S5 Calibration Status

Brian O'Reilly

For the Calibration Committee

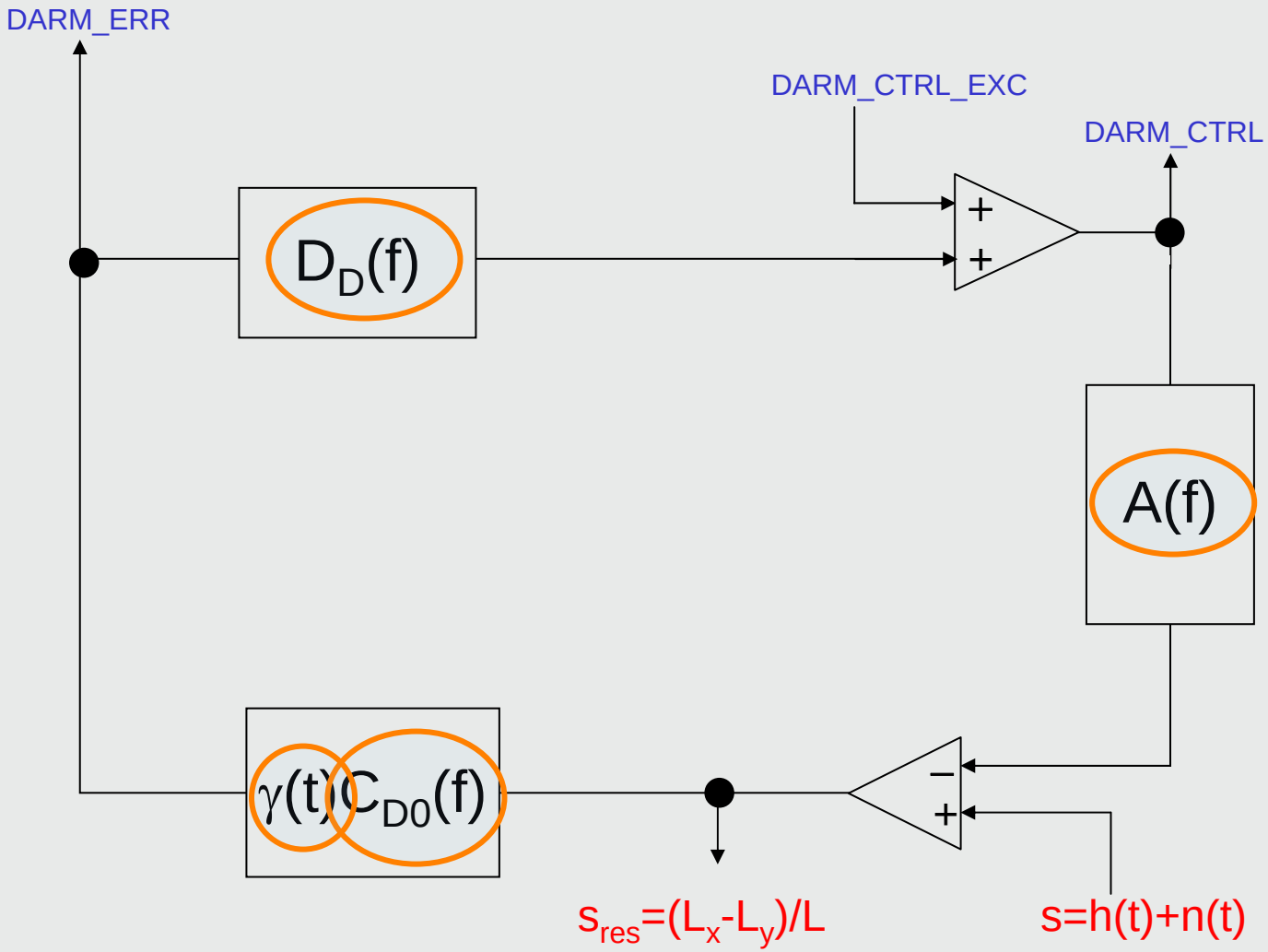
LSC August 2006

Calibration Committee

- "The Calibration Committee is responsible for organizing, delivering, and documenting the calibration information for the detectors in the Collaboration":
  - Frequency Domain
  - Time Domain
  - Photon Calibrator
  - High Frequency
- S. Giampanis, E. Goetz, G. González, M. Hewitson, E. Hirose, P. Kalmus, A. Lazzarini, B. O'Reilly, M. Landry, R. Savage, M. Sung, X. Siemens.
- Review Committee: D. Coyne, A. Lazzarini, V. Mandic, J. Zweizig

Frequency Domain Calibration

- We model the DARM loop in MATLAB
- Compare this model to measurements of the open-loop gain, electronics in the Actuation and Sensing chains and DC value of the Actuation.
- Optical and loop gain are tracked by time-dependent coefficients which are generated on minute or second time scales.
- These coefficients are used to propagate measurements at t_0 to other times.


DARM_ERR
DARM_CTRL_EXC
DARM_CTRL
$D_D(f)$
+
+
A(f)
$\gamma(t)C_{D0}(f)$
−
+
$s_{res}=(L_x-L_y)/L$
$s=h(t)+n(t)$

Frequency Domain Calibration

- Measure Open-Loop Gain at a reference time t_0
  - $G_0(f) = A(f)C_{D0}(f)D_D(f)$
  - $h(f,t) = R_{DERR}(f,t)DERR(f,t)$

$$R_{DERR}(f,t) = \frac{1+G(f,t)}{C_D(f,t)} = \frac{1+\gamma(t)G_0(f)}{\gamma(t)C_{D0}(f)}$$

- Similar equations for AS_Q

S5 Frequency Domain

- We changed how we store the data, filenames etc.
- Specification document **T040175** has been updated to reflect changes.
- ASCII file names:

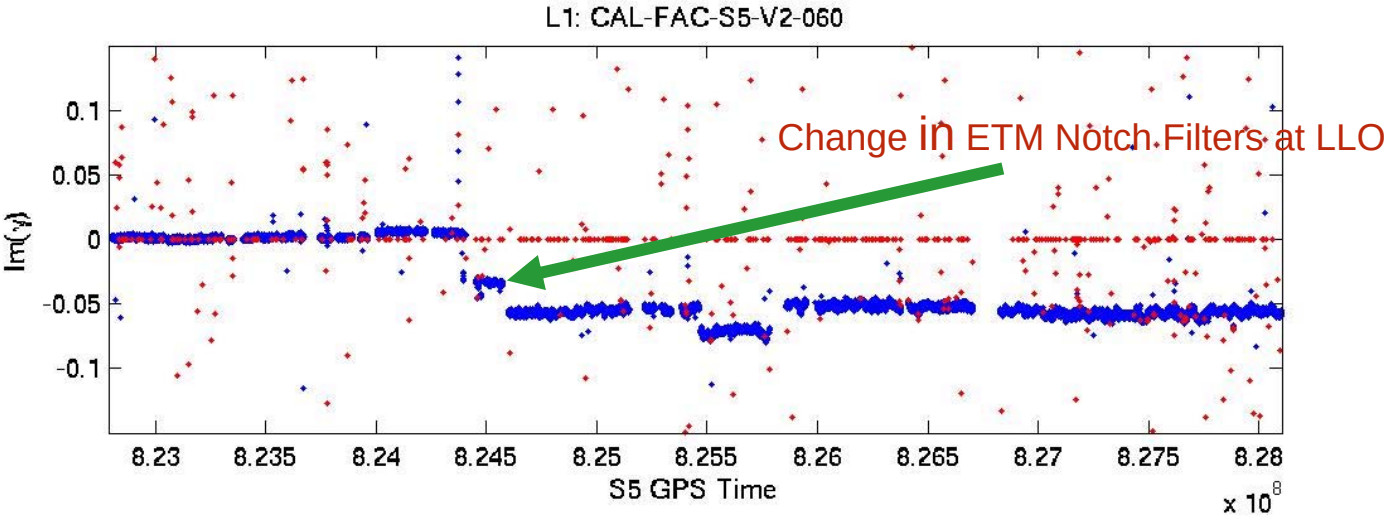
  "H-H1_CAL_REF_RESPONSE_DARM_ERR_S5_V2-815155213-9540480.txt"

  - More closely matches naming convention for frames.
- The "V" now has a different meaning. The highest "V" number will now contain the latest calibration for **all** times during S5.
  - This means some duplication, but greater simplicity for searches.
- Official frame files still not available. Working with DASWG to finalize.

S5 Frequency Domain

- We started S5 with a calibration which we feel is already quite accurate, similar to final S4 errors for L1.
- All three IFOs used the same technique and obtained similar accuracy.
- Calibration coefficients are being generated in close to real-time. However, we have only released non-unity coefficients up to Apr-03-06.
- SenseMon coefficients are not official, but do exist.
- Already at V2 for S5, from commissioning break at LHO.

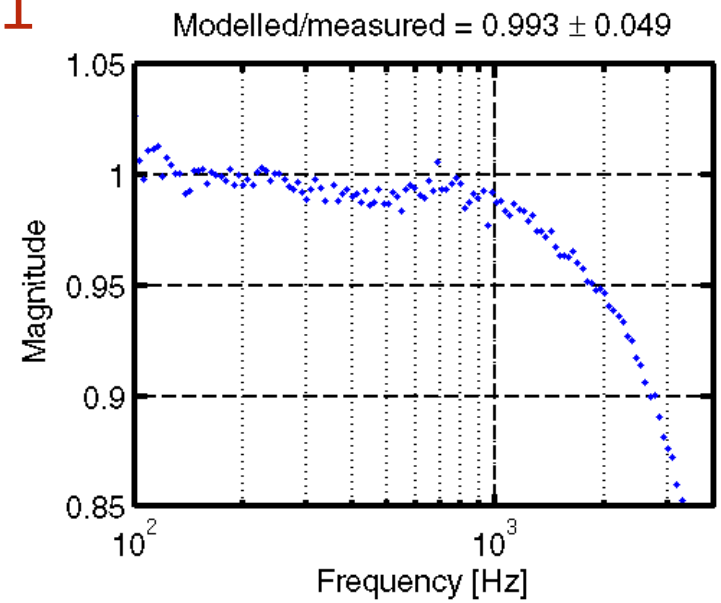
S5 Frequency Domain



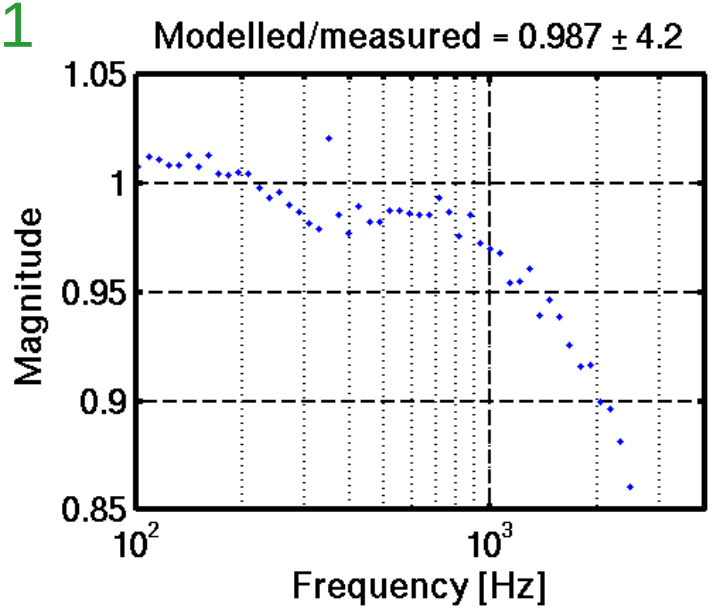
- This would mean a new epoch at L1 to correct for this effect (<1% in range).
- Will we make new epochs for short time periods during LHO commissioning?
- Only if detection candidate in this time. Need to DQ Flag this data.

Open Loop Gain Discrepancy

L1



H1

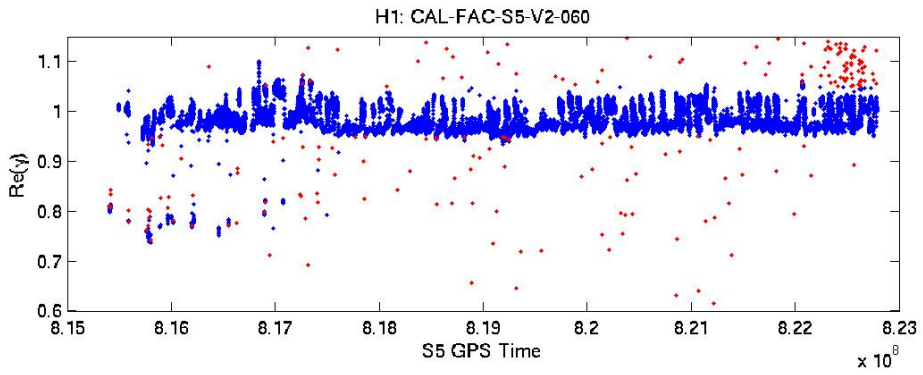


$$\left(\frac{\Delta|R_D|}{|R_D|}\right)^2 = \left(\frac{\Delta|A|}{|A|}\right)^2 + \left(\frac{\Delta|D_{D0}|}{|D_{D0}|}\right)^2 + C_R^2\left(\frac{\Delta\gamma}{\gamma}\right)^2 + C_R^2\left(\frac{\Delta|G_0|}{|G_0|}\right)^2 + C_I^2\left(\Delta\phi_{G_0}\right)^2$$

5-10% error on response at 2 kHz

$$C_R = \Re\left(\frac{1}{1+G_0}\right)$$

Propagation Factors

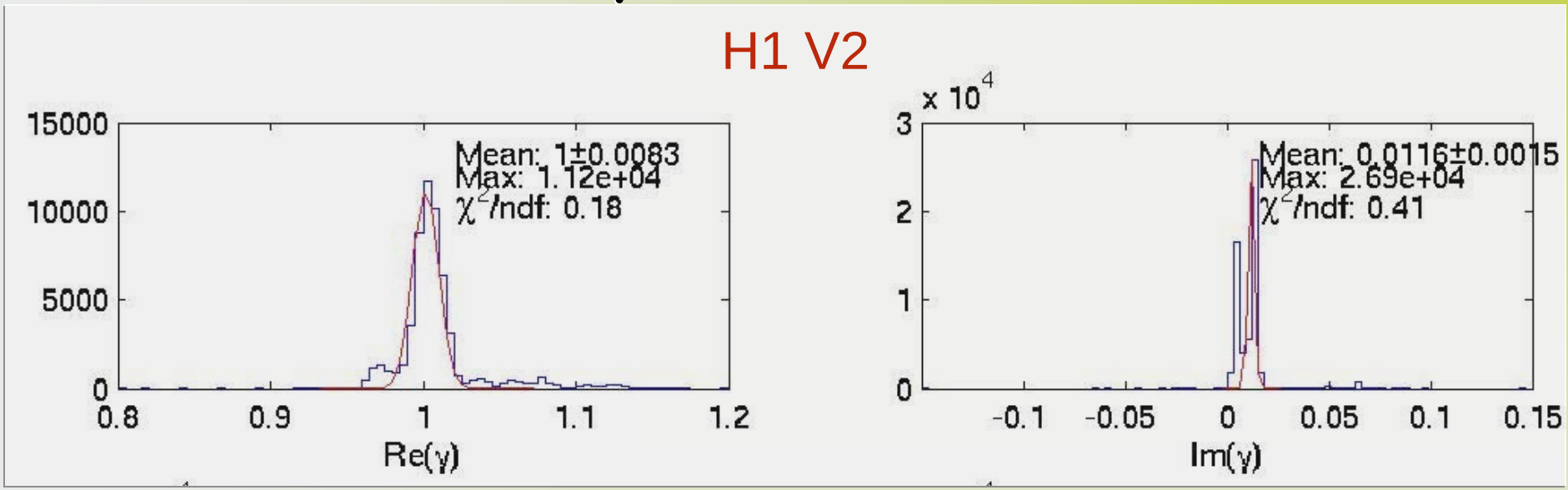


- Being generated in near real-time by M. Sung on grid.
- Extensive cross checking and validation.
- Official factors are on a minute time-scale, also producing factors on second time-scale.

http://ligo.phys.lsu.edu/sung/Factors/S5/V2/S5V2R2.html

γ Factors

H1 V2



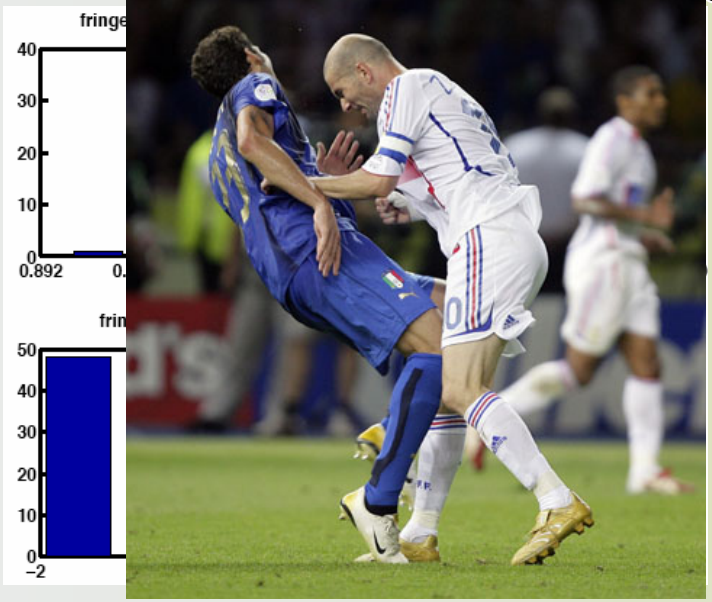
- After a small correction at the calibration line frequency the factors used for propagation are well behaved.
- Im(γ) is a measure of our error 0(1%).
- Input matrix element does a good job of tracking optical gain…
- Initial values within 5% of official ones.

Measurement Consistency

Arm	Date	ITM cal nm/ct	r_i	ETM cal nm/ct	ETM mode
X	051016	0.46 ± 0.01	0.939 ± 0.008	0.43 ± 0.01	run
X	051111	0.489 ± 0.006	0.92 ± 0.01	0.450 ± 0.007	run
X	060629	0.49 ± 0.01	0.94 ± 0.01	0.46 ± 0.01	acq
Y	051016	0.49 ± 0.01	0.856 ± 0.006	0.42 ± 0.01	run
Y	051111	0.516 ± 0.007	0.84 ± 0.01	0.433 ± 0.008	run
Y	060629	0.54 ± 0.01	0.804 ± 0.008	0.435 ± 0.009	acq

- LLO measurements Test Mass DC calibrations are all consistent within 5%.
- Similar consistency at LHO.

Fringe Fitting Results from LHO



Test Mass	S5 Value	Fringe Fit	Ratio
H1 ITMX	0.98	0.92	1.06
H1 ITMY	0.81	0.88	0.92
H2 ITMX	0.92	0.94	0.98
H2 ITMY	0.87	0.91	0.96

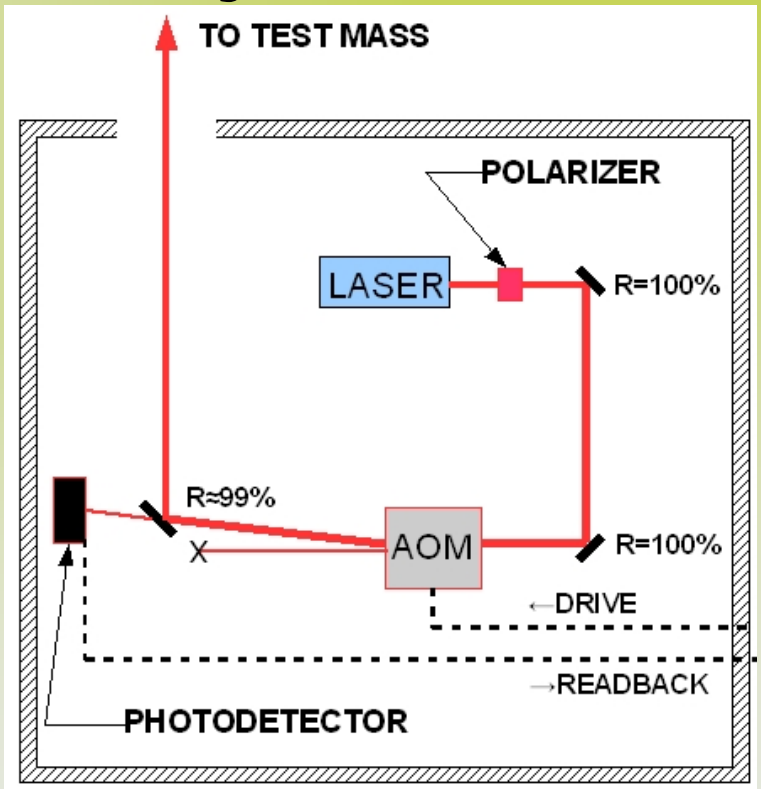
Code from Luca Matone

- H1 agreement worse? Still being investigated.
- Fringe Fitting data from LLO was too noisy to get a good fit. Re-measure?
- Other cross-checks?

Photon Calibrator System

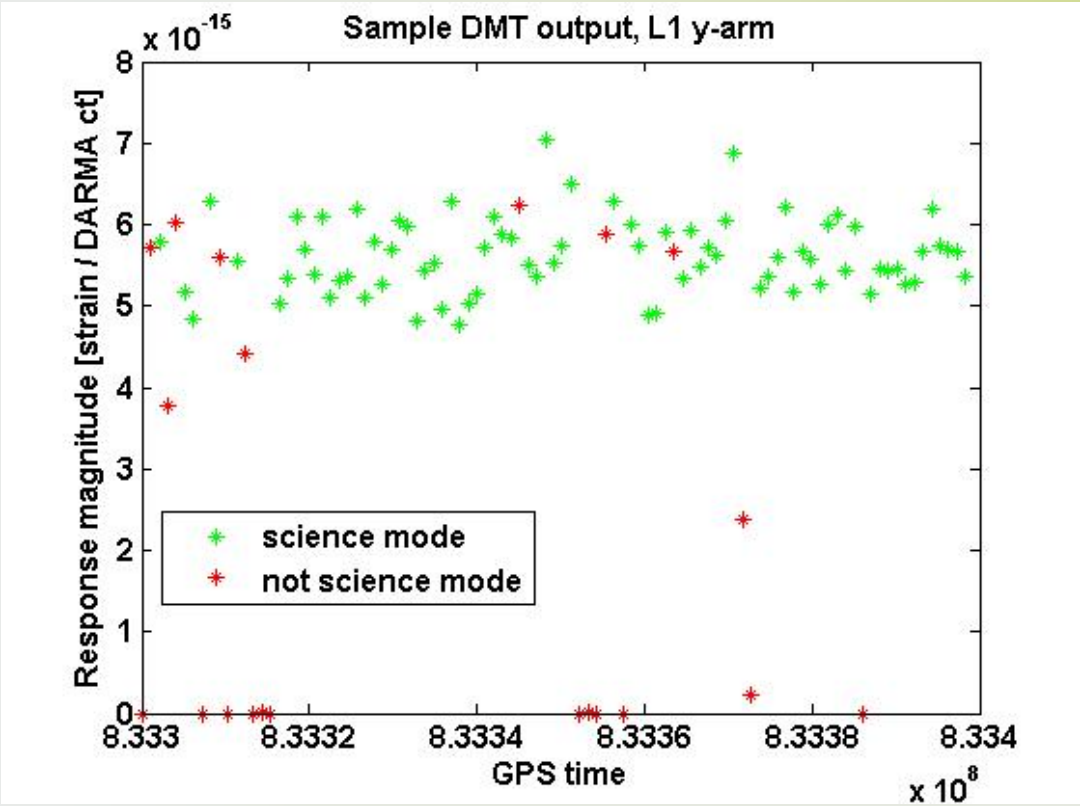
- Intensity modulated radiation pressure excites ETM, approximately sinusoidally, at a chosen frequency.
- Displacement is estimated with basic physics. Power is deduced from a photo-detector looking at beam pickoff.

$$x_{exc}(\omega) = \frac{2P\cos\theta}{Mc\omega^2}$$



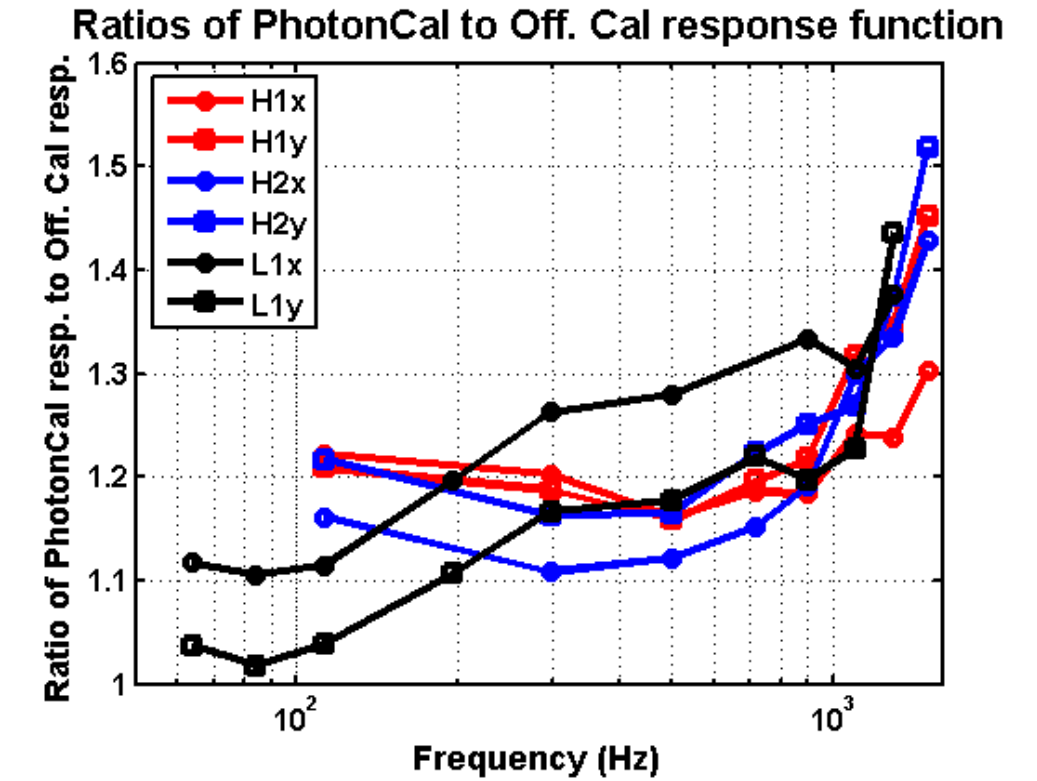
See talks by Peter Kalmus and Evan Goetz in the **DetChar** session.

PhotonCal DMT Monitor



- Measures R(f_{pcal}) in strain per DARM_ERR cts
- Propagates coil calibration for comparison purposes
- Not yet admitted to DMT production environment

Frequency Dependence

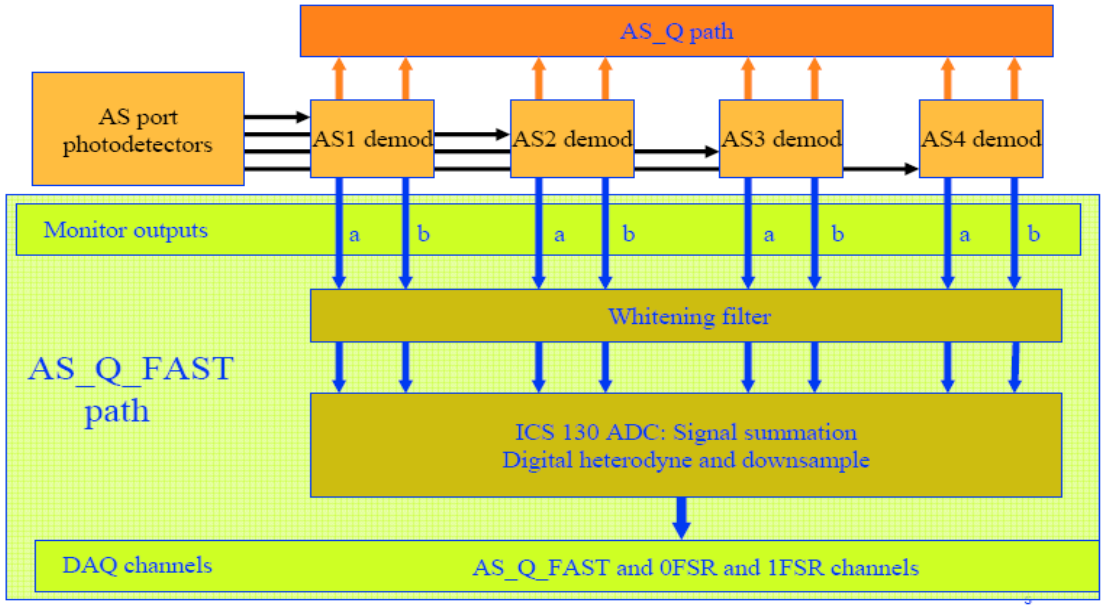


- Does this indicate a problem with our AC technique?
- Resolving this issue is a priority for S5.
- Gain confidence from cross-checks.

Time-Domain Calibration

- Data is being generated on-line under ONASYS with ½ hour latency, and published. Many thanks go to Kipp Cannon, Ben Johnson and Stuart Anderson.
- All science and injection data from start of S5 up to a ½ hour ago is available and calibrated using the v2 calibration version.
- http://www.lsc-group.phys.uwm.edu/~siemens/ht.html for more information
- Data is used by Pulsar and Burst groups
- Eiichi Hirose and Philip Charlton have done valuable validation work (need more!)
- Review of S4 TD calibration procedure is underway (about half done):
  - Digital filter generation is reviewed (still some action items to finalise)
  - review of LAL and LALApps codes will resume in early September.

High Frequency Calibration

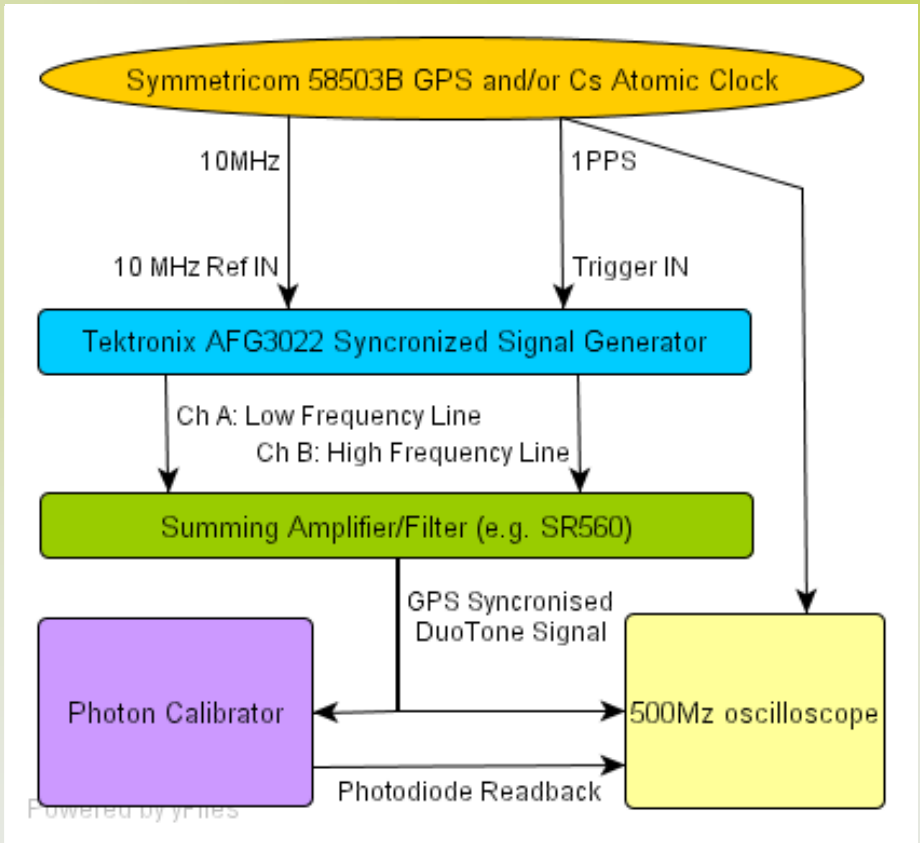


- AS_Q_FAST channels 262kHz sampling rate
- Signals digitally heterodyned at 1024Hz (AS_Q_0FSR) and 37.504kHz (AS_Q_1FSR) at 2048Hz sampling rate
- Work in progress to calibrate 0FSR. May extend to 1FSR

See talk by Stefanos Giampanis in the DetChar session.

Sign, Timing, Phase Check

- Use photon calibrator to cleanly and unambiguously determine the sign of the interferometers.
- Should get timing and phase information for free
- Initial test planned for LLO.
- Collaborating with Szabi Marka and Peter Kalmus from Columbia.



Plans

- Resolve the photon calibrator discrepancy.
  - Be confident that our current scheme is valid.
- Finalize S5 calibration up to second LLO break.
  - V2 calibration errors are on the order of 5-10%
  - Strike a balance between promptness and accuracy
  - There will be a V3
- Finalize h(t) review.
- Write a technical paper on the S5 calibration.
- Start discussions with Virgo on calibration issues.