Update on the Frequency Noise Budgeting and Controls

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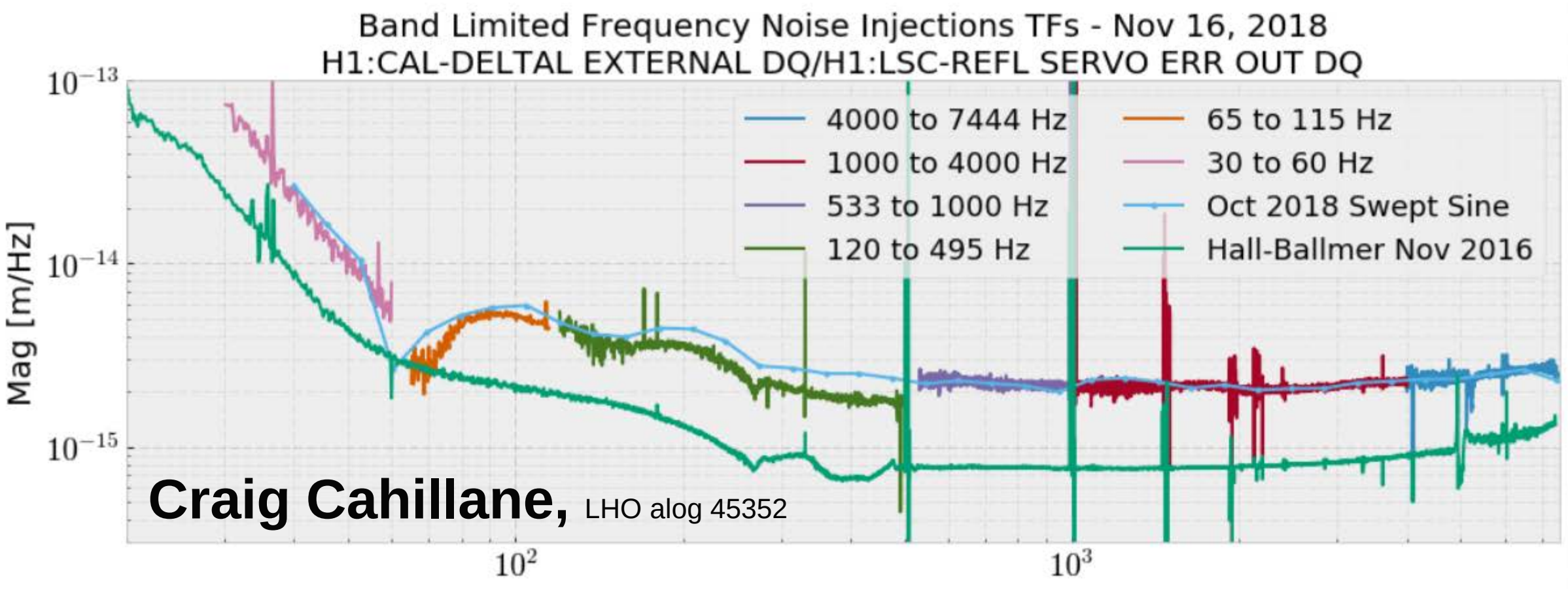
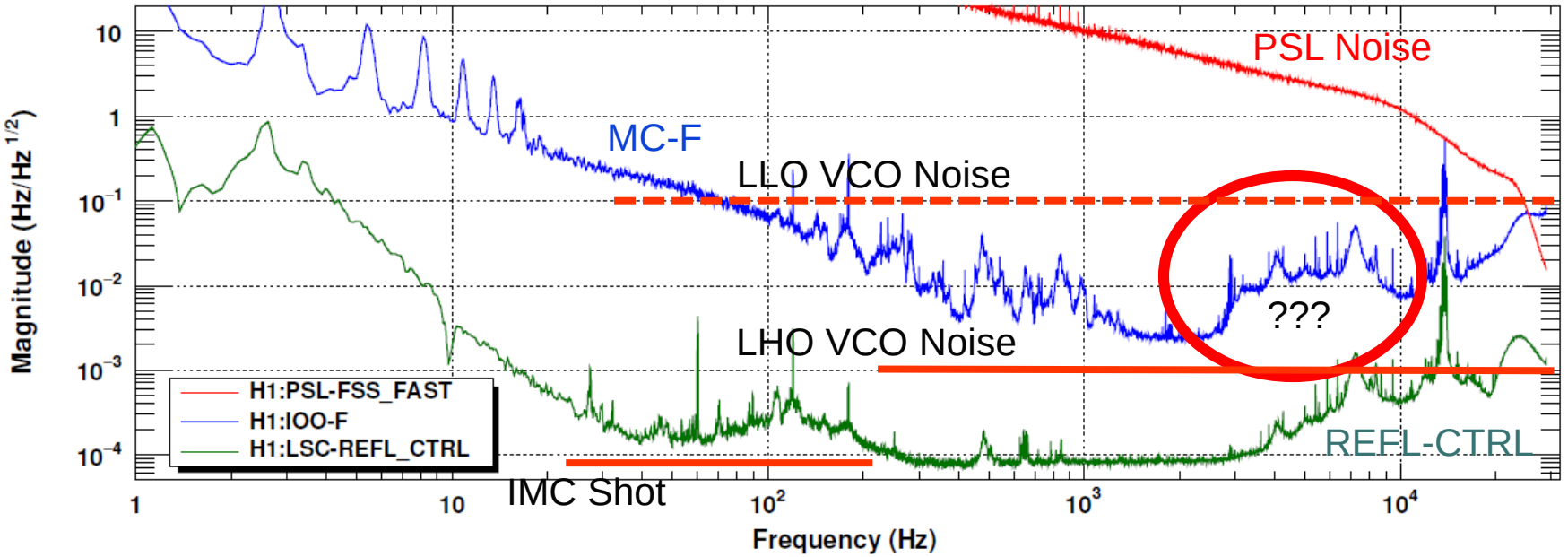
- Frequency noise coupling to DARM tends to be non-negligible for f>~1kHz
- Frequency noise coupling to DARM flattens out due to higher order mode couplings at >100Hz, measured 1-2 x 10^{-15} m/Hz (also ~flat in W/rad)
- Frequency noise coupling depends on differential heating
  Can only get worse the higher the power



Power spectrum

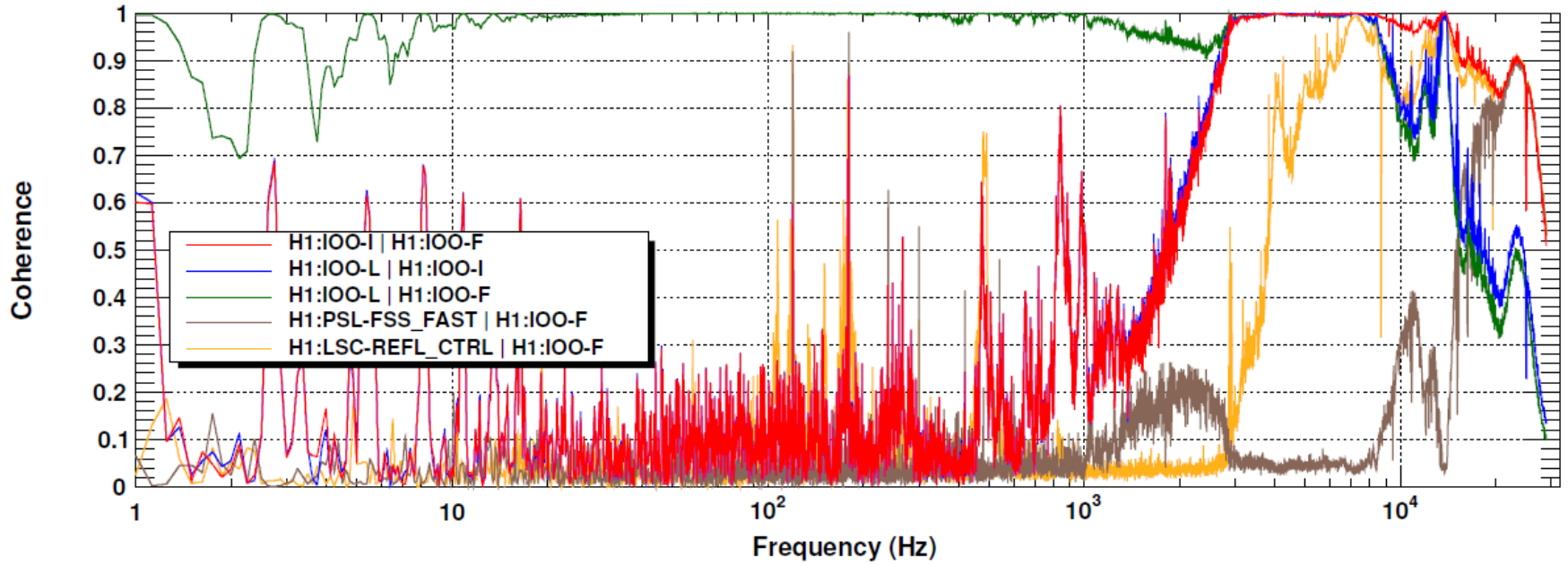


37W at input of IMC

Feature at 3-10kHz:
- Not NPRO noise
- Ref. cavity noise?
- From PSL?
- From IMC?
- Not IMC sensing noise

IFO-REFL BW ~10-15kHz

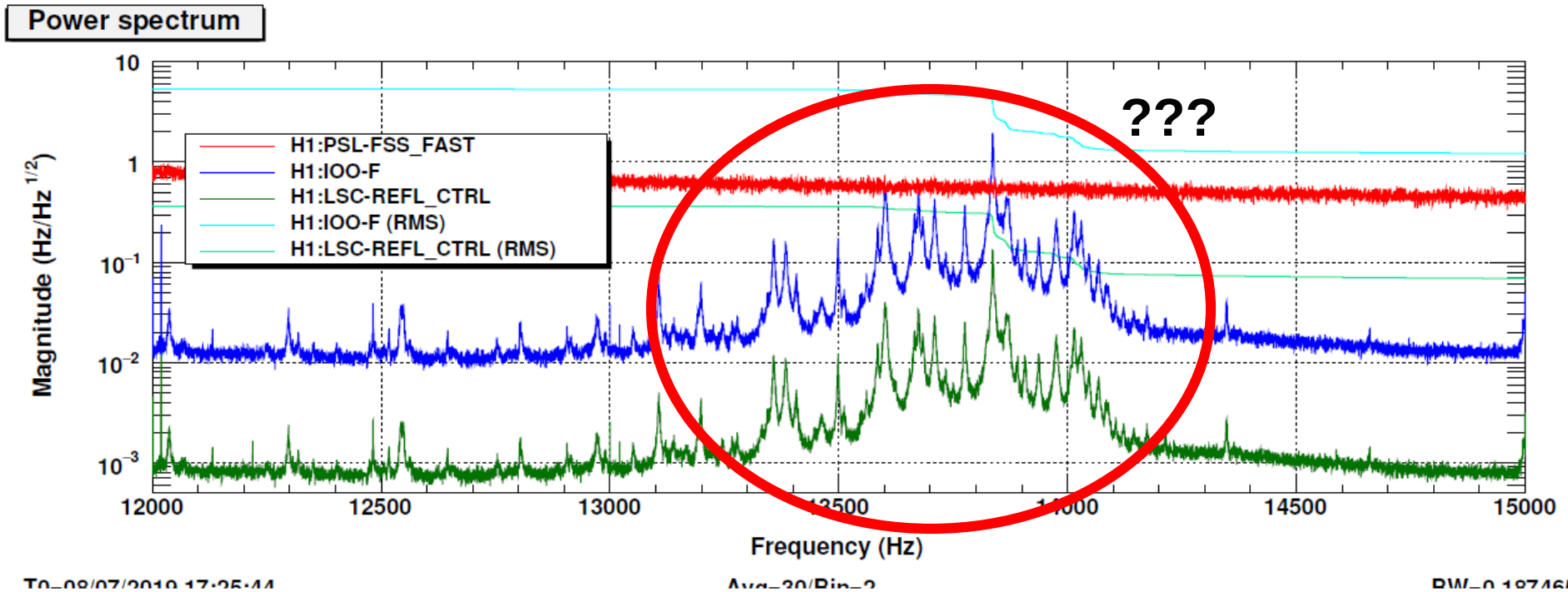
Coherence



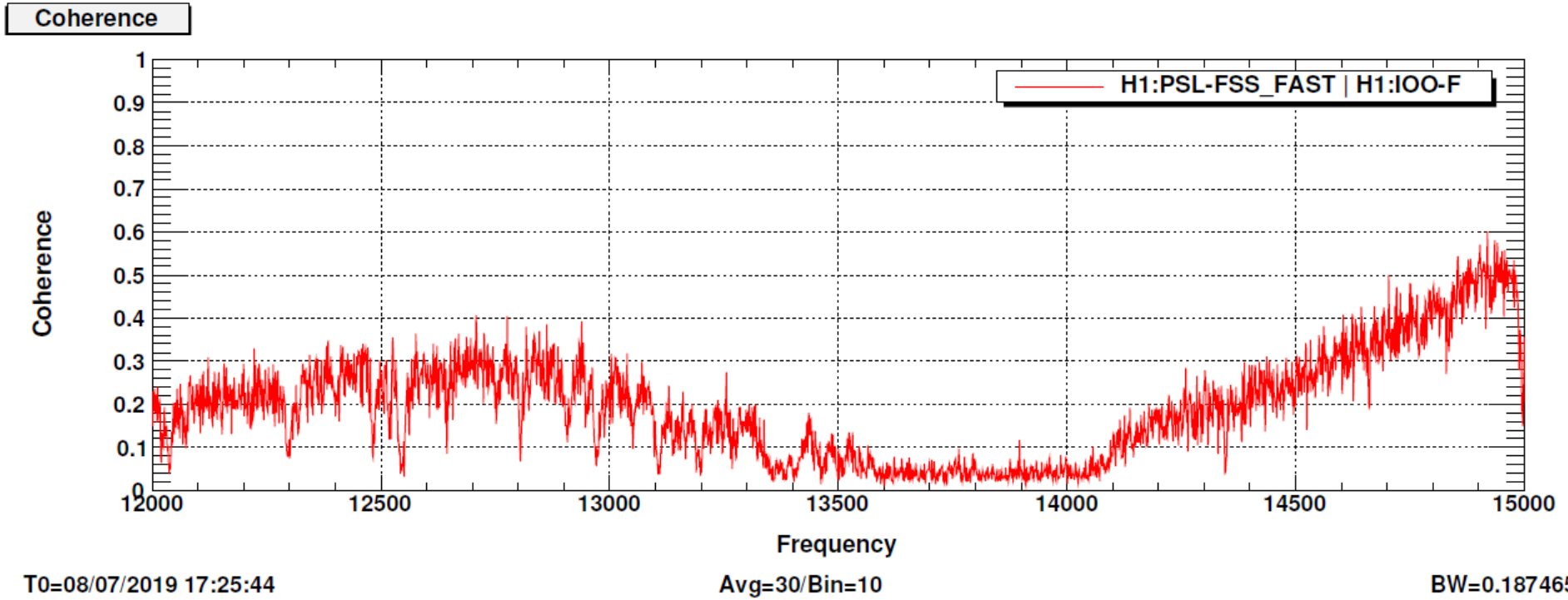
IMC sensing noise limited by poor modulation index:
20x Γ → 10x lower sens. noise
PD: 750mW unlocked
9mW locked (99% carrier)

T0=08/07/2019 17:25:44 Avg=30/Bin=23L BW=0.187465

G1901316-v1



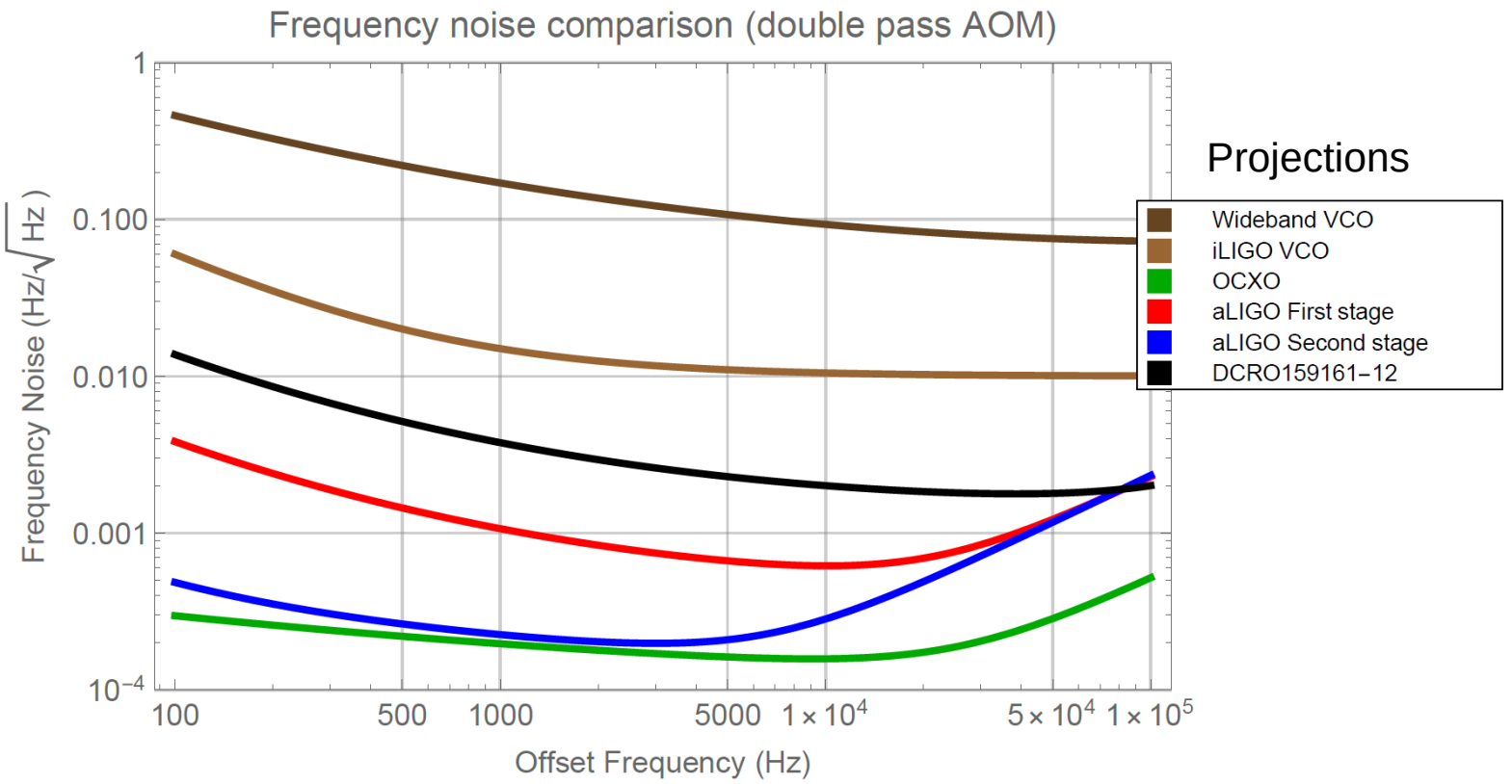
Peaks not in FSS FAST
Ref. cavity resonance?
Why so many?



G1901316-v1

Available Options for VCOs (SAW)

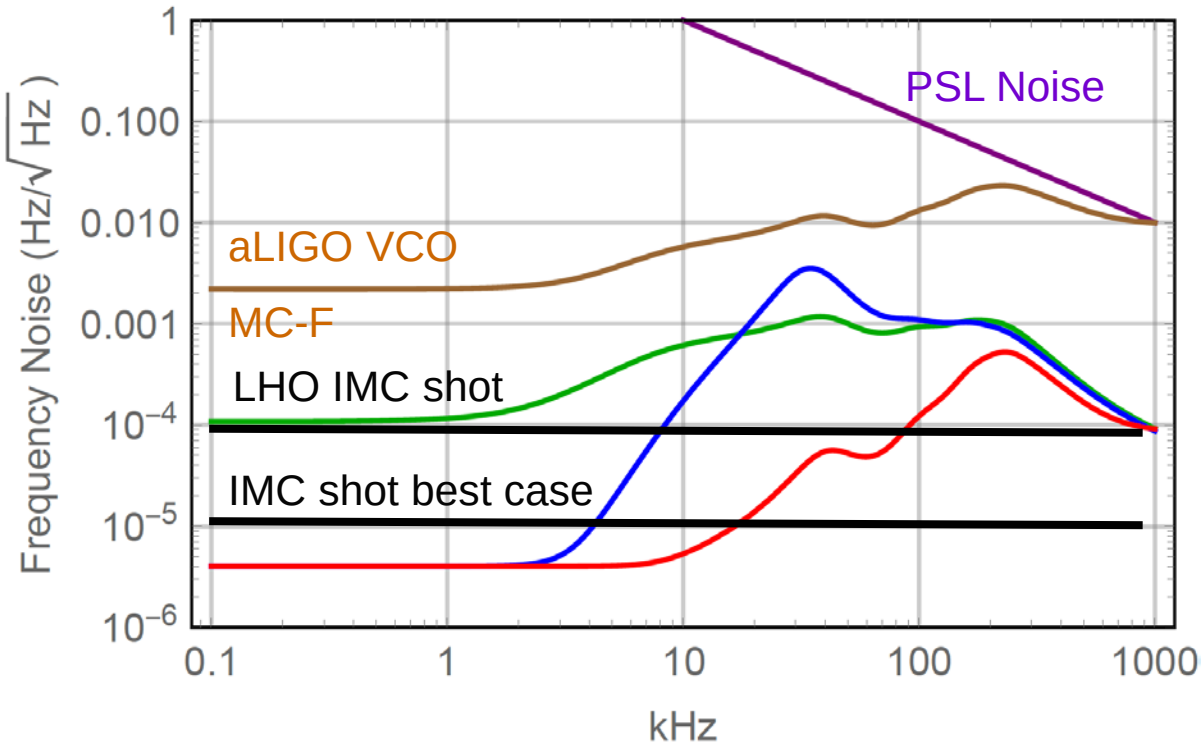
- Advanced LIGO VCO: 79.4±1.2MHz
  1.05±0.14 GHz VCO (MCF91119-10) divide by 128 & mix with 71 MHz OCXO
- Initial LIGO VCO: 80±5 MHz
  800±50 MHz VCO (CRO750SA) divide by 10
- Best available SAW VCO: 79.6±1.2MHz
  1.595±0.025GHz VCO (DCRO159161-12) divided by 20
- 80 MHz VCO wideband (e.g., DCMO514-5)

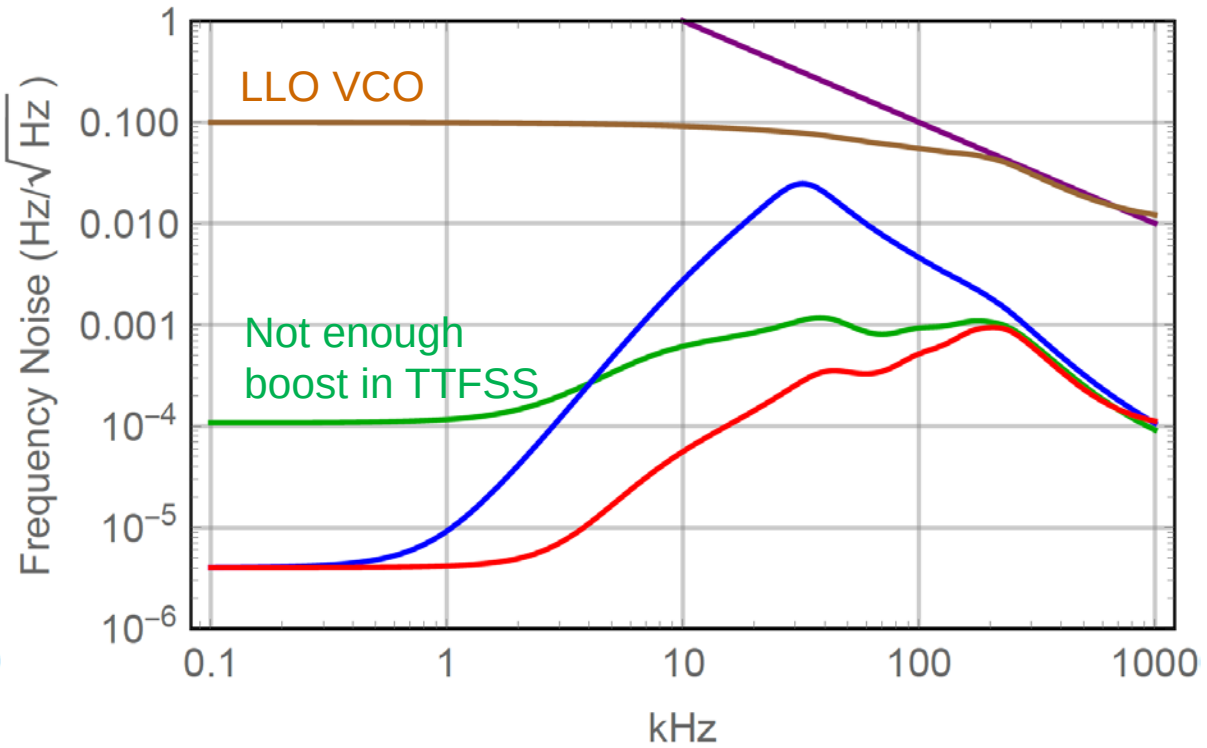


Are we gain limited at high frequencies?

- Hierarchical approach: PSL ~ 500kHz BW, IMC ~100kHz BW
- No reference cavity: IMC ~500kHz BW, current TTFSS
- Serial approach: PSL ~500kH BW, IMC ~500kHz BW
  Requires IMC TTFSS and separate EOM

Conclusion: Serial approach & increasing modulation index will help >1kHz and allow for increased VCO noise



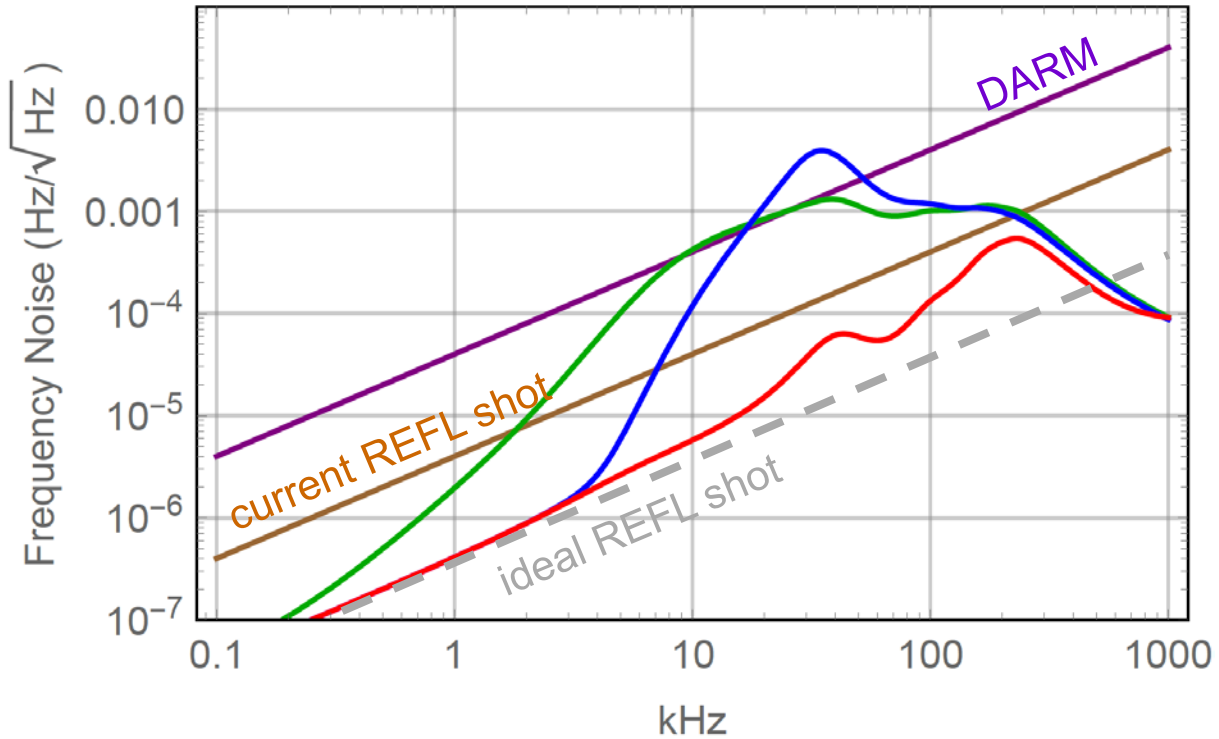


Interferometer Projection (assuming ideal IMC sensing noise)

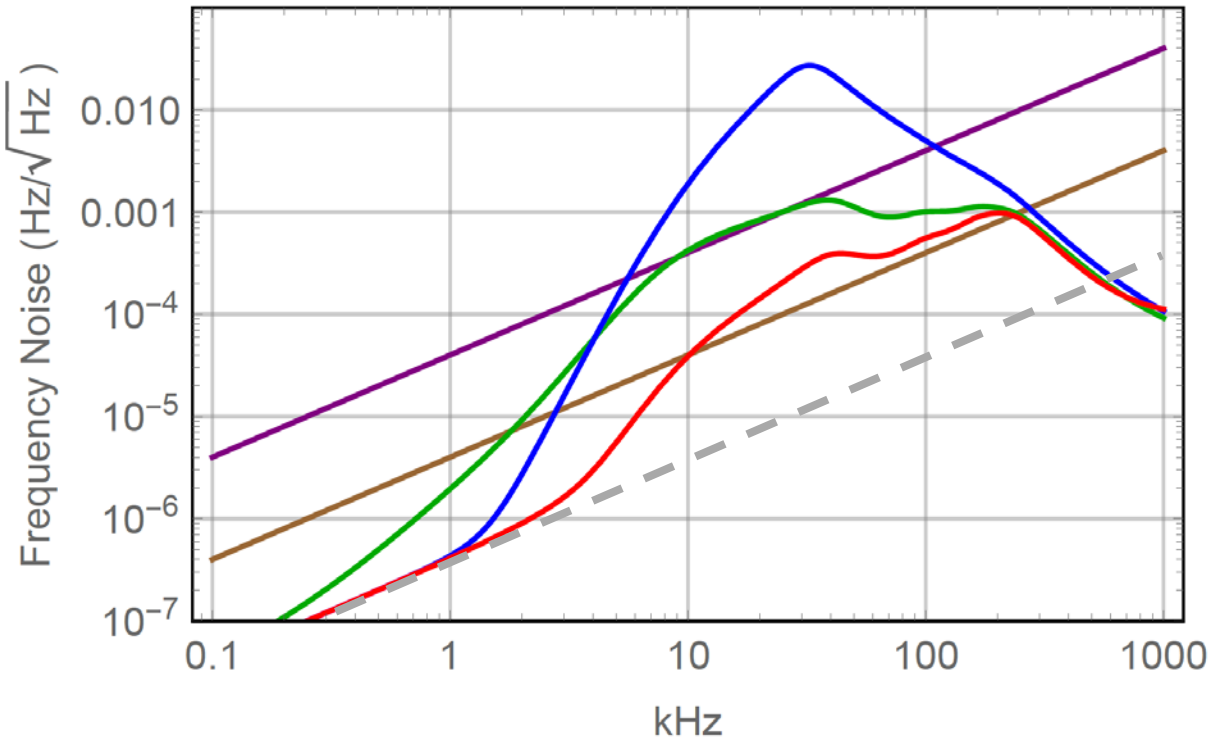
- Hierarchical approach: PSL ~ 500kHz BW, IMC ~100kHz BW, REFL ~15kHz BW
- No reference cavity: IMC ~500kHz BW, current TTFSS, REFL ~15kHz BW
- Serial approach: PSL ~500kH BW, IMC ~500kHz BW, REFL ~15kHz BW
  Requires IMC TTFSS and separate EOM

Below a 3-5 kHz: REFL sensing noise dominates

aLIGO VCO



LLO VCO

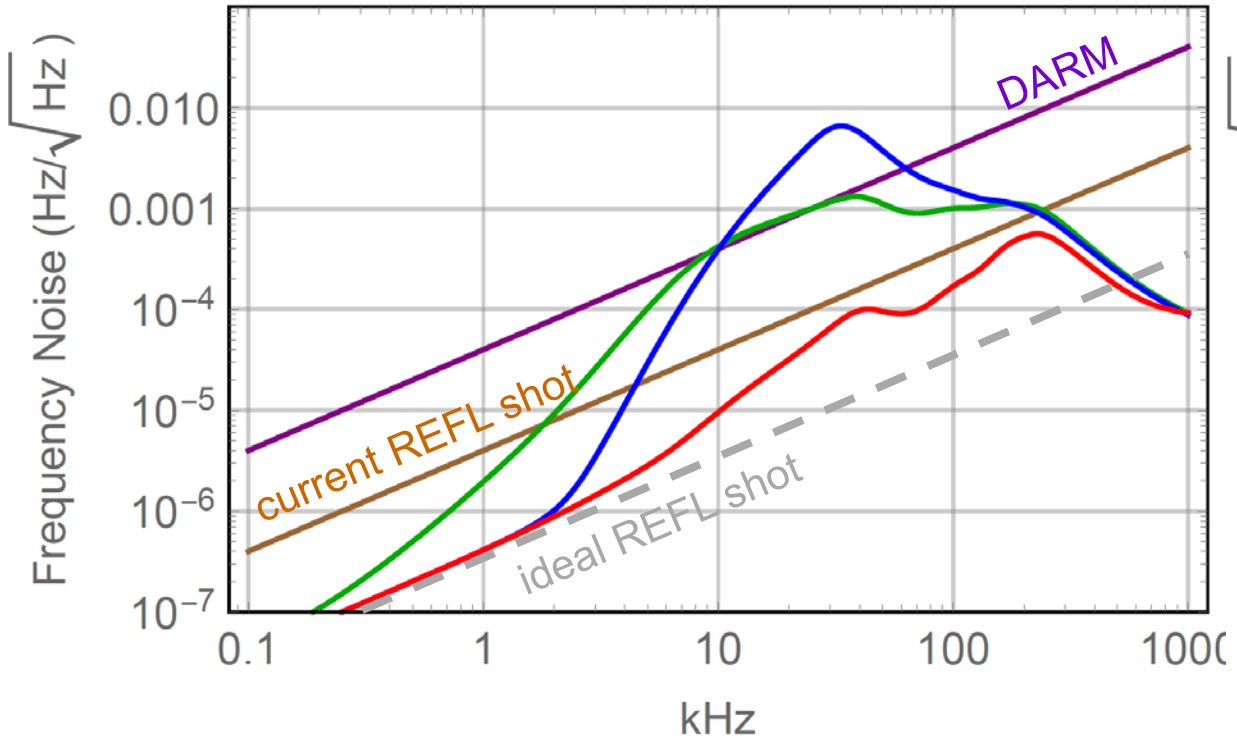


Interferometer Projection (Comparing IMC sensing noise)

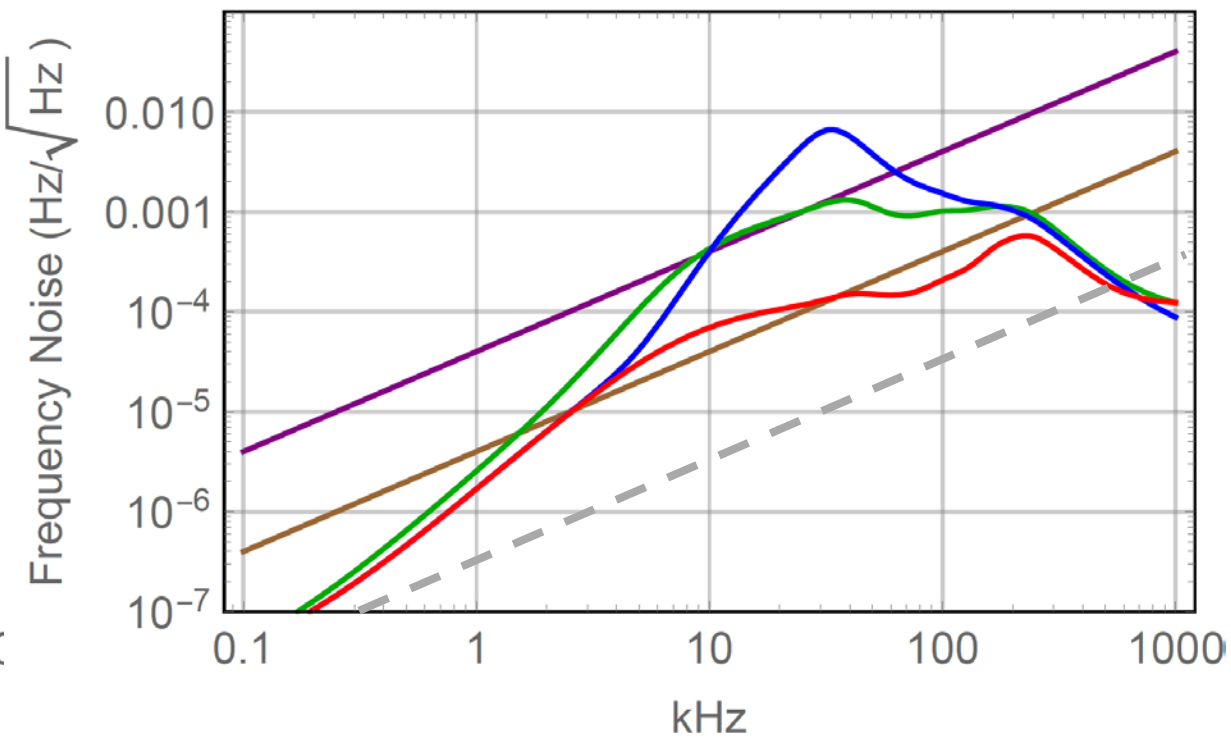
- Hierarchical approach: PSL ~ 500kHz BW, IMC ~100kHz BW, REFL ~15kHz BW
- No reference cavity: IMC ~500kHz BW, current TTFSS, REFL ~15kHz BW
- Serial approach: PSL ~500kH BW, IMC ~500kHz BW, REFL ~15kHz BW
  Requires IMC TTFSS and separate EOM

Above 3-5kHz: Better IMC sensing noise is required to take advantage of any REFL improvement

Ideal IMC Sensing Noise / iLIGO VCO



Current IMC Sensing Noise / iLIGO VCO



REFL Sensing (LHO)

- REFL shot is high (estimate 10x over ideal): carrier dominated

	Input		AS (contrast?)		POP	REFL		Expect
Carrier	97.6%	37W	19.4%	=25mW	98.4%	82.5%	8.5mW	
9.1 MHz	0.9%	0.33W	6.3%	8mW	1.3%	3.9%	0.4mW	~4mW
45.5 MHz	1.5%	0.56W	74.3%	96mW	0.3%	13.6%	1.4mW	

Total AS port power is 240-270mW; numbers need to be multiplied by 2 to account for OMC.
REFL split ratio 1.25%, unlocked ~400mW.
40-50% of 45.5MHz sideband power is not accounted for.

70-80% of 9.1MHz sideband power is not accounted for: Loss where/why?

Recommendation:

- Investigate the 9.1MHz vanishing act
- Check carrier mode matching and high order mode content in reflection
- Maybe consider new RM with better optimized coating
- Increase REFL power (maybe limited by RF signals due to sideband imbalance)

Possible Actions

- Unknown prospects to reduce the frequency noise coupling
  - Higher power and improved squeezing will make frequency noise coupling more significant
- Investigate 9MHz sideband mystery
  - Is the poor sideband power related to optical distortions by the ITMs which produce HOMs?
  - Does this correlate with the high frequency noise coupling?
- Increase power in REFL
  - We are using 2 PDs at LHO already
  - Power is only 5mW/PD at 37W input, but RF signals tend to be large
- Reduce carrier in reflection by adjusting RM reflectivity
  - Is the REFL power dominated by carrier TEM00?
- New VCO: Propose to try 1.6GHz device
  - What's the excess noise seen by IMC-F above 3kHz?
- IMC sensing noise reduction (higher modulation index)
  - Dedicated EOM for IMC or dedicated electrode on existing EOM?
  - TTFSS for IMC (better performance by keeping reference cavity)
  - Neither will help <3kHz unless we also improve the REFL sensing noise