The Arm Length Stabilization System for Advanced LIGO Lock Acquistion

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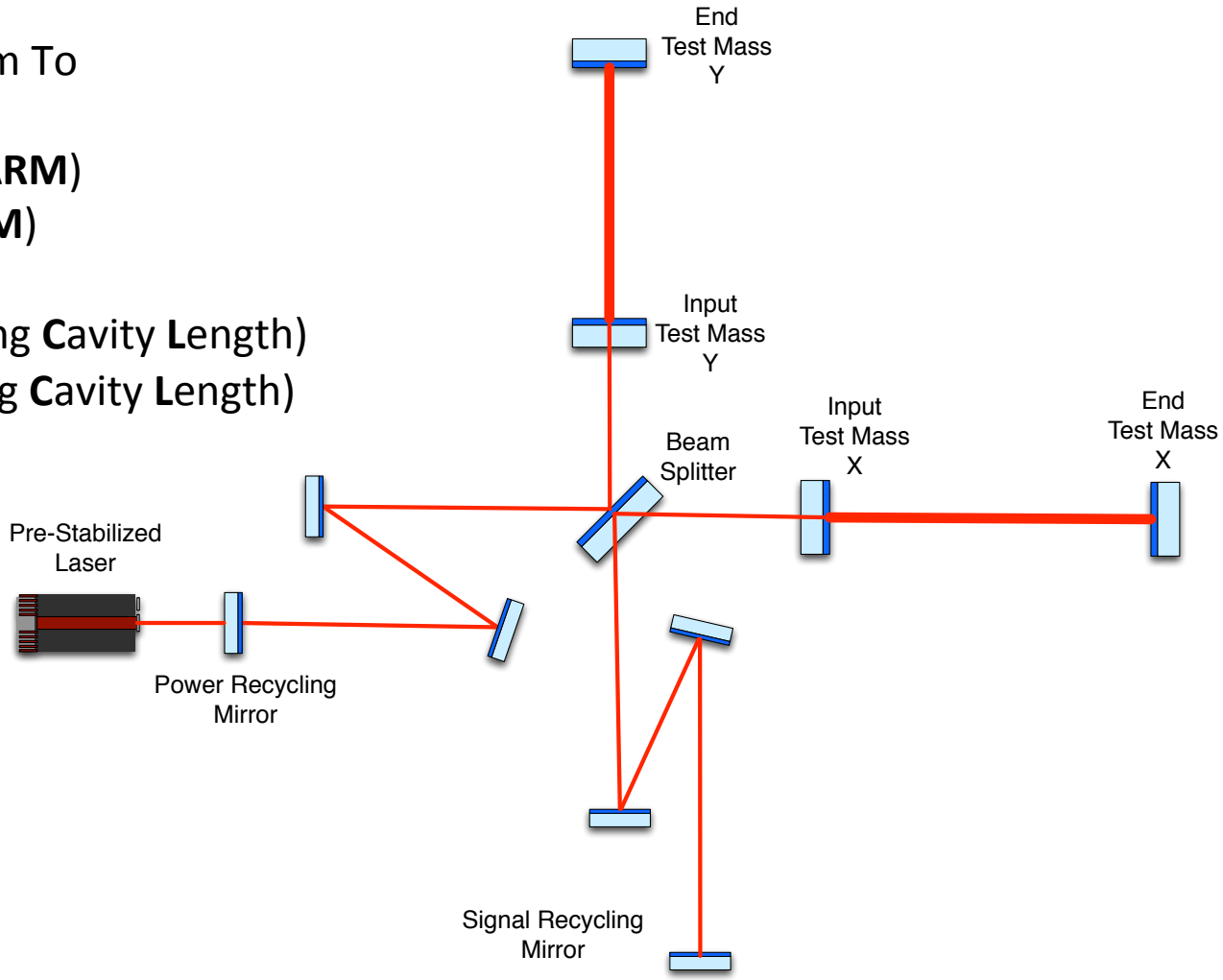
Lock Acquisition

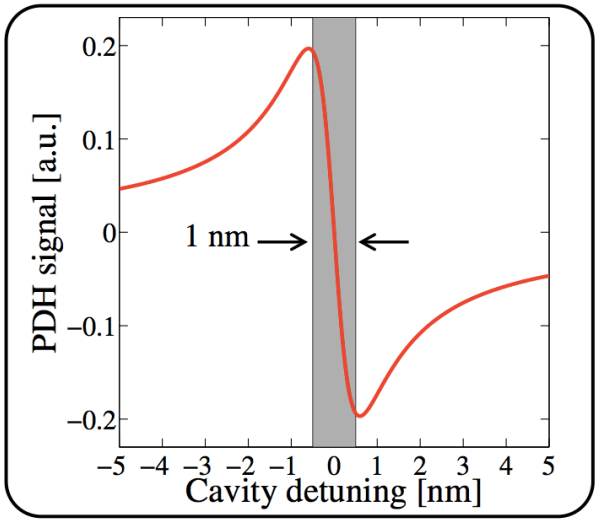
Five Degrees Of Freedom To Sense and Control:

- **DARM** (**D**ifferential **ARM**)
- **CARM** (**C**ommon **ARM**)
- **MICH** (**MICH**elson)
- **PRCL** (**P**ower **R**ecycling **C**avity **L**ength)
- **SRCL** (**S**ignal **R**ecycling **C**avity **L**ength)



Difficulties

- Narrow locking range
  - Cavity swinging too fast
  - Actuators too weak to catch lock



- Coupled Free Swinging Cavities
  - Sensing matrix in a state of flux

$$\begin{pmatrix} S_1 \\ S_2 \\ \bullet \\ \bullet \\ S_N \end{pmatrix} = \left(\text{Dynamic Sensing Matrix} \right) \begin{pmatrix} \text{DARM} \\ \text{CARM} \\ \text{MICH} \\ \text{PRCL} \\ \text{SRCL} \end{pmatrix}$$

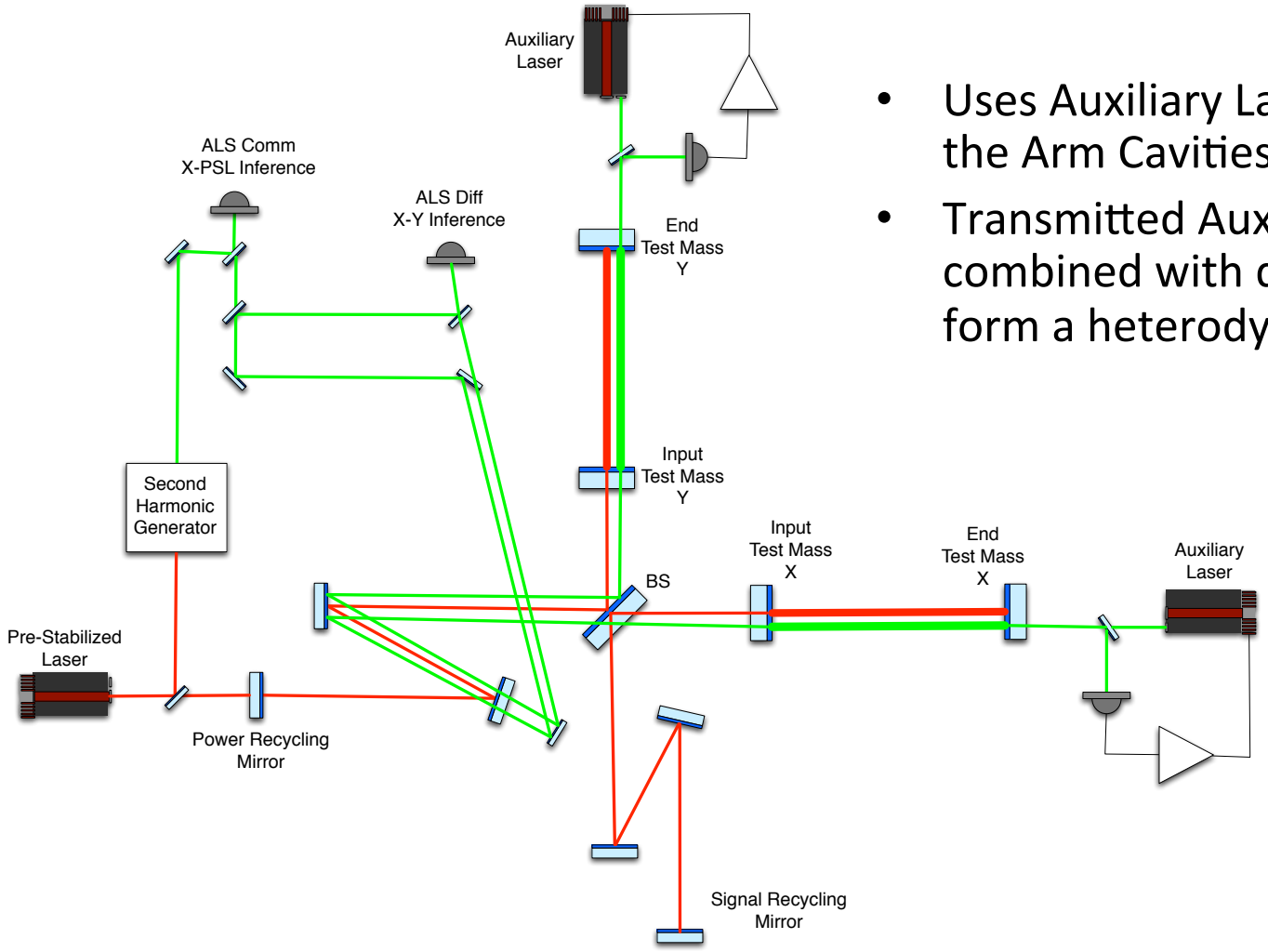
Lock Acquisition

- Simplify the problem by decoupling CARM and DARM, using independent sensors.

$$\begin{pmatrix} ALS_{DARM} \\ ALS_{CARM} \\ S_1 \\ S_2 \\ \bullet \\ S_N \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} \\ 0 & 0 & M_{21} & M_{22} & M_{23} \\ \bullet & \bullet & \bullet & \bullet & \bullet \\ 0 & 0 & M_{N1} & M_{N1} & M_{N3} \end{pmatrix} \begin{pmatrix} \mathrm{DARM} \\ \mathrm{CARM} \\ MICH \\ PRCL \\ SRCL \end{pmatrix}$$

- Introducing the Arm Length Stabilization system

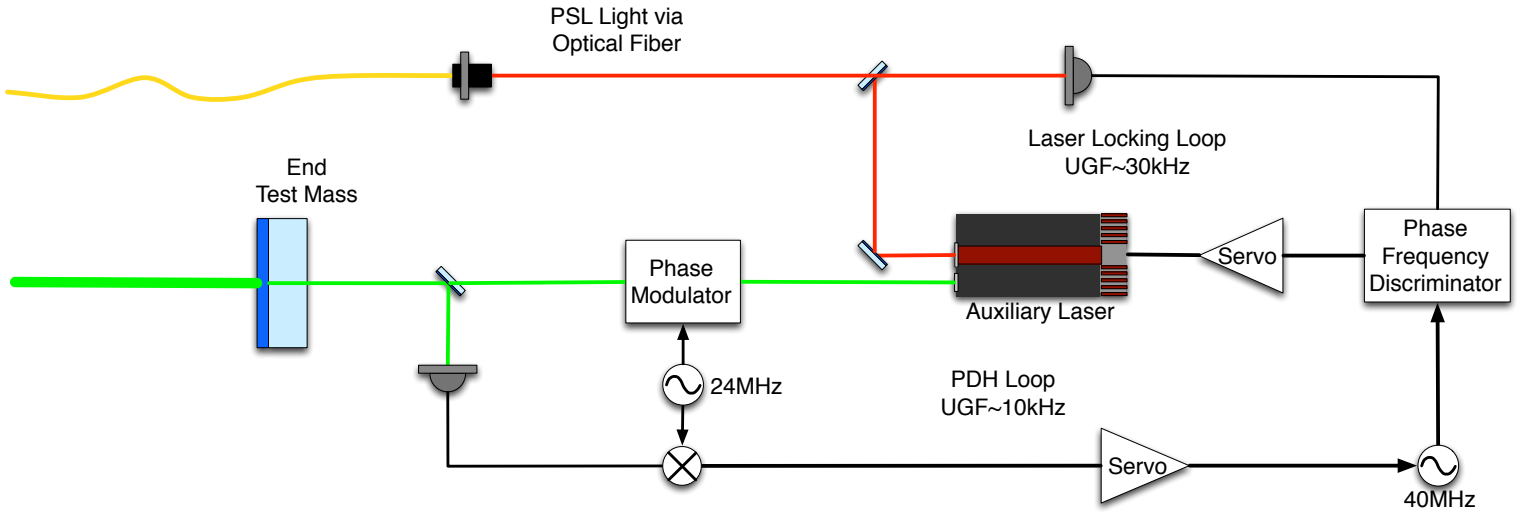
Arm Length Stabilization



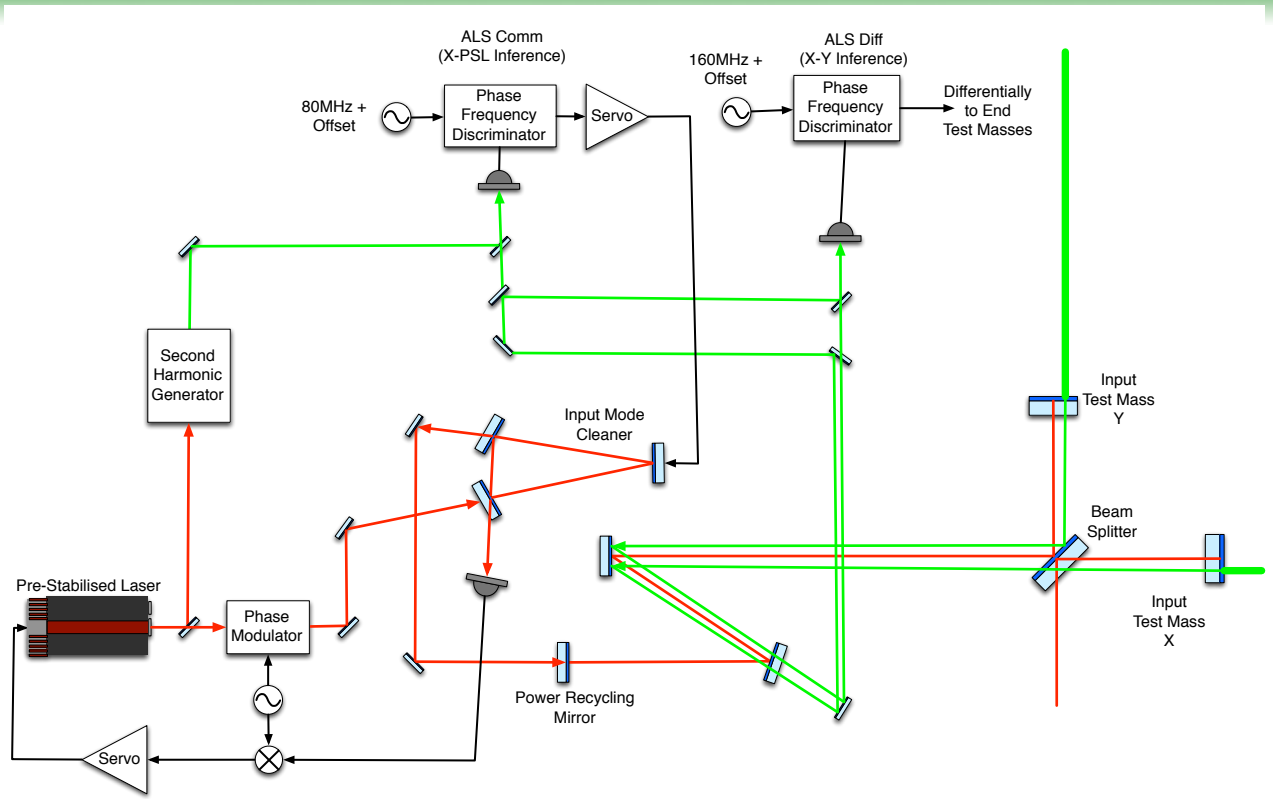
- Uses Auxiliary Lasers locked to the Arm Cavities
- Transmitted Aux light combined with doubled PSL to form a heterodyne signals

End Station

- Auxiliary Laser
  - Dual Wavelength (532nm and 1064nm)
  - First Locked to PSL
  - Locked to Arm Cavity, via PDH technique and fed back to 40MHz VCO



ALS - Corner Station

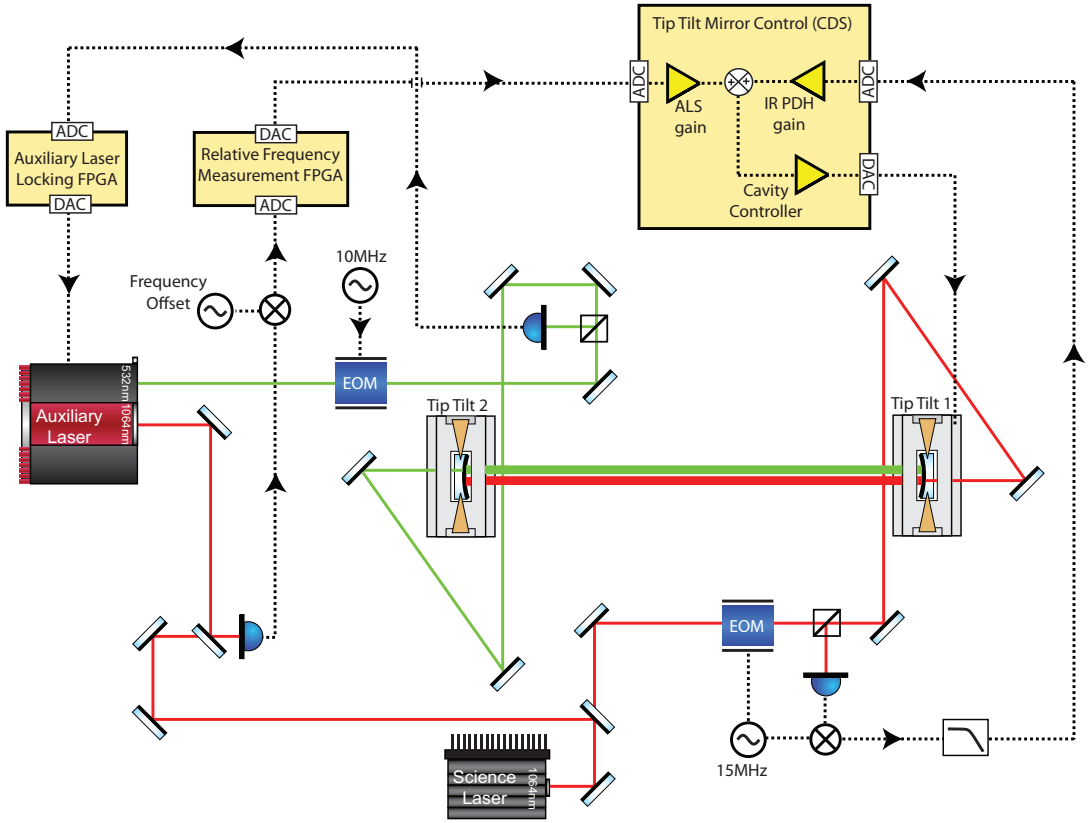


- ALS Comm
  - fed back to PSL frequency (via IMC)
  - Offset injected into loop for tuning of resonance
- ALS Diff
  - fed back differentially to ETMs

Prototype Experiments

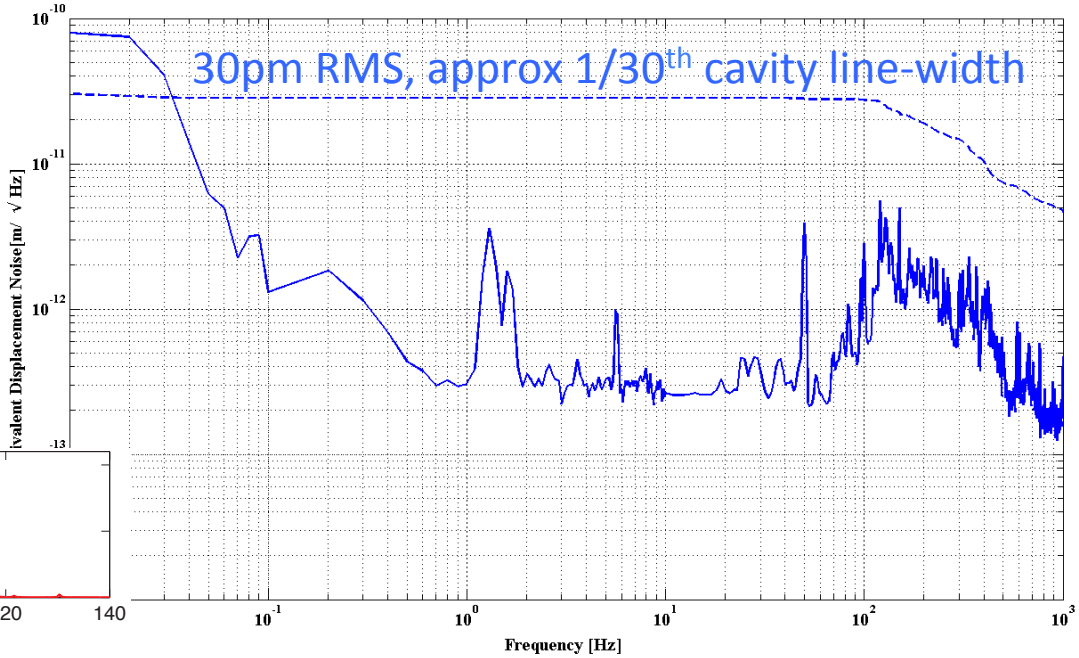
- Couple of experiments to test out ALS technique on single cavity:
  - ANU Benchtop Experiment ([1] Mullavey et. Al)
  - Caltech 40m Experiment ([2] Izumi et. al)

ANU Benchtop Experiment

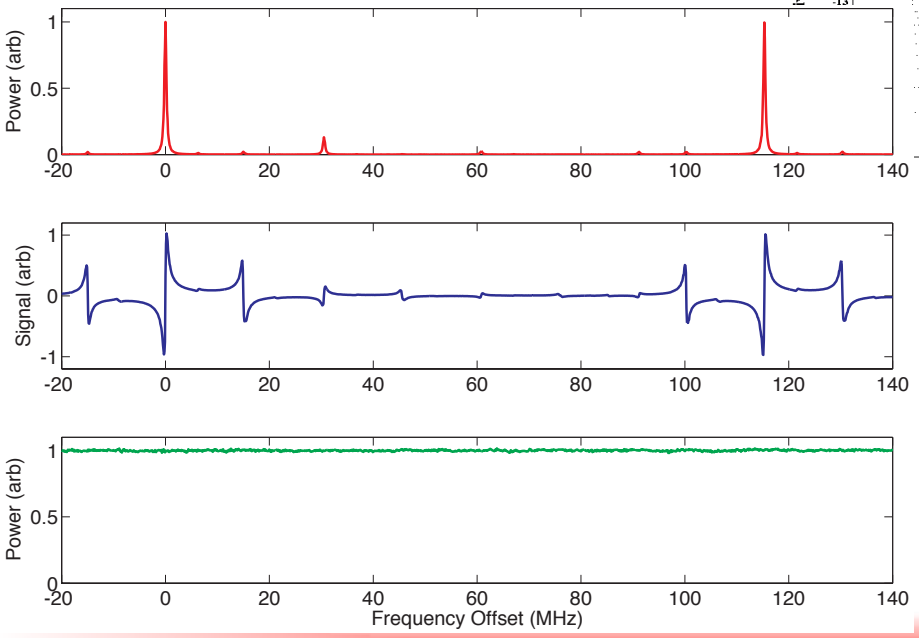


- 1.3m cavity
- Suspended mirrors
- Beatnote from 1064nm, not 532nm
- Feedback to arm length not Science Laser

ANU Bench-top Results

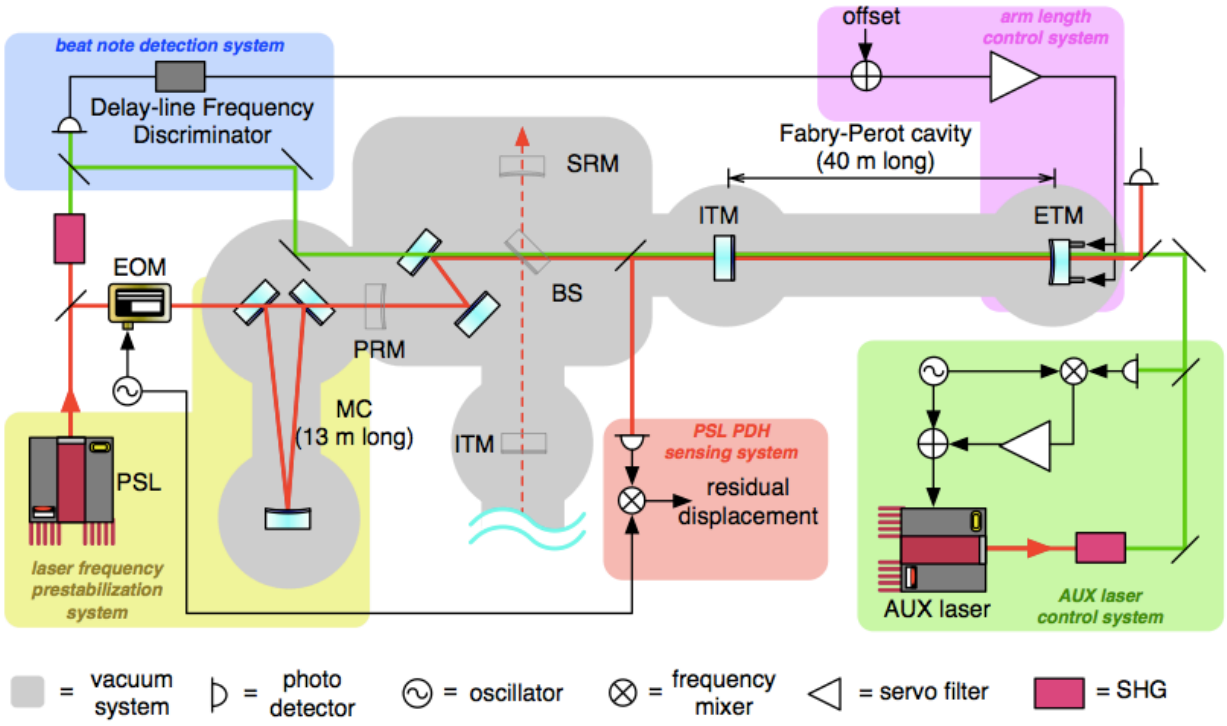


Tuneable over full free spectral range



Mullavey et al

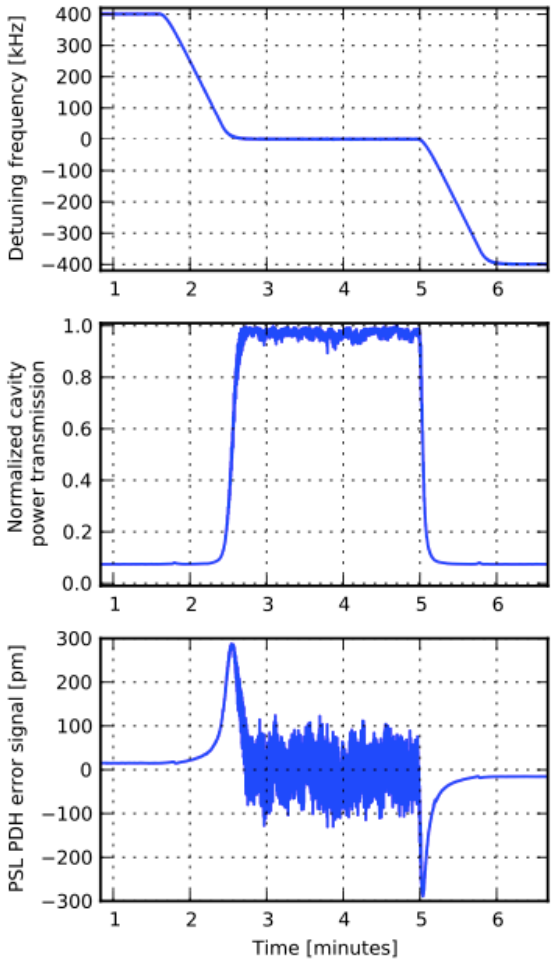
Caltech 40m Experiment

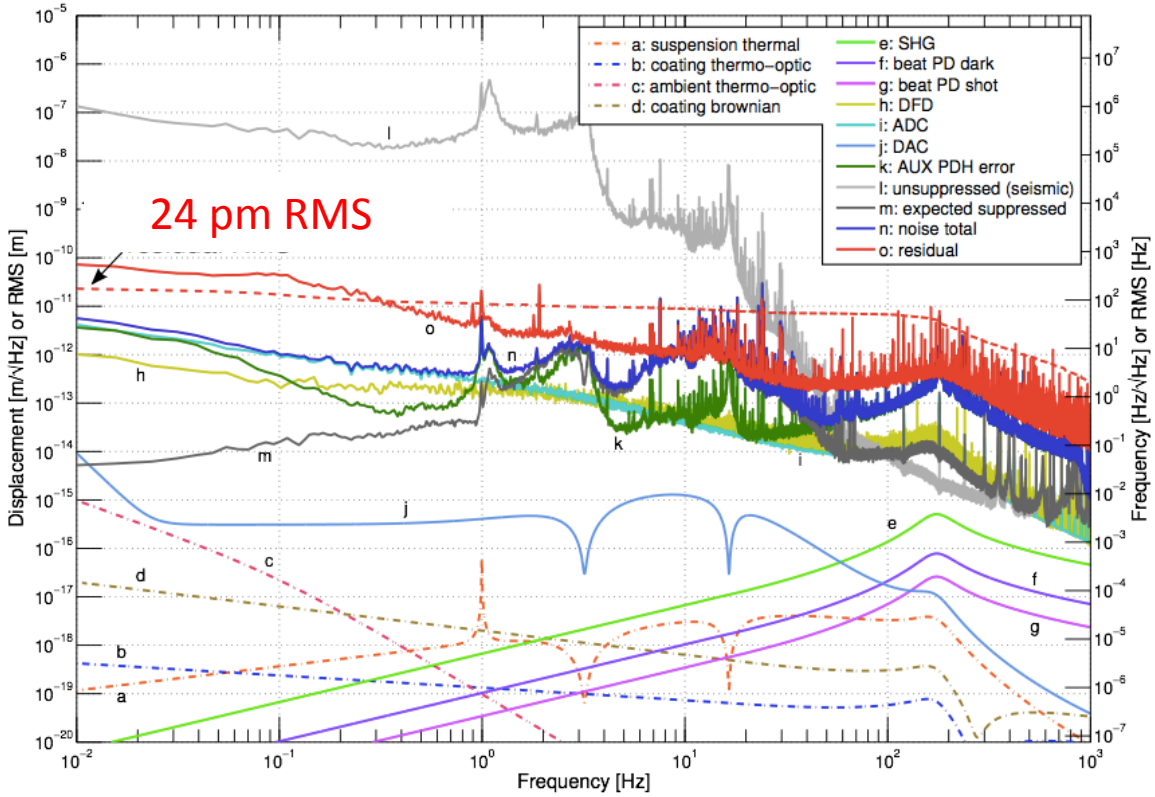


- 40m cavity
- Beatnote from 532nm
- Feedback to arm length

Caltech 40m Results

Tuning On and Off Resonance





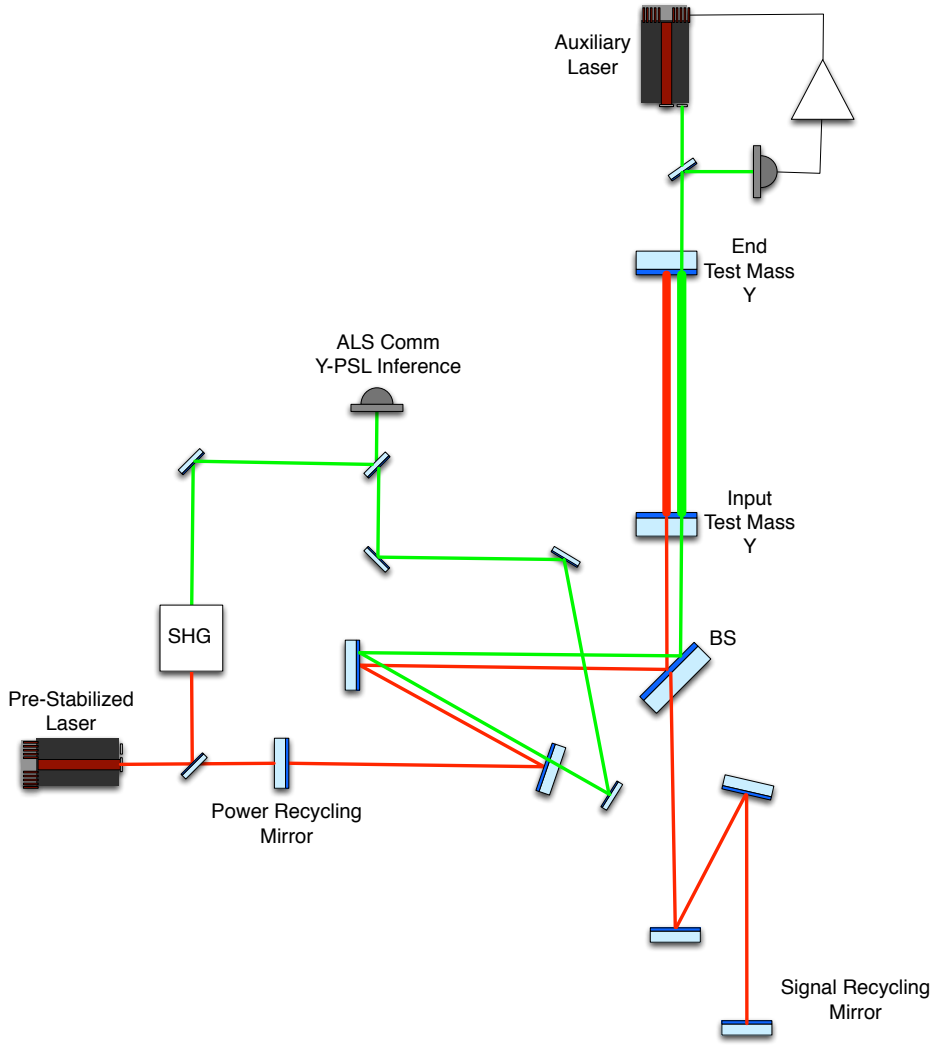
24pm RMS Izumi et. al.

Progress at the Sites

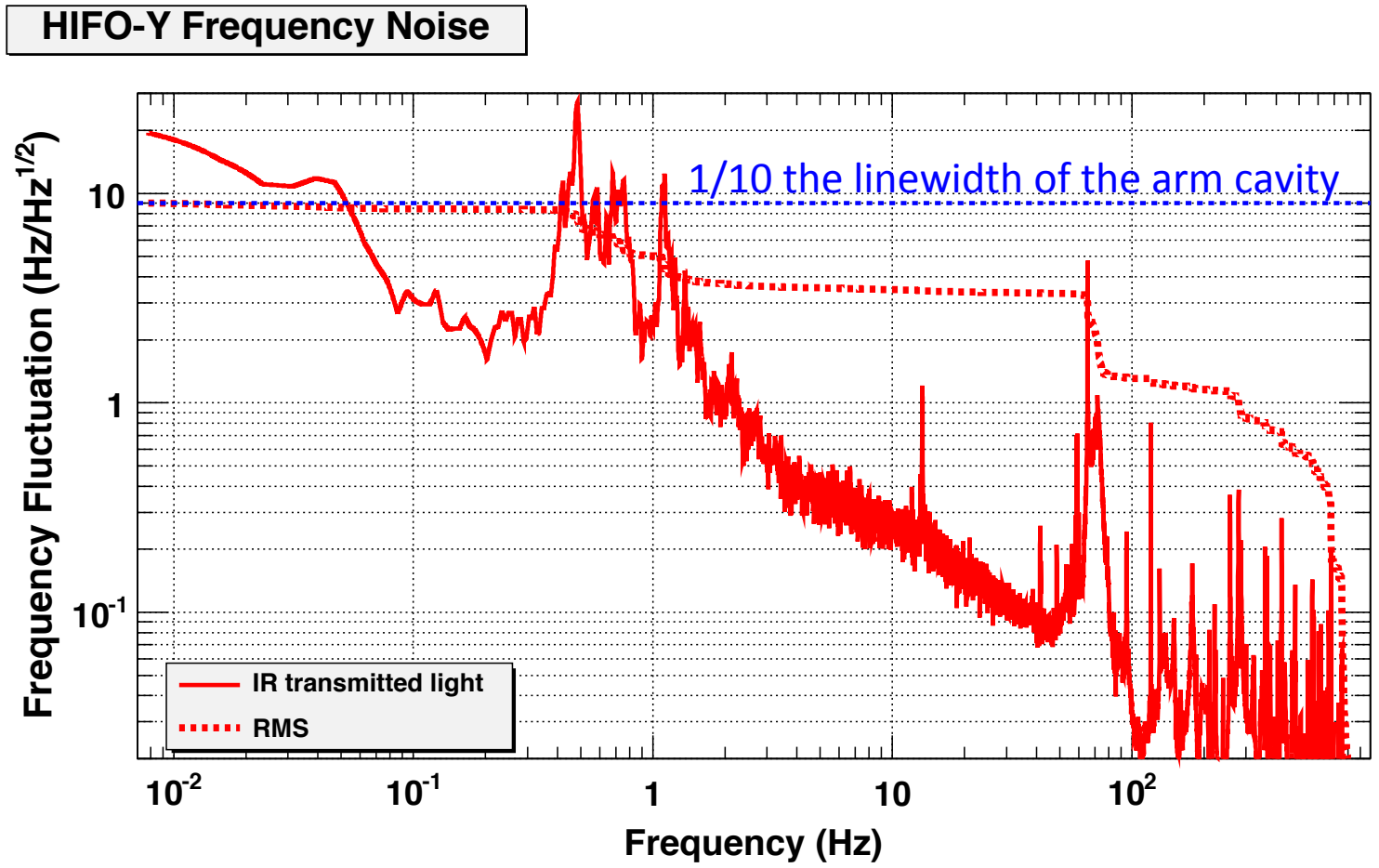
- Hanford
  - Y station ALS installed and commissioned (One Arm Test)
  - Half Interferometer (HIFO) test, i.e. effectively ALS-Comm loop
- Livingston
  - Basically nothing yet (waiting for an arm)

Hanford HIFO test

- Beat signal between Y-ARM and doubled PSL
- Using actual LIGO ALS system: electronics, etc.
- Feeding back to PSL (via IMC)



HIFO Residual Noise



Future

- Hanford
  - Continue Noise Hunting, < CARM linewidth (100 times smaller than Arm Linewidth)
  - HIFO X (soon)
  - Full IFO (May 2014)
- Livingston
  - HIFO X (October 2013)
  - Full IFO (February 2014)

References

[1] Mullavey et. al, Optics Express, Vol 20, Issue 1, pp 81-89 (2012)

[2] Izumi et. al, JOSA A, Vol. 29, Issue 10, pp. 2092-2103 (2012)

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