LHO 2km Arm Cavity Tests: Suspensions

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Director's Review

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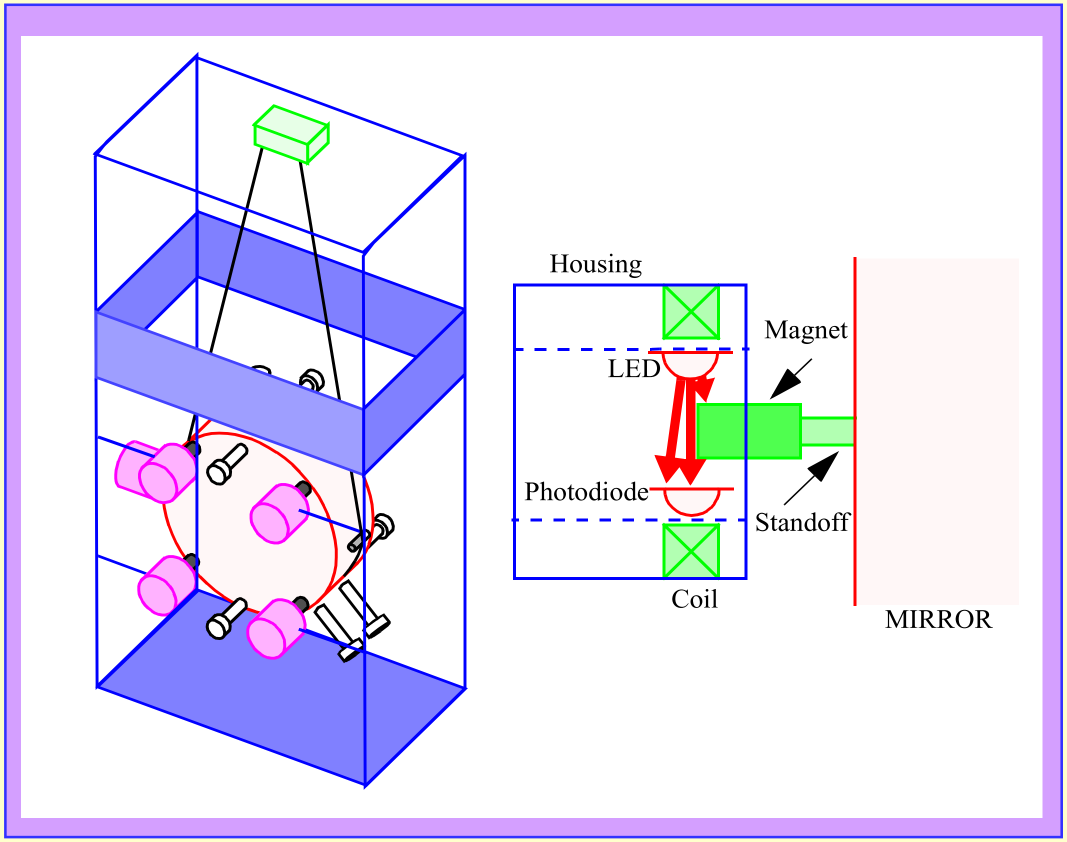
Outline

- Suspension controls
  - Diagonalization
    (Gonzalez, Barton, Penn, Black, Whitcomb, Nash, Mavalvala)
  - Damping
    (Fritschel, Gonzalez, Penn, Yoshida, Mavalvala)
  - Calibrations
    (Schofield, Matone, Kells, Sigg, Mavalvala)
  - Scattered light coupling
    (Weiss, Rong, Heefner, Fritschel, Shoemaker, Mavalvala)
- Internal resonances of the test masses
  - Resonant frequencies and Q's
    (Weaver, Rong, Whitcomb, Weiss, Gustafson, Mavalvala)

Suspension



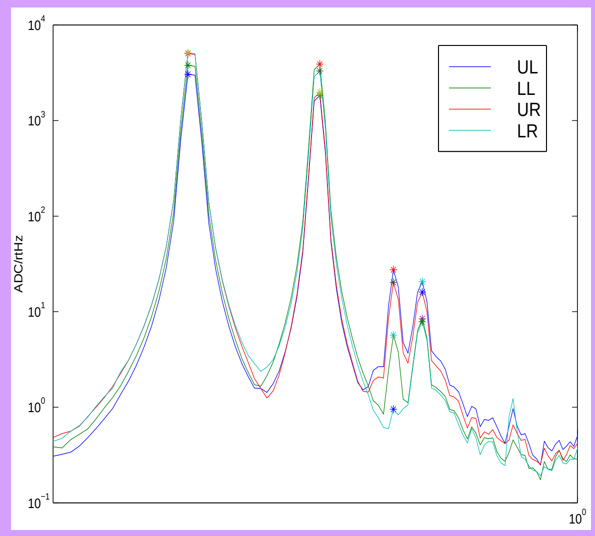
Diagonalization

- Four Sensors
  - Want monitors that independently sense the primary degrees of freedom (translation, pitch, yaw)
- Four Electromagnet Actuators
  - Want actuators that independently move the primary degrees of freedom?
- Diagonalization: find the coefficients that generate “pure” sensor and actuator signals?

Sensor Diagonalization

❑ Sensors

- Let mirror swing freely
- Measure amplitudes (and relative phases) of each eigenmode as it appears in each sensor
- Determine sensor coefficients (taking into account the natural coupling of the position (translation) and pitch eigenmodes)



Actuator Diagonalization

Procedure

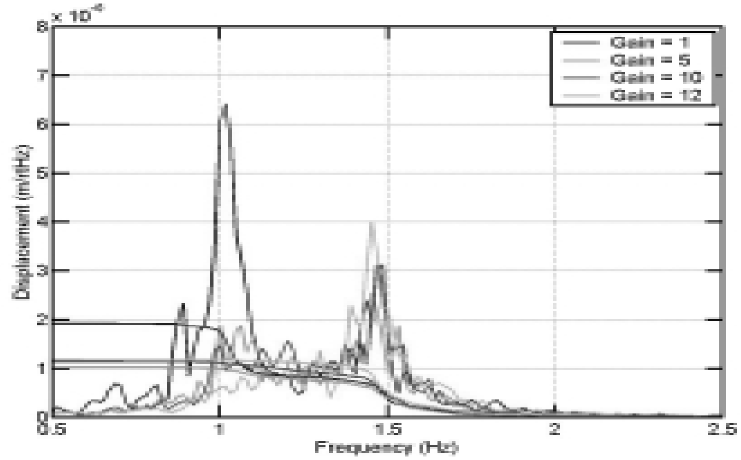
- Apply drive signals to all four coils
- Determine drive strengths (actuator coefficients) that minimize excitation of other (orthogonal) degrees of freedom
- Frequency dependent coefficients
- Diagonalize at frequencies where largest control forces are applied
- Different for lock acquisition and for operational states of ifo

Can use local sensors or optical levers

- Some discrepancies between using these two still being resolved

Local Damping

- Optimal damping gain for suspension eigenmodes
  ⇨ minimize the rms motion of the optic
- Underdamp ⇨ eigenmode dominates rms
  Overdamp ⇨ stack resonance dominates rms
- Optimal damping
  ⇨ eigenmode Q ~ 8



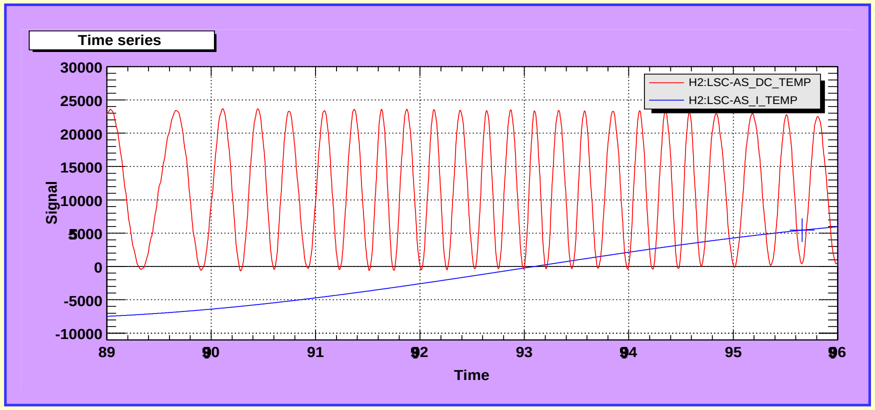
Calibration of actuators

Position actuators

- Lock simple Michelson
- Apply drive signal to Position input of coil driver
- Count Michelson fringes

⇨ 1.54 µm/Volt

- Smaller than predicted by electronics/coil strengths



Angle actuators

- Optical levers or wavefront sensors

Scattered light coupling

- Problem: 1.06 μm laser light scattered off optics couples to local sensors at a level of ~35 nm/W
  - Causes motion of optics due to local damping feedback path
  - In resonant cavities this angular misalignment of one mirror causes misalignment of other mirror ⇨ unstable
- A solution: modulate the LEDs and demodulate PD signals from local sensors (coherent detection)
  - Prototype circuits tested on mode cleaner
  - Successfully resonated 4.5 W of power without exciting instability
  - But noisy ⇨ circuit redesign

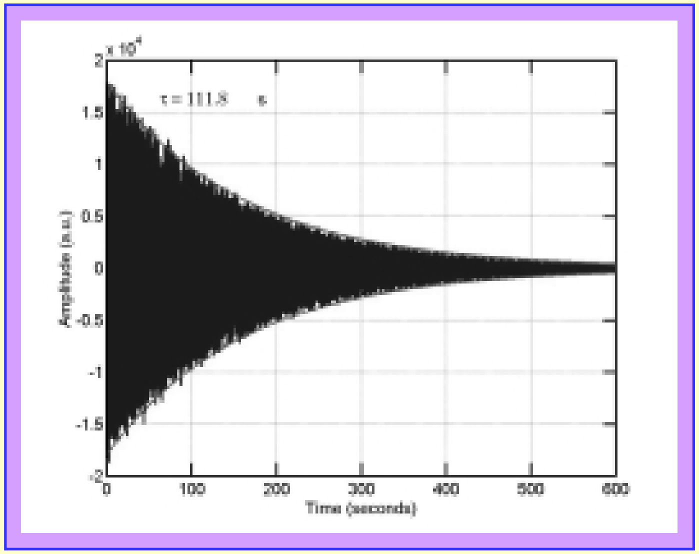
Internal Resonances of Optics

❑ Internal mode eigenfrequencies and Q factors

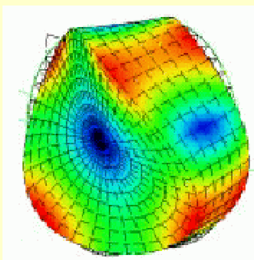
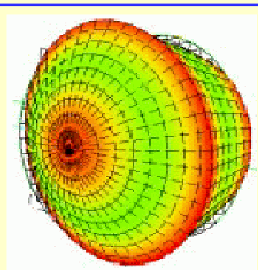
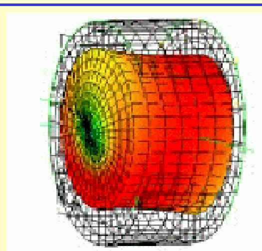
- Test mass internal thermal noise
- Stability of length control loops

❑ Measurement

- Excite optic with drive signal on coil drivers
- Identify mirror internal resonances in spectrum of length sensor signal
- Turn off drive
- Measure decay time



Internal Modes

Mode		Optic	Frequency (kHz)	Q factor
	Butterfly	ITMx	6.748	1.4×10^{6}
		ETMx	6.639	2.8×10^{6}
		BS	3.7337	1.85×10^{6}
	Drumhead	ITMx	9.395	6×10^{5}
		ETMx	9.254	7.8×10^{4}
		BS	5.478	2.5×10^{4}
	Breathing	ITMx	14.374	1.2×10^{7}
		ETMx	14.372	5.1×10^{6}
		BS	11.1387	3.6×10^{5}

Near Future…

- Redesign of suspension controllers
  - Digital controllers
  - Allow for frequency dependent tuning coefficients
- Redesign of LED/PD shadow sensor
  - 1.06 µm insensitive LED/PD package
  - Coherent detection
- Continue diagonalization on all installed optics
- Identify more internal resonances, measure Qs