vacuum thermal management is required to be passive and must be part of the mechanical design associated with the photodetector element and amplifier electronics.

3. **LSC Photodetector Design Data**
   - 3.1. **Nomenclature:** To identify a specific photodetector operating frequency, a shorthand notation for the offset frequency from the optical carrier has been adopted. In general, there is a 1:5 relationship between the first and second RF modulation frequencies of the optical carrier, but other mixing products are present on the light.
     - 3.1.1. A letter prefix – I or Q – designates the in-phase or quadrature component of a specific RF sideband
     - 3.1.2. A numerical suffix – 1 or 2 – designates the first and second modulation sidebands applied by the IO modulators. Nominally, this refers to 9 MHz and 45 MHz. The exact frequencies will likely change slightly, but the frequency ratio of 1:5 will be preserved.
     - 3.1.3. A letter suffix – M or P – identifies the difference or sum frequency respectively of the first and second RF modulation sidebands.
     - 3.1.4. An abbreviation is used – consistent with previous LIGO naming conventions – to identify the specific optical port.
     - 3.1.5. Examples
       - 3.1.5.1. REFL I1 – Reflected Port, I-phase, 9 MHz sideband
       - 3.1.5.2. REFL IM – Reflected Port, I-phase, 36 MHz product (difference between 45 MHz and 9 MHz sidebands).

3.2. **Photodetector frequencies and locations** (displayed assuming 9 MHz and 45 MHz modulation)

Table 1

Modulation F1(MHz)	9	Modulation F2 (MHz)	45
Optical Port	**Shorthand Identifier**	**Frequency (MHz)**	**Notes**
REFL	I1	9	
REFL	IM	36	REFL IM&IP should be derived from the same photodiode
REFL	IP	54	REFL IM&IP should be derived from the same photodiode
REFL	I2	45	
POX	I1	9	
POX	Q2	45	
AS (Locking)	I2	45	

3.3. **Noise**

3.3.1. Minimum photocurrent for which a shot noise limited electronics performance applies - 30mA

3.3.2. Minimum offset frequency relative to RF center frequency for which a shot noise limited sensitivity requirement exists is 20Hz. This isn't really an impact on the detector design, but will influence demodulator design.

3.3.3. Shot noise at 30mA - 80pA/rtHz

3.3.4. Safety factor for electronics noise - ~4, more if possible

3.3.5. Electronics front end current noise requirement - 20pA/rtHz

3.4. **Dynamic Range**

3.4.1. Maximum sustained photo-current – 100mA

3.5. **Inputs and Outputs**

3.5.1. DC Power - +/-15VDC, +/-5% will used for DC power.

3.5.1.1. DC power filtration will be used in the vacuum system, but not active regulation

3.5.1.2. Reverse polarity protection will be used to avoid damage is DC power polarity is reversed.

3.5.2. RF Outputs – One or more RF outputs will exist for each detector assembly. The exact number of outputs per detector will be the subject of a tradeoff study during the prototype process.

3.5.3. RF Inputs – One or more ASI type cancellation inputs will be required per detector. The characteristics of this input are **TBD**.

3.5.4. DC Output – A DC output will be supplied with internal whitening consistent with signal amplification to greater than 100nV/rtHz for noise immunity. Additional whitening will occur once the signal leaves the vacuum envelope.

3.5.5. Temperature Readback – A temperature sensor will be included in each in-vacuum detector assembly.

3.5.6. The need for external photodiode bias adjustment to compensate detector de-tuning resulting from variations in photocurrent depends on final circuit topology and the degree to which the design must be insensitive to this effect. The detectors must exhibit less than **TBD** degrees of phase variation over the range of photocurrent from **TBD** to 100mA. Provided the detector design intrinsically meets this requirement, there will be no provisions for external bias adjustment.