Broadband PD improvement

BBPD intermodulation issue (LHO ALOG 14901 KA)

- 3f signals misbehave at higher power
- Caused by intermodulation
  via nonlinearity at the RF preamp

2nd-order intermod. => 2nd harmonic, or f_A+/-f_B
e.g. 9 + 18, 36 - 9 -> 27 [MHz]
45 + 90 -> 135 [MHz]

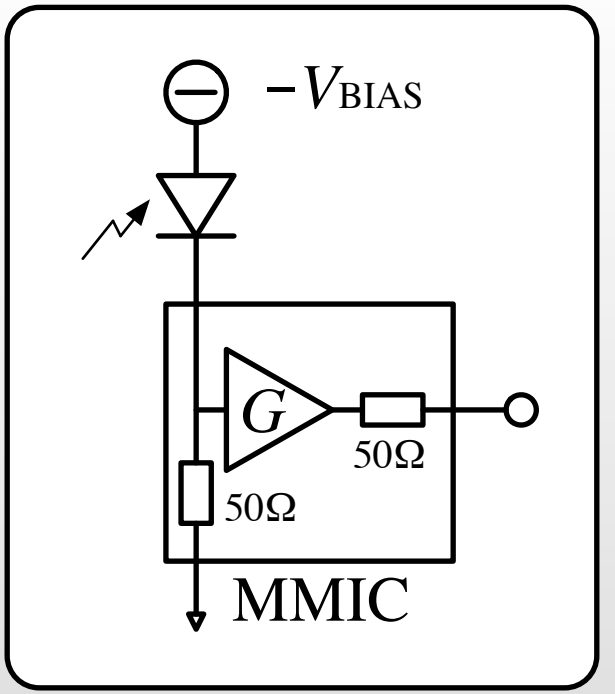
3rd-order intermod. => 3rd harmonic, etc

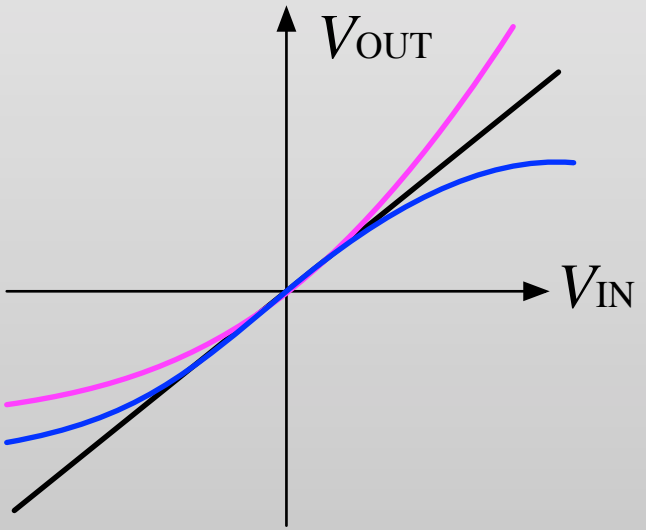
Influence of the intermod.

- Unwanted offset
- Meaningless signal from 2f component
- Unwanted coupling from 1f component

=> Deviation of the operating point
Fluctuation of the optical plant

BBPD RF preamp stage





Broadband PD improvement

BBPD noise issue

- Mitigation for the intermodulation
  => Input current noise (or shot-noise intercept current) increases

Influence of the higher noise

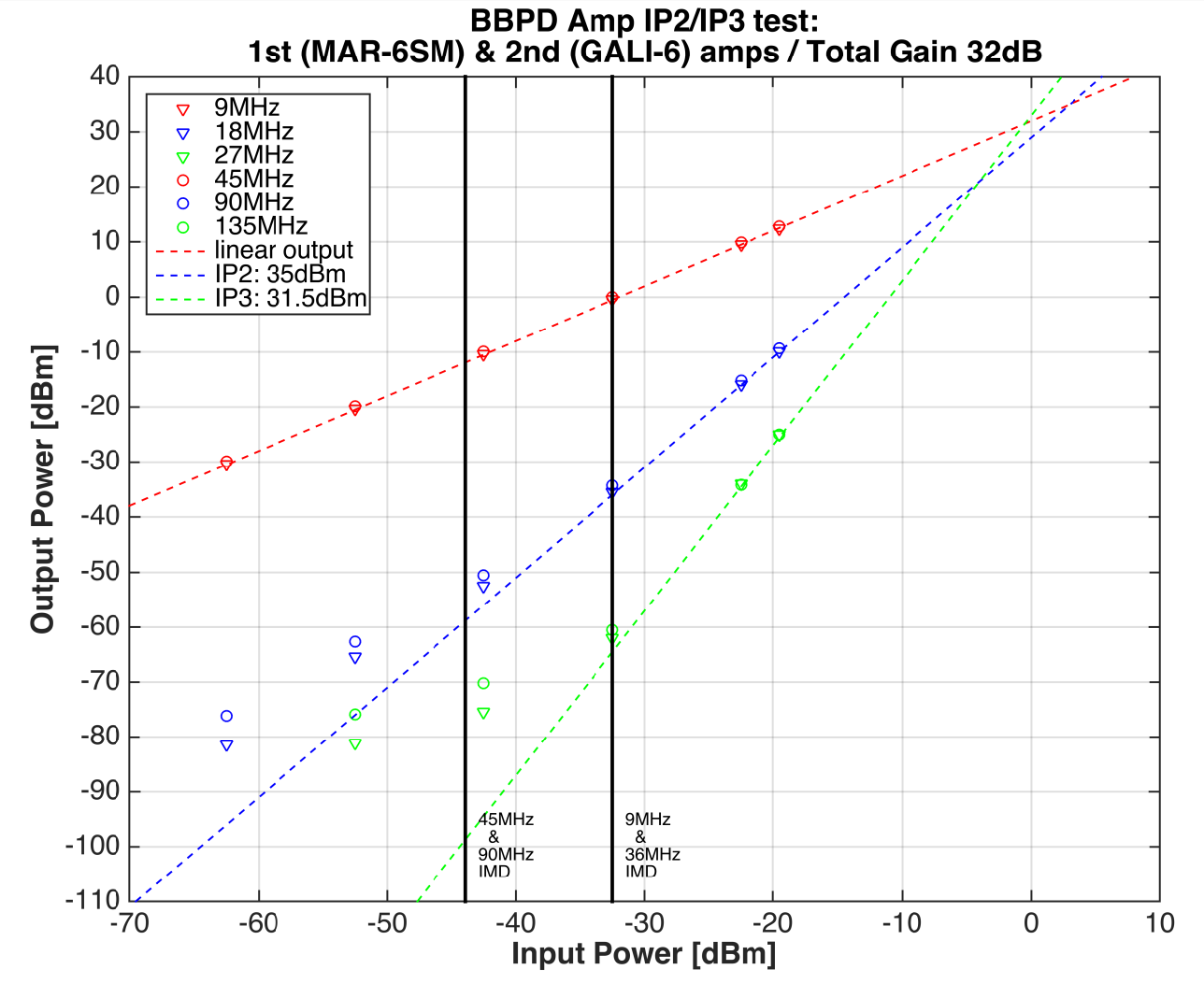
- Limits DRMI control bandwidth during lock acquisition sequence
  or at least constraints DRMI roll-off design (LHO ALOG 16197 Rana A.)

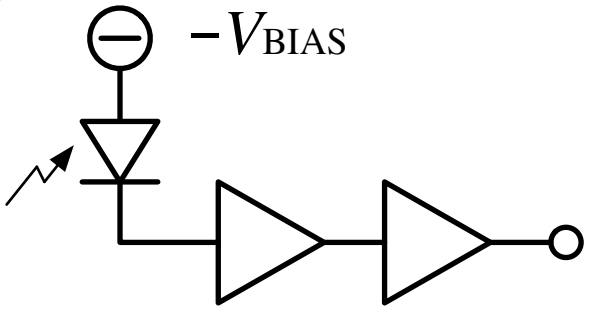
- Limits SNR at some of the in-air 2f PDs

=> Constraints minimum modulation depths

Broadband PD improvement

2nd&3rd-order Intercept Point (IP2, IP3)



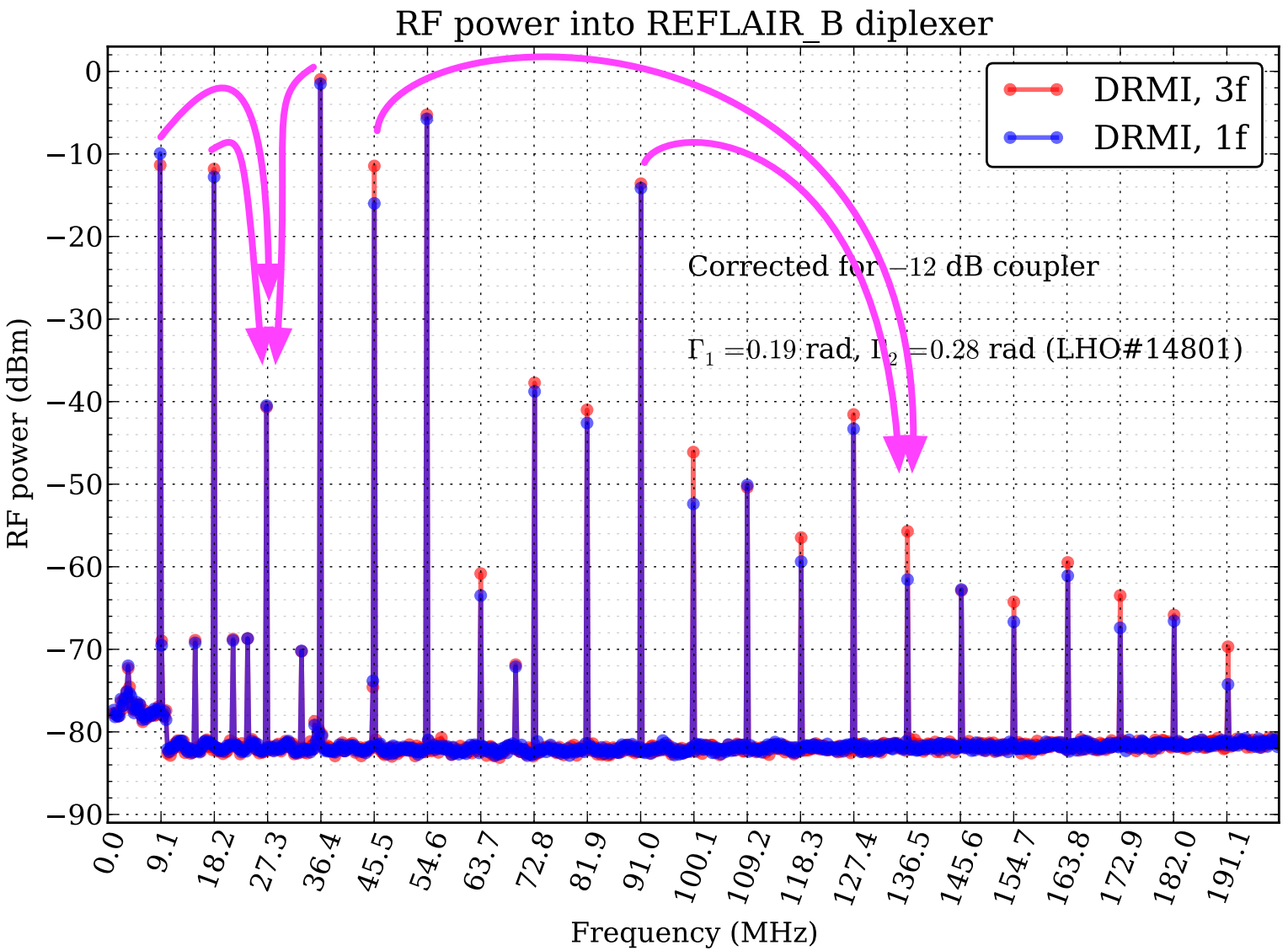


MAR-6SM Low noise Low power

GALI-6 Med. noise Med. power

Our case:
IP2 of the 1st amp was the issue

Broadband PD improvement



LHO ALOG 14796 (Evan H.)

Broadband PD improvement

Intermodulation mitigation

- Use notch filters (LLO) **(LLO ALOG 15504 Matt E.)**
  Excellent effective IP2, requires fine tune, some signal loss
- Remove the 1st preamp (LHO) **(LHO ALOG 14925 Daniel S.)**
  Very easy, noise level limited by the 2nd amp
- Remove the 1st preamp, replace the 2nd amp to GALI-52 (CIT)
  Very easy, noise level recovered

Performance comparison

	Gain [dB]	IP2 [dBm]	FOM [dBm]	Shot-noise intercept current @27MHz [mA]	@135MHz [mA]
Original	32	35	3	0.25	2.0
LLO	27	87	50	0.70 (estimated)	7.8 (estimated)
LHO	13	53	40	0.63	3.8
CIT	23	~70	47.5	0.29	2.1

$P_{sig} = P_{in(3f)} + G$
$P_{spur} = 2\,P_{in(non\text{-}3f)} + 2\,G - IP2$
$P_{sig}/P_{spur} = P_{in(3f)} - 2\,P_{in(non\text{-}3f)} - G + IP2$
=> Figure of Merit: IP2 – G

Broadband PD improvement

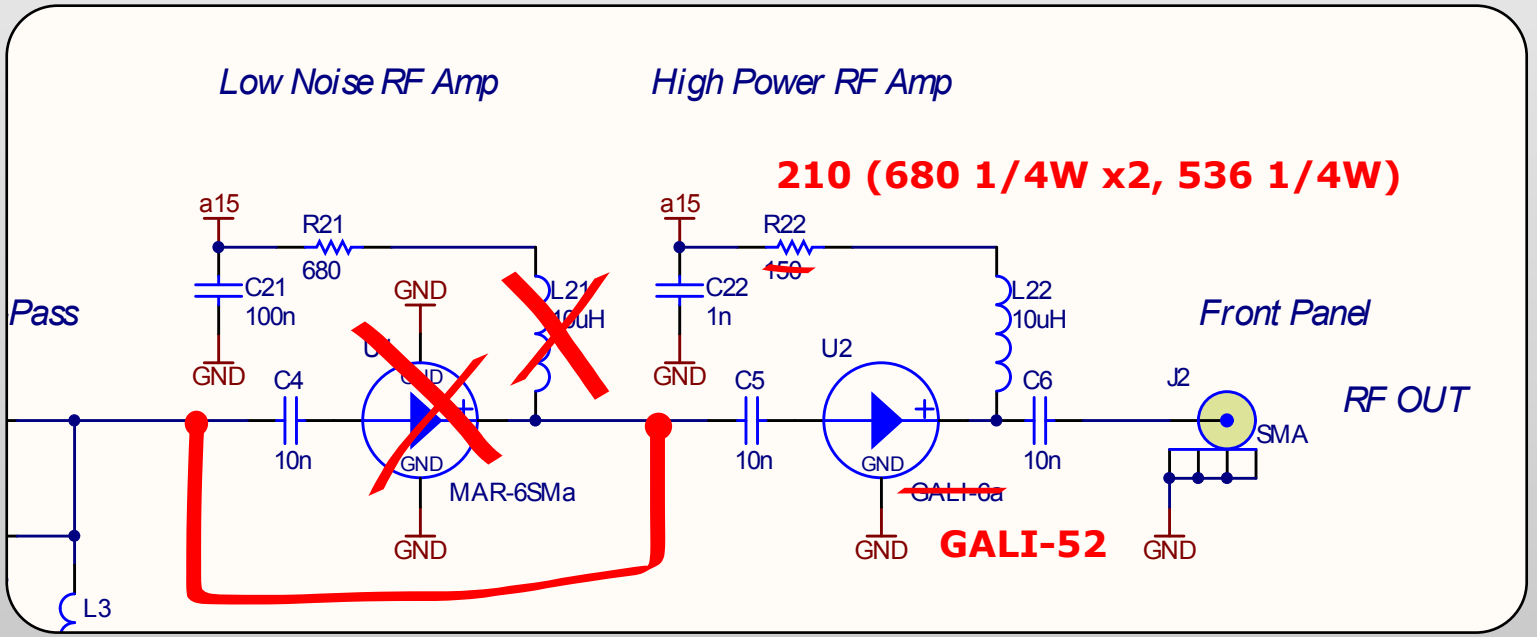
Conclusion & proposal for the improvement

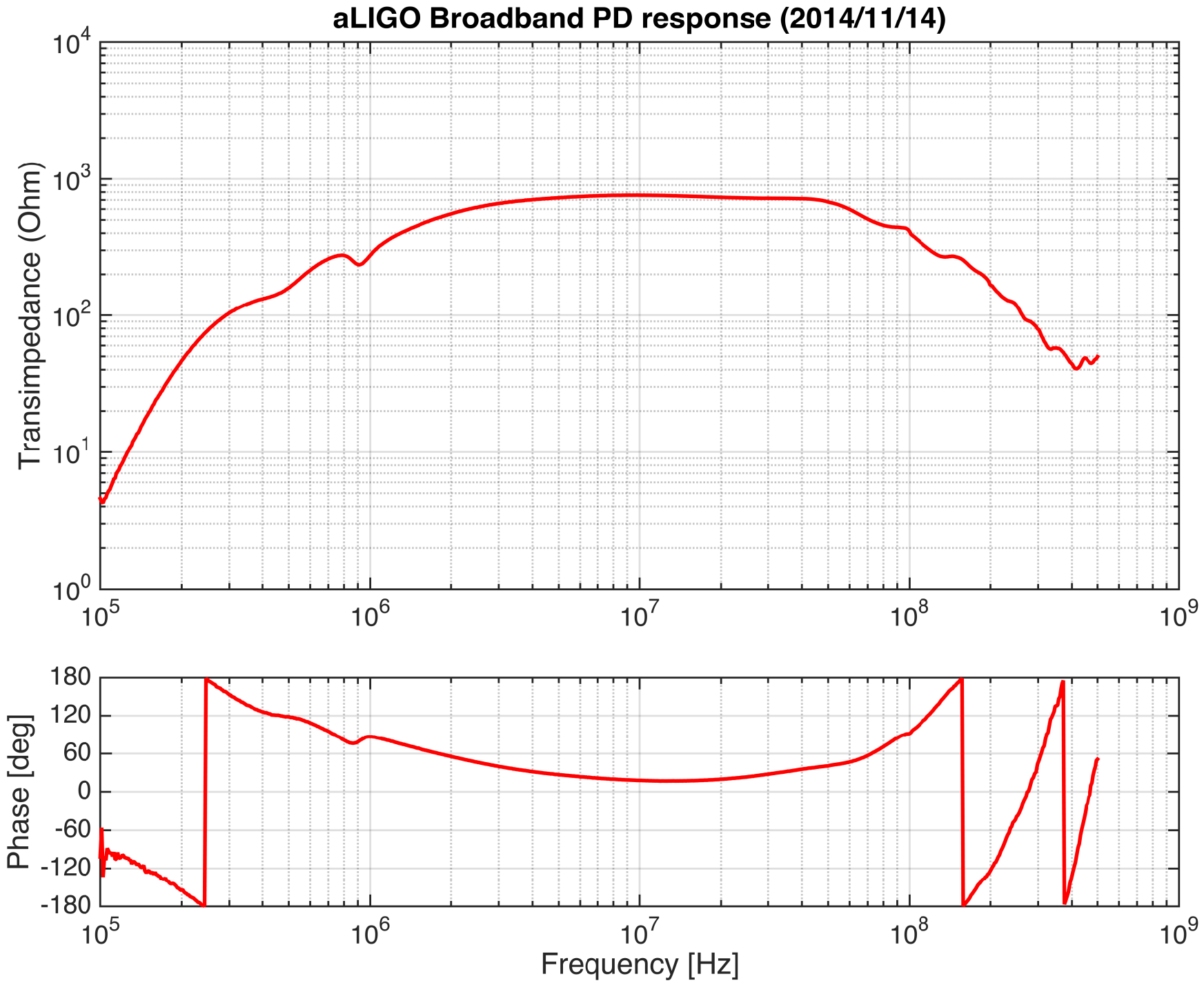
- Remove the 1st amp

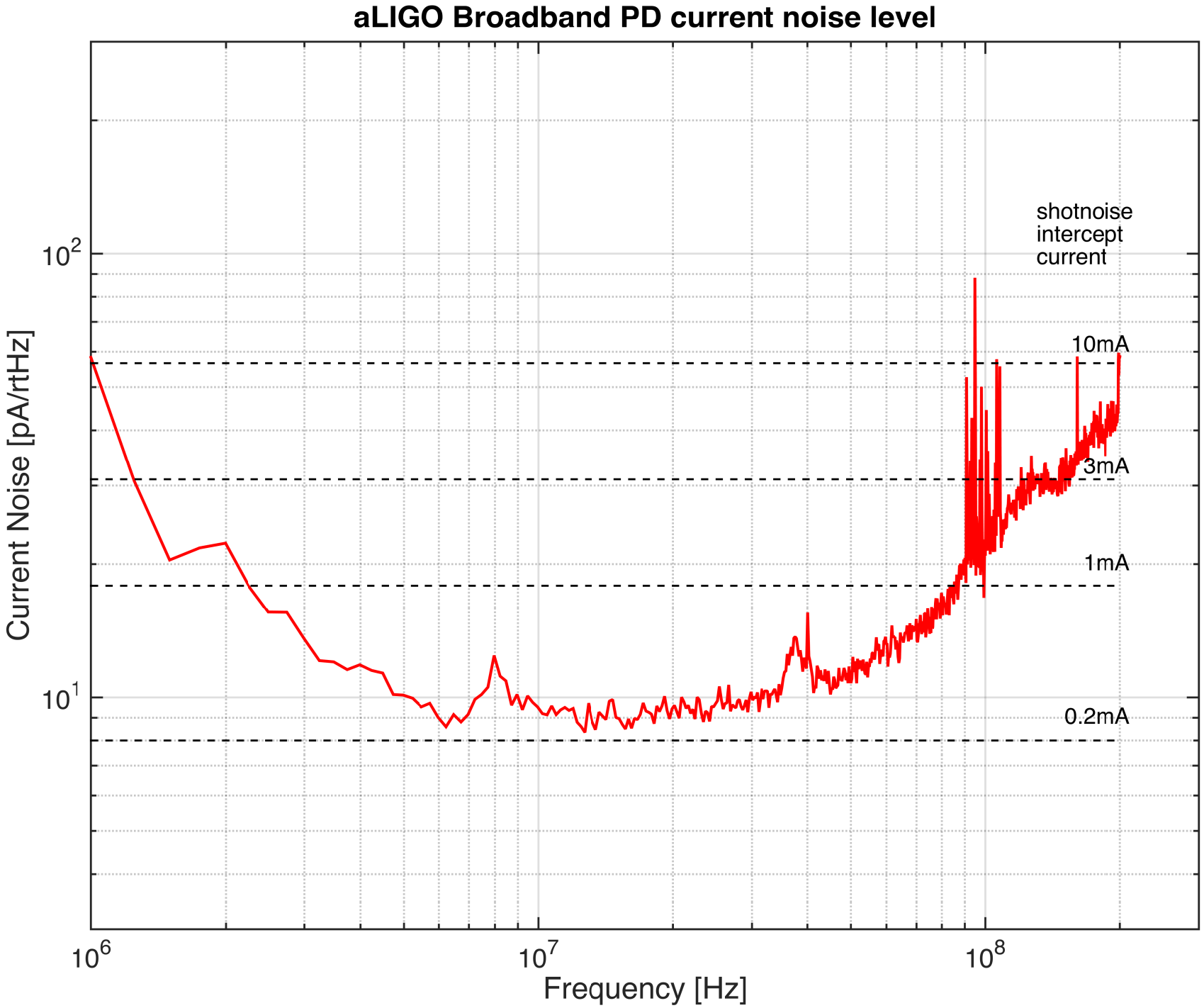
- Replace the 2nd amp

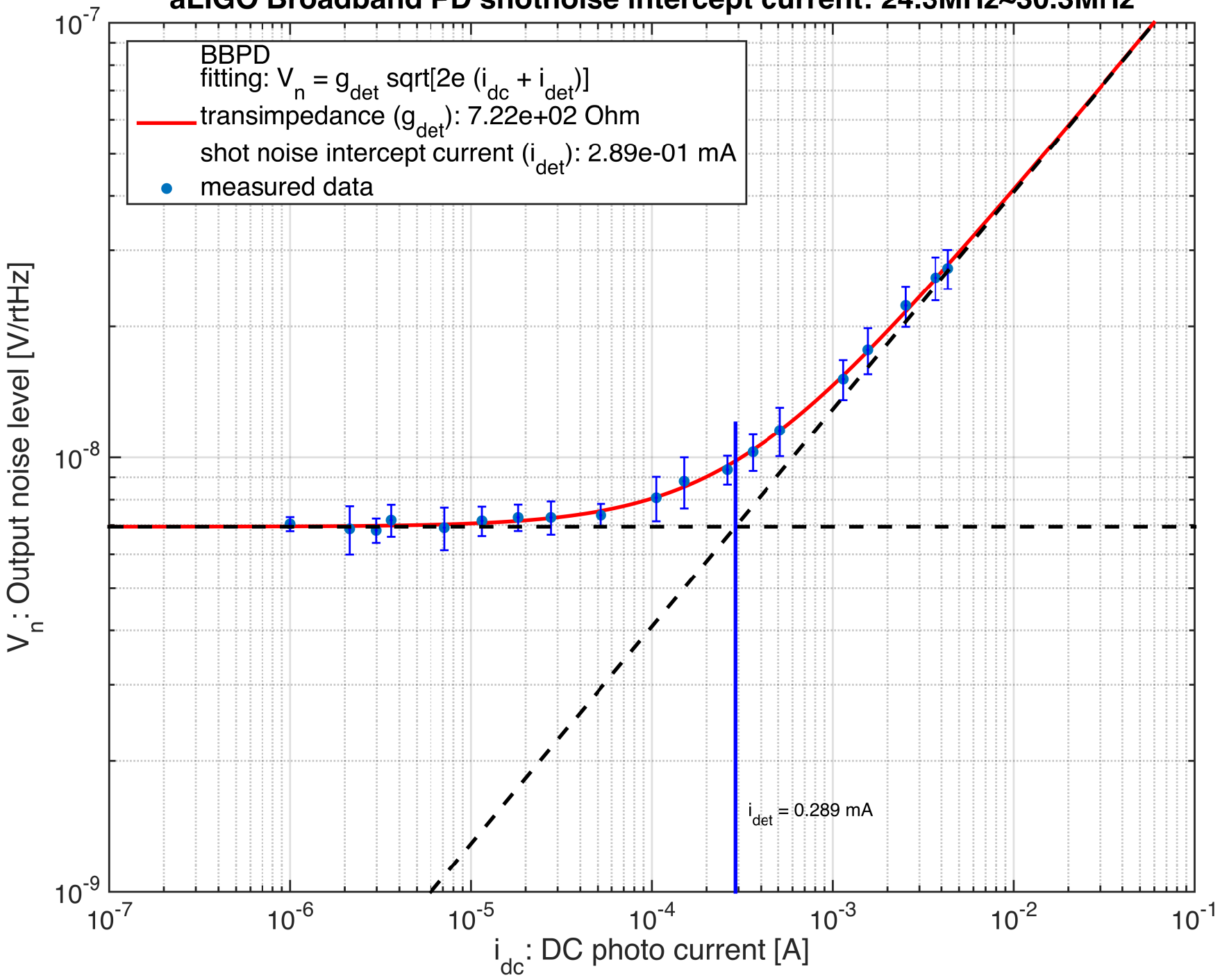
  GALI-6 => GALI-52

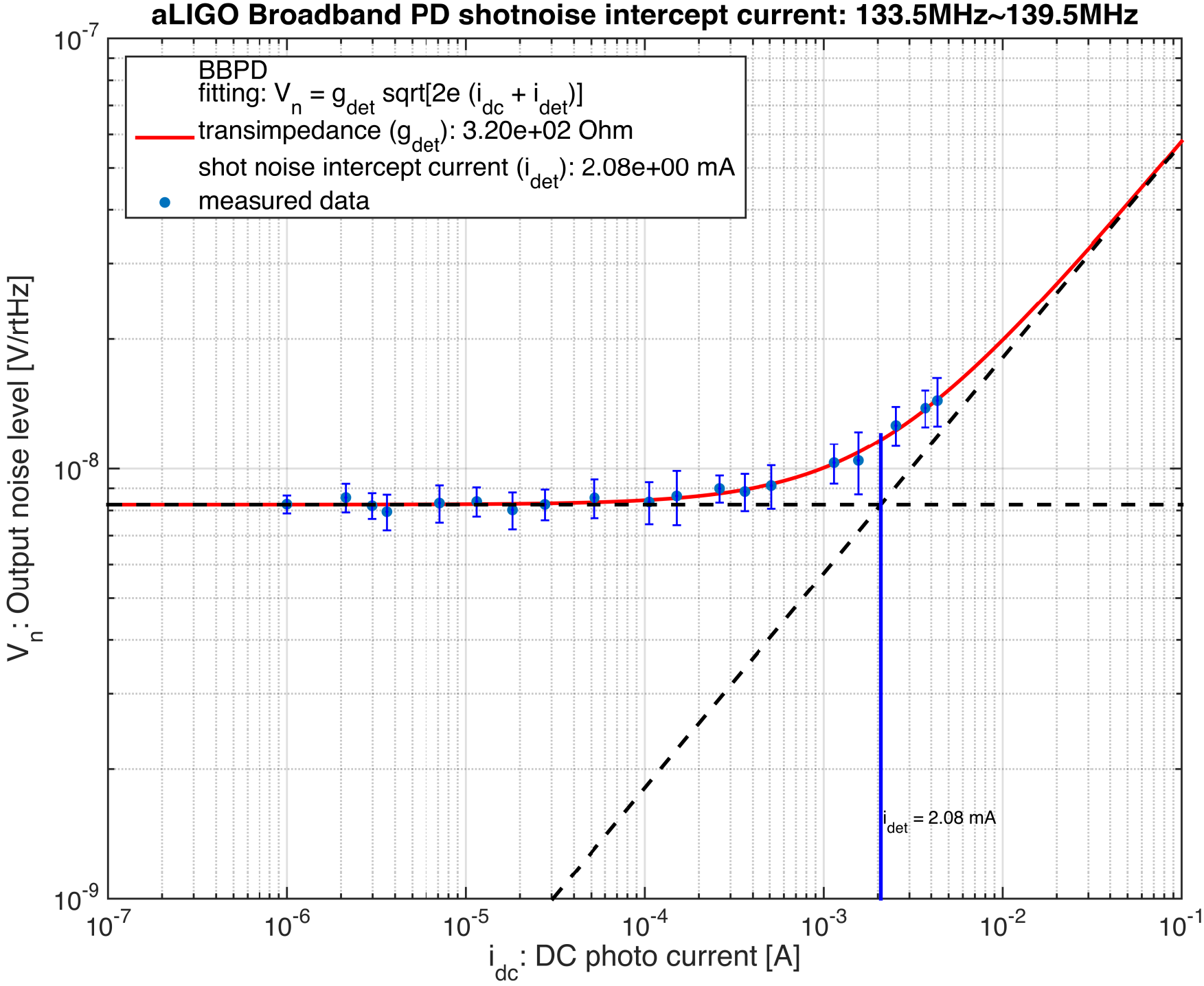
- Update the power supply resisters

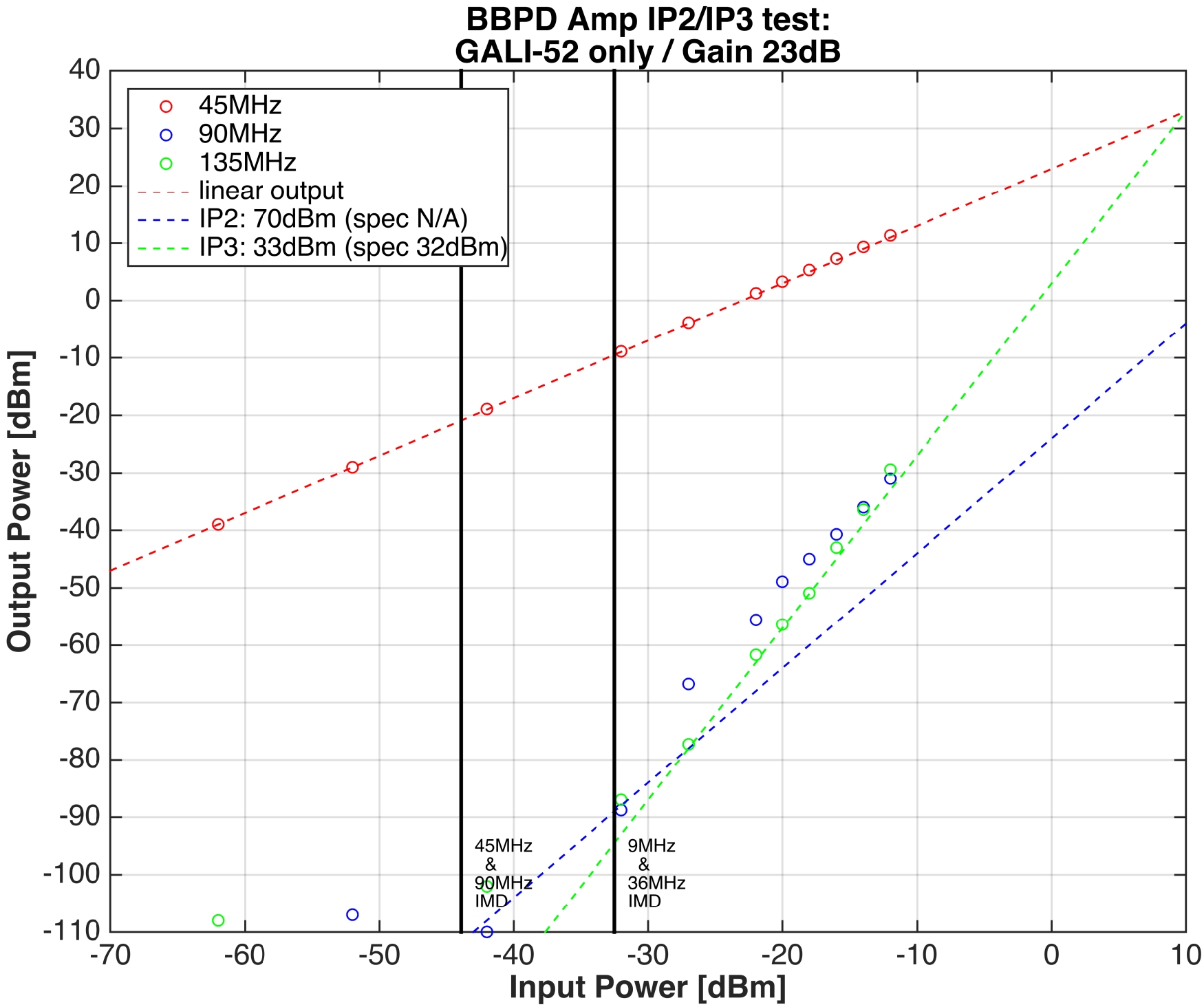



aLIGO Broadband PD response (2014/11/14)
Transimpedance (Ohm)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
Phase [deg]
180
120
60
0
-60
-120
-180
Frequency [Hz]


aLIGO Broadband PD current noise level
shotnoise
intercept
current
10mA
3mA
1mA
0.2mA
Current Noise [pA/rtHz]
10^2
10^1
10^6
10^7
10^8
Frequency [Hz]


aLIGO Broadband PD shotnoise intercept current: 24.3MHz~30.3MHz
BBPD
fitting: V_n = g_det sqrt[2e (i_dc + i_det)]
transimpedance (g_det): 7.22e+02 Ohm
shot noise intercept current (i_det): 2.89e-01 mA
measured data
i_det = 0.289 mA
V_n : Output noise level [V/rtHz]
i_dc : DC photo current [A]
10^-7
10^-8
10^-9
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
10^-1


aLIGO Broadband PD shotnoise intercept current: 133.5MHz~139.5MHz
BBPD
fitting: V_n = g_det sqrt[2e (i_dc + i_det)]
transimpedance (g_det): 3.20e+02 Ohm
shot noise intercept current (i_det): 2.08e+00 mA
measured data
i_det = 2.08 mA
V_n : Output noise level [V/rtHz]
i_dc : DC photo current [A]
10^-7
10^-8
10^-9
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
10^-1


BBPD Amp IP2/IP3 test:
GALI-52 only / Gain 23dB
45MHz
90MHz
135MHz
linear output
IP2: 70dBm (spec N/A)
IP3: 33dBm (spec 32dBm)
45MHz & 90MHz IMD
9MHz & 36MHz IMD
Output Power [dBm]
Input Power [dBm]
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-70
-60
-50
-40
-30
-20
-10
0
10