Baffle Diodes

Baffle diodes are Excelitas YAG-444-AH

These are circular quadrant pin photo-diodes.

Active Diameter: 16 um
Active area: 200 mm^2

Responsivity for similar diodes from Excelitas:
http://www.excelitas.com/downloads/DTS_YAG-quadrants.pdf

Responsivity at 1064 nm: ~.47

The transimpedance is taken care of by the Beckhoff, but all baffle diodes have the same transimpedance: 20k Ohms

Channel Names:
H1:AOS-ITMX_BAFFLEPD_N_POWER
H1:AOS-ETMX_BAFFLEPD_N_POWER
H1:AOS-ITMY_BAFFLEPD_N_POWER
H1:AOS-ETMY_BAFFLEPD_N_POWER

N = 1, 2, 3, or 4. There are 4 diodes for each baffle.

Amplifier/Whitening: https://dcc.ligo.org/D1200543

Optical Lever Diodes

Channels:
H1:SUS-ETMY_L3_OPLEV_SUM_OUT_DQ
H1:SUS-ITMY_L3_OPLEV_SUM_OUT_DQ
H1:SUS-PR3_M3_OPLEV_SUM_OUT_DQ
H1:SUS-ITMX_L3_OPLEV_SUM_OUT_DQ
H1:SUS-SR3_M3_OPLEV_SUM_OUT_DQ
H1:SUS-BS_M3_OPLEV_SUM_OUT_DQ
H1:SUS-ETMX_L3_OPLEV_SUM_OUT_DQ

We would like to analyze the difference in measured diode power between a locked detector state and an unlocked detector state. To do this we need to understand the calibration and circuit for each diode.

The diodes are Hamamatsu S5981 Si PIN Photodiodes.
Website: http://www.hamamatsu.com/us/en/product/alpha/S/4106/S5981/index.html#1328449179787
Data Sheet: http://www.hamamatsu.com/resources/pdf/ssd/s5980_etc_kpin1012e.pdf

For all of the optical lever diodes, and 1064 nm laser light, the responsivity ~.35 .
Active surface area = .0001 m^2

Amplifier Boards:
https://dcc.ligo.org/LIGO-D1100290

Transimpedance Values [Ohms]:
BS: 200k
PR3: 20k
SR3: 200k
ITMX: 20k
ITMY: 20k
ETMX: 20k
ETMY: 200k
(Red values were not installed by Jason Oberling. Values should be confirmed)

ISC Whitening Filters:
https://dcc.ligo.org/LIGO-D1001530

Whitening Gains
https://dcc.ligo.org/T1500556

BS: 15 dB
PR3: 18 dB
SR3: 3 dB
ITMX: 0 dB
ITMY: 0 dB
ETMX: 18 dB
ETMY: 0 dB

Counts → Power

How to obtain a power in SI units from the oplev diode sum channels (counts):

- Convert counts to volts with factor (40 V / 2^{16} cts)
- Convert voltage to current with the transimpedance and whitening gain values.
- Convert current to power with the responsivity.
- Measured power can be easily used to approximate total power scattered via half sphere approximation.

Explicit Formula:
Power = (Diode Sum cts) * (40 V / 2^{16} cts) * $(\text{transimpedance})^{-1}$ * $(\text{whitening gain})^{-1}$ * $(\text{responsivity})^{-1}$

Total power emitted can be estimated with a half sphere approximation (d = distance to optic, .0001 m^2 is area of diodes).

Total Power = Power * (4 * pi * d^2) / .0001

Example Table with Power Calculations
All data comes from January 19th and 20th of 2016.

Oplev	Locked Counts (1/19/16 13:00 - 15:00 UTC)	Unlocked Counts (1/19/16 18:32 - 21:00 UTC)	Difference (counts)	Difference (uW)	~Distance to Optic (m)	Total Power (W)
ETMY	29065.192 +- 34.72	28047.207 +- 32.47	1018 +- 65.19	8.876	5.57805	17.352
ITMY	5411.4 +- 1.73	5367.1 +- .85	44.3 +- 2.58	3.863	33.06035	265.29
PR3	30693.59 +- 5.85	30649.44 +- 6.64	44.15 +- 12.49	0.4846	13.8631	5.852
ITMX	3592.53 +- 1.37	3565.3 +- 1.79	27.23 +- 3.16	2.374	33.05735	163
SR3	40791.2 +- 9.73 (1/20/16 1:37 - 2:22 UTC)	40769.07 +- 9.64 (1/20/16 2:45 - 3:05:55 UTC)	22.13 +- 19.37	0.1366	13.75045	1.623
BS	29911.88 +- 13.80	29824.13 +- 14.73	87.75 +- 28.53	0.1361	2.01085	0.03458
ETMX	45947.46 +- 42.42	44869.27 +- 79.24	1078.19 +- 121.66	11.835	5.58105	23.16

Distances to Optics and Coordinates (approximate):
https://dcc.ligo.org/LIGO-E1200836

Optic Coordinates for LHO (as-built):
https://dcc.ligo.org/LIGO-E1400205

LHO as built Optic Coordinates (x, y, z) [mm]:
ITMX = (5012.6, -199.8, -83.1)
ITMY = (-200.8, 4982.7, -79.2)
ETMX = (3999485.0, -200.3, -80.0)
ETMY = (-200.0, 3999455.7, -79.7)

Optic Coordinates for LLO (as-built):
https://dcc.ligo.org/LIGO-E1400204

Source/Receiver Coordinates LHO:
https://dcc.ligo.org/LIGO-E1000601

Source/Receiver Coordinates LLO:
https://dcc.ligo.org/LIGO-E1000608

Distances to each optic [m] for LHO (as designed, as built measurements do not exist):
ETMY: 5.57805
ITMY: 33.06035
PR3: 13.8631
ITMX: 33.05735
SR3: 13.75045
BS: 2.01085
ETMX: 5.58105

Angle of Sight for ETMs and ITMs [radians, degrees]:
ITMX: 0.02122, 1.2160º
ETMX: 0.1335, 7.6498º
ITMY: 0.02128, 1.2195º
ETMY: 0.13352, 7.6503º

This the angle from the x-arm for ITMX/ETMX, angle from y-arm for ITMY, ETMY.

Scattering Heat Map Script

Code was written to study whether or not the diode readouts were dependent on the beam position. The goal was to make heat maps of the diode sum vs beam position to determine whether there were hotspots on the optics of increased scattering. To obtain the beam position a script was written that calculates beam position based off of the optical lever pitch and yaw data. At the beginning of the code's analysis it assumes that the input test masses (optics) and the output test masses are perfectly aligned. Then, throughout the lock stretch as the pitch and yaw vary each optic's center of curvature will move around accordingly. The beam is always assumed to pass through the two optics' centers of curvature, meaning the beam position can be calculated on each optic. The beam positions calculated in this way are always relative to the beginning of analysis.

The code was written and the analysis carried out, however the results were less than accurate. The movement of the beam position, when calculated in this way, was always on the order of centimeters, when in reality the beam should only move around fractions of a millimeter within a single lock. Extensive hand calculations and rewriting of code were performed but the numbers did not change. Eventually it was concluded that optical lever angular stability was the issue and the cause of our unrealistic calculations.

As of Feb. 1st 2016, the code is located here:
https://ldas-jobs.ligo.caltech.edu/~vincent.roma/diodes/beam.py

And its supporting library:
https://ldas-jobs.ligo.caltech.edu/~vincent.roma/diodes/beam_lib.py

Currently the code is not well-commented or explicitly clear to a third party, however it may be updated.

Scattering Power Script

Another script was written to automate the power calculations outlined earlier in this document. This is a script that can be run over long stretches (containing both locked and unlocked intervals) and calculates the difference in power detected for optical lever diodes between locked and unlocked times. It analyzes a few different channels to find out when the detector was locked and when it was unlocked. To prevent taking data when the arms were flashing, intervals shorter than a duration threshold are thrown out. It then looks at the locked and unlocked intervals for each optical lever diode to find a pair of segments (one locked, one unlocked) that have similar pitch/yaw values. Those two segments are used to calculate a difference in power for the diodes (between locked and unlocked), which is then extrapolated to a total scattered power value (half sphere approximation).

The file is currently here:
https://ldas-jobs.ligo.caltech.edu/~vincent.roma/diodes/diode_script.py

And its supporting library:
https://ldas-jobs.ligo.caltech.edu/~vincent.roma/diodes/diode_script_lib.py