Pcal actuation of the TST stage of the DARM servo loop

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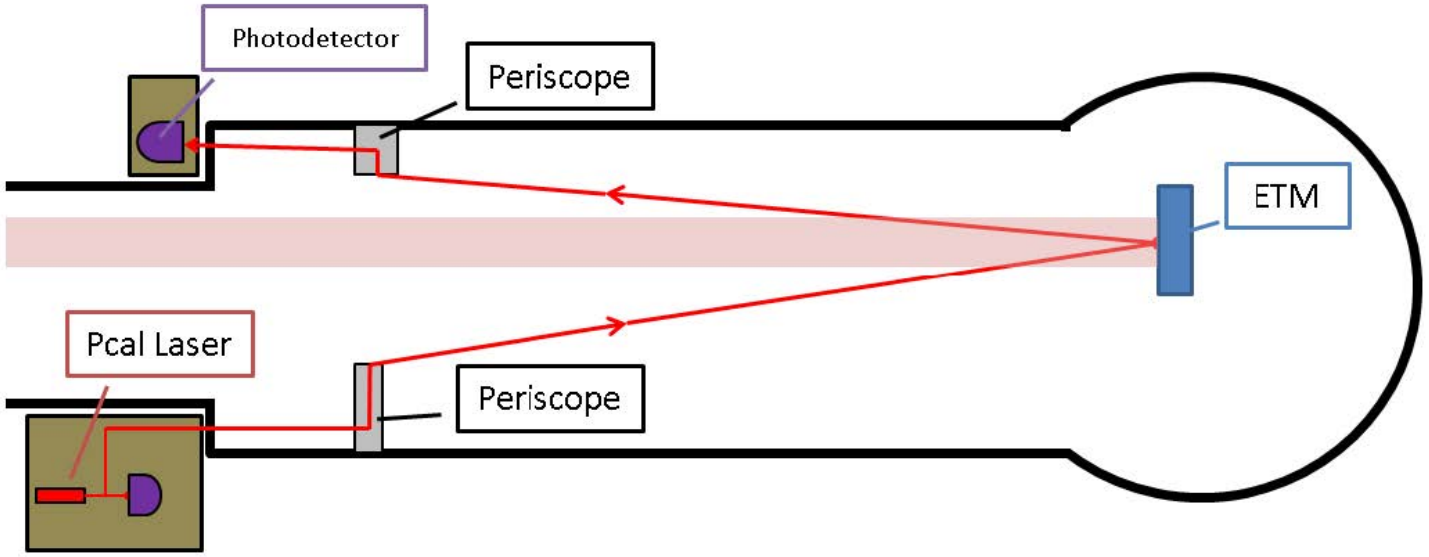
Overview

- Planning to test full or partial actuation of DARM loop using Photon Calibrator (part of Darkhan's UTRGV Ph.D. thesis work).
  - » Potential actuator for future GW detectors
  - » May have advantages such as
    - – Simplicity - no reaction mass required, no ESD bias drift, etc.
    - – Lower noise (or not)

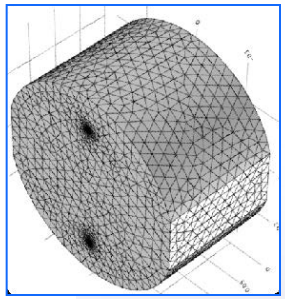


Current use of Pcals in aLIGO

- Pcals currently used for
  - » Ifo. calibration
    - – Yend, lines at 36.7 (34.7) Hz and 331.9 (331.3) Hz
  - » Calibration monitor
    - – Yend, line at 1083.7 (1083.1) Hz
    - – Xend, line at 3001.3 (3001.1) Hz
  - » Hardware signal injections (in testing)
    - – Xend Pcals (requires giving up 3 kHz line)

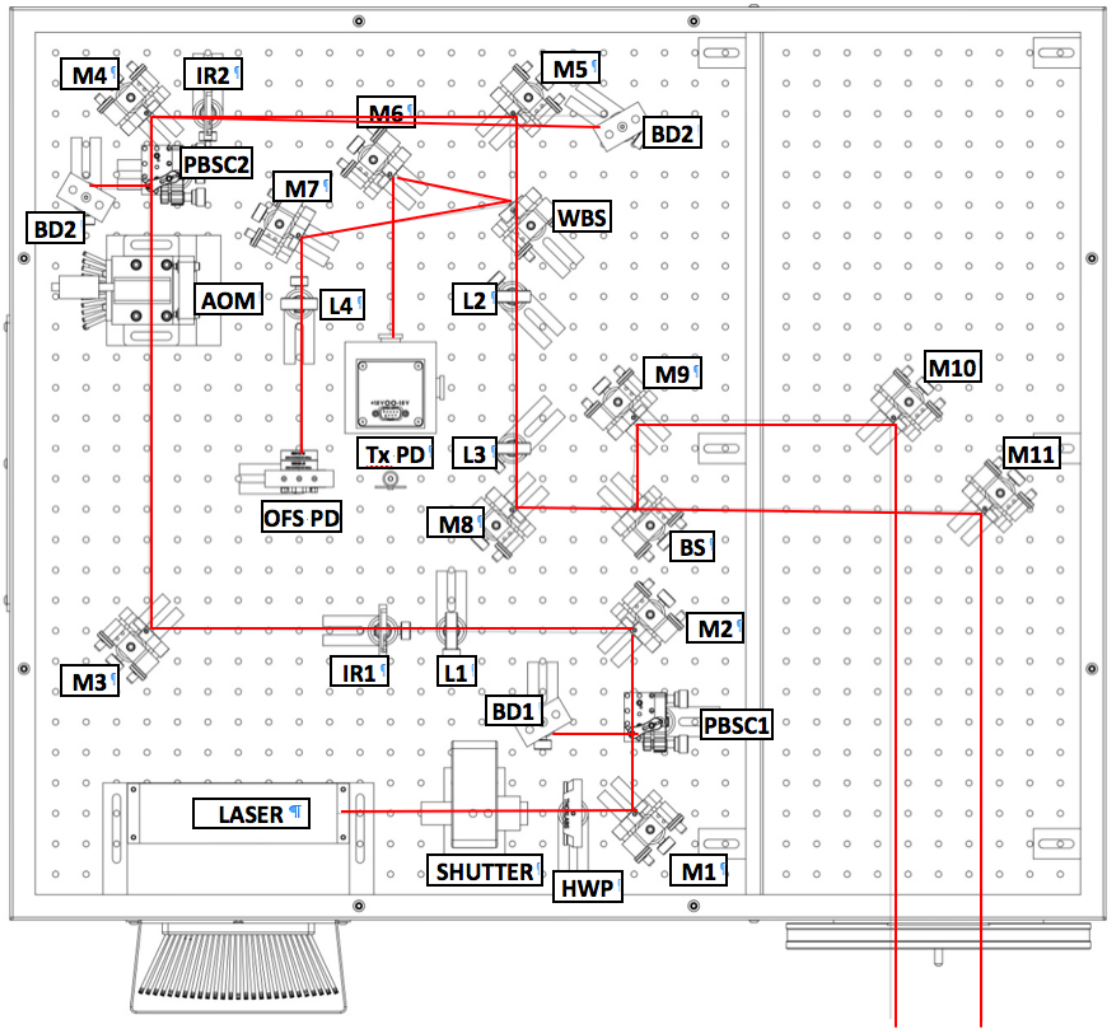
Pcal optical path

- Beams enter vacuum horizontally displaced
- Pcal periscope directs beams toward BT axis to avoid occlusion by ACB
- Beams propagate in horizontal planes and impinge on ETM vertically displaced at drumhead mode nodal circle
- Pcal periscopes relay ETM camera views too



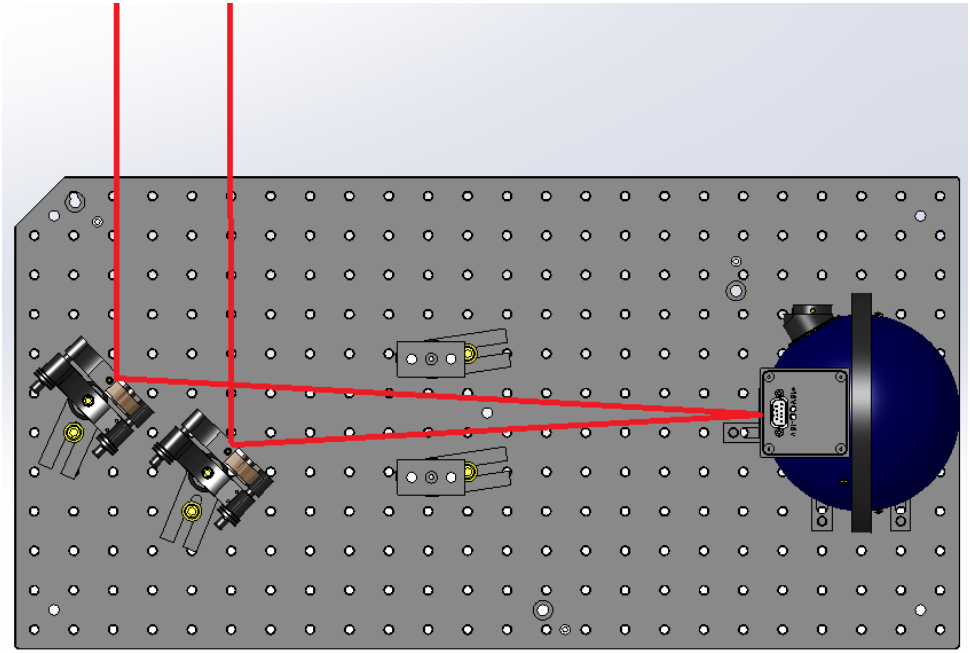
Pcal transmitter module layout

- 2-W YLF laser
  - » 1047 nm
- Isomet AOM
  - » Use the diffracted beam
- New LIGO PDs
  - » OFS, Tx, Rx
- Integrating spheres for
  - » Tx PD and Rx PD
- Two output beams
  - » Power balanced to 1%
- Could add a second AOM, and maybe a second laser, for independent control of two beams (and twice the laser power)

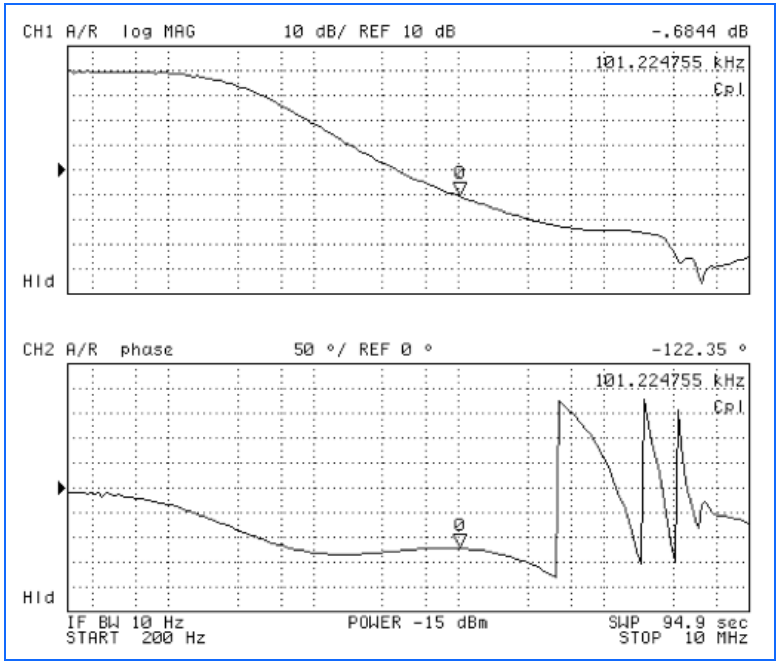


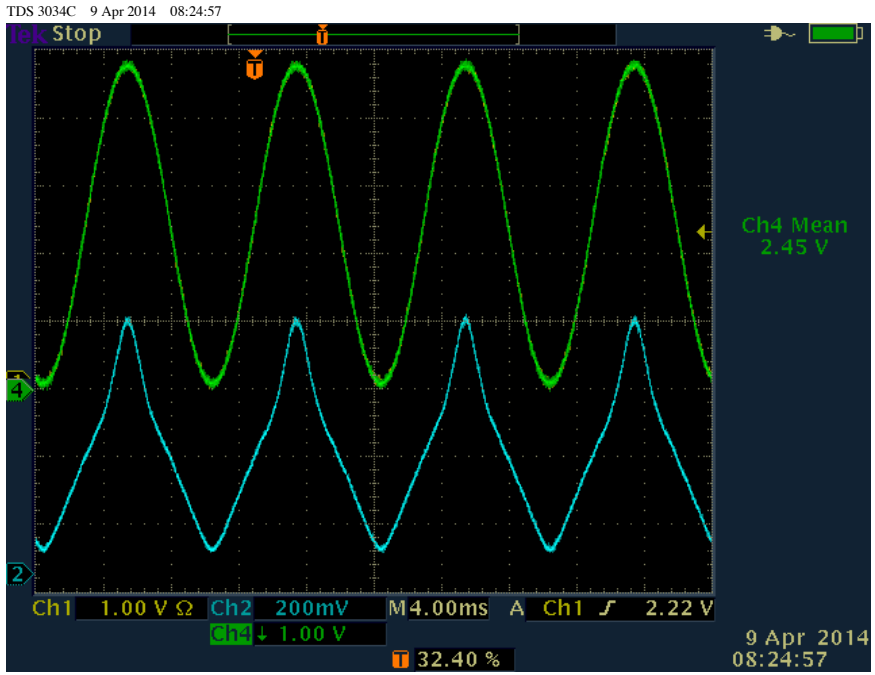
Pcal receiver module

- 4” integrating sphere with LIGO InGaAs PD
- Relay mirrors direct both beams into one sphere
- Optical efficiency from Tx to Rx: 98 – 99 %
  - » Two AR-coated windows
  - » 4 or 5 relay mirrors
  - » Reflection from ETM



Optical Follower servo

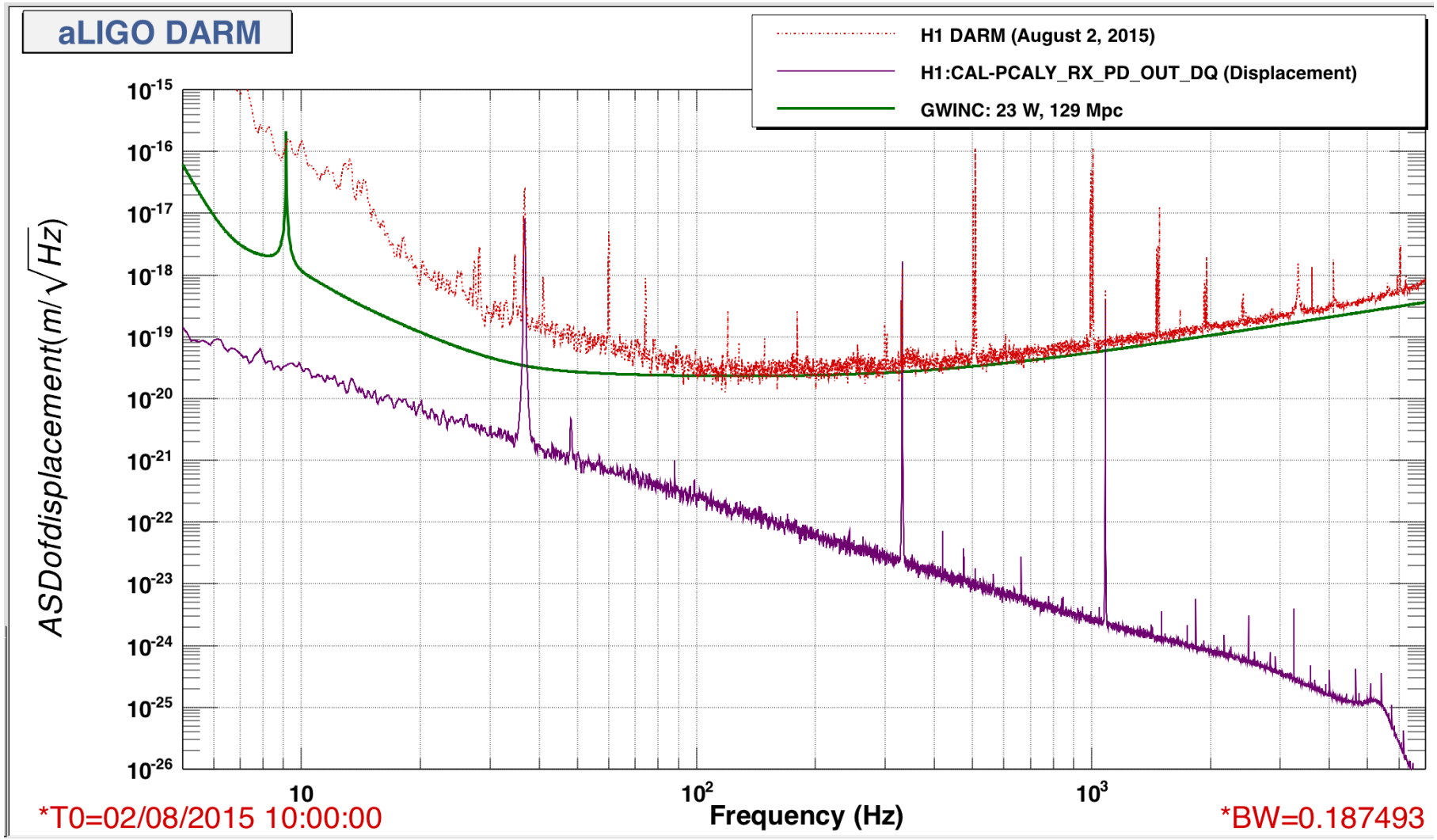




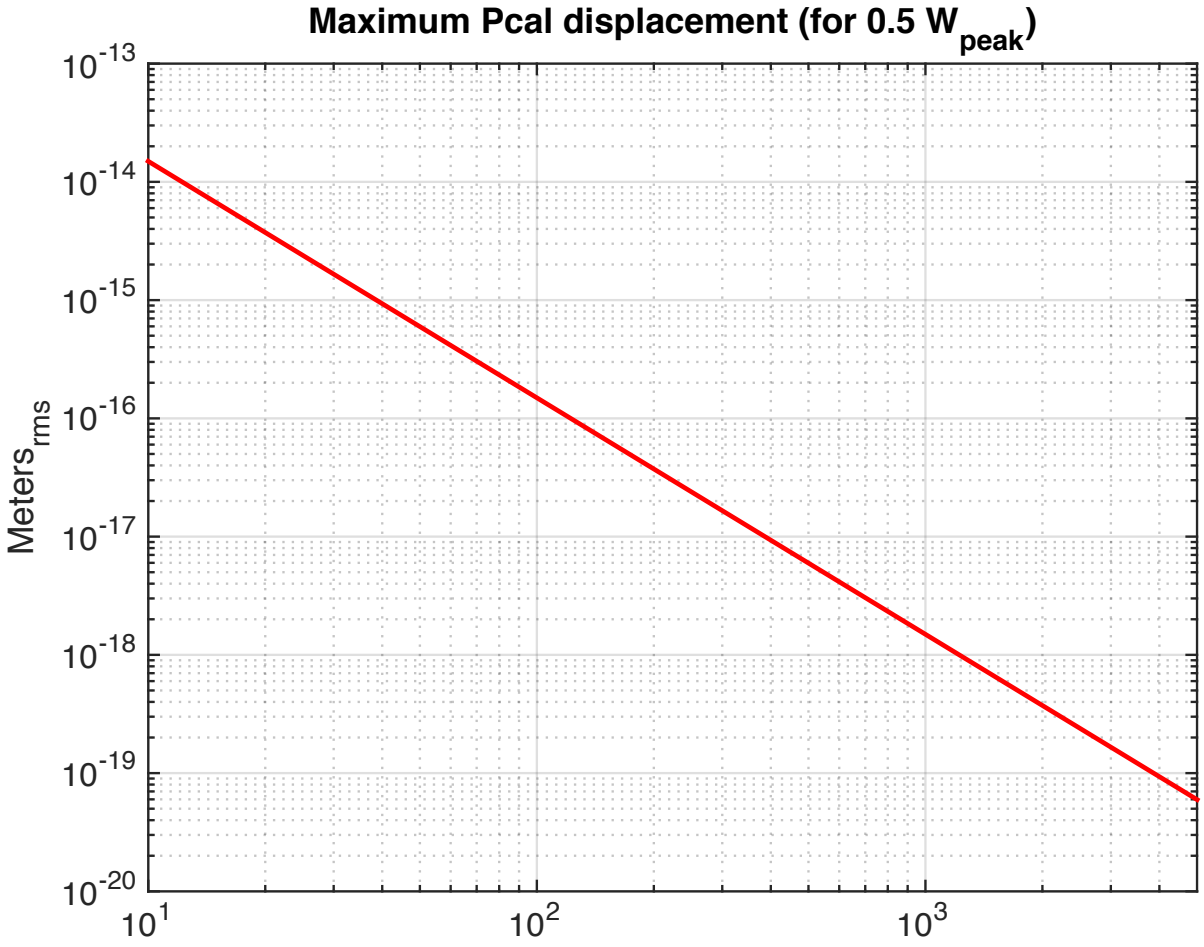
- 100 kHz, UGF
  58 deg. phase margin
- 50 dB gain at low freq.

- 95% modulation depth
- Reference waveform (in yellow), behind output waveform (in green)
- Blue trace is AOM drive signal

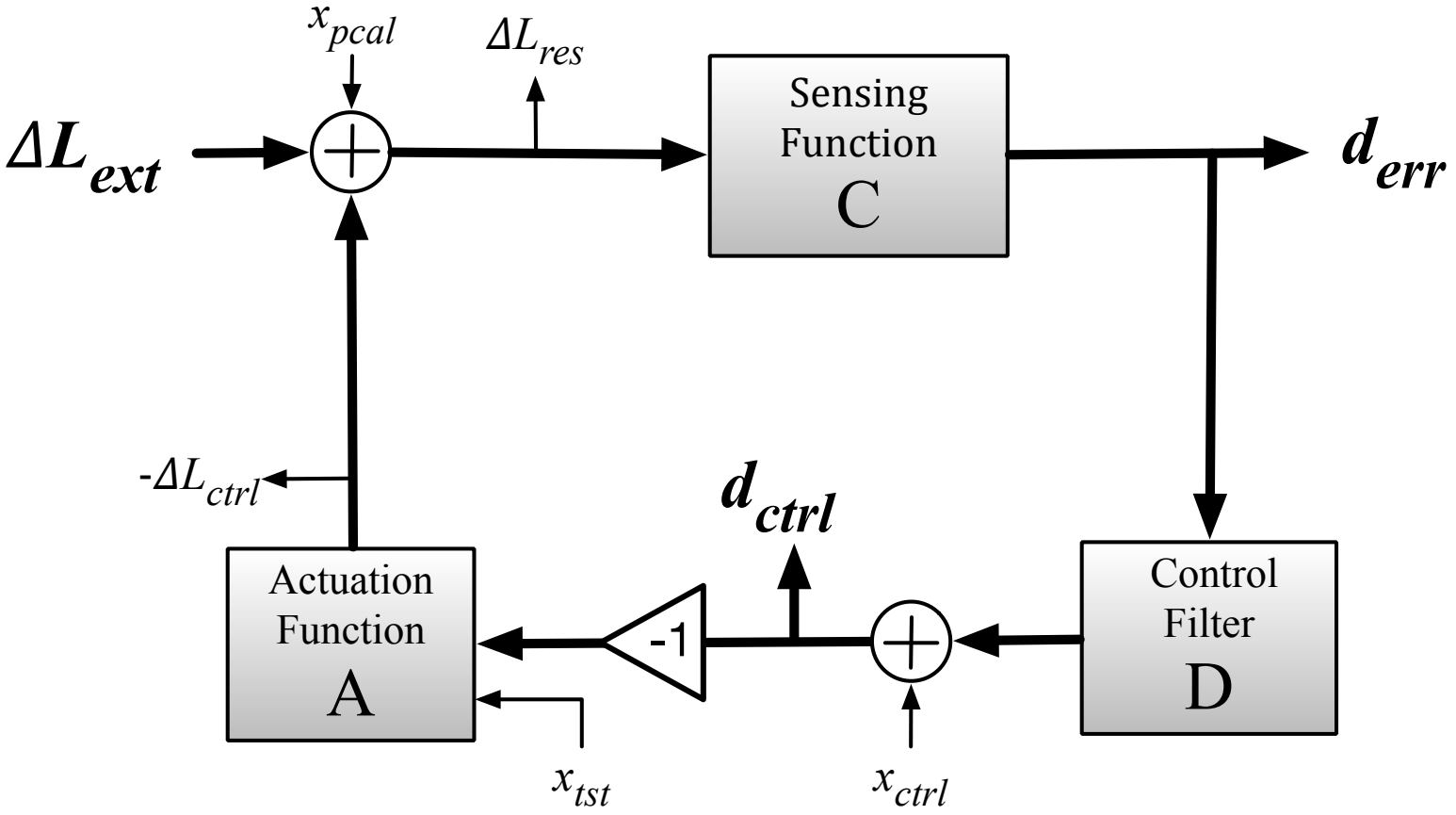
Pcal-induced displacement noise



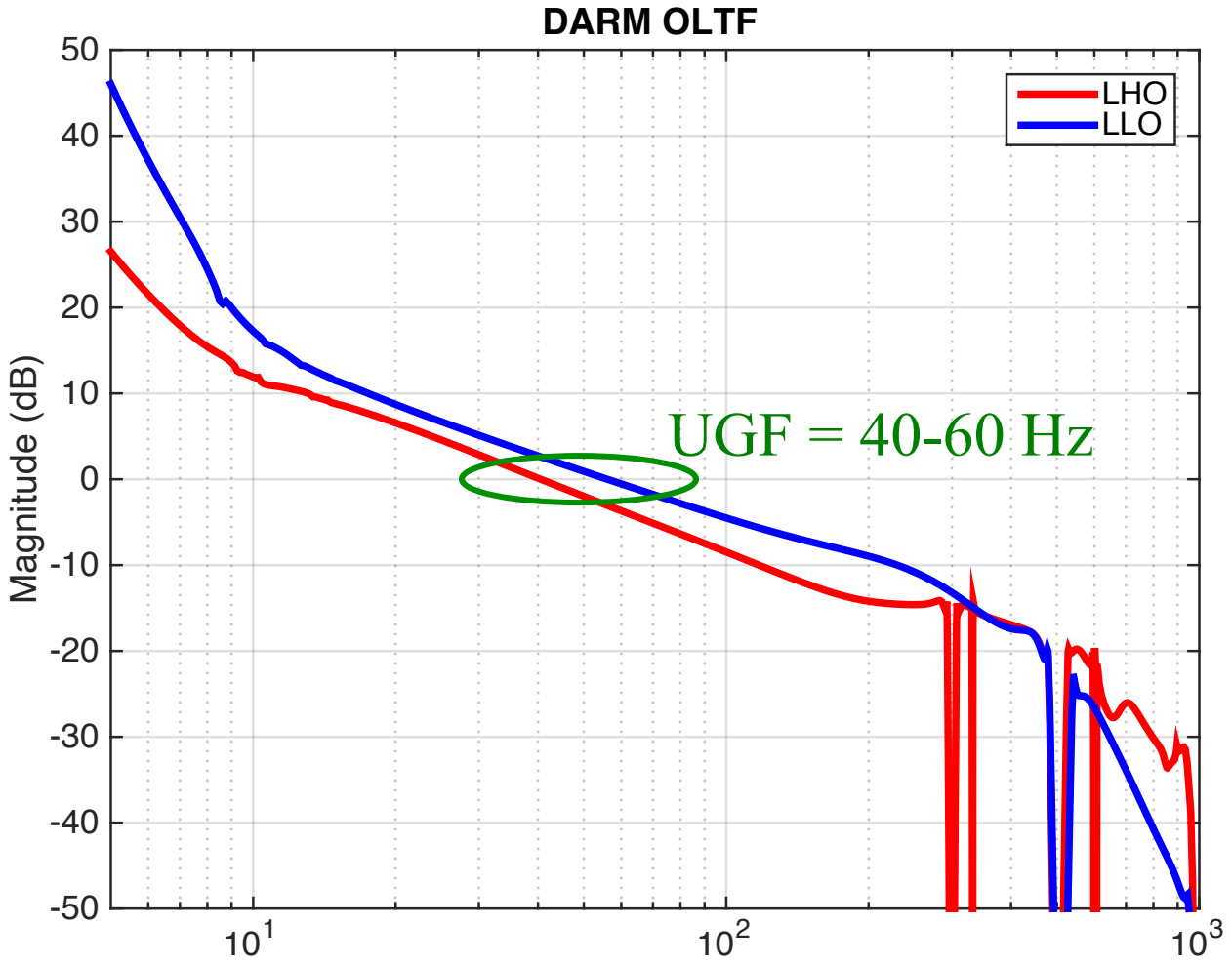
Max Pcal range at a given freq.



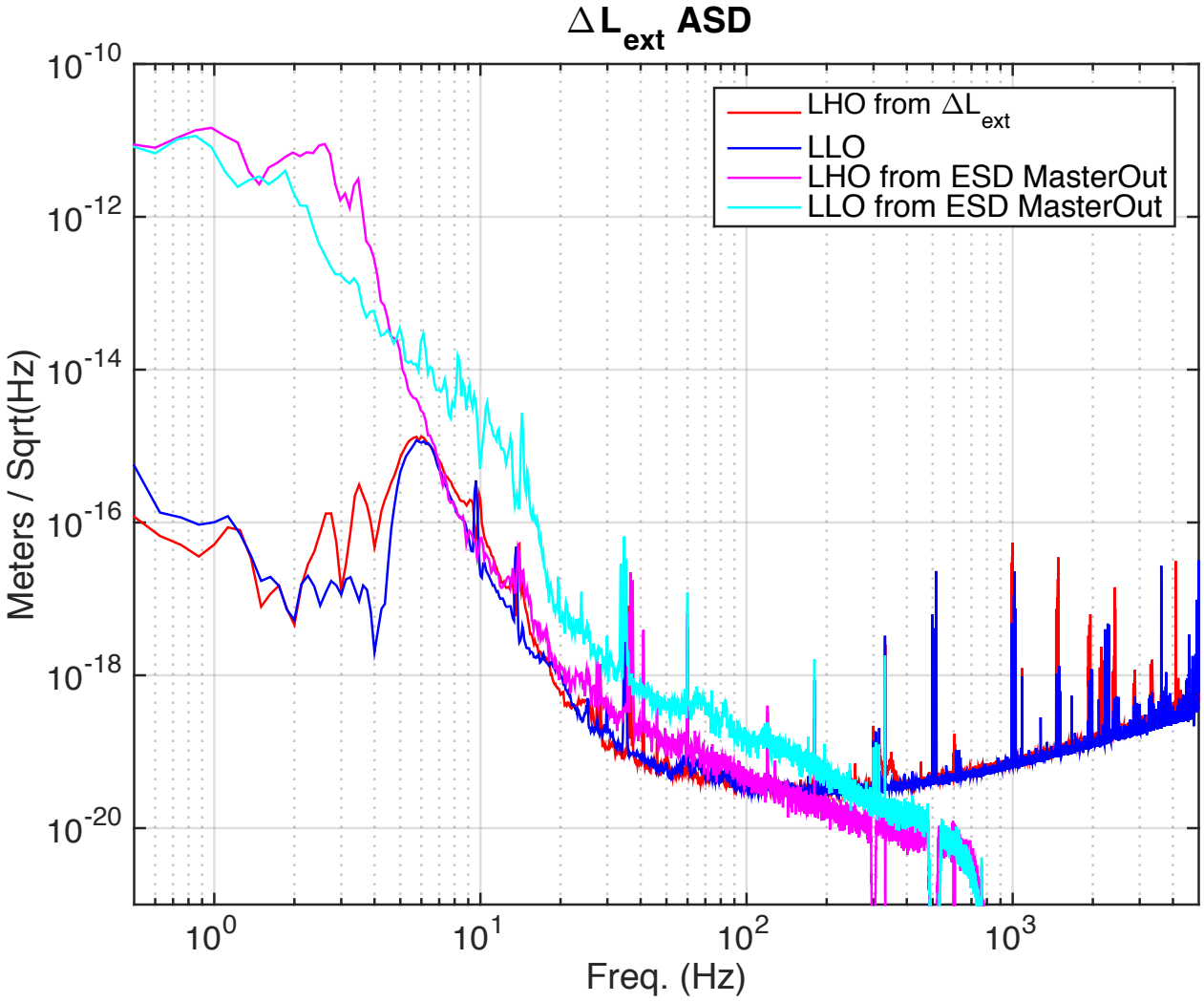
DARM loop simplified schematic



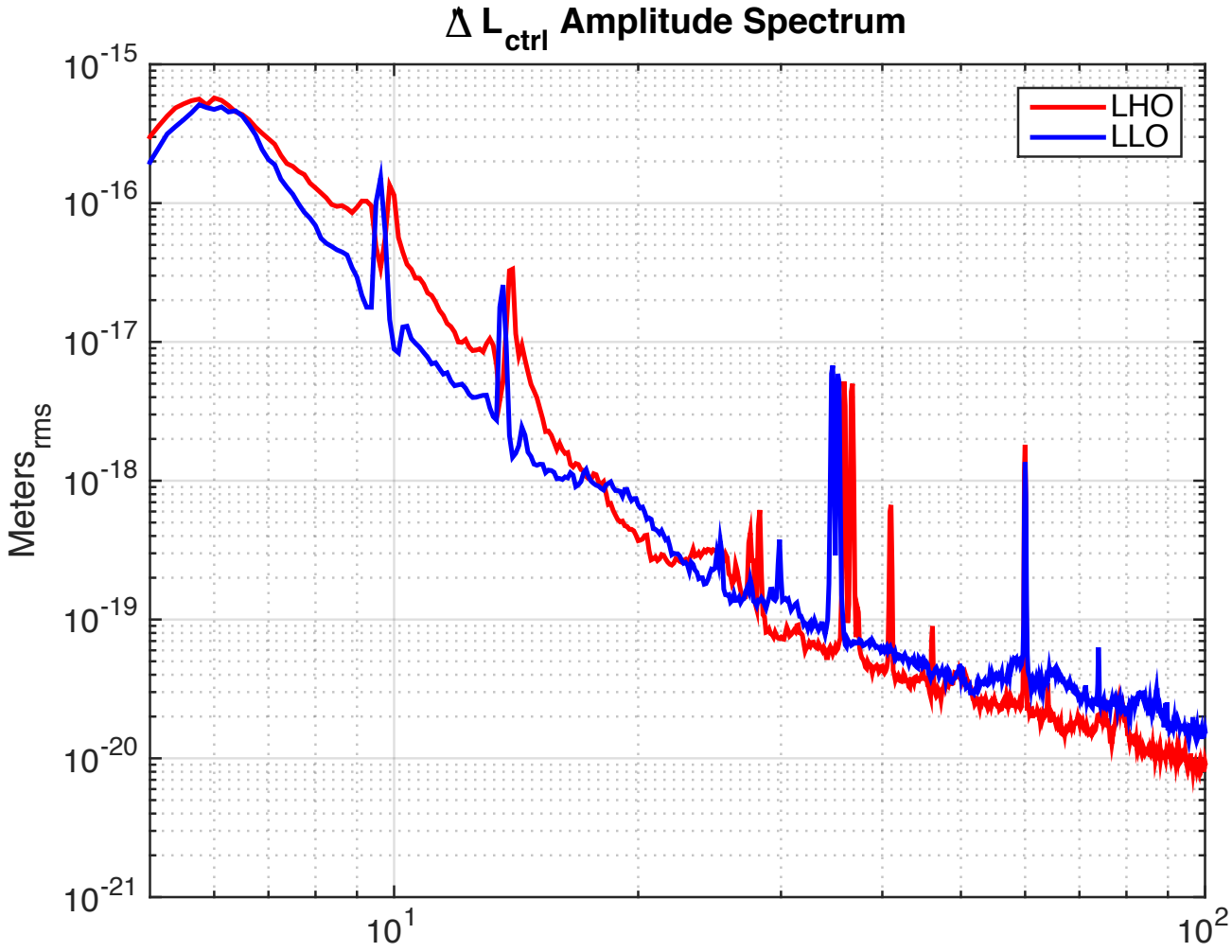
DARM OLTF


DARM OLTF
LHO
LLO
UGF = 40-60 Hz
Magnitude (dB)
50
40
30
20
10
0
-10
-20
-30
-40
-50
10^1
10^2
10^3

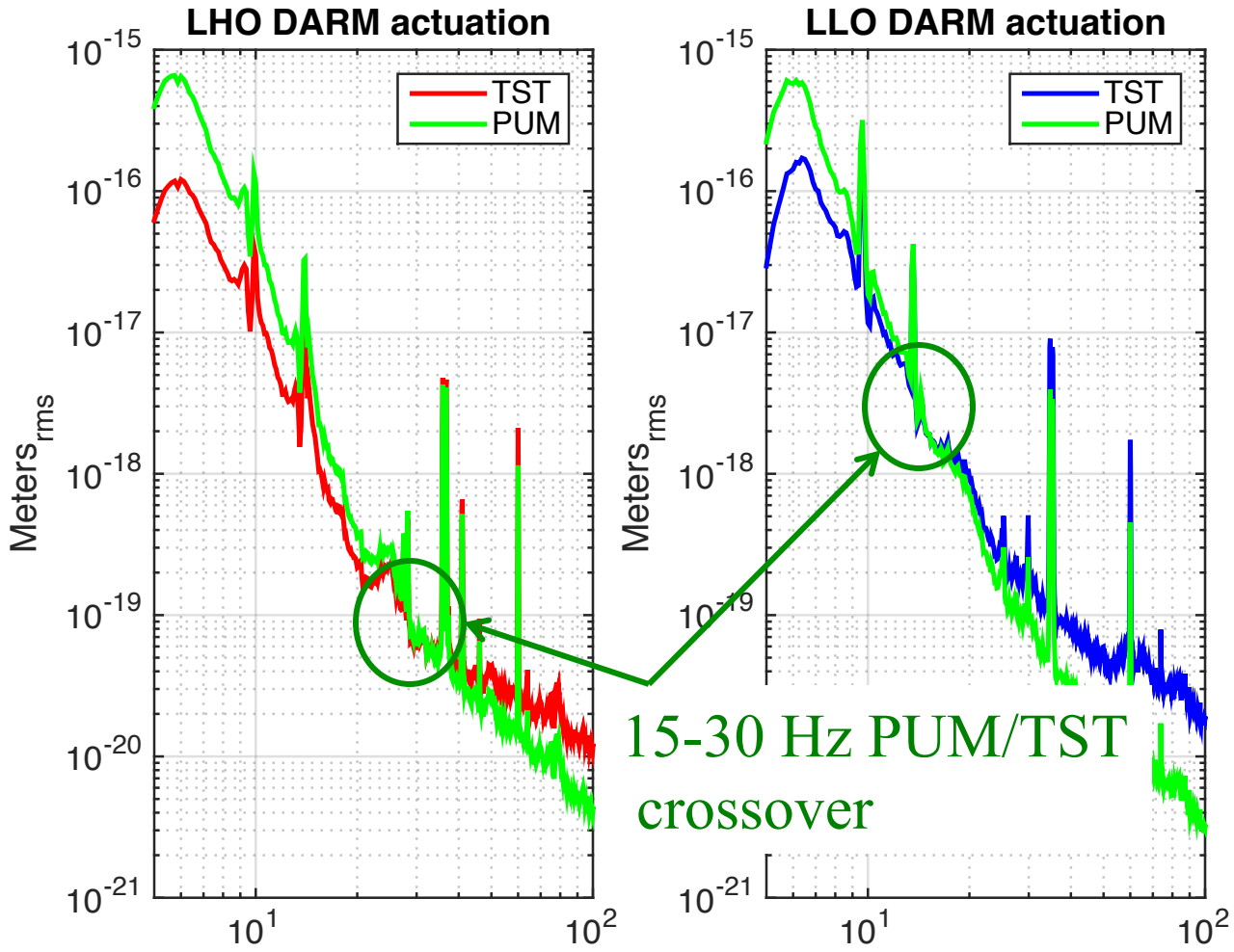
DeltaL external



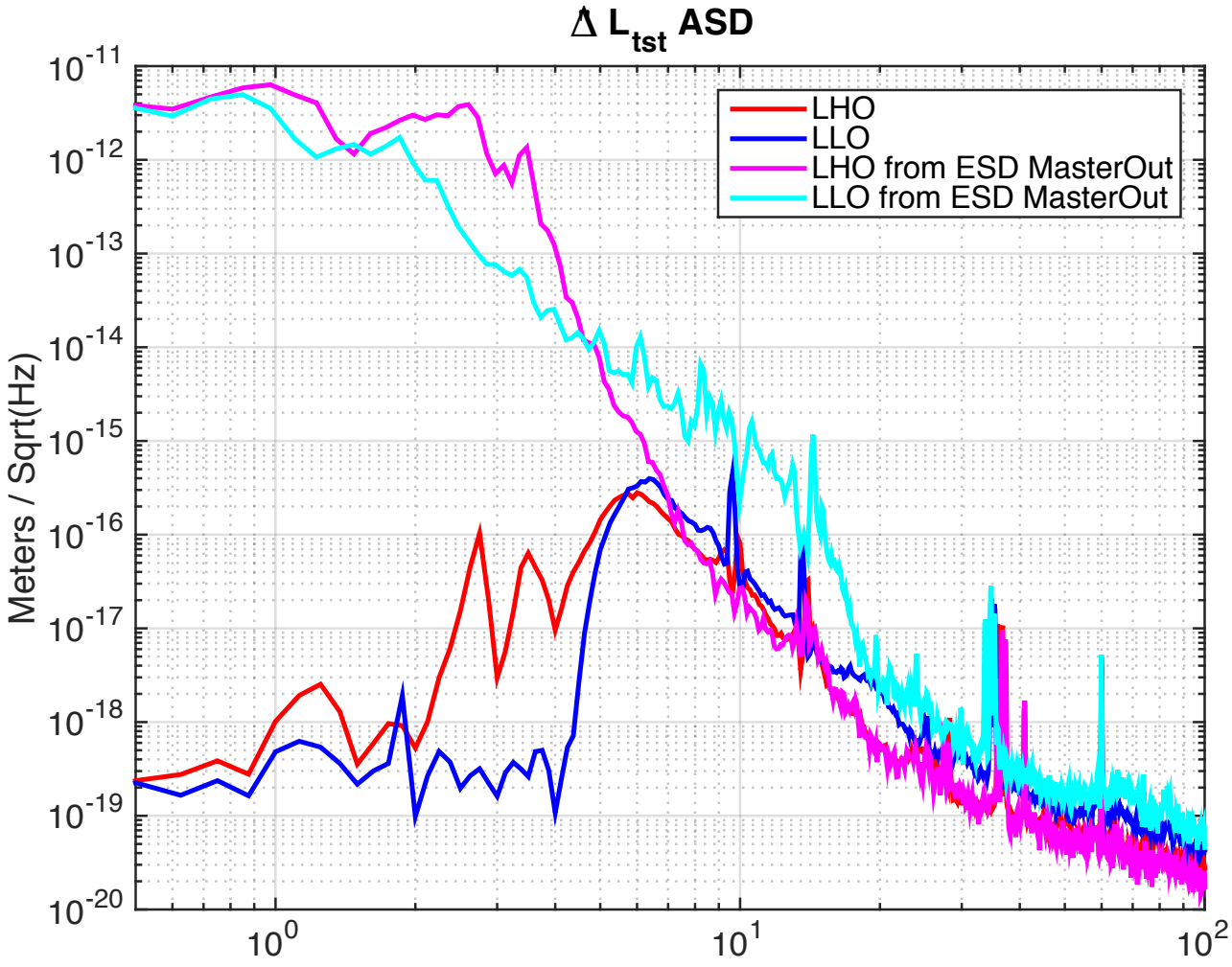
DeltaL control (all SUS stages)



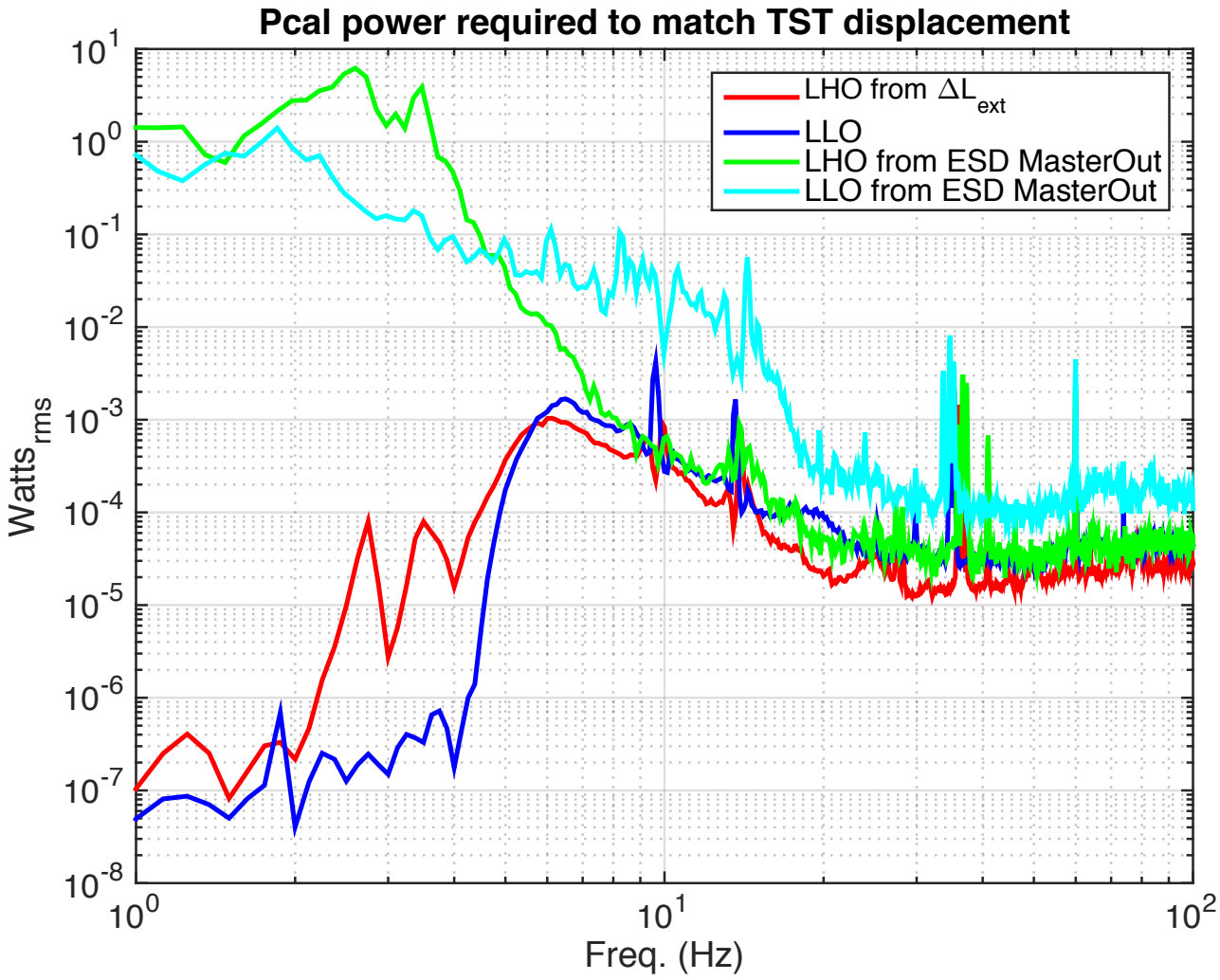
DeltaL control from PUM and TST



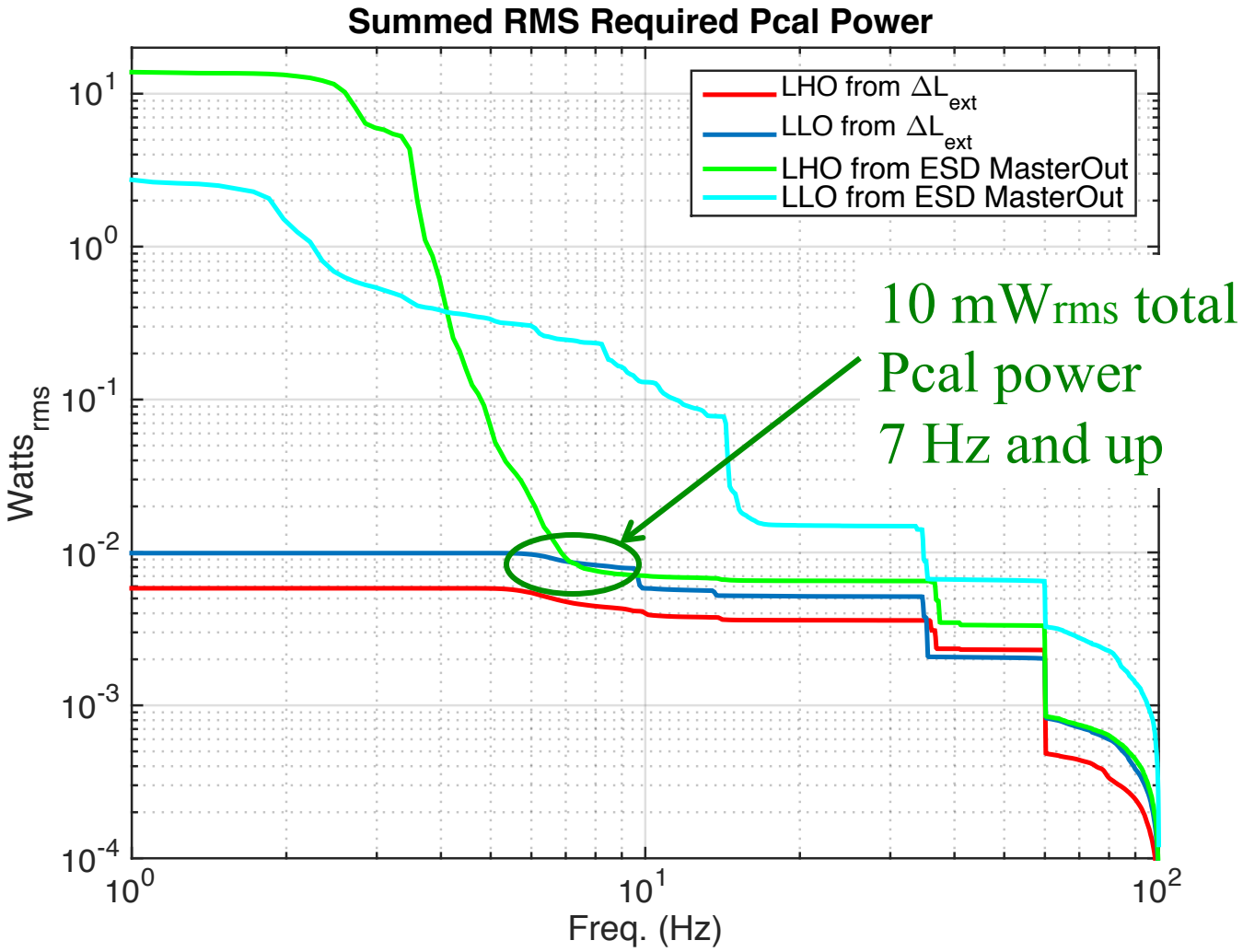
DeltaL control from TST stage



Pcal power required for TST drive



Total rms Pcal power (sum upward)



Summary, next steps

- At “first blush,” looks like Pcal could replace TST in DARM actuation (once DARM servo locked).
- Some work on high-pass filtering, PUM/TST crossover, likely required
- Loop model with phases, stability, etc.
- Noise analysis
- Scheme for transitioning from TST to Pcal
- Etc.