LIGO

Noise Budget Development for the LIGO 40 Meter Prototype

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Caltech, Aug. 19, 2005

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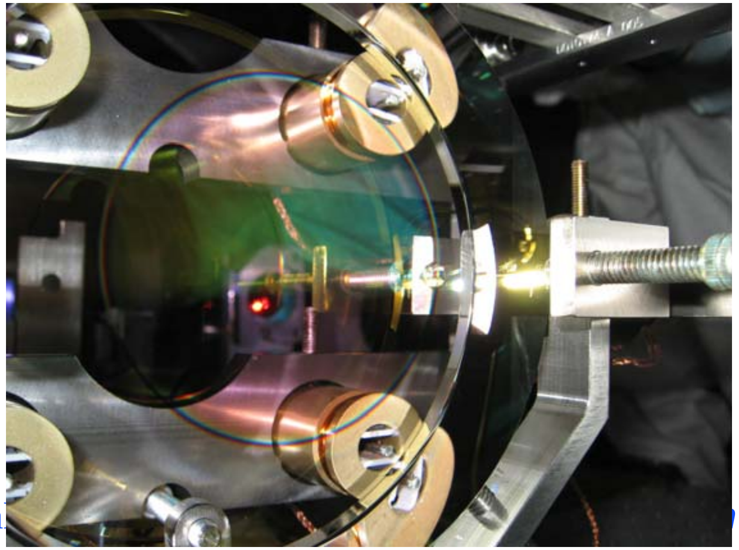
LIGO-G050464-00-R

Introduction

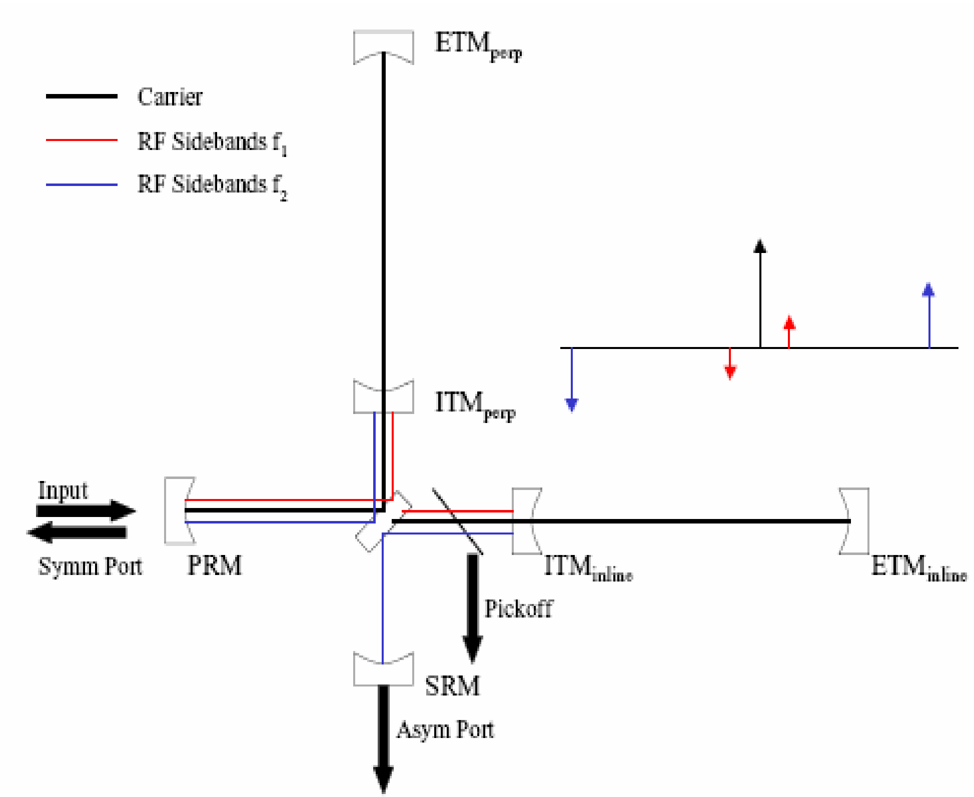
- LIGO 40 meter prototype
- Transfer Functions
- What is a Noise Budget?
- Seismic Noise Example



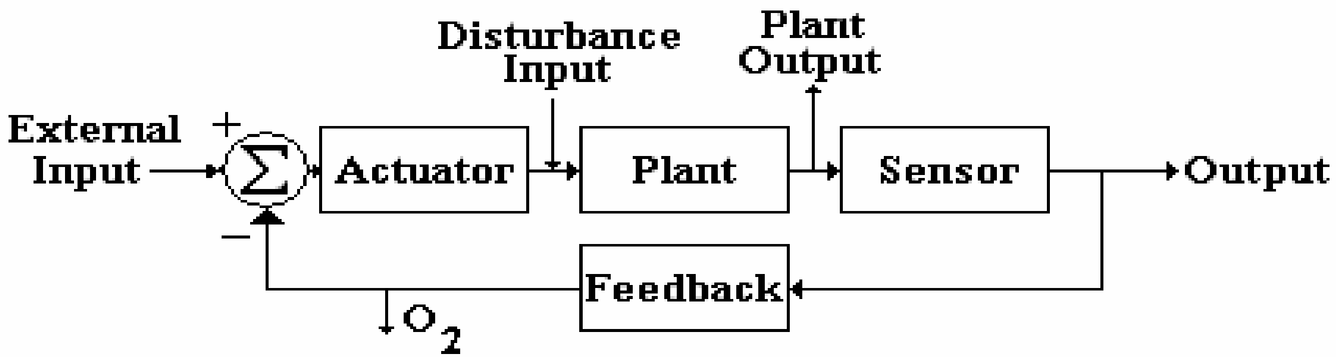
40m Prototype

- Purpose: To test new designs and techniques to be used for Advanced LIGO.
- Basic Components:
  - Fabry-Perot cavities
  - Power Recycling
  - Mode Cleaner
  - Pre-Stabilized Laser
  - Signal Recycling**

**= not at LIGO



Transfer Functions for the Non-Believer



- For linear time-invariant systems, a transfer function is a ratio of a system output given a known input (e.g. a sinusoidal wave).

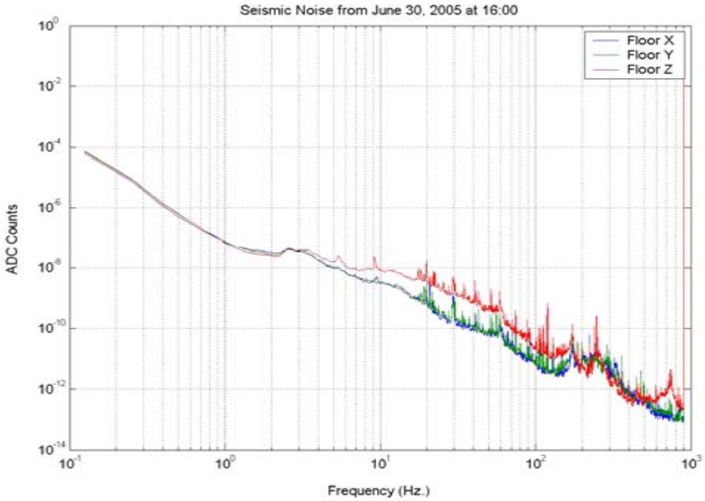
$$T(Input \Rightarrow Output) = \frac{Output}{Input}$$

- An open loop transfer function, G, has the feedback disconnected while a closed loop transfer function has the feedback connected. At O_2 (a test point), The functional forms are

$$T_{ol} = APSF = G \qquad T_{cl} = \frac{G}{1-G}$$

Noise Sources

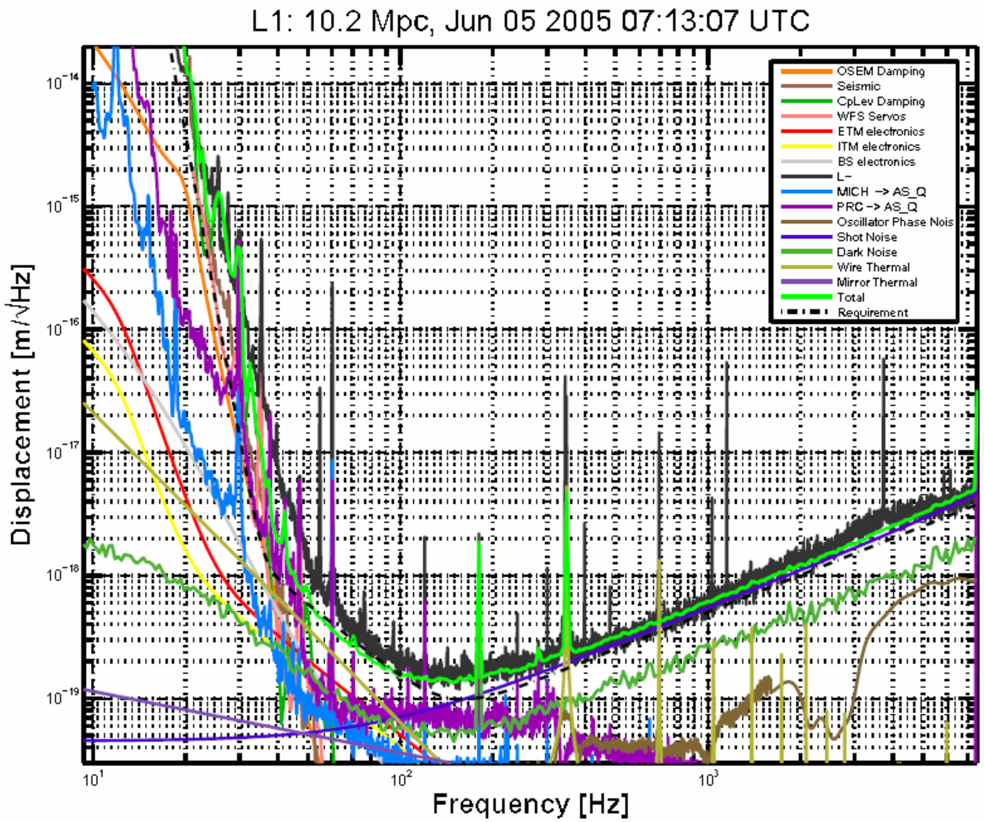
- Fundamental: Noise sources that are intrinsic to the detection method
  - Seismic
  - Shot
  - Thermal
- Technical: Noise sources that are a result of the electronics and control system
  - OSEM
  - OpLev
  - Electronics



LIGO

What is a Noise Budget?

- A noise budget is simply a plot of all known sources of noise in the interferometer calibrated to show their effect on the DARM gravity wave data signal
- Shows the IFO sensitivity to GWs
- Used to track noise sources for eventual reduction

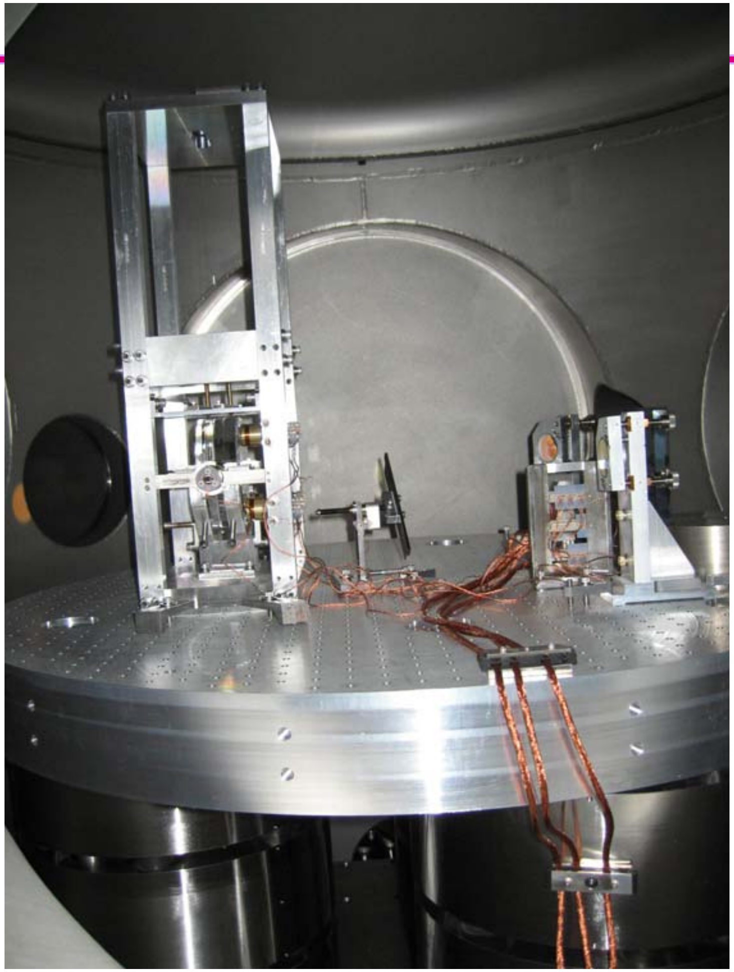


Process

- Pick Noise source
- Measure noise spectrum (power spectrum)
- Calibrate to units of meters/rtHz (calibration constants and transfer functions)
- Plot against DARM signal

Seismic Noise

- Effects all ground based interferometers
- Seismic Isolation System (passive)
  - Stacis
  - Stacks
  - Pendulum
- Measurements were taken with six orthogonally mounted Wilcoxon 731A accelerometers



Calibration

- Step 1: The accelerometers volt to g (acceleration) gain conversion
  - Wilcoxon calibrated the accelerometer to output 10 V/g for a gain of 1 and 1000 V/g for a gain of 100
  - The noise budget seismic measurements have a gain of 100
- Now, the signal has units of Volts per g or Volts per acceleration

Calibration

- Step 2: Get position from acceleration
  - The optic is modeled as a simple pendulum
  - From basic mechanics, divide acceleration by ω^2 to get position (magnitude only)

$$y(t) = A\sin(\omega t)$$

$$\ddot{y}(t) = -\omega^2 A\sin(\omega t)$$

$$y(t) = \frac{\ddot{y}(t)}{-\omega^2}$$

  - The signal has units of meter/Volt

Calibration

- The 40m has a digital control and readout system, therefore all data must be converted from an analog voltage to optic position information
- Step 3: ADC voltage resolution (Volt/count)
  - The ICS110B has a range of ± 2 V and a 16 bit resolution
  - The conversion factor from counts back to volts is

$$V_R = \frac{range}{resolution} = 61.035 \frac{\mu V}{count}$$

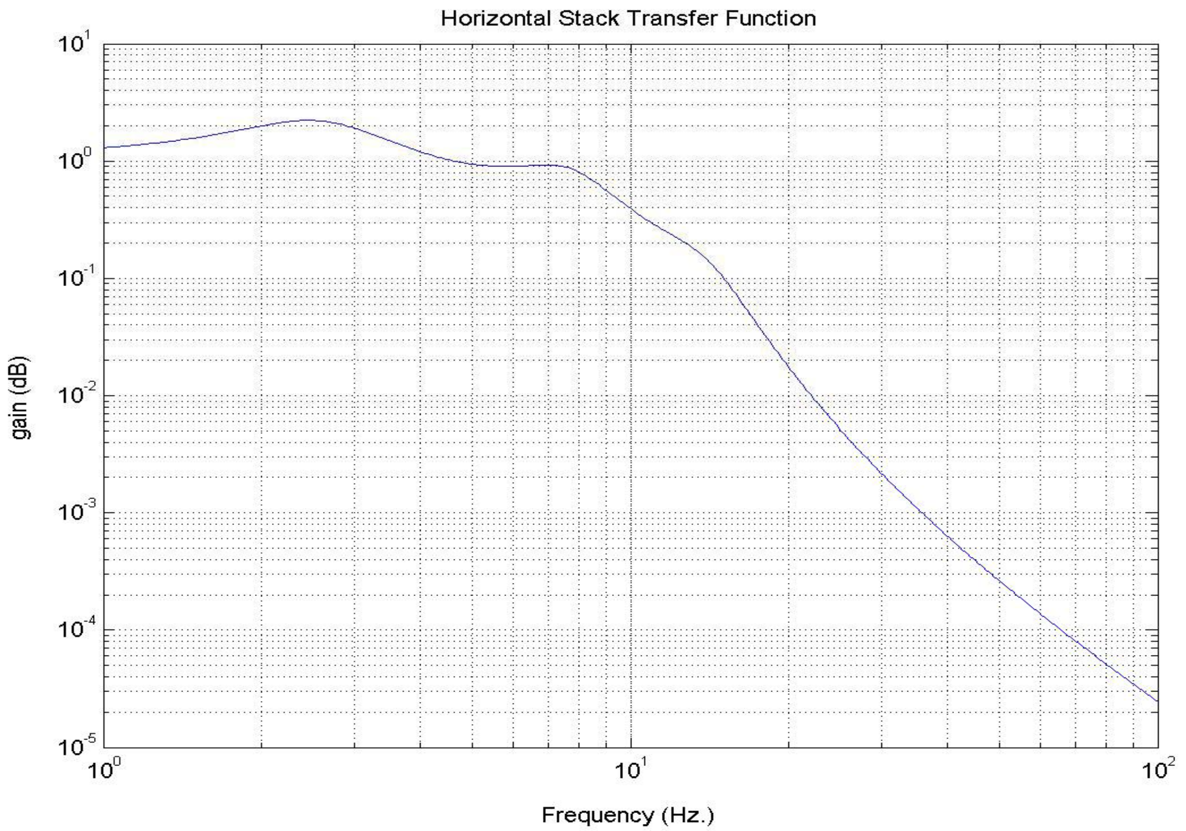
- The signal has correct units (meters/count), but does not produce the correct response to seismic input

Seismic Isolation Transfer Function

- Step 4: Multiply the calibrated signal by the seismic isolation transfer function to get the correct response of the optic to seismic motion
- This transfer function incorporates the stacks and the pendulum, but leaves out the stacis units passive contribution to noise damping
- Horizontal Stack transfer function
  - Resonant at 3, 8.25, and 15 Hz
- Pendulum transfer function
  - Resonant at 0.8 Hz.

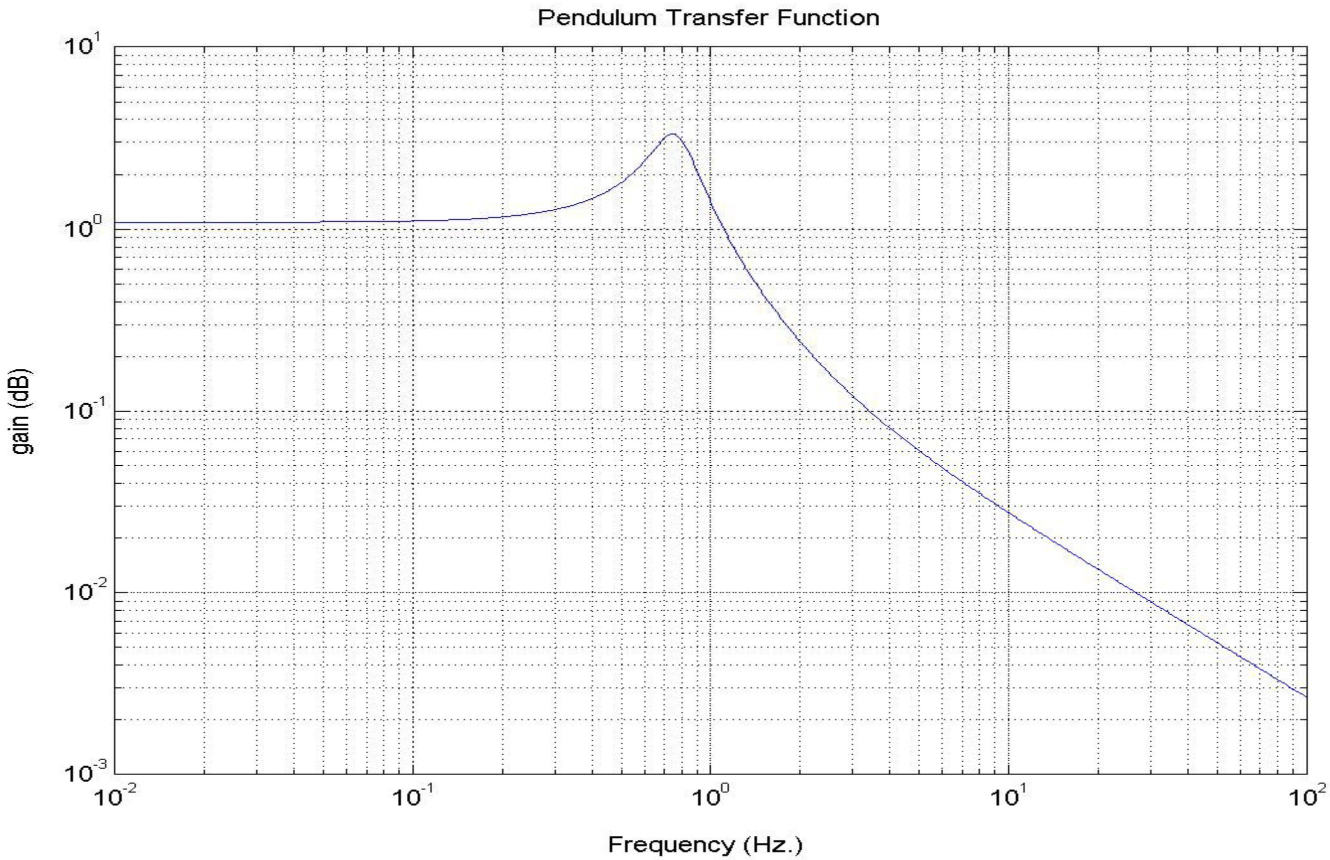
Seismic Isolation Transfer Function

- Horizontal Stack TF



Seismic Isolation Transfer Function

- Pendulum TF



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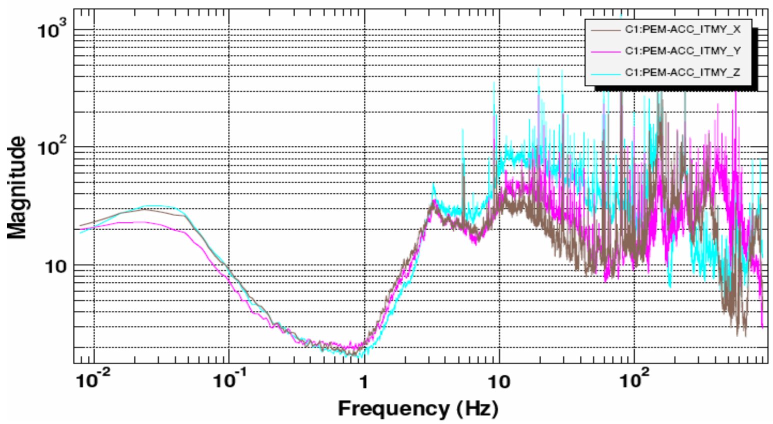
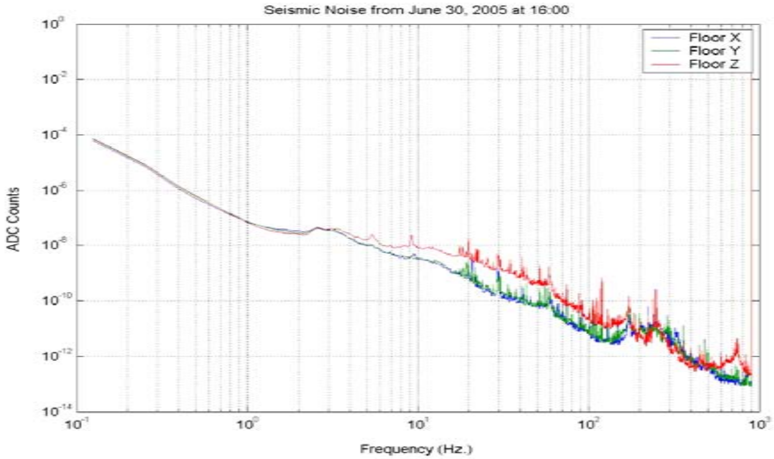
Seismic Budget

- To get the seismic noise budget, multiply the noise spectrum from the accelerometers by the calibration constants and the transfer functions
- From this

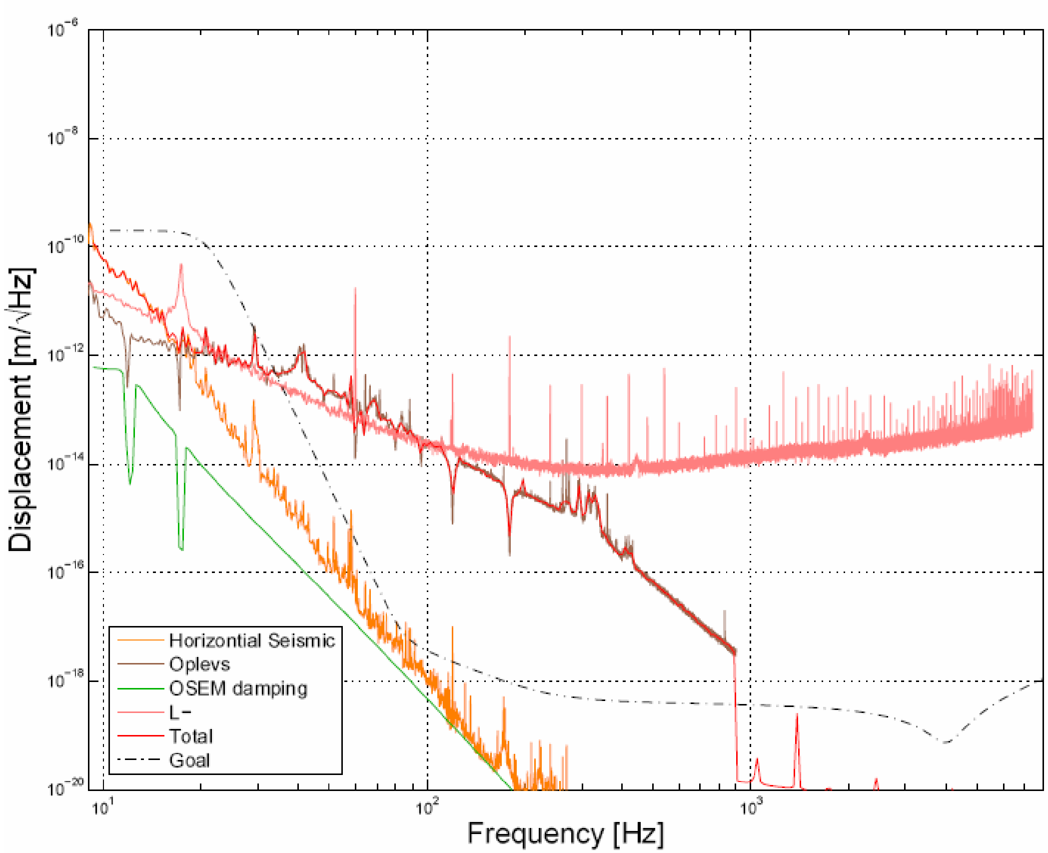


- To this



Noise Budget

- The preliminary noise budget for the 40m
- Noise sources budgeted here: Seismic, OSEMs
- Soon to be budgeted: Shot, Dark, Wire and Mirror Thermal, OpLevs



Future Work

- Complete the noise budget by including more noise sources
- Known noise sources: Wire Thermal, Mirror Thermal, Shot, Dark, Electronic, Intensity, Frequency, MICH, PRC, SRC
- Unknown sources: Find and budget
- Use the budget to improve the 40m IFO performance

Recognition

I would like to thank

- Dr. Alan Weinstein
- Dr. Rana Adhikari
- Dr. David Blair
- Dr. Vuk Mandic
- Dr. Osamu Miyakawa
- Dr. Monica Varella
- Ben Abbott
- Dan Busby
- Jay Heefner
- Steve Vass
- Rob Ward
- National Science Foundation
- California Institute of Technology