



LIGO Laboratory / LIGO Scientific Collaboration

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Material Qualification RGA Test Results:
High Quantum Efficiency InGaAs Photodiode

Bob Taylor, Dennis Coyne

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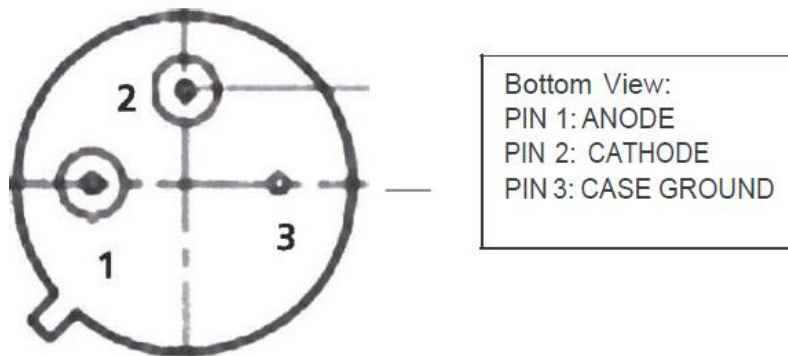
<http://www.ligo.caltech.edu/>

1 Introduction

Custom high quantum efficiency InGaAs photodiodes were purchased from Laser Components Inc. The part number is IGHQEX3000. They have a 3 mm diameter active area. The specifications (per [C1500393-v1](#)) are as follows:

- High Quantum efficiency of $\geq 99\%$ at the wavelength of 1064nm
- Diameter of active area: 3mm or 0.5 mm (two types)
- AR coating for approx. AOI 10° ($R < 0.05\%$)
- AOI for p polarization
- SOT9/TO5 header without fixed cap, with a removable protection cap only, anode and cathode is separated of the frame ground
- Optimized for low dark current (approximately 50 nA)
- Delivery in dust reduced packing

Figure 1: Pin connections (IGHQEX3000)



The package dimensions¹ are similar to the photodiode currently used in aLIGO (Perkin Elmer/Excelitas C30665), as indicated in Figure 2. The PDs came in a “reduced dust” case (Figure 3). The bottom of the case has a spongy (presumably conductive) material.

The diodes have no window. Each came with an adhesive seal over the opening (no window) and serial numbering in marker on the side. (Figure 4 and Figure 5).

The seals were removed and the area where an adhesive residue might have been left was wiped with isopropyl alcohol. The seals were replaced with FirstContact.

¹ Measured by Koji Arai and reported in the OMC elog: http://nodus.ligo.caltech.edu:8080/OMC_Lab/247

Figure 2: Package dimensions (in mm).

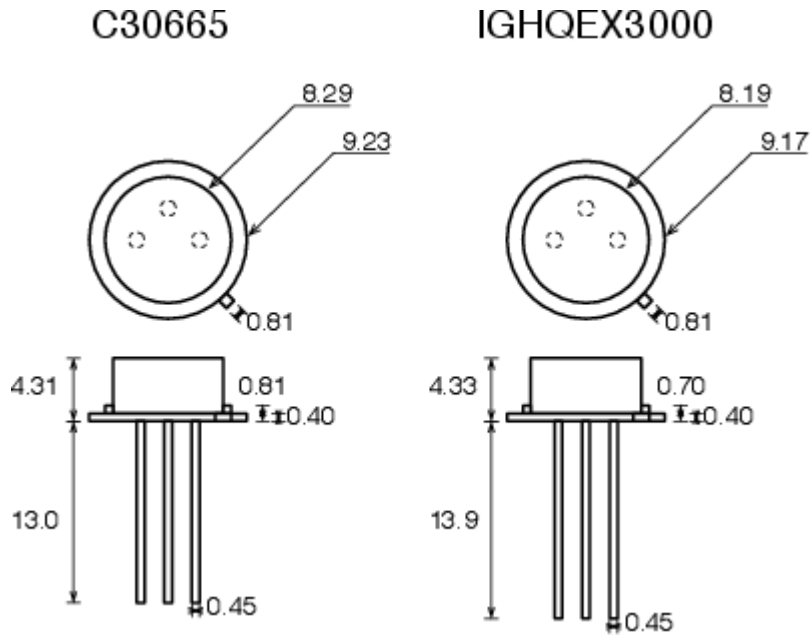


Figure 3: As-received packaging container.



Figure 4: IGHQEX3000 InGaAs Photodiode (as-received with removable adhesive cap and serial number marking on the side)

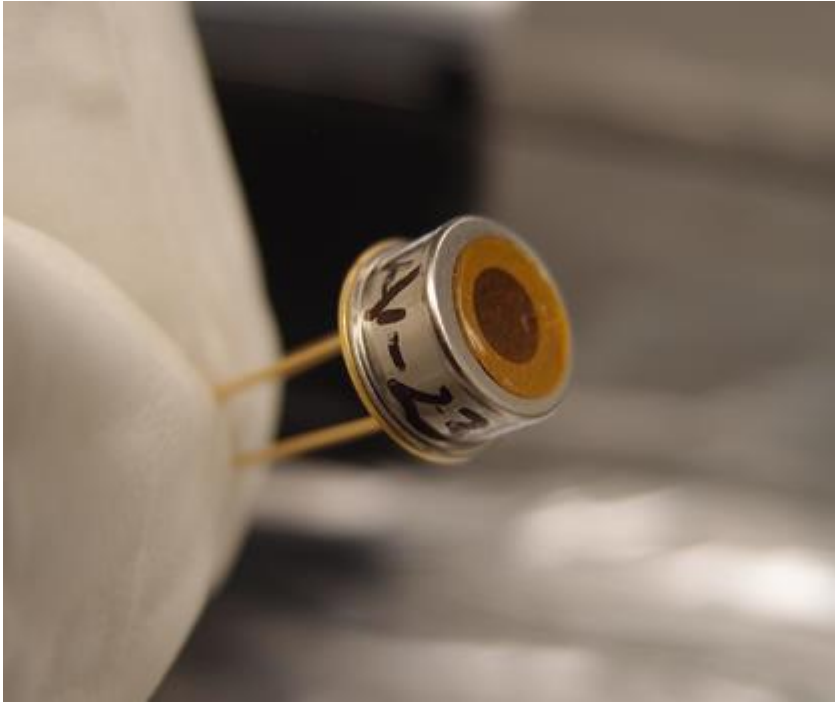


Figure 5: IGHQEX3000 InGaAs Photodiode with seal removed



2 Material composition

We do not have a list of materials (other than obviously InGaAs). However we trust that the manufacturer has chosen low outgassing materials in the packaging, given that this is a sensitive semiconductor detector.

3 Cleaning procedure

The cleaning steps are intentionally minimal; We do not want to risk damage to the bond wires and we do not want to deposit contaminants on the active area (and risk spoiling the high responsivity of the device).

- 1) Perform all handling and cleaning in a clean room, or on a laminar flow bench.
- 2) Remove the polymer seal over the photodiode opening.
- 3) Carefully wipe the perimeter of the opening with a clean room grade wipe moistened with isopropyl alcohol in order to remove any potential adhesive residue from the polymer seal. Take care not to drip any alcohol into the interior of the photodiode, or to contaminate the interior with any particulates.
- 4) Clean the exterior of diode can with isopropyl alcohol to remove any marking, taking care not to get the solvent with dissolved marker into the interior of the package
- 5) Allow diode package to dry.
- 6) Place the photodiodes into their custom protective transport and handling fixtures (aka cage, see [D1500487](#))
- 7) Do not bake the photodiodes (neither air bake, nor vacuum bake).
- 8) Do not expose the photodiodes to storage temperatures² in excess of 125C

4 RGA qualification test

In order to qualify the above cleaning (no baking) procedure, we performed an RGA test on two (2) of the IGHQEX3000 InGaAs photodiodes. (These particular PDs had relatively high dark current.) For this RGA qualification test we used a vacuum bake oven that had been recently baked empty and had a clean RGA scan.

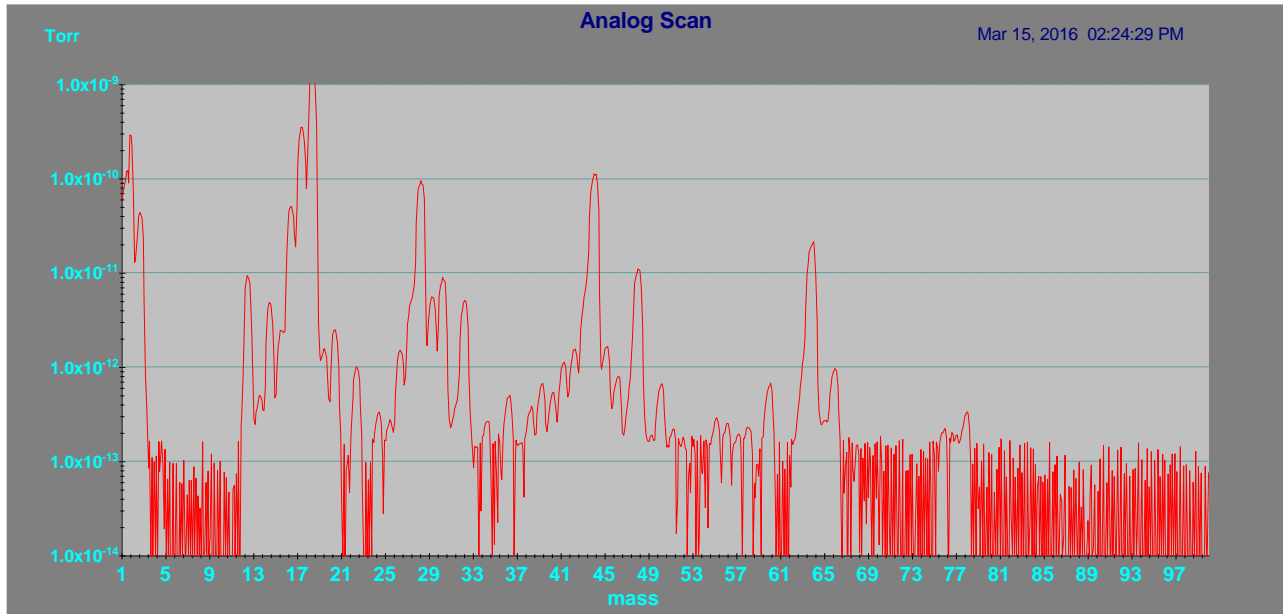
- 1) Handle with care; These PDs are windowless and so have exposed bond wires. Leave in the protective cage at all times.
- 2) Bring the vacuum oven to atmospheric pressure with dry N₂ just before placing these two (2) PDs into the chamber, i.e. do not let the chamber walls get wet waiting a long time before putting the PDs into the oven.
- 3) Pump down to high vacuum and take an RGA scan.
- 4) With the RGA head valved off from the oven, bake at 40C for 48 hrs, in order to drive water off of the PDs and their protective cage.
- 5) Take an RGA scan at 40C after the 48 hr dwell period.
- 6) Cool to room temperature and take RGA scans: RGA background (valved off from the oven), RGA scan of the oven load with and without a calibrated leak open

The RGA scan of the two “wet” photodiodes after pumping down to vacuum () shows a fair amount of hydrocarbon outgassing. Although a scan with a calibrated leak was not taken at this

² Laser Components Inc, www.lasercomponents.com/lc/IR-Detectors/

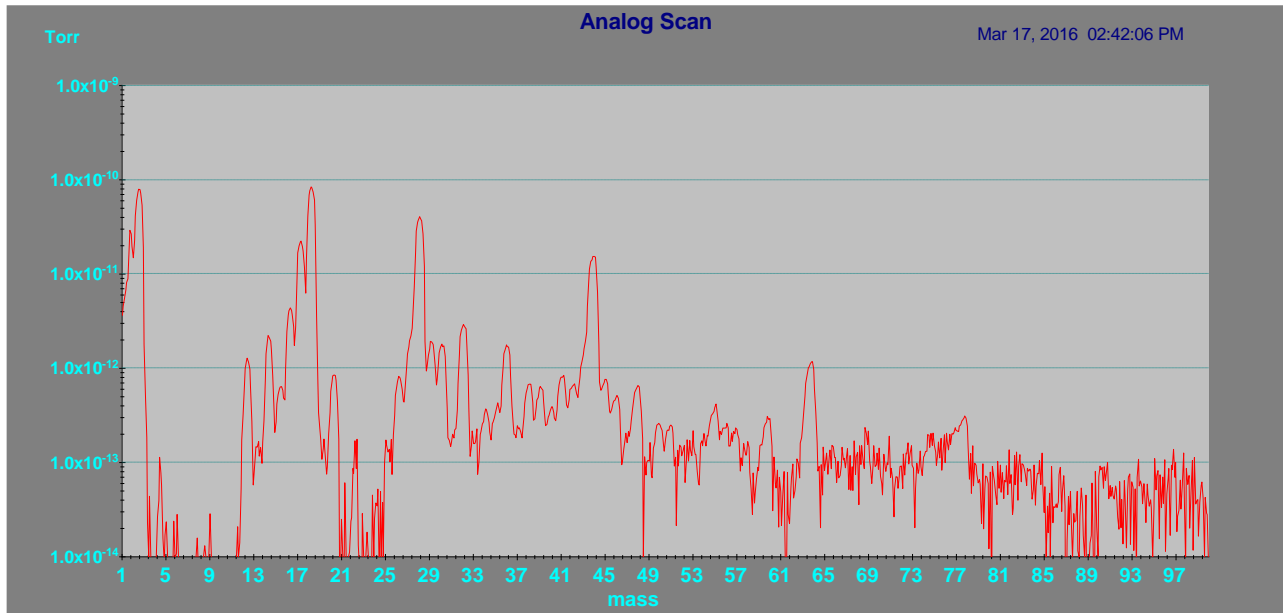
time, if one uses the post-bake, calibrated leak scan the apparent hydrocarbon outgassing is WHAT Note in particular a very high peak at AMU 64.

Figure 6: Pre-bake RGA Scan



The post bake (40C, 48 hours) RGA scan at 40C shows some hydrocarbon signature/components in the spectrum (including a prominent peak at AMU 64).

Figure 7: Post-bake (40C, 48 hours) RGA Scan taken at 40C



The post bake (40C, 48 hours) RGA scan at room temperature shows a clean spectrum except for a peak at AMU 64 above the background. The apparent hydrocarbon outgassing is $2.7\text{E-}11$ torr-L/s based on the standard five hydrocarbon flag AMUs (or $3.8\text{E-}11$ torr-L/s including AMU 64). This is pretty clean, considering only a 40C bake. It is higher than the desired $\sim 2\text{e-}12$ torr-L/s level for a

small oven load (limited by mass spectrometer noise floor), but much less than the maximum acceptable level of $\sim 4 \times 10^{-10}$ torr-L/s for a large oven load (per [E080177](#)).

Figure 8: Post-bake (40C, 48 hours) RGA Scan taken at room temperature

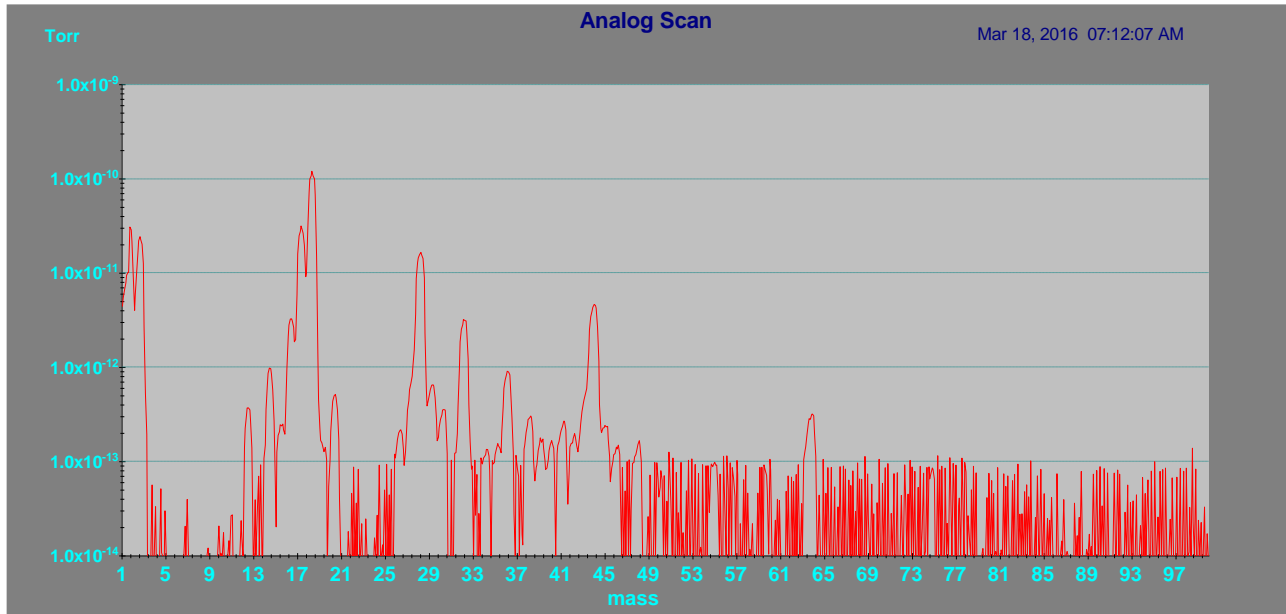


Figure 9: Post-bake (40C, 48 hours) RGA Scan taken at room temperature with a Calibrated leak Open (2.36×10^{-10} torr-L/s Argon)

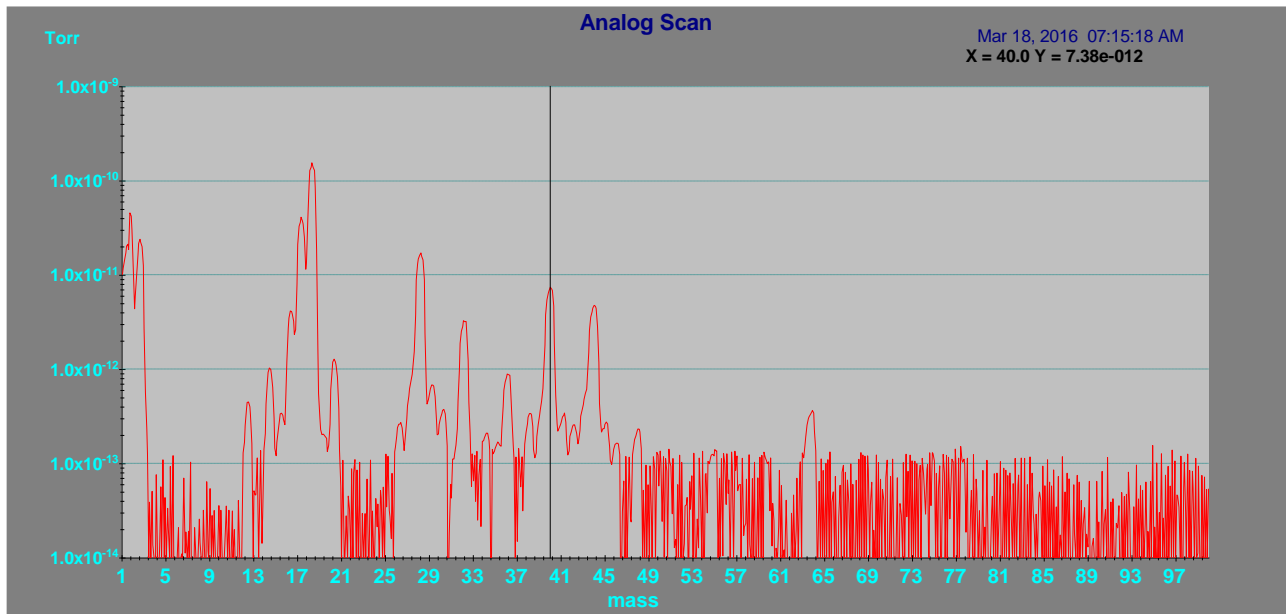


Table 1: Flag Hydrocarbons

Pressure Contribution from Flag Hydrocarbons			
40M Lab RGA Scan Results			
		Description:	High Quantum Efficiency Photodiodes
		Oven Used:	D Date: 3/15/2016
AMU 41	2.12E-13	amps	from RGA scan listing
AMU 43	4.11E-13	amps	from RGA scan listing
AMU 53	1.53E-14	amps	from RGA scan listing
AMU 55	9.72E-14	amps	from RGA scan listing
AMU 57	1.02E-13	amps	from RGA scan listing
AMU 63.9	3.17E-13	amps	from RGA scan listing
Sum Flag H/C AMUs	1.15E-12	amps	
Calib leak rate	2.36E-10	torr l/s (Argon)	
AMU 40 (w/leak open)	7.38E-12	amps	
AMU 40 (background)	1.50E-13	amps	
Calib leak contributes	7.23E-12	amps	= (w/leak open) - (background)
Flag H/C Outgassing	3.77E-11	torr l/s	= (Sum Flag H/C AMUs) x (Calib leak rate)/(Calib leak contrib.)
# Test items	2.00E+00	ea	
Normalized outgassing	1.88E-11	torr l/s/diode	
Full description:	Two (2), Laser Components Inc., IGHQEX3000 InGaAs high QE photodiodes (3 mm dia.)		
Pre-scan bake:	40C for 48Hrs. Just to drive off water		
	NO cleaning, other than isopropyl alcohol wipe down of the tape residue and exterior of the packag		

5 Summary & Recommendation

The initially observed, apparent hydrocarbon contamination was pumped away during the 40C, 48 hour “bake”. No doubt the warm temperature accelerated the depletion of the outgassing. However it is our contention that this would occur even at room temperature (albeit over a longer period of time). The slightly elevated temperature should not have been high enough to activate any breakdown or decomposition of any high molecular weight hydrocarbons. Ideally more testing would be conducted to verify this hypothesis. For example, performing a long duration pump down test, without elevating the temperature, on another pair of photodiodes. However (i) the costs for each diode are high (\$3.3K for each 3 mm PD), (ii) the lead time for replacements is long (4 months) and (iii) resolution of vacuum preparation is urgently needed since these PDs must be installed very soon in support of ER9/O2.

Given the following considerations:

- legitimate concern of contaminating the active surface of these high quantum efficiency photodiodes,
- small size and small quantity of these photodiodes (2 per interferometer),

- the fact that these photodiodes are installed in the HAM6 chamber, (a vacuum volume separated from the main vacuum volumes)

we recommend to the Vacuum Review Board (VRB) that these photodiodes be cleaned as described above and not baked or RGA scanned.