The Mechanics of an Engineering Run Amplitude Calibration

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Detector Characterization Session

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Calibration ingredients

1. Absolute calibration of ETM control signal
2. Swept sine of interferometer, AS_Q/ETM
3. Power spectrum of AS_Q for locked, quiet IFO

- Run through the steps to produce a noise curve
- Rana will show another related procedure

ETM calibration

To extrapolate the calibration of the input test masses (ITM's) to the end test masses:

Lock single arm and dither the ITM in-band (known amplitude). Assume the ETM follows exactly, then

$$a_{\mathrm{ETM}} = \frac{control\_signal(f_{\mathrm{ITM}})}{control\_signal(f_{\mathrm{ETM}})} a_{\mathrm{ITM}}$$

Calibrations for the ETM's are currently

α_{ETMX} = 1.33 nm/count

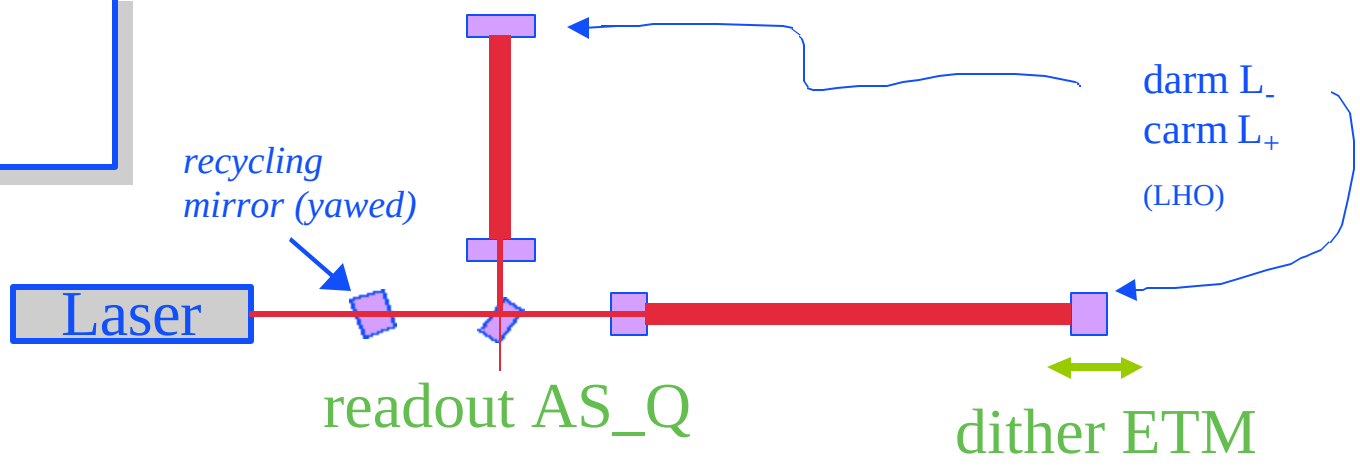
α_{ETMY} = 1.35 nm/count

Other methods: fine actuator, locked ETM Michelson?

IFO configurations

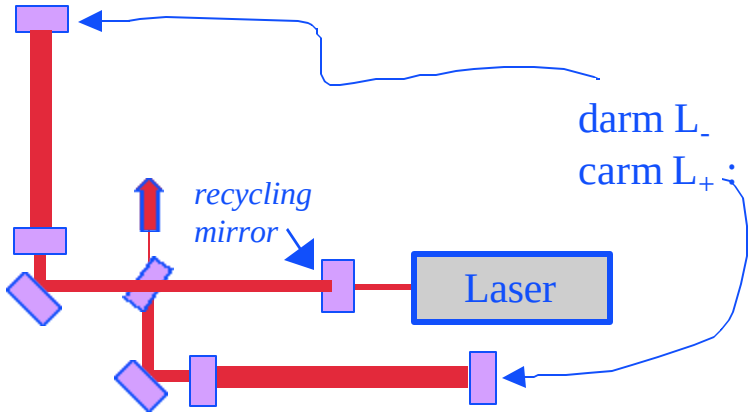
LLO 4k
LHO 4k

Recombined
Interferometer
with Fabry-Perot
Arm Cavities



LHO 2k

Power Recycled
Michelson
Interferometer
with Fabry-Perot
Arm Cavities



Transfer function analysis procedure and production of noise curve

- RDS frames written during sweeps, to save excitations (“test points”) in addition to AS_Q error signals (n.b. excitations never stored)
- Transfer functions recomputed offline from RDS frames using C routine, statistical error of amplitude and phase obtained. Result is ASCII data file for a given sweep – posted at calibration webpage
- Root macro (.cc file) applied to transfer function to produce pole-zero-gain fit
- Amplitude scaled by ETM control signal calibration (unit conversion)
- Obtain PSD of AS error signal of locked interferometer
- Apply calibration record (pzk) to divide out transfer function from AS error signal

Functional form of fit

$$Amplitude = A_0 \sqrt{\frac{\prod_{i=1}^{2}\left(1+\frac{f^2}{z_i^2}\right)}{\prod_{j=1}^{5}\left(1+\frac{f^2}{p_j^2}\right)}}$$

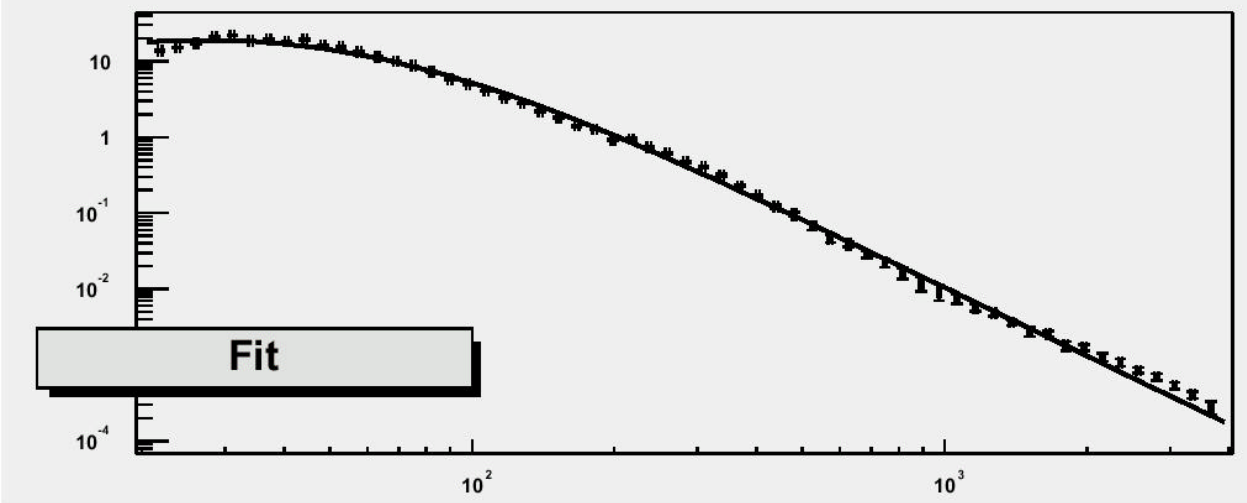
Nine fit parameters (A, phi, delay, 2 zeros, 3 single poles and 1 double pole)

$$Phase = j_0 + 2\pi f dt + \sum_{i=1}^{2}\tan^{-1}\left(\frac{f}{z_i}\right) - \sum_{j=1}^{5}\tan^{-1}\left(\frac{f}{p_j}\right)$$

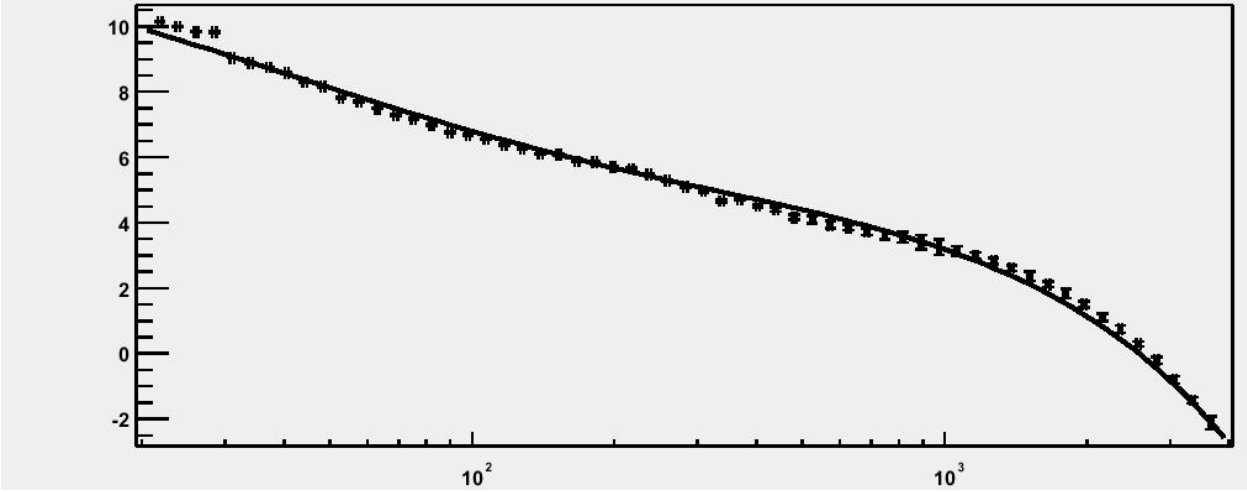
Example: 2k Transfer function

- sweep test mass, take transfer function between AS error signal and excitation

TF Magnitude (AS_Q/ETMX_exc)



TF Phase, radians (AS_Q/ETMX_exc)

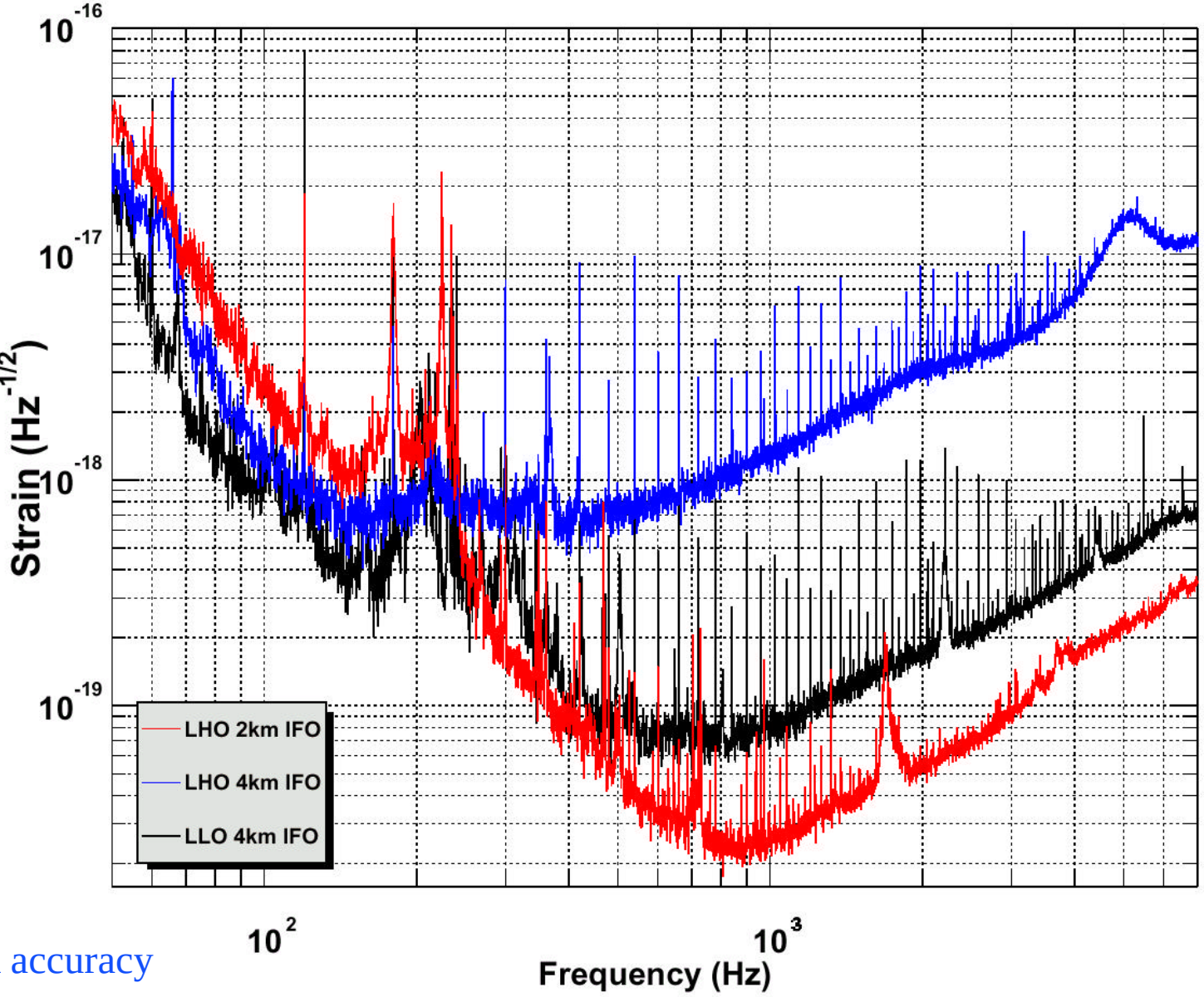


Sample fit parameters

Parameter Name	Fitted value	Initial value
Amplitude0	2.30e-3 +- 0.02e-03	0.01
Phase0	9.558 +- 0.006	0
Delay (s)	0.000304936 +- 2.03028e-06	0.001
Pole1 (Hz)	68.5893 +- 0.695477	20
Pole2 (Hz)	117.11 +- 0.46	100
Pole3 (Hz)	37.43 +- 0.63	180
DoublePole1 (Hz)	16.25 +- 0.12	10
Zero1 (Hz)	0.13 +- 0.0001	0.1
Zero2 (Hz)	0.13 +- 0.0001	0.1

Chisquare = 5027 with 109 degrees of freedom = 46

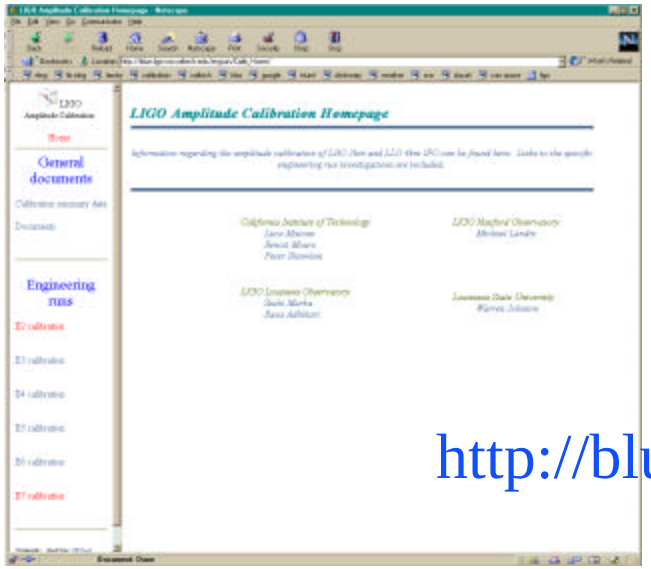
E7 Strain sensitivity



- 30% calibration accuracy

Summary

- Currently recalculating pzk fit of E7 transfer functions
- Multiple methods for both absolute calibration of control signals and production of sensitivity curves (Rana on deck)
- Calibration group needs to know: what data products expected, needed, and in what format
- Calibration lines in place during E7 (at least part-time); run Klimenko line-monitor to characterize stability
- Best strain sensitivity during E7 was LHO 2k, approximately 2.5×10^{-20} /$Hz^{1/2}$ at 900Hz



Amplitude calibration homepage:
http://blue.ligo-wa.caltech.edu/engrun/Calib_Home/