LIGO

Beam Jitter Estimate at the OMC: Enhanced and Advanced LIGO

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LSC Meeting

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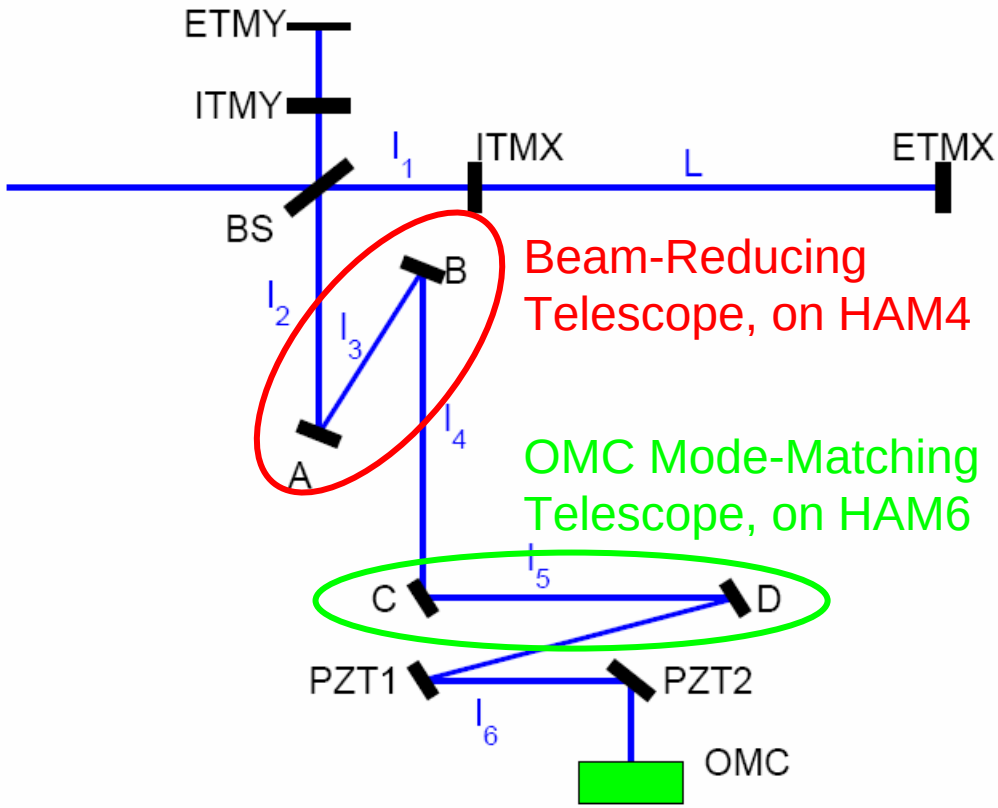
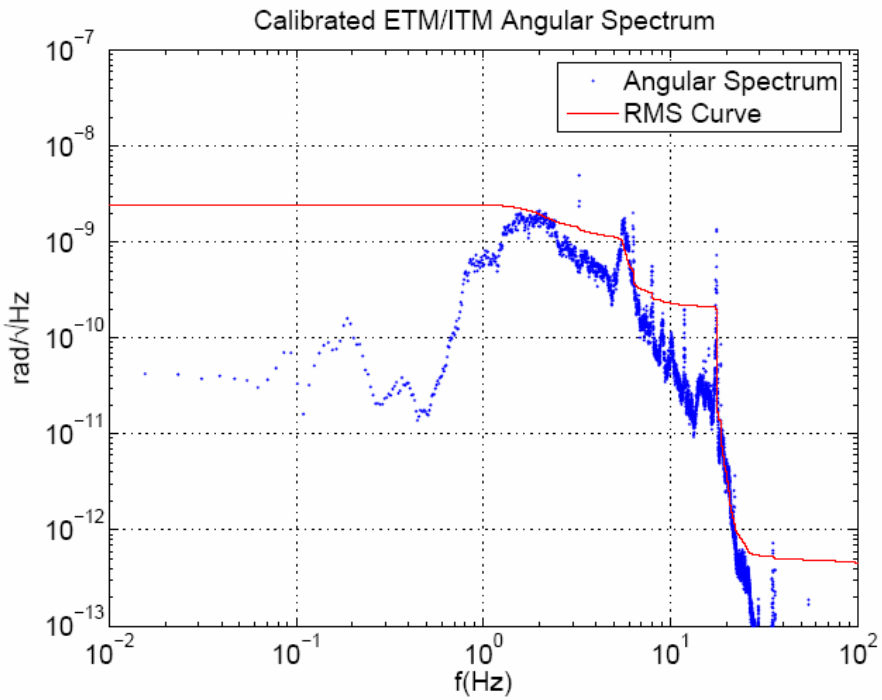
Outline of Calculation

- Estimate angular motion of TMs
  - » Propagate to OMC waist
- Estimate BRT motion
  - » Measure ground motion, propagate through LIGO HAM model
  - » Propagate to OMC waist
- Tune OMC MMT to match the waist of the OMC cavity.
- Convert beam displacement and tilt into power (and strain) fluctuations at OMC.
- Compare with expected strain sensitivity.
  - » Check how much isolation is necessary for OMC.



ELIGO: Details

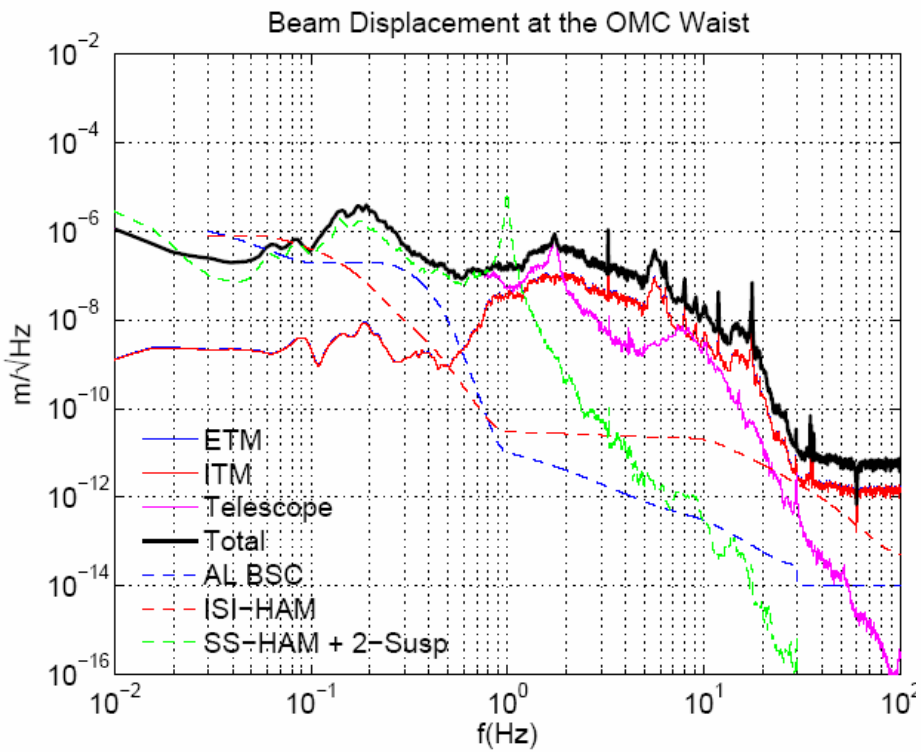
- TM angular spectrum obtained by calibrating WFS sensing signal.
- Determine displacement and tilt of the beam as it leaves ITM.
- BRT:
  - » Measure ground motion (calibrate accelerometers (>5 Hz) and seismometers (<5 Hz))
  - » Run it through HAM stack model.
- Propagate all contributions to OMC waist, add in quadrature.
- OMC MMT:
  - » Assume beam waist of 1cm at input of MMT1.
  - » R_1 = 1m, R_2 = 0.14m, dephasing 4.5mm gives beam waist of 0.4 mm, 0.8 m from MMT2



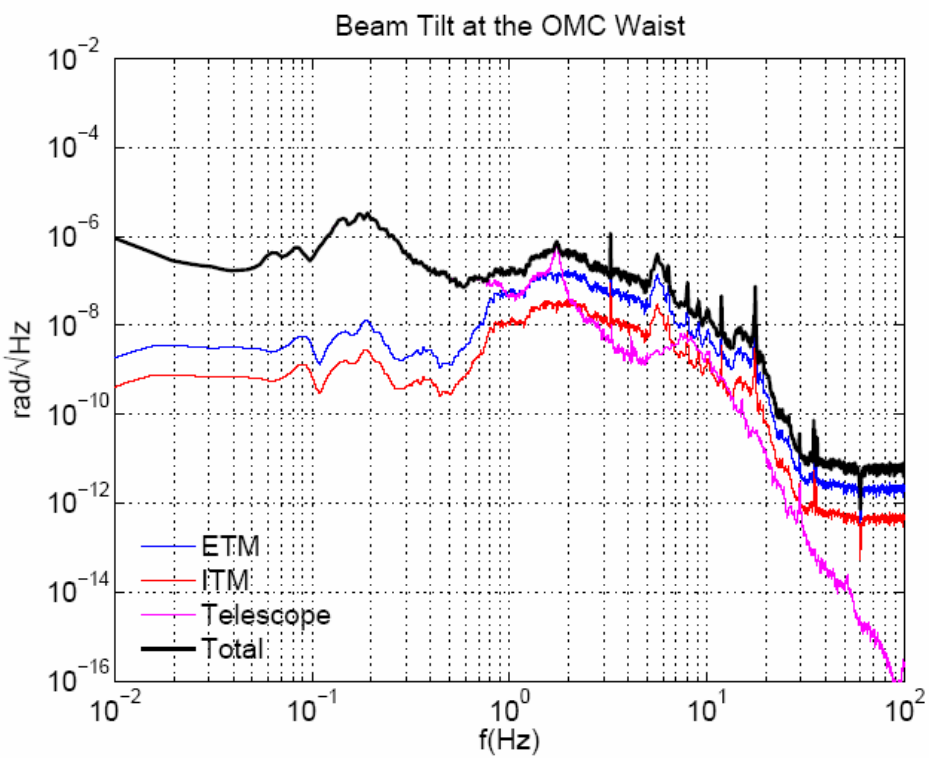
$$\alpha = \arctan \frac{R_{ETM} \sin\theta}{R_{ITM} + R_{ETM}\cos\theta - L} \approx 0.44\,\theta$$

ELIGO: Beam Jitter at OMC Waist

Displacement



Tilt



ELIGO: Power/Strain Spectra

- Beam Displacement:

$$\psi(x-a) = A\left(\frac{2}{\pi x_0^2}\right)^{1/4} \exp\left[-\left(\frac{x-a}{x_0}\right)^2\right] = \left(1-\frac{a^2}{x_0^2}\right)\psi(x) + 01\ \text{Term} + \ldots$$

Beam Waist

- Beam Tilt:

Divergence Angle

$$\psi(x) = U_0(x)\exp(\frac{2\pi i\alpha x}{\lambda}) = \left(1-\frac{\alpha^2}{\theta_D^2}\right)U_0(x) + \frac{\pi i\alpha x_0}{\lambda}U_1(x) + \ldots$$

- Power:

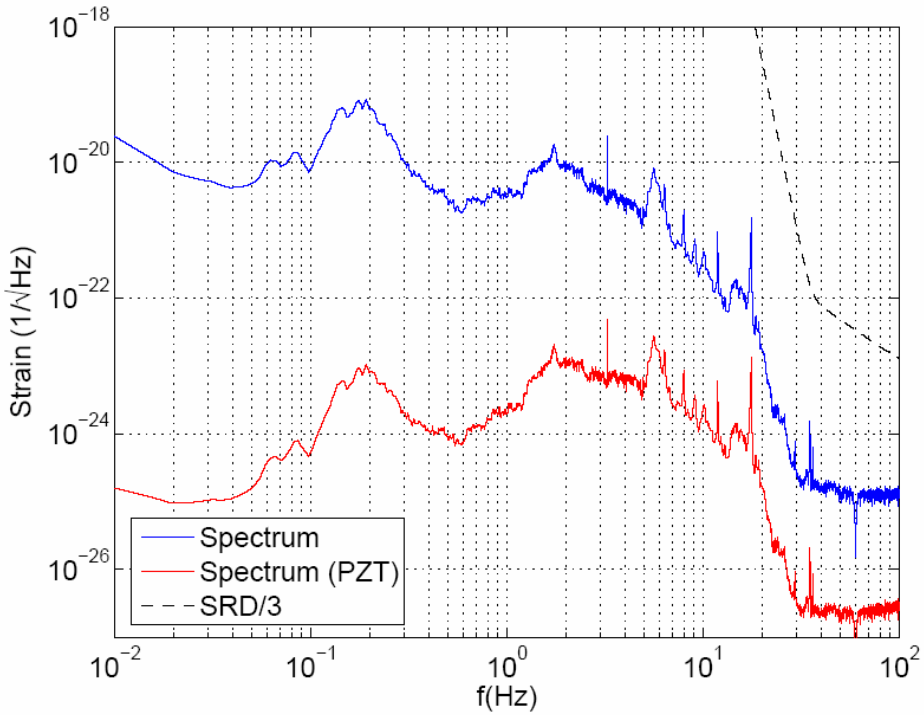
$$P(x,a,\alpha) = P(x)\left(1-\frac{2a^2}{x_0^2}-\frac{2\alpha^2}{\theta_D^2}\right)$$

- Strain:
  - » Assume simple Michelson, DC readout, and 10 pm offset

$$\delta L_- = \frac{\delta P_{AS}}{dP_{AS}/dL_-} = \frac{\lambda\epsilon(f)}{4\pi N_{arm}}\tan\frac{2\pi N_{arm}L_-}{\lambda}$$

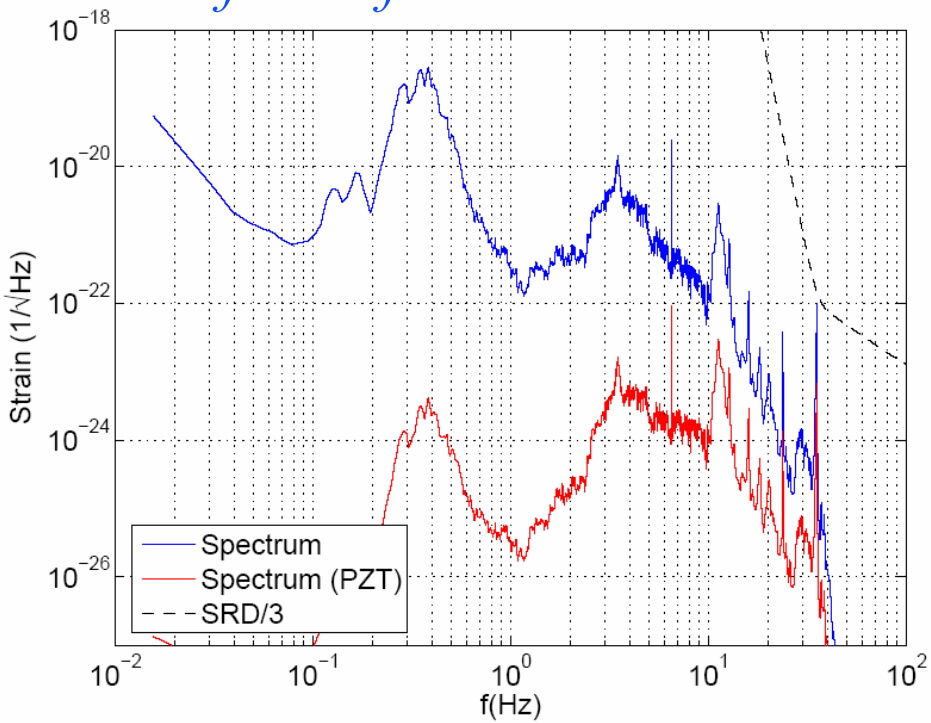
ELIGO: Strain due to Beam Jitter

$a^2(f) \equiv a(f) \times RMS(a)$



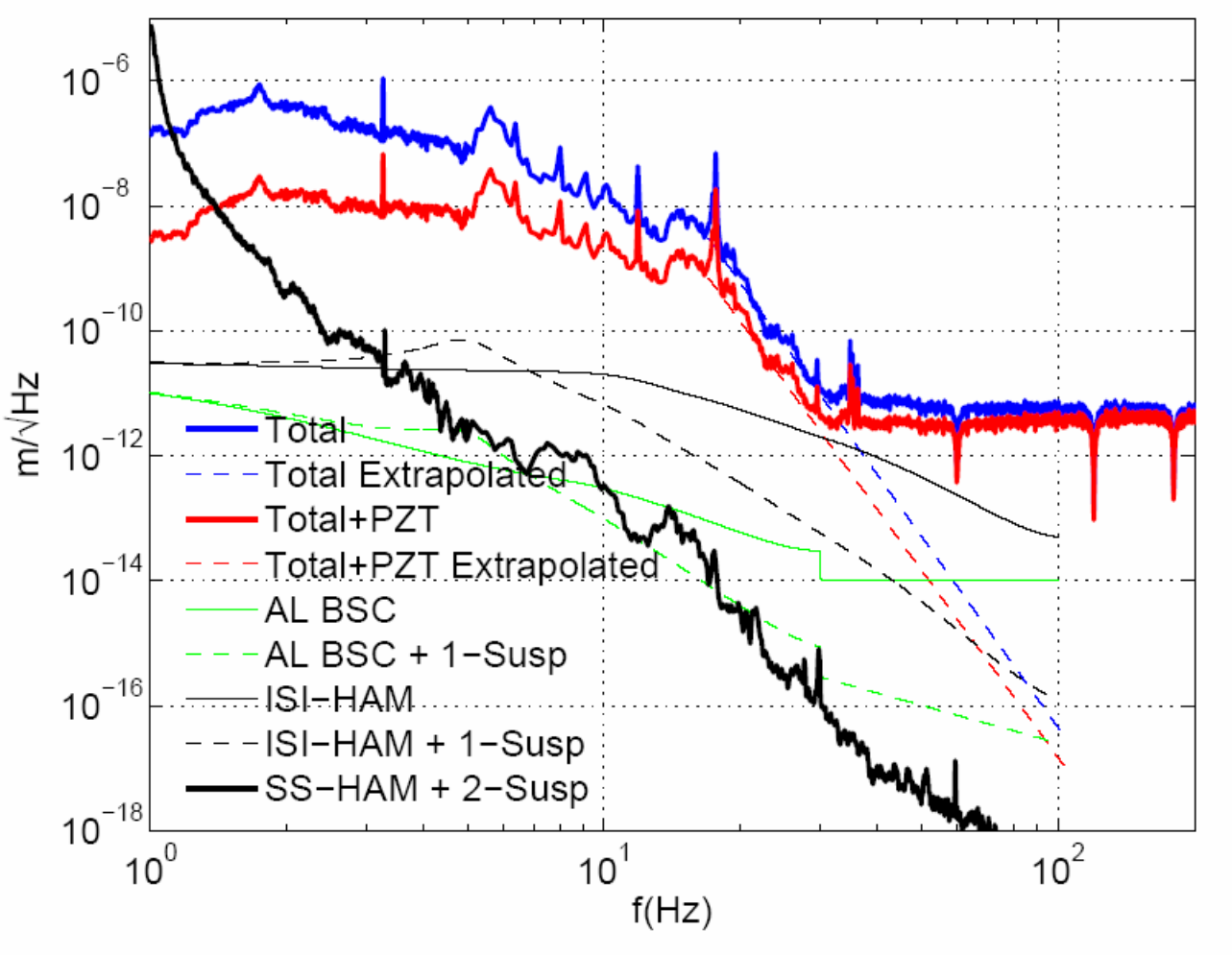
$a^2(f) \equiv a(f) \times a(f)$

$f \rightarrow 2f$



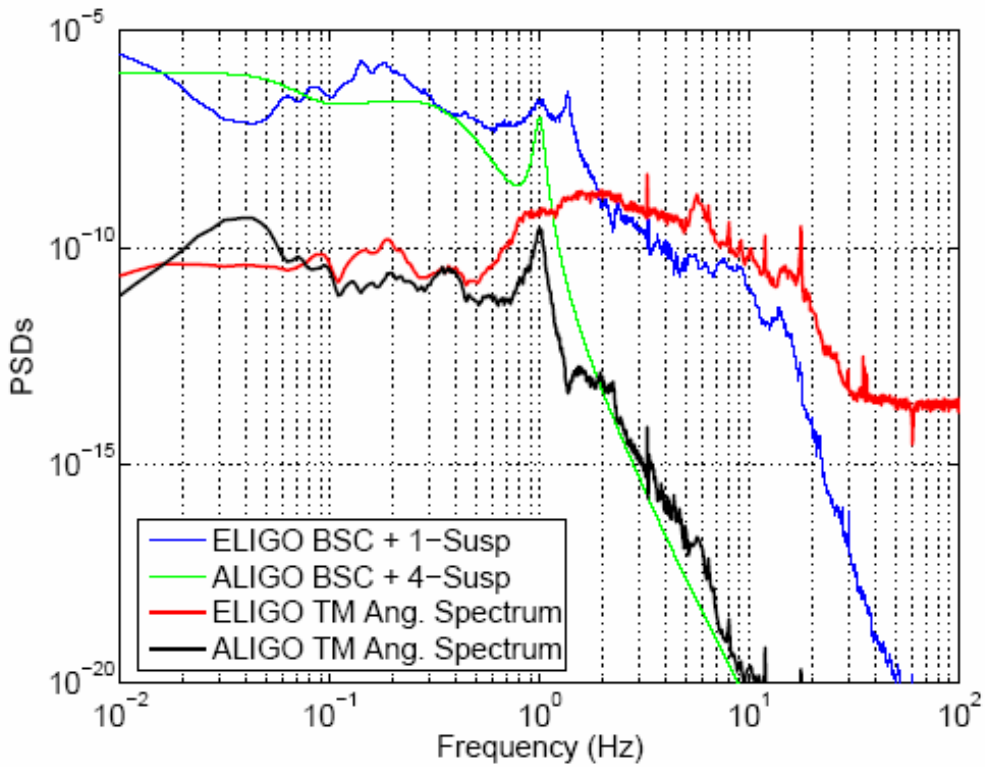
ELIGO: OMC Suspension Requirements

- Beam jitter at the OMC typically much larger than:
  - » ALIGO BSC + single pendulum
  - » ISI-HAM (1-stage) + single pendulum
  - » SS-HAM (super-stiff, i.e. a table) + double pendulum



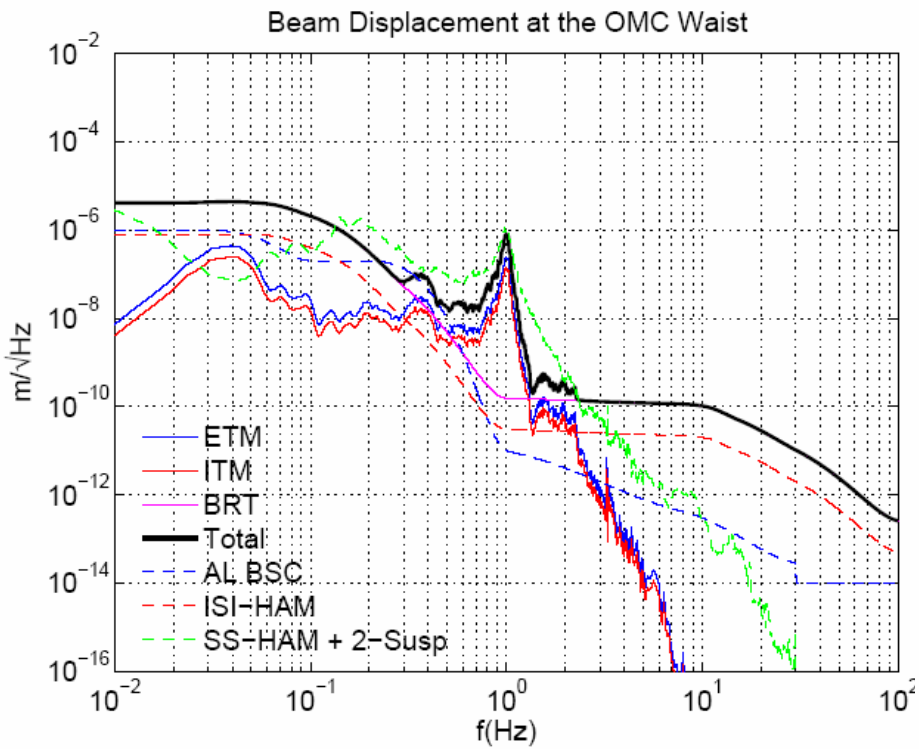
AdvLIGO Modifications

- Guess angular motion of TM's:
  - » Scale LIGO angular spectrum by the ratio of AdvLIGO and LIGO BSCs.
- Assume BRT on ISI-HAM (1-stage)
  - » Angle = displacement / 10
- New BRT specs from Mike Smith.
- New OMC MMT. Designed assuming:
  - » 60mm beam waist at input of BRT
  - » Same OMC waist and position
  - » R_1 = 0.43 m, R_2 = 0.132 m, dephasing = 4 mm

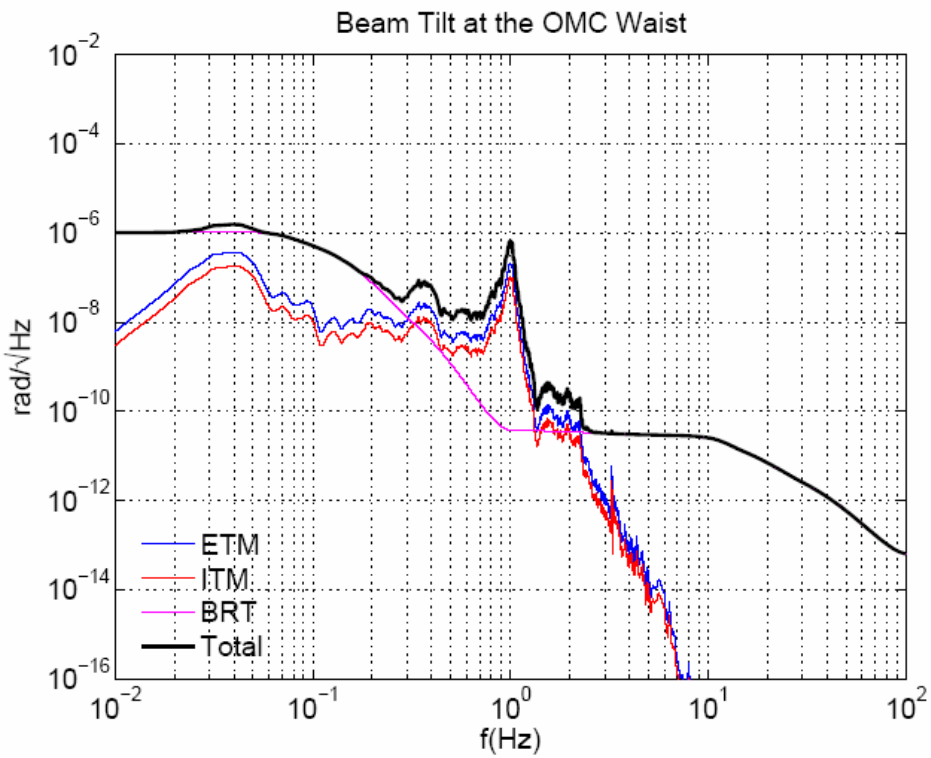


ALIGO: Beam Jitter at OMC

Displacement



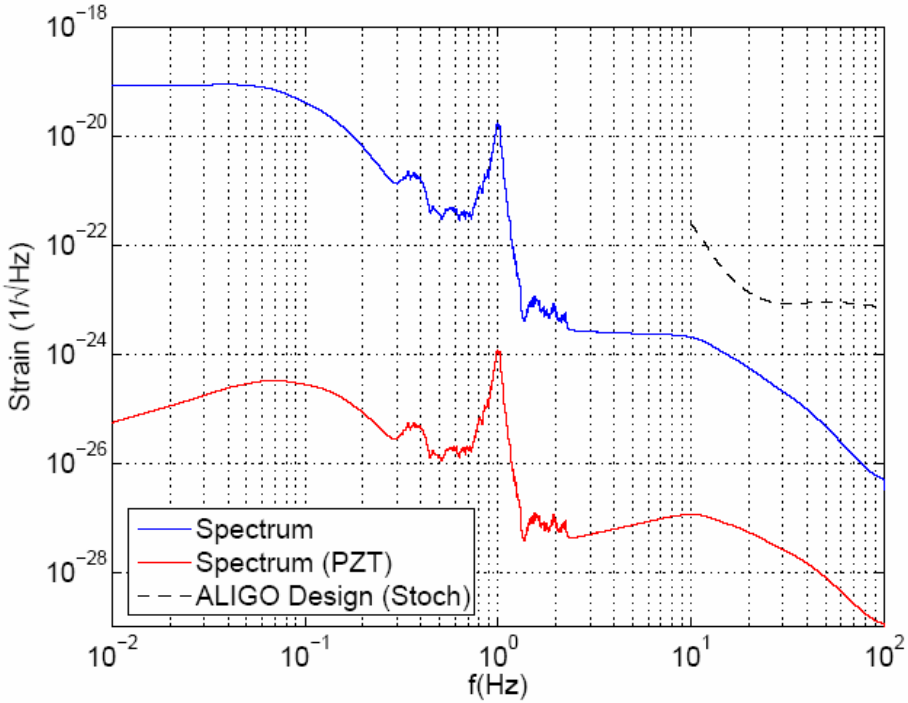
Tilt



ALIGO: Strain due to Beam Jitter

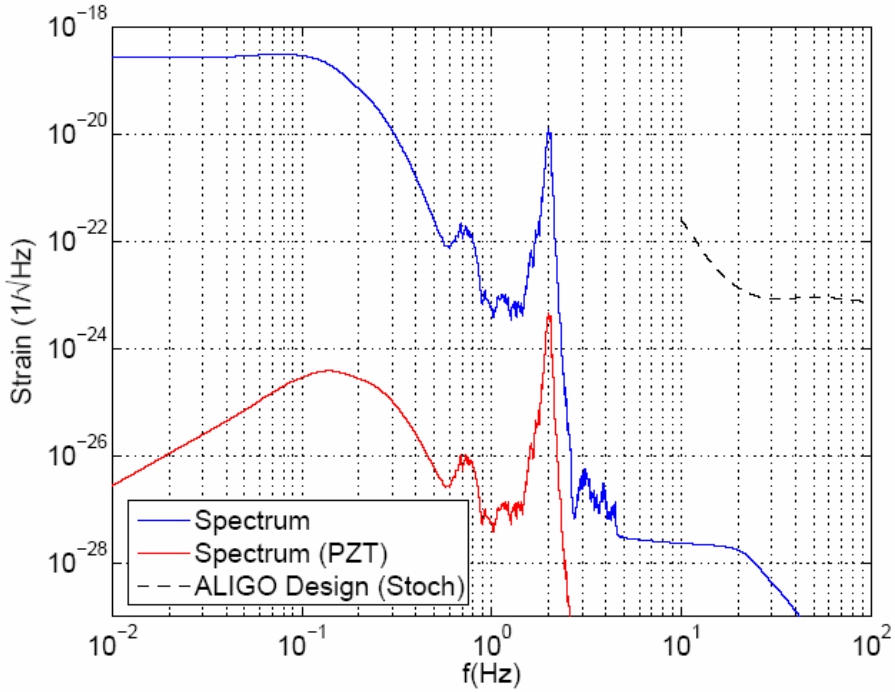
- Assume 10 pm offset
- Ignore SRC

$$a^2(f) \equiv a(f) \times RMS(a)$$



$$a^2(f) \equiv a(f) \times a(f)$$

$$f \rightarrow 2f$$



ALIGO: OMC Suspension Requirements