

PDFRs

June 29, 2020

1 Photodiode response functions

This is a summary of the **measured** transfer functions of the 40m RFPDs/WFS.

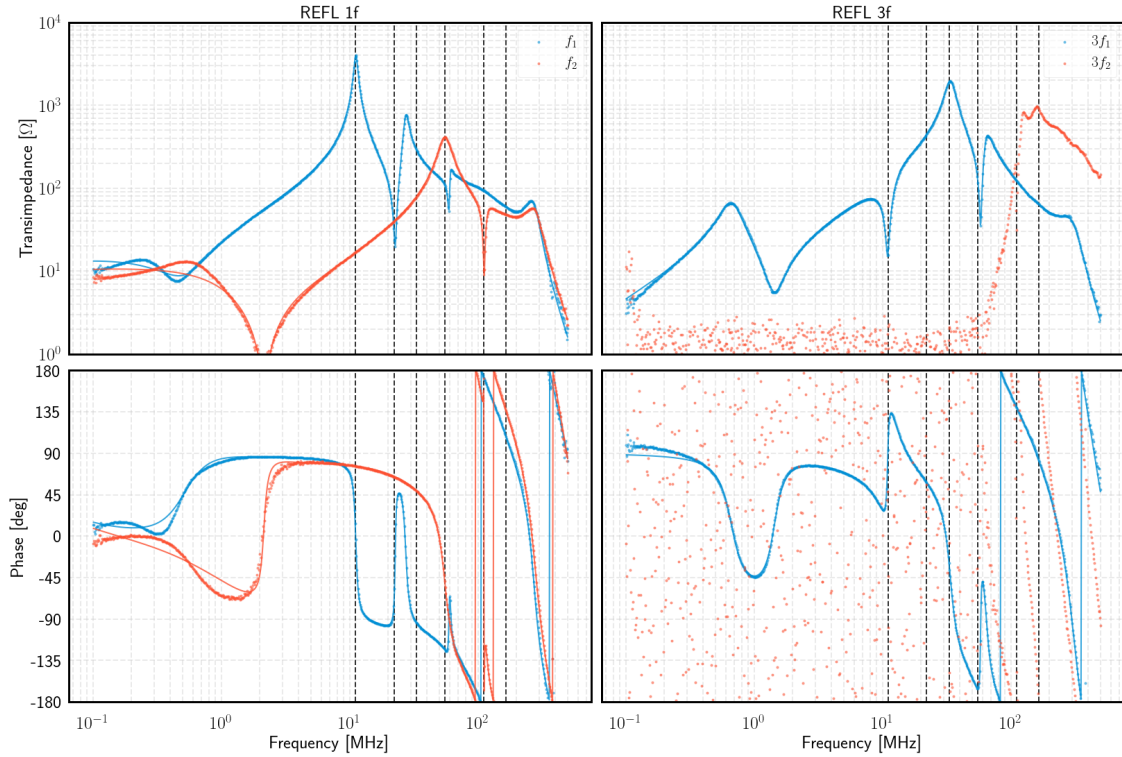
- Setup used for measurement is the [fiber-coupled AM laser](#).
- One of the collimators from the PDFR SURF project was used (rather than a F220-APC), because it gives a smaller collimated beam. -The collimated beam was pointed straight at the photodiode in all cases, *except* REFL165, in which case, due to space constraints, I placed the collimator just upstream of the [R = 90% beamsplitter](#).
- With an Ophir power meter, I measured $\approx 260 \mu\text{W}$ coming out of the collimator for all measurements. Assuming the fiber-beamsplitter splitting the beam between Device-Under-Test (DUT) and reference photodiode is balanced, we expect $10 \text{ k}\Omega \times 0.8 \text{ A/W} \times 260 \mu\text{W} \approx 2 \text{ V}$ at the DC monitor point of the NF1611. I measured more like 1.65 V, which would mean $\approx 200 \mu\text{W}$, assuming the DC transimpedance spec of the NF1611 is accurate. Seems consistent enough for now, depends on if we want to trust the absolute calibration of the power meter or the NF1611.
- In all cases, the “reference” [NF1611](#) photodiode was assumed to have an AC response of 700Ω .
- The quantity measured was the transfer function $\frac{A}{R}$ on the AG4395 network analyzer, where the NF1611 RF output was connected to the R input, and the DUT’s RF output was connected to the A input. The RF source amplitude was set to -20 dBm, which was found empirically to give “clean” transfer function measurements. Each measurement consisted of 10 averages, taken on the network analyzer.
- To convert the measured transfer functions into units of Ω , I assume that the NF1611 has an AC response of 700Ω . The DC monitor points (on the photodiode box itself for the Gold RFPDs, and the Acromag DC readbacks for the WFS) were used to estimate the DC photocurrent from the photodiode.
- All of the “Gold Box” RFPDs are supposed to have a DC transimpedance of 50Ω . Going through the same logic as for the NF1611, for $200 \mu\text{W}$ of power incident on the DUT, we expect $50 \Omega \times 0.8 \text{ A/W} \times 200 \mu\text{W} \approx 8 \text{ mV}$. This is consistent with what was measured
- To convert the measured transfer function, G , into the transimpedance, Z , I used the following formula:

$$Z = G \times 700 \text{ V/A} \times \frac{V_{\text{NF1611}}^{\text{DC}}/10 \text{ k}\Omega}{V_{\text{DUT}}^{\text{DC}}/Z_{\text{DUT}}^{\text{DC}}}$$

2 REFL port photodiodes

First, we look at the transimpedance of the RFPDs at the REFL port. The REFL 165 photodiode has a DC transimpedance of $\approx 2 \text{ k}\Omega$, and is a *silicon* photodiode, [Hamamatsu S3399](#). Furthermore, we have to account for the $R = 90\%$ beamsplitter. So, we expect $0.9 \times 2 \text{ k}\Omega \times 0.15 \text{ A/W} \times 200 \mu\text{W} \approx 54 \text{ mV}$. I measured more like 30 mV . So one of these parameters must be wrong. Let's trust the DC transimpedance number of $2 \text{ k}\Omega$, and so the inferred power incident on the photodiode becomes $\approx 100 \mu\text{W}$, which is nearly half of what we assume is incident on the reference PD. The measured DC voltages used to scale the transfer function measurements are:

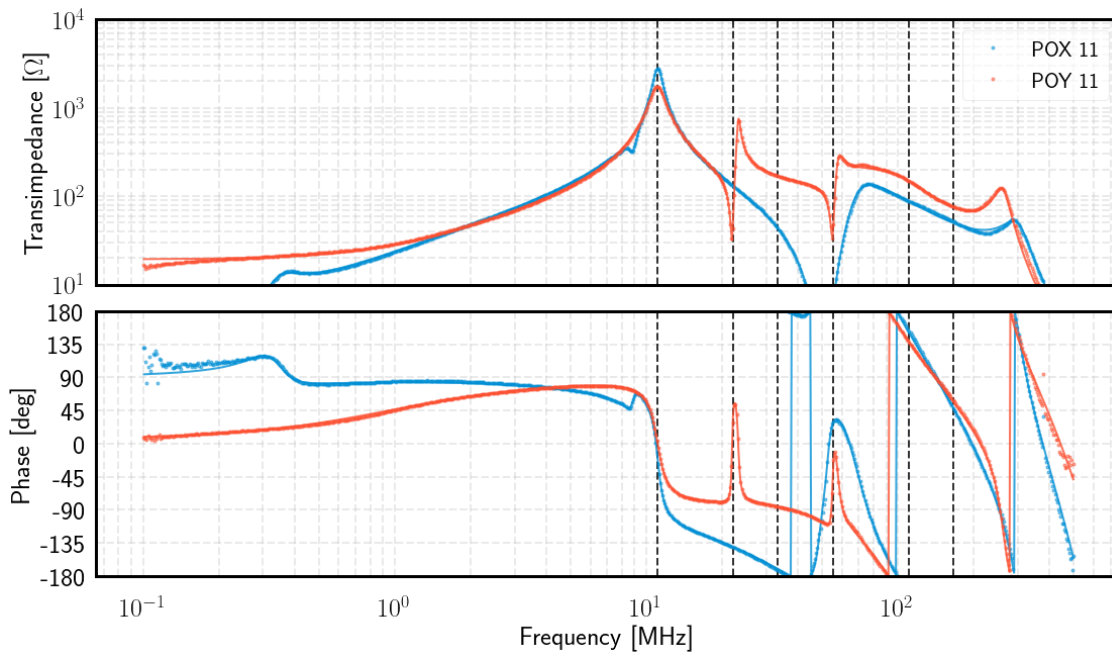
DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
REFL 11	1.64	8.96	50
REFL 55	1.63	8.52	50
REFL 33	1.63	8.91	50
REFL 165	1.63	27.86	2000



3 POX and POY photodiodes

These are used for the single arm locking. The POY11 photodiode has a label on it that says the DC transimpedance is 1010Ω . So we expect $\approx 20 \times$ the DC voltage at the DC monitor compared to the other gold-box PDs, for the same light level incident on the diode. This is roughly what I saw. The measured values were:

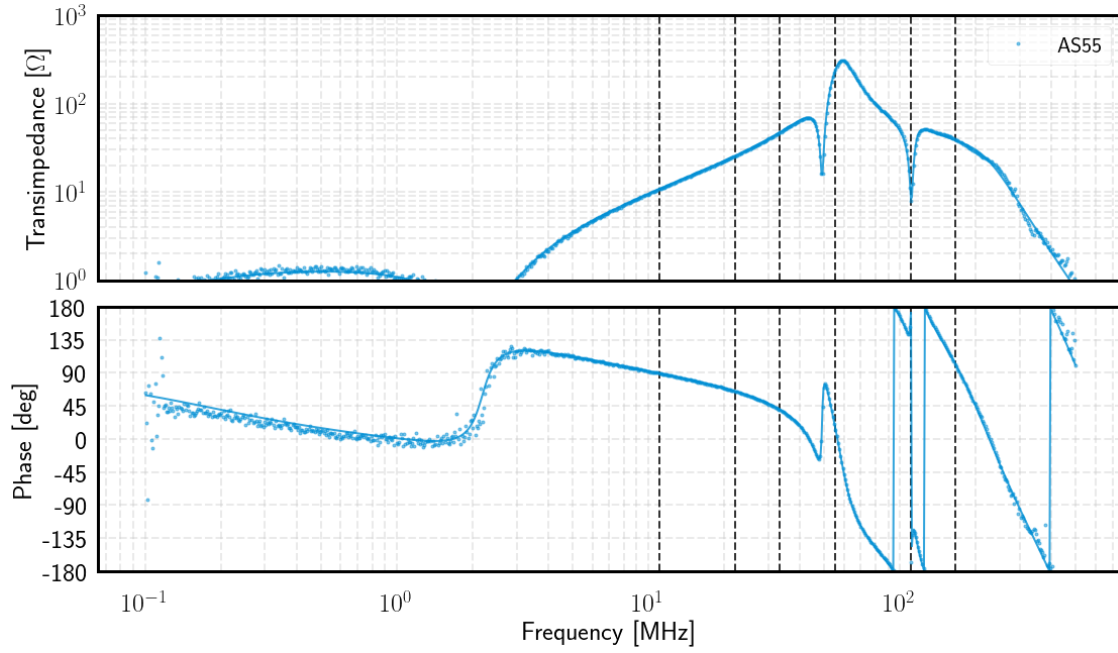
DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
POX11	1.62	10	50
POY11	1.62	189	1010



4 AS55

This is the DARM sensor in RF lock. The measured DC photocurrent value was:

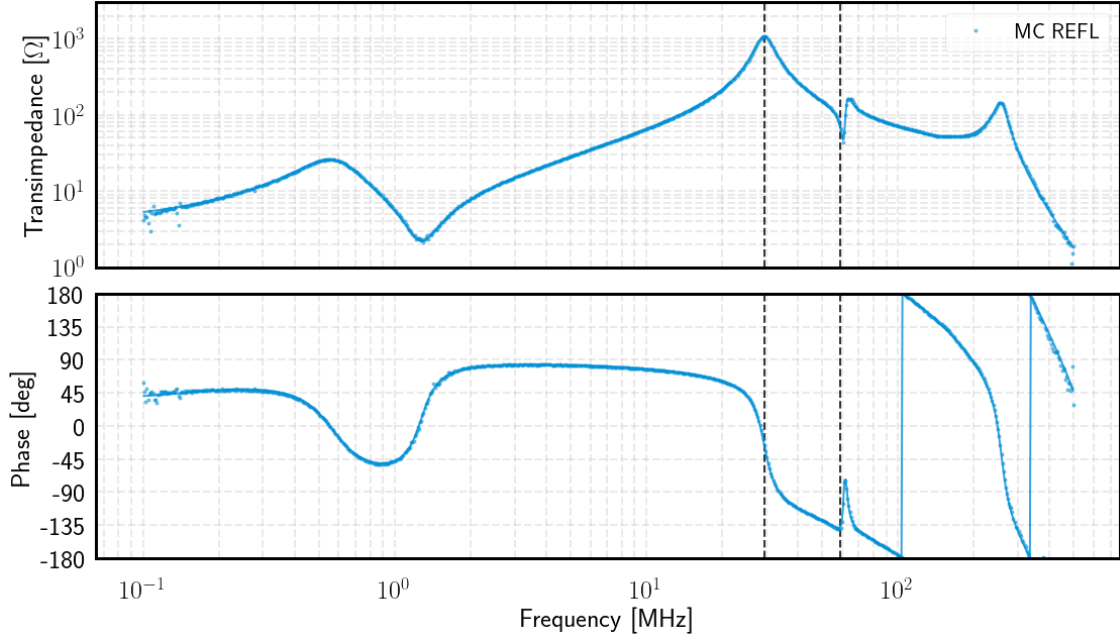
DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
AS 55	1.64	9.04	50



5 MC REFL

This photodiode is used for the IMC locking. The measured DC photocurrent value was:

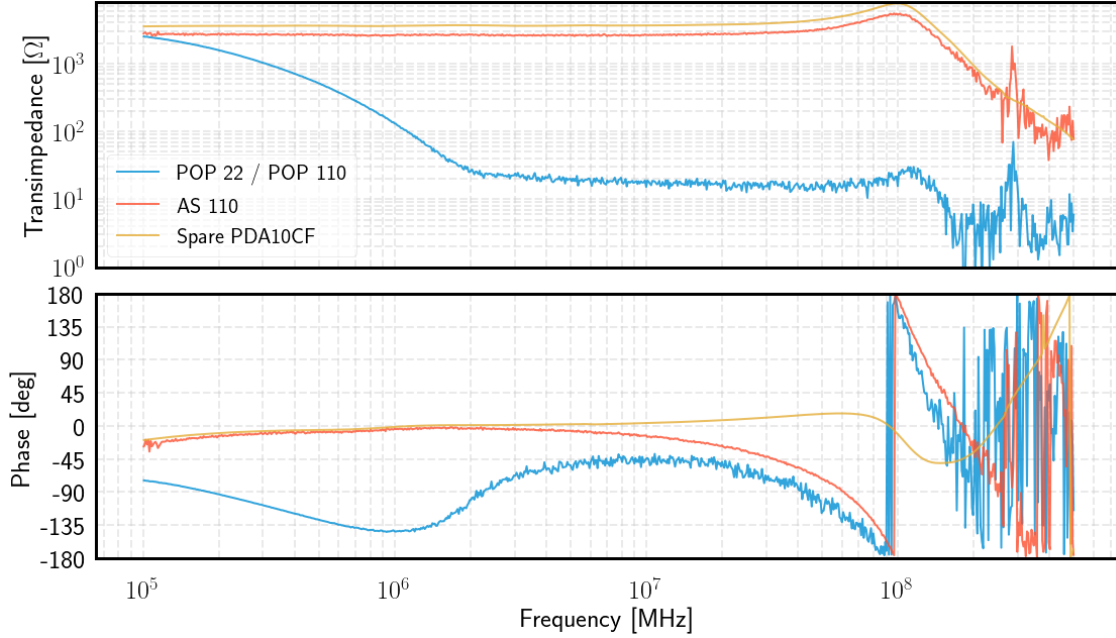
DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
MC REFL	1.63	7.17	50



6 Sideband buildup monitors

These photodiodes are used to measure the sideband field buildups, and are Thorlabs PDA10CF. According to the [datasheet](#), the transimpedance is 10 k Ω (5 k Ω) into a High-Z (50 Ω) load. The measured DC photocurrents were:

DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
AS 110	1.63	4.31	10k
POP110	1.62	90	10k



7 WFS head response by quadrant

The schematic may be found [here](#). The 40m IMC PDH modulation frequency is ≈ 29.5 MHz. The equivalent circuit for the YAG-444-4A photodiode may be found [here](#). To get the resonant frequency of the circuit to be 29.5 MHz, and for the notch frequencies to be twice that, I use the following component values (see the Cathode1 channel):

- L10 = 1.08 μ H, L9 = 0.75 μ H, L10 = 0.87 μ H.
- All other component values are as on the schematic.
- Note that the presence of C69 means the resonant frequency cannot simply be calculated using the usual LC tank formula, $\omega_0 = \frac{1}{\sqrt{LC}}$, where L is the inductance of L8 and C is the photodiode capacitance.

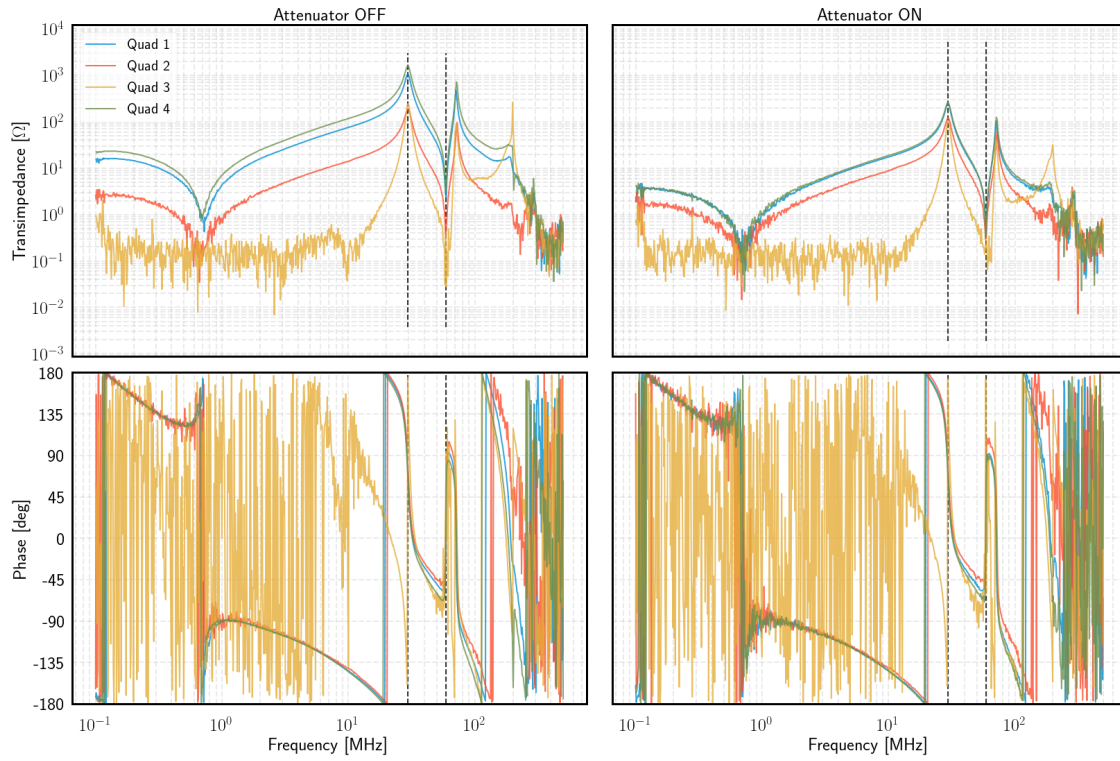
With these component values, the transimpedance before amplification by U11 and U10 is ≈ 1.4 k Ω . Each amplifier stage has a gain of 6, so we expect the nominal transimpedance gain to be 50 k Ω , while the attenuated setting should yield a transimpedance of 5 k Ω .

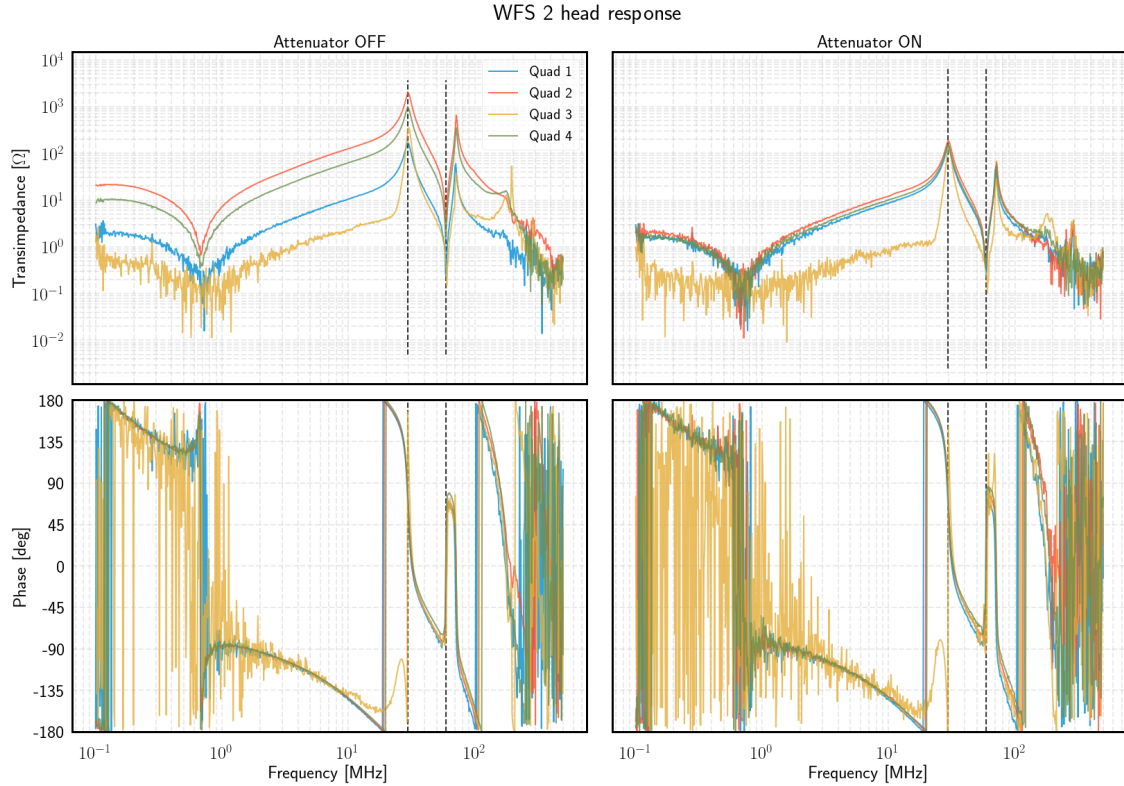
The WFS QPD is supposedly a YAG-444A-4. This has a responsivity of ≈ 0.47 A/W at 1064nm. The DC transimpedance of each quadrant is supposed to be ≈ 1 k Ω . So, we expect $1 \text{ k}\Omega \times 0.47 \text{ A/W} \times 200 \mu\text{W} \approx 90 \text{ mV}$. I measured more like 120 mV. Once again, roughly consistent - the remaining discrepancy could be due to miscalibration in the Acromag monitoring this voltage. Once again, I choose to trust the DC transimpedance value of 1 k Ω and *infer* the light level incident on the photodiode. The measured values were:

DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
WFS1 Q1	1.62	125	1000

DUT	NF1611 DC [V]	DUT DC [mV]	DC Transimpedance [Ω]
WFS1 Q2	1.62	125	1000
WFS1 Q3	1.62	120	1000
WFS1 Q4	1.62	120	1000
WFS2 Q1	1.62	120	1000
WFS2 Q2	1.62	125	1000
WFS2 Q3	1.62	120	1000
WFS2 Q4	1.62	120	1000

WFS 1 head response





8 Conclusions

Photodiode	Expected transimpedance [Ω]	Measured transimpedance [Ω]
REFL11	4080	$\approx 4k$
REFL55	615	≈ 400
REFL33	2140	$\approx 2k$
REFL165	1000	$\approx 1k$
POX11	3150	$\approx 3k$
POY11	1980	$\approx 1.8k$
AS55	≈ 350	≈ 300
MC REFL	$\approx 1.5k$	$\approx 1.2k$
POP 110	5k	broken???
AS 110	5k	$\approx 3k$
WFS, unattenuated	50k	broken???
WFS, attenuated	5k	broken???

1. There is something seriously wrong with the IMC WFS heads.
2. Many transimpedances measured in gautam June 2020 are different from what was [measured](#) by KA in ~ 2012 . It'd be nice to get another estimate for the same quantity based on the

shot-noise intercept current.