



S5 Calibration

M. Sung
for the Calibration Committee

LSC Meeting @ Baton Rouge
March 21, 2007

LIGO-G070120-00



- **Calibration Committee**

- S.Giampanis, G.González, E.Goetz, E.Hirose, P.Kalmus, K.Kawabe, M.Landry, E.Messaritaki, **B.O'Reilly**, R.Savage, M.Sung, X.Siemens

- Review Committee

- h(f) - D.Coyne, **K.Kawabe**, V.Mandic, J.Zweizig

- h(t) - S.Fairhurst, **K.Kawabe**, V.Mandic, X.Siemens, M.Sung, S.Waldman

- High frequency calibration - **R.Savage**, M.Rakhmanov, D.Sigg, K.Kawabe

- Virgo: B.Lieunard, M.Frederique, R.Loic, B.Mours

- GEO: M.Hewitson, S.Hild

- **Activities:**

- Frequency domain calibration, $h(f)$

- Time domain calibration, $h(t)$

- High frequency calibration

- Photon calibrator

Frequency Domain Calibration

$$h(f, t) = R_{DERR}(f, t) DERR(f, t)$$

$R_{DERR}(f, t)$ - Response function of LIGO interferometers

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

Open loop gain:

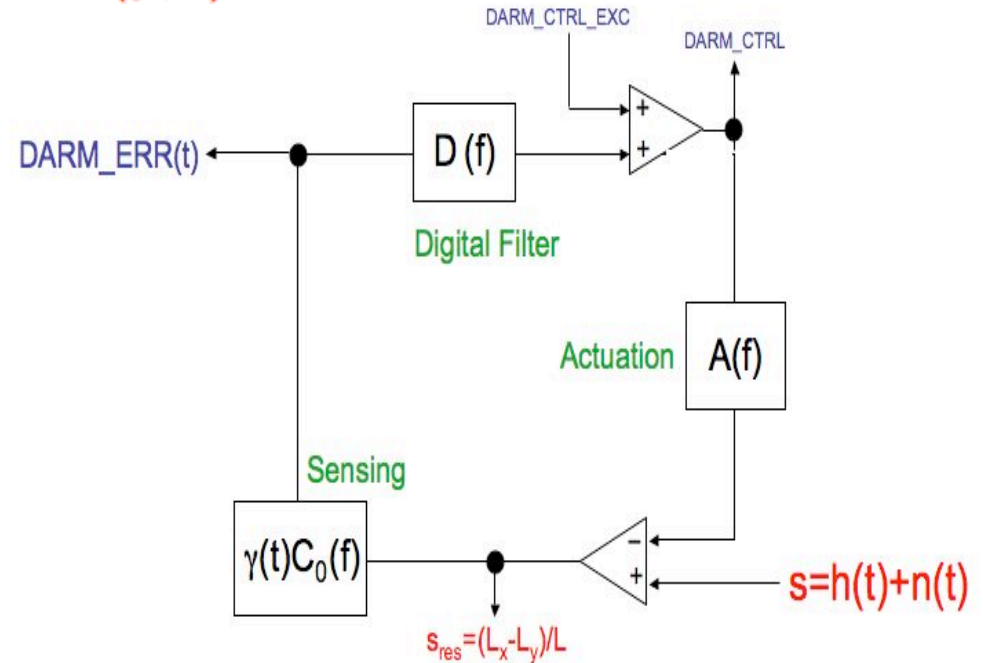
$$G(f, t) = \gamma(t)G_0(f)$$

and

$$G_0(f) = A(f)C_{D0}(f)D_D(f)$$

also

$$C_D(f, t) = \gamma(t)C_D(t_0, f) = \gamma(t)C_{D0}(f)$$

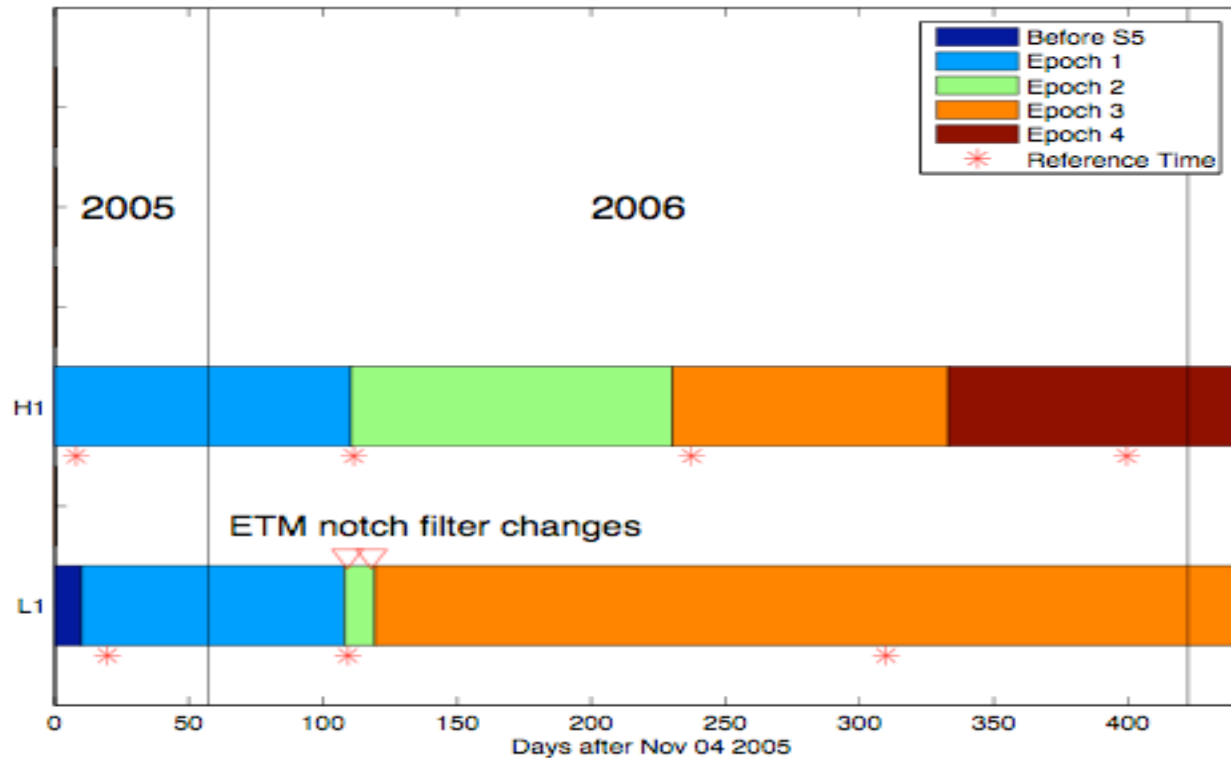


- Model the DARM loop
- Compare the model to measurements of $G_0(f)$, $A(f)$
- Time dependent coefficients, $\gamma(t)$, generated in 60 second and 1 second intervals

Frequency Domain Calibration: S5 V3

- Same technique for all three IFOs
- From the beginning of S5 up to 1600UTC Jan. 21, 2007.
- L1 and H1
 - Three epochs for L1 and four epochs for H1
 - All transfer functions and response functions at reference times are produced for all epochs and available as ASCII files from the calibration CVS as "S5_V3_0" tag.
 - Time dependent coefficients generated from mid-frequency (~400Hz) calibration line with DQ lists.
 - Under review.
 - Frame files are being generated.
 - $h(t)$ production started based on V3.
- H2
 - Working on model.

S5 V3 Calibration: Epochs - Different $G_0(f)$ & $C_0(f)$



L1:

- Epoch 1: 816019213 - 824497827 (Nov 14 2005 16:00:00 - Feb 20 2006 19:10:13 UTC)
- Epoch 2: 824497827 - 825465258 (Feb 20 2006 19:10:13 - Mar 03 2006 23:54:04 UTC)
- Epoch 3: 825465258 - 853516814 (Mar 03 2006 23:54:04 - Jan 22 2007 16:00:00 UTC)

H1

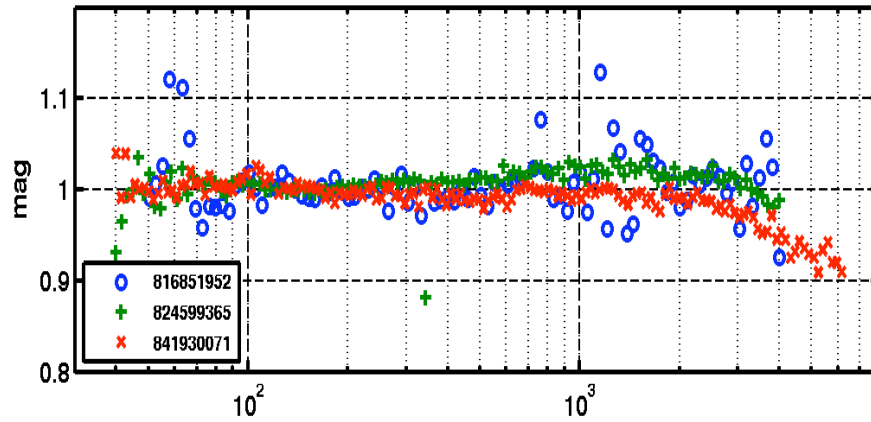
- Epoch 1: 815155213 - 824695694 (Nov 04 2005 16:00:00 - Feb 23 2006 02:08:00 UTC)
- Epoch 2: 824695694 - 835044014 (Feb 23 2006 02:08:00 - Jun 22 2006 20:40:00 UTC)
- Epoch 3: 835044014 - 843942254 (Jun 22 2006 20:40:00 - Oct 03 2006 20:24:00 UTC)
- Epoch 4: 843942254 - 853516814 (Oct 03 2006 20:24:00 - Jan 22 2007 16:00:00 UTC)

Model and measurements at reference:

$$\frac{G_0^{\text{model}}(f)}{G_0^{\text{measure}}(f)}$$

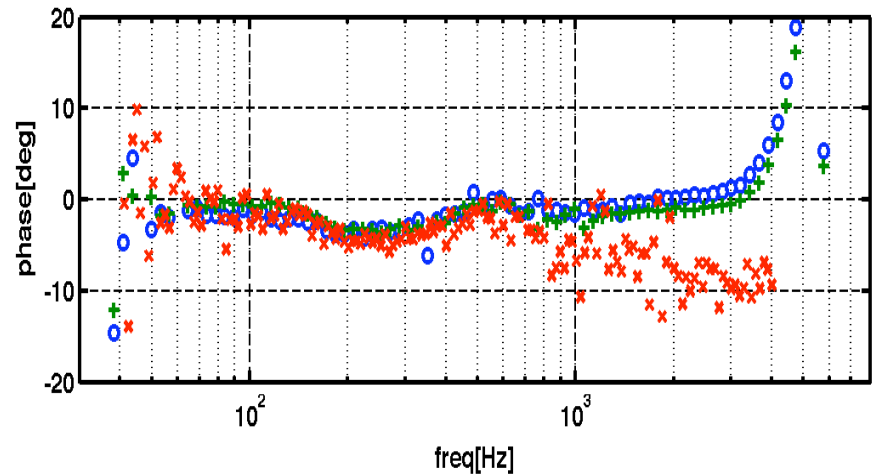
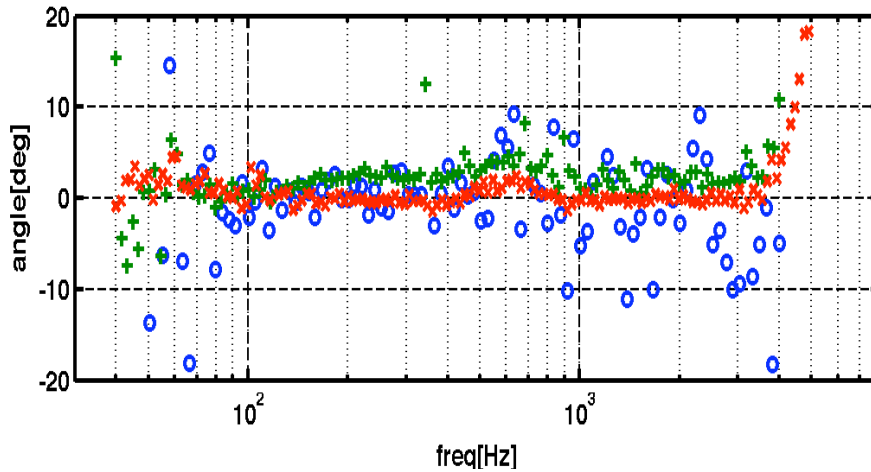
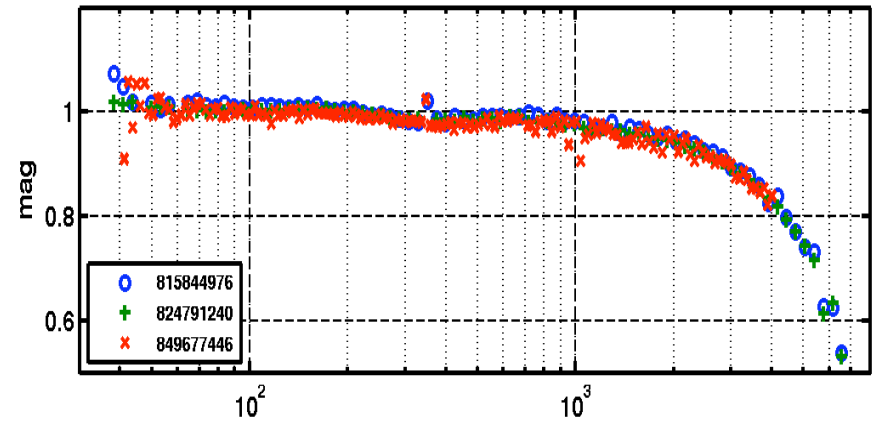
L1

L1 model/measurement ratio



H1

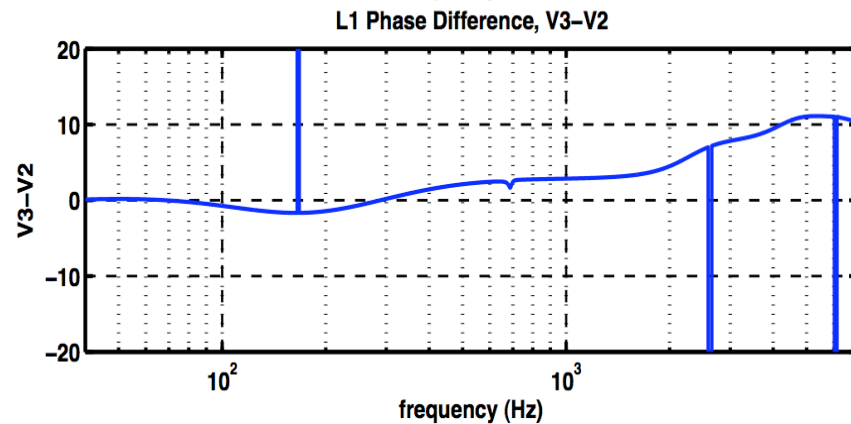
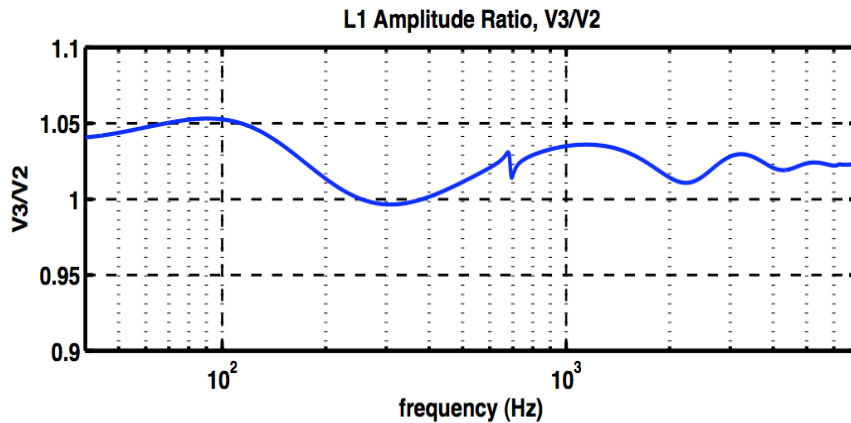
H1 V3 model/measurement ratio



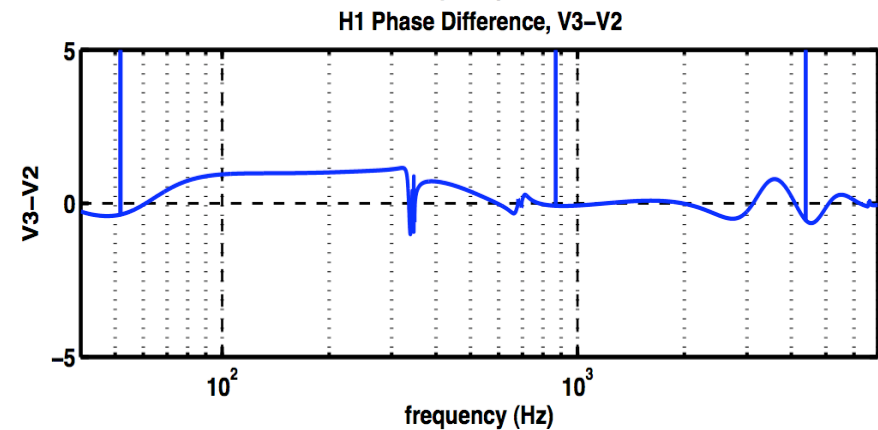
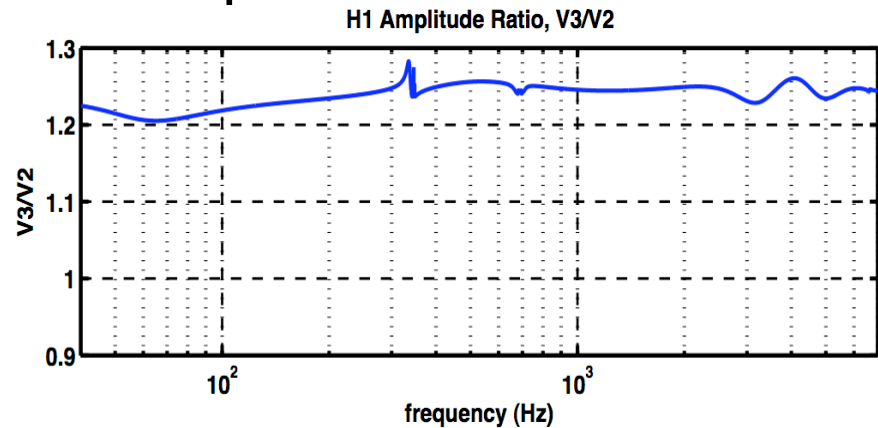
Error($R(f)$) ~ 5% below 2 kHz, somewhat higher above.

Comparison of $R_{DERR}(f)$: V3 and V2

L1 Epoch 3



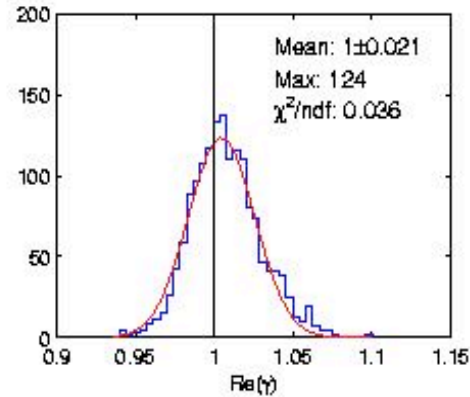
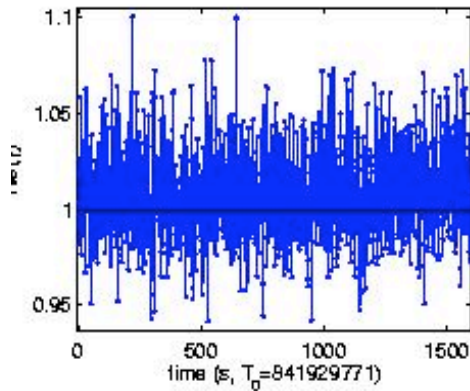
H1 Epoch 4



The 22% change in H1 was due to a DARM_GAIN change.

Time dependent coefficients at reference

L1: Epoch 3



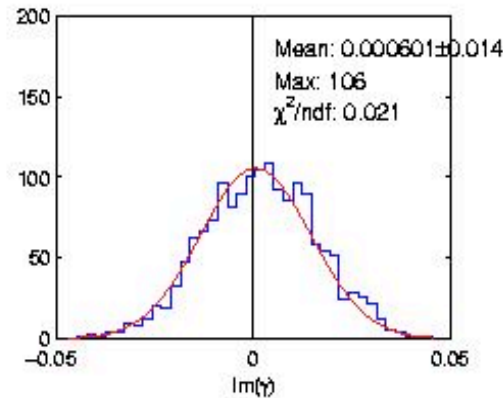
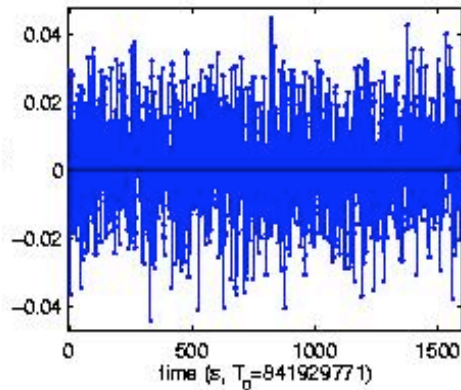
$$\gamma(t) = -\frac{1}{g_0} \frac{DARM(t) - EXC(t)}{DARM(t)}$$

where

$$g_0 = G_0(f_{cal})$$

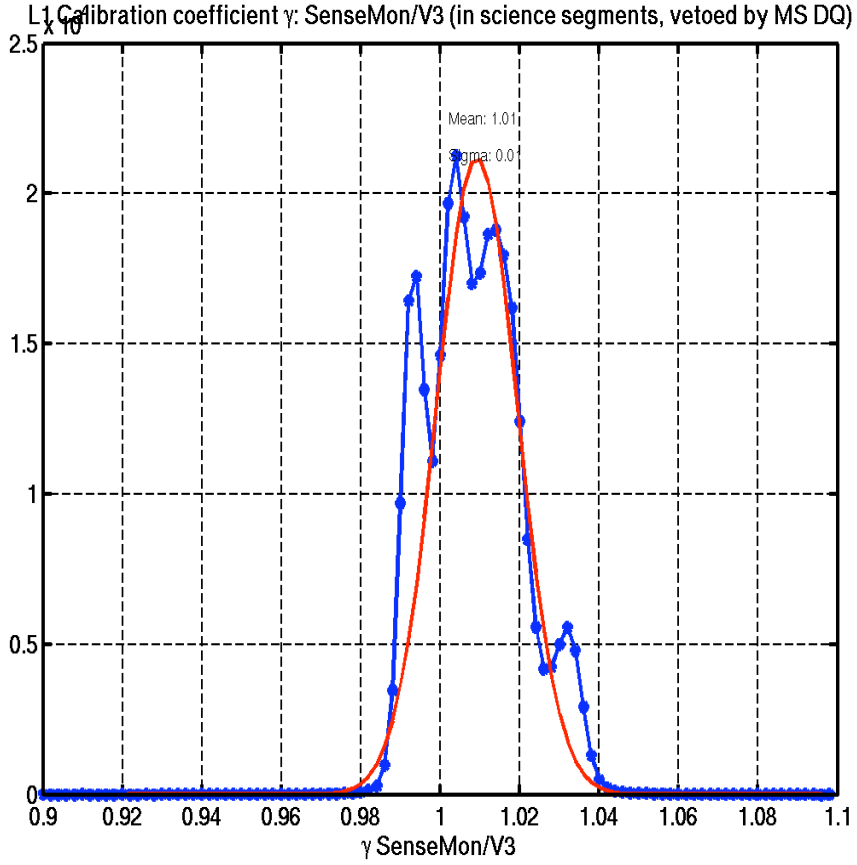
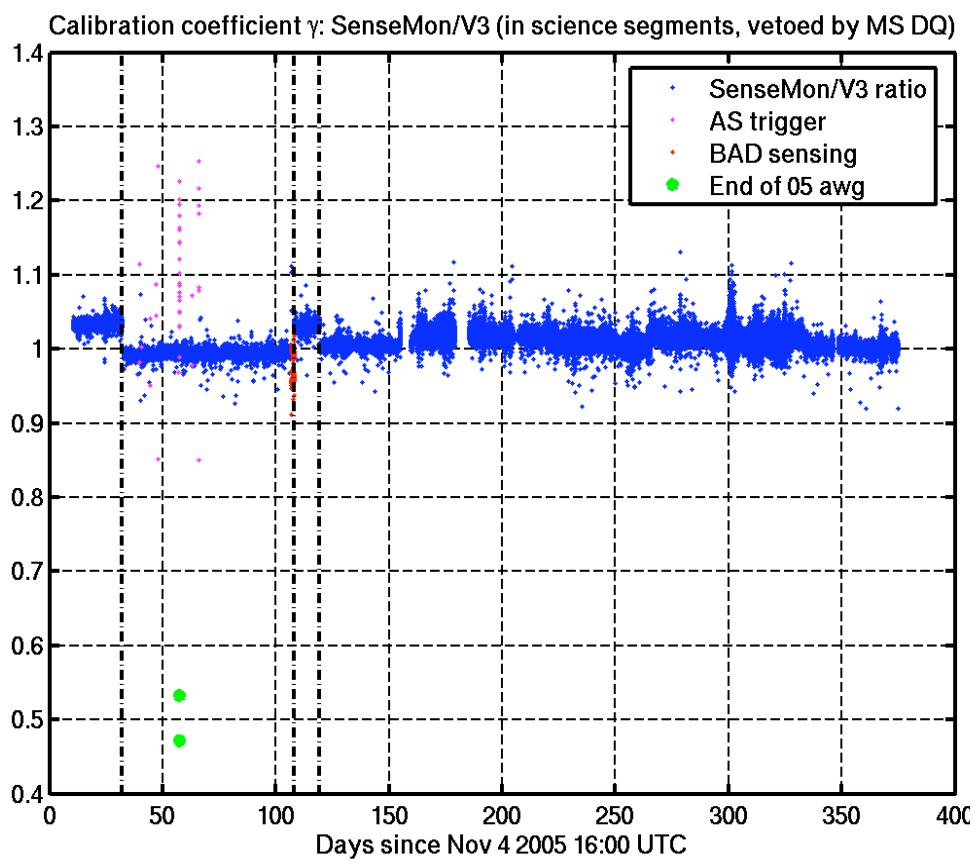
$$DARM(t) : DARM_CTRL$$

$$EXC(t) : DARM_CTRL_EXC$$



Detail study: <http://ldas-jobs.ligo.caltech.edu/~sung/factors/index.html>

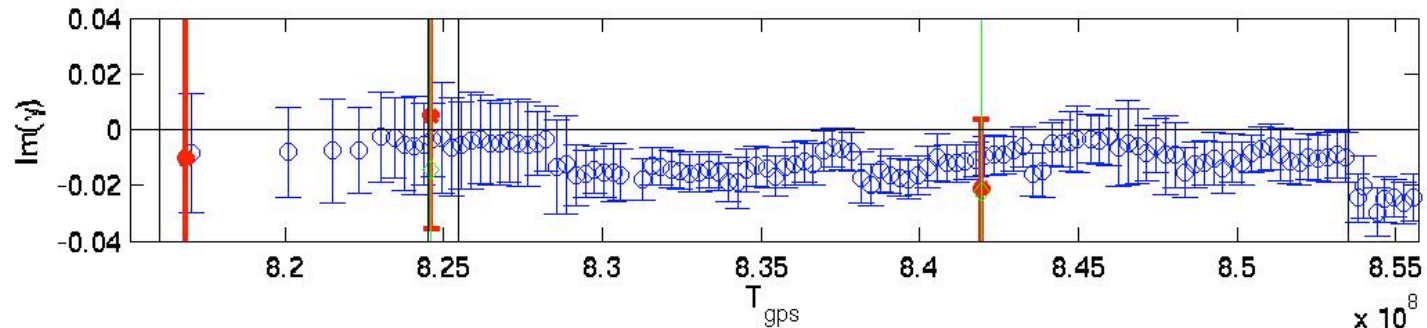
L1 Time dependent coefficients: SenseMon(V2E1) / V3



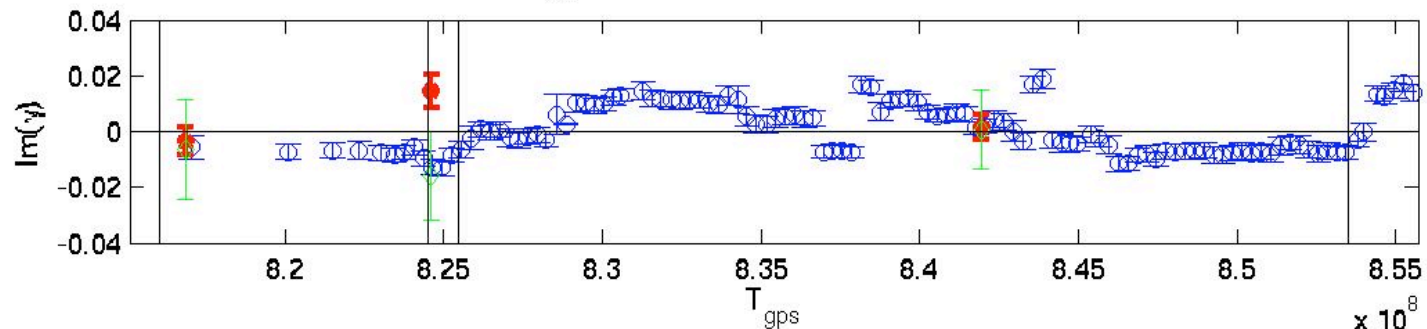
Good agreement for all S5 V3 period within a few %.

Imaginary part of $\gamma(t)$ - Estimate of systematic error

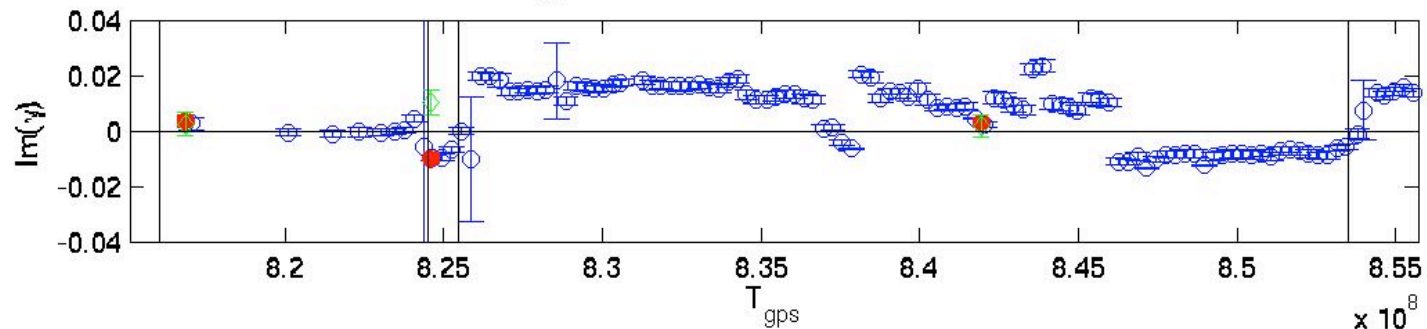
60 second factors at $f_{cal} = 54.7\text{Hz}$ [Reference time check - 60s(red) 1s(green)]



60 second factors at $f_{cal} = 396.7\text{Hz}$ [Reference time check - 60s(red) 1s(green)]



60 second factors at $f_{cal} = 1151.5\text{Hz}$ [Reference time check - 60s(red) 1s(green)]





Time-Domain Calibration Update

Eiichi Hirose, Xavier Siemens

Have begun working on V3 TD calibration (to generate RDS_C03 frames)

Have time-domain digital FIR calibration filters for H1, L1

Will generate frames with more info and channels (complex gammas, calibration FD reference functions, calibration filters, provenance ...) – See recent DASWG e-mail traffic

On-line generation will be moved to RDS generator (go Greg Mendell!)

We expect to have all V3 calibrated $h(t)$ data in about 4-6 weeks, in the meantime V2 should be suitable for pipeline tuning



Time-Domain Calibration Update

Will use DARM_CTRL for most of the run (DARM_ERR only prior to DARM_CTRL whitening time)

Regarding S4, the review committee (Steve Fairhurst, Keita Kawabe, Vuk Mandic, Myungkee Sung, Sam Waldman) is nearing closure on S4

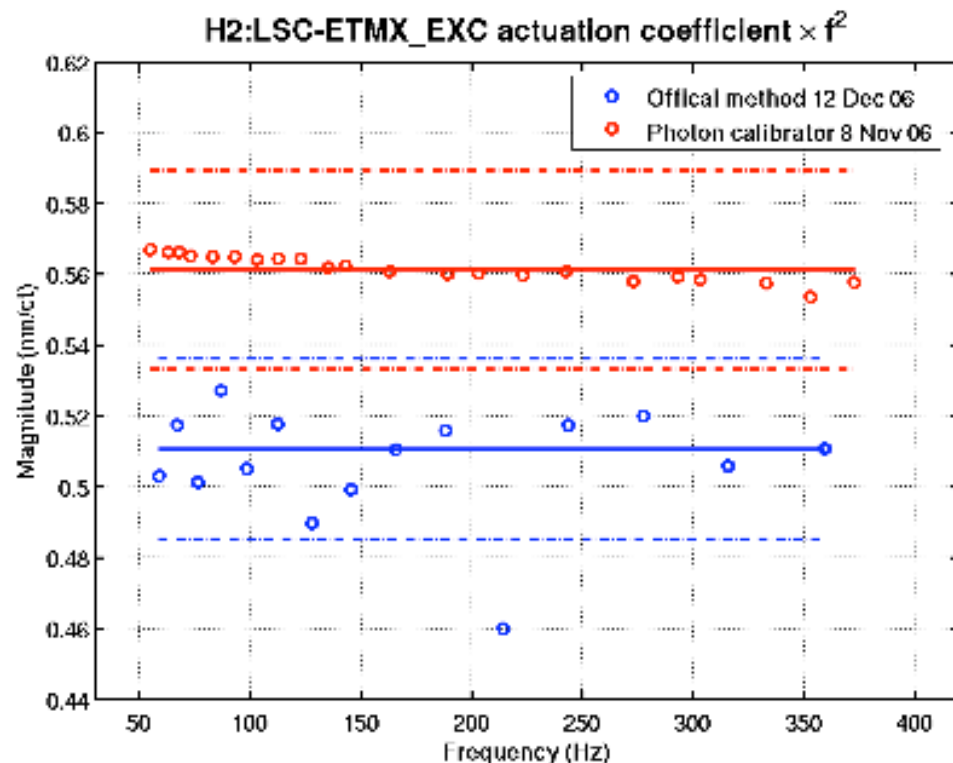
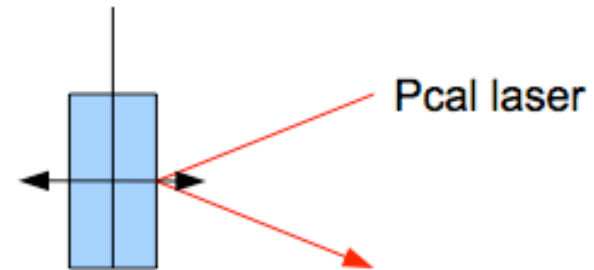
Good lessons learned in review (particularly with regard to use of factors) which will be applied to S5



LIGO Photon calibrator

(E. Goetz, P. Kalmus, R. Savage)

- Alternate coil calibration method using photon pressure
- ~200 mW amplitude power-modulated laser beam at 1047 nm
- Comparison/validation of “official” calibration method
- Agreement within 20 percent for all 6 ETM coil actuators of LIGO IFOs
- Investigating systematic and statistical errors
- Thurs. morning DetChar talks
 - » E. Goetz (LIGO)
 - » S. Hild (GEO)

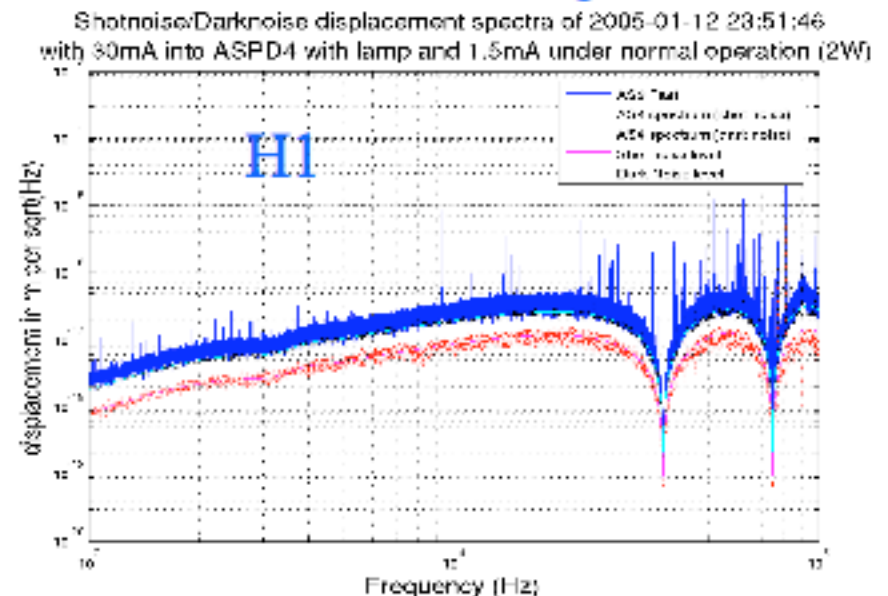
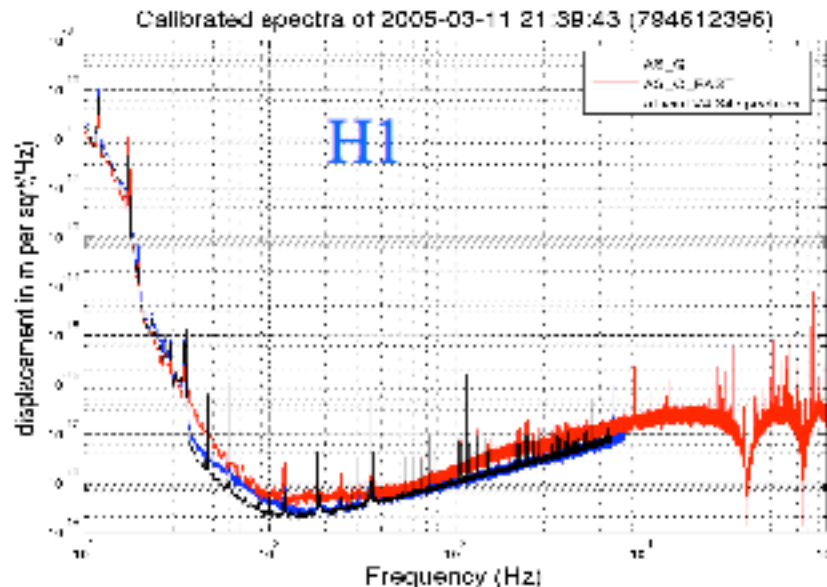




Calibration of Fast Channels

(Detail report at DC tomorrow by S.Giampanis)

- S4 FSR Calibration currently under review (Rick et al)
<http://apex.ligo-wa.caltech.edu/~rick/Calibration/HFcalibration>
- Producing a response function for the Fast Channel
- 2 calibration measurements (March 11, 27)
- 1 shot noise measurement (January 12)
- Continuous monitoring of calibration lines in S5, better modeling





Summary

- S5 Calibration - V3
 - Frequency domain calibration: $h(f)$
 - Done with L1 and H1 (except review, frame files)
 - Still working on H2
 - Time domain calibration: $h(t)$ - Started V3 production for H1 & L1
- Time domain calibration - S4 review almost done
- Photon calibrator, High frequency calibration
- DetChar calibration session - Mar. 22, 9:00-10:30 (Victory)
 - LIGO Photon Calibrator Status (Evan Goetz)
 - Photon-Pressure-Induced Test Mass Deformation (Stefan Hild)
 - VIRGO Calibration (Loic Rolland)
 - Calibration of the LIGO High-Frequency Channels (Stefanos Giampanis)