LIGO Photon Calibrators

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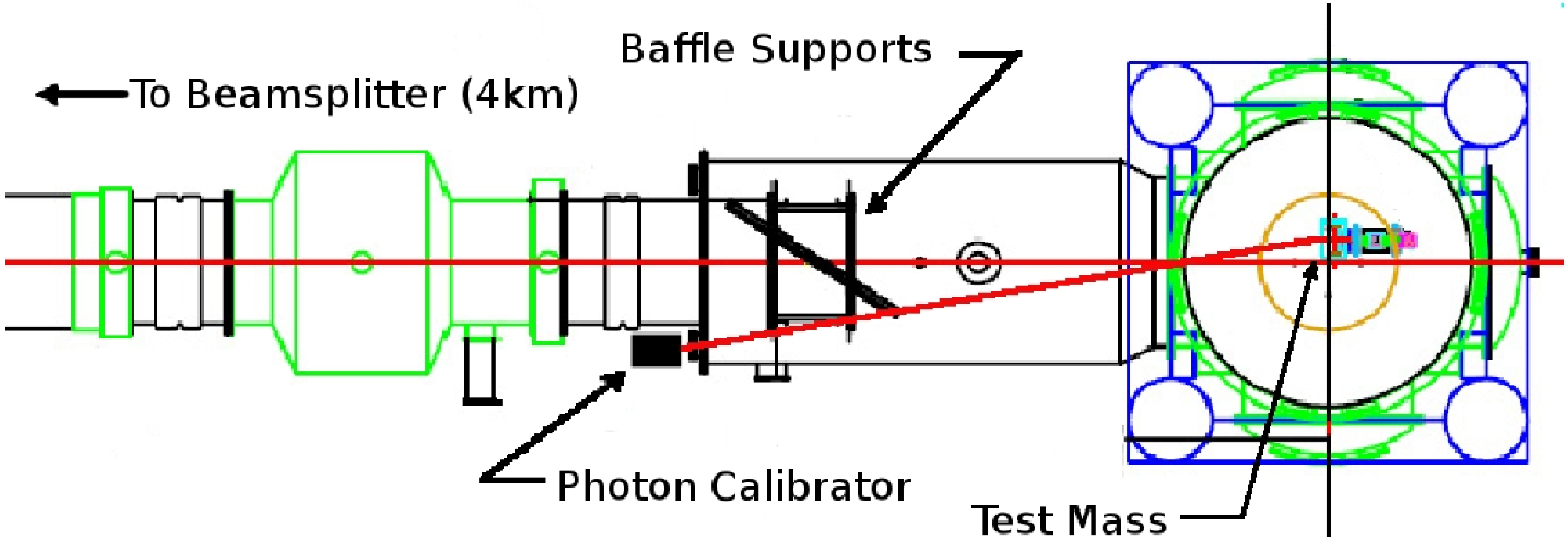
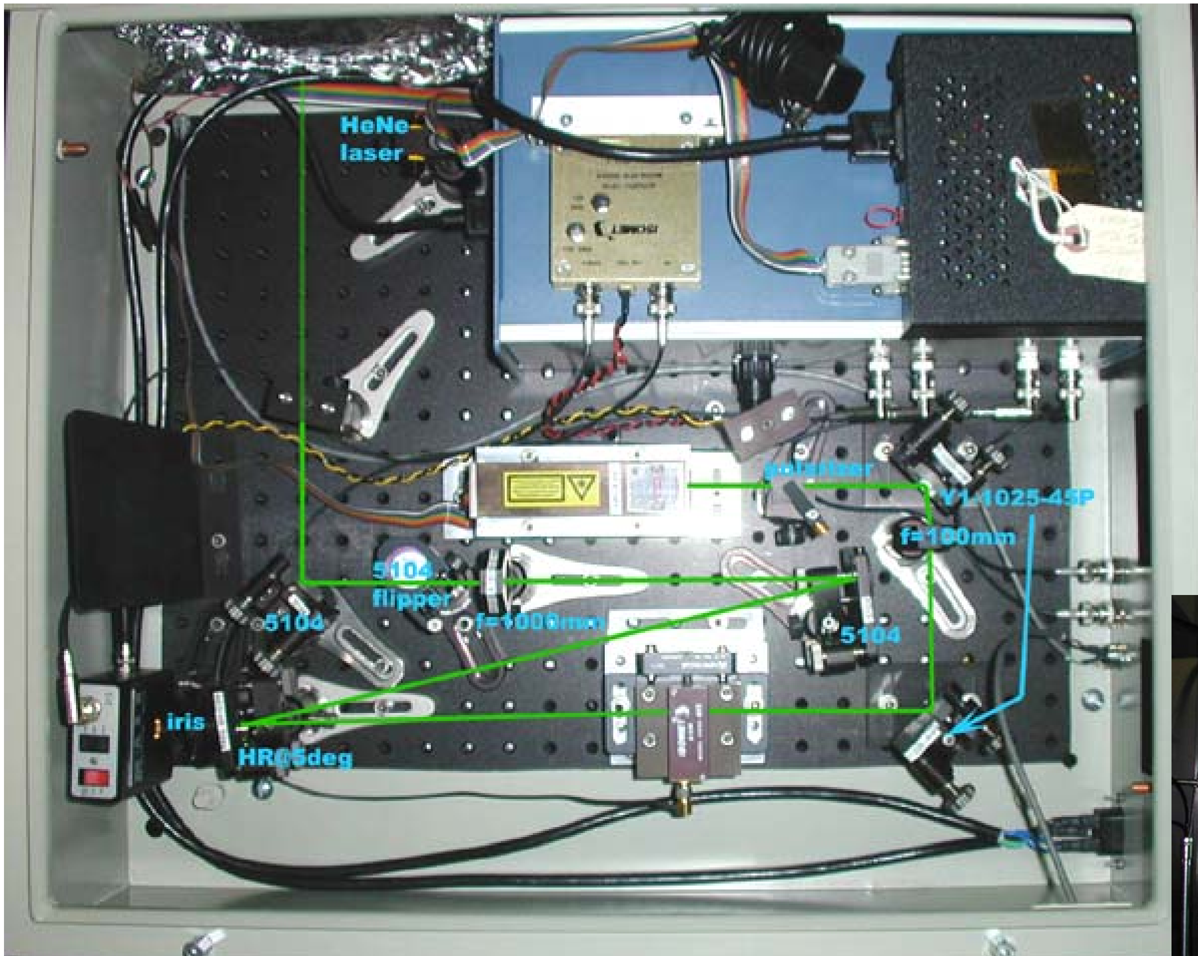
LIGO-G060666-00-W

Configuration

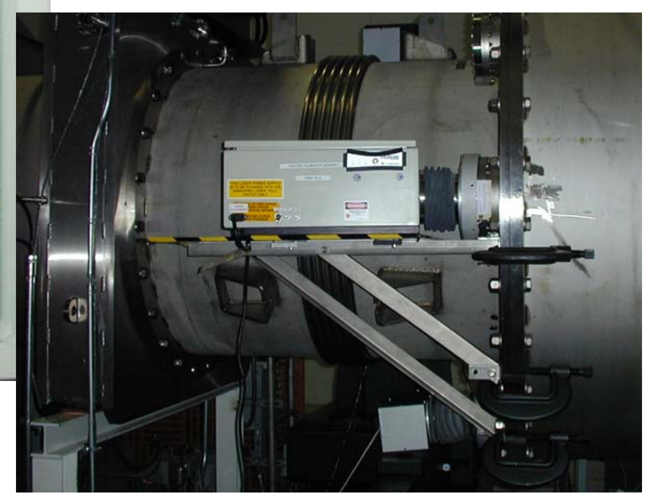


- Pcal beams incident on ETMs from HR side (p-pol)
- Incidence angle 9.1 deg.
- Reflected beam dumps on chamber wall
- Except for H1, Pcal beams can be centered on ETMs
  - » Baffle supports occlude TM centers on H1

Hardware



- 1047 nm diode laser from Crystal systems
- Maximum output power ~ 500 mW
- Use AOM diffracted beam
- Modulation depth ~80%
- PD inside box monitors output power
- PD calibrated using thermal power meter

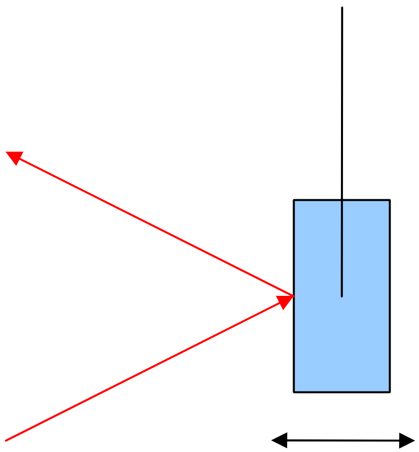


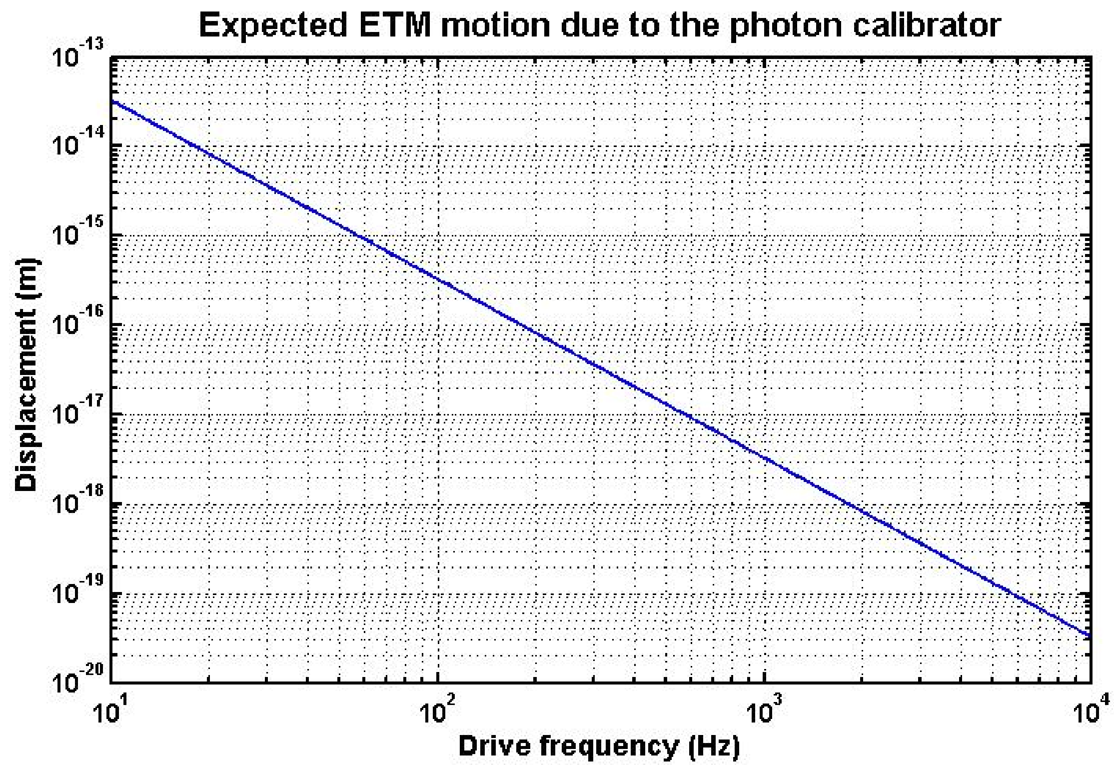
Expected motion

$$x_0(\omega) \simeq \frac{-2P_0\cos(\theta)}{Mc\omega^2}\left(1+\frac{bMa}{I}\right)$$

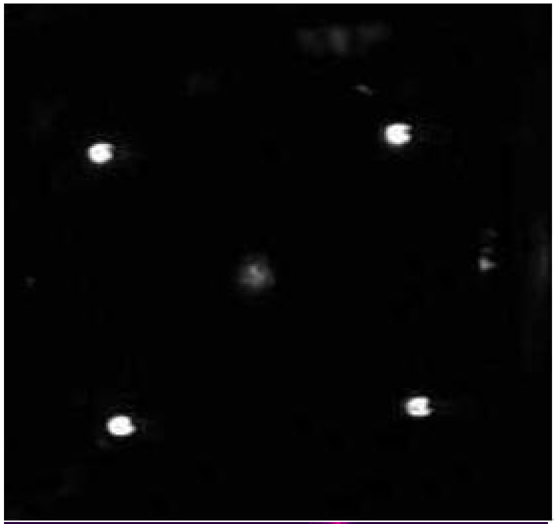
b is the ifo. beam offset from center

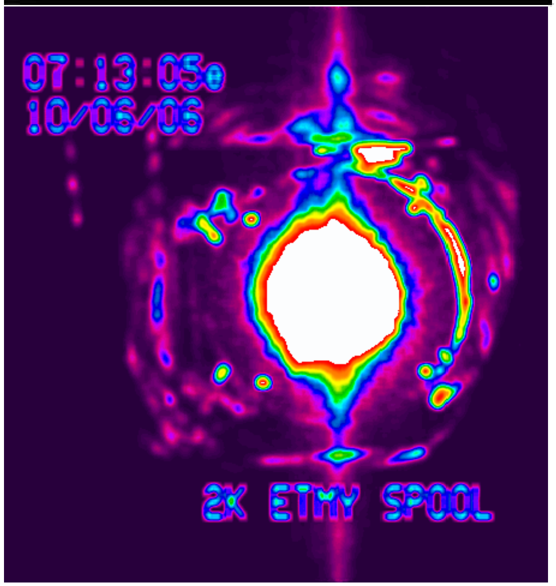
a is the photon calibrator beam offset from center

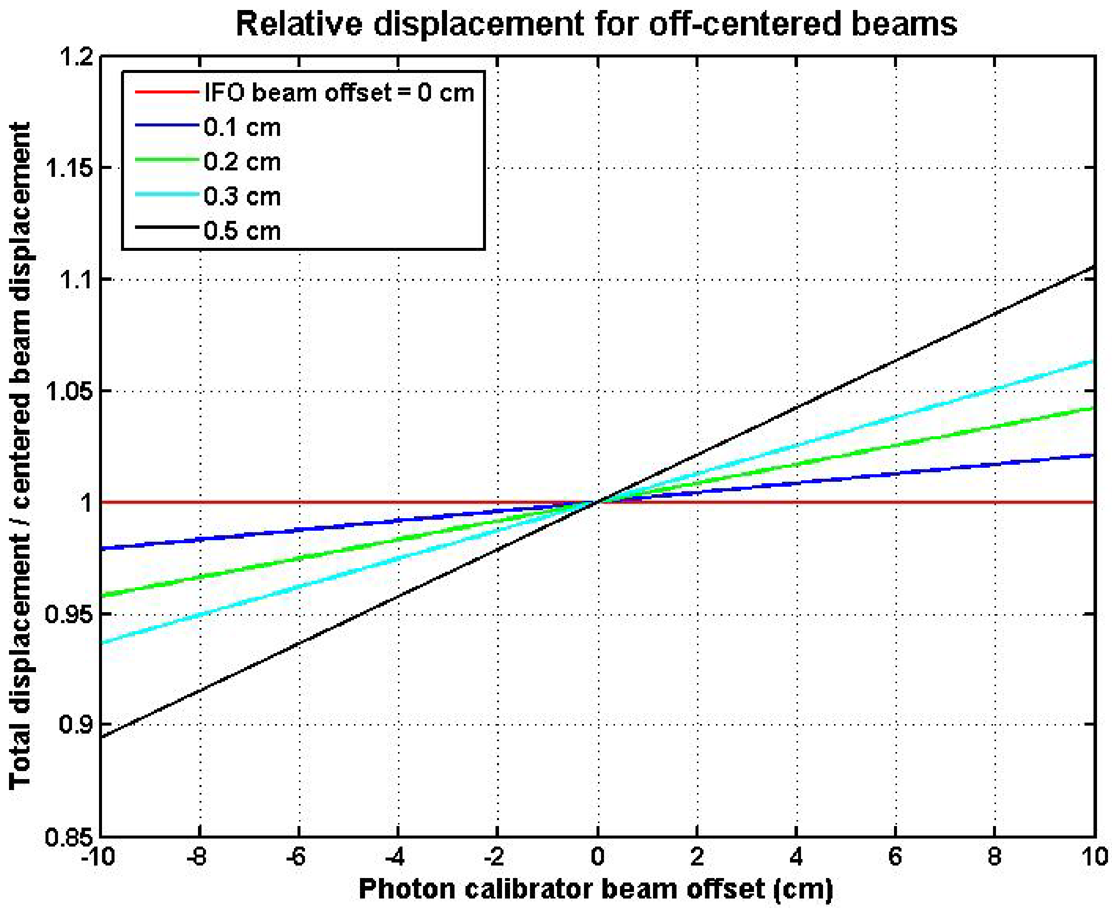




Correction for beam offsets from center

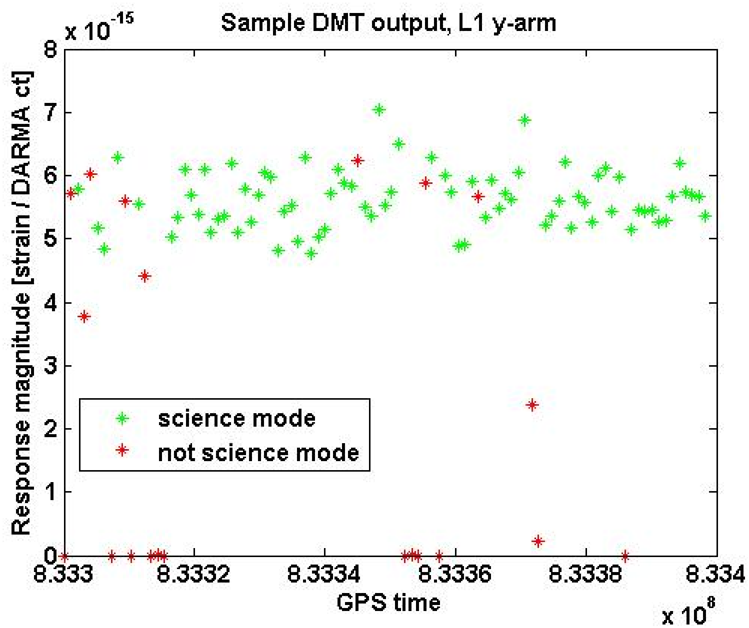


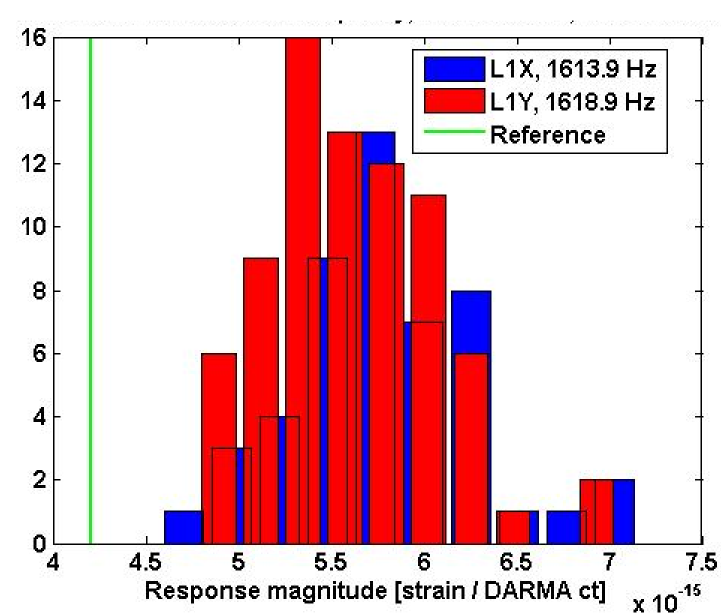




Standard configuration during S5

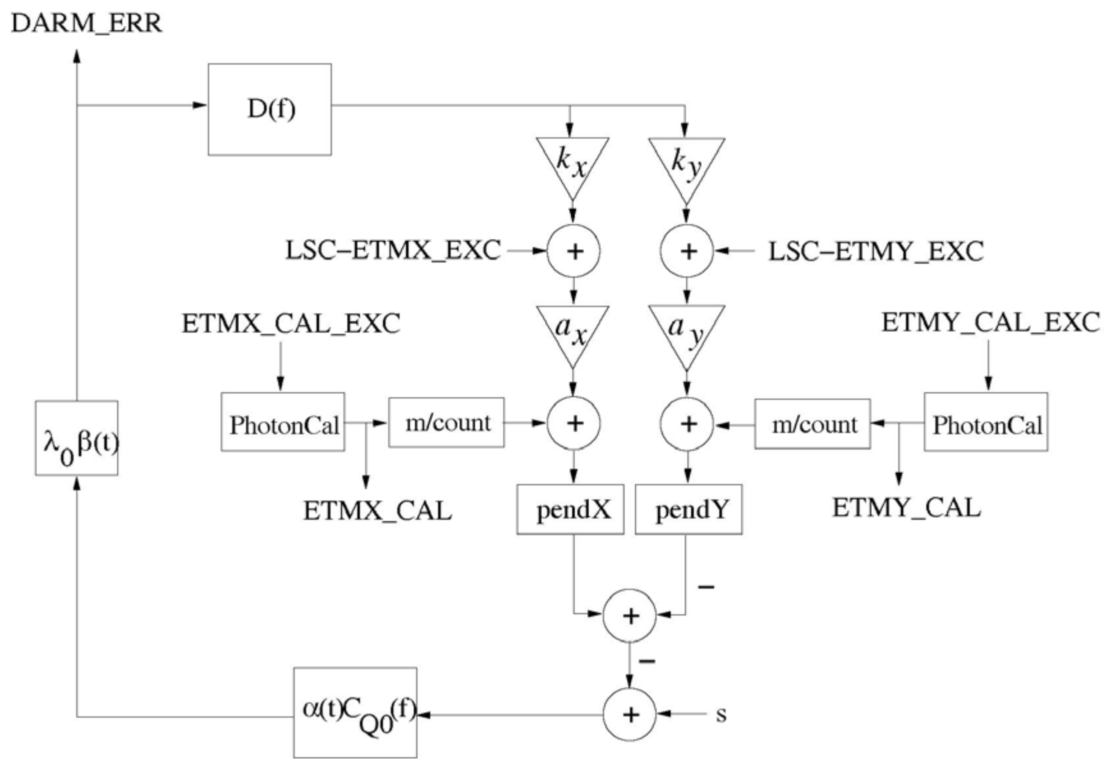
- Photon calibrators installed on all end test masses
- Only operating on one ETM per ifo. at any time, switching each month
- Operating frequencies near 1600 Hz (1609.7, 1626.7, 1622.9, 1605.7)
  - » High enough to limit harmonics below 2 kHz; low enough for reasonable integration times (~1000 sec.)
- DMT monitor measures amp. of lines in DARM_ERR and Pcal PD spectra





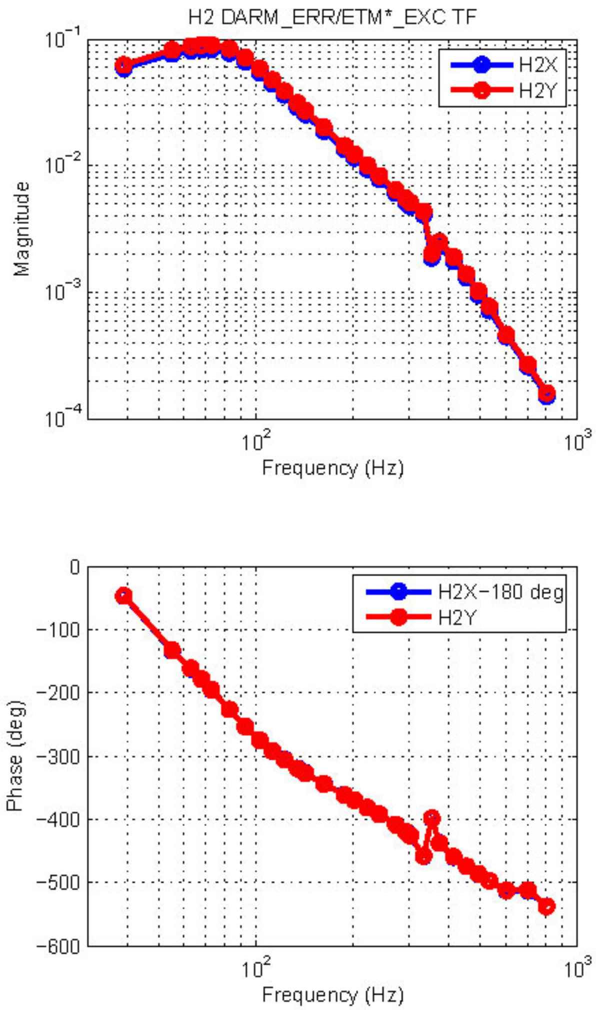
Comparison with "official" calibration

- Measure Pcal to DARM_ERR TF
- Measure ETM coil to DARM_ERR TF
- Ratio of TFs gives calibration of ETM drive via calculated ETM motion induced by Pcal
- Measurements performed almost simultaneously (staggered by one or two frequency points)
- Ratio gives the actuation "DC gain" based on the Pcal expected displacement
- Ratio of this number to the "official" DC gain gives the Pcal/Official cal factor

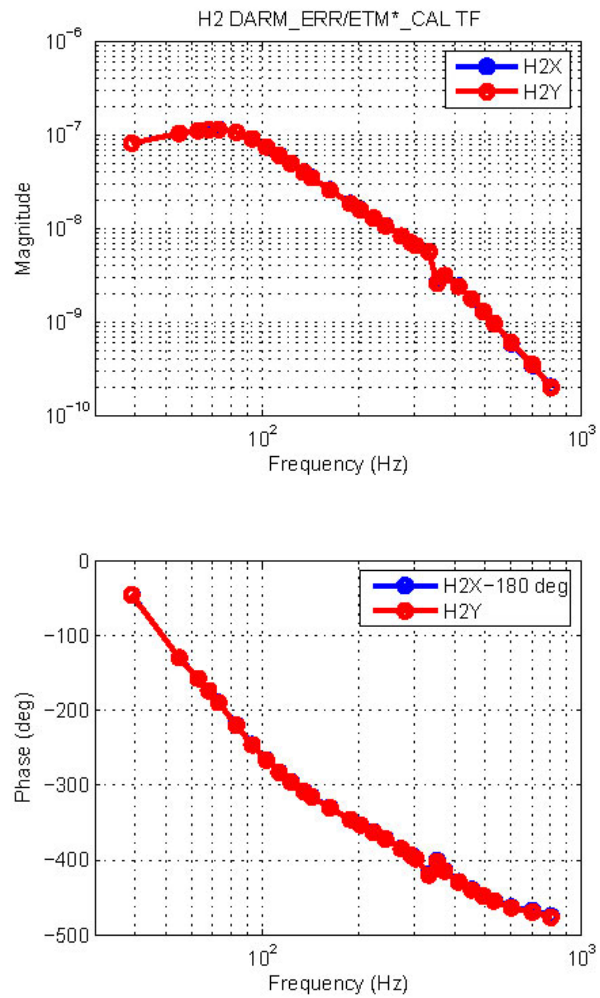


Transfer functions

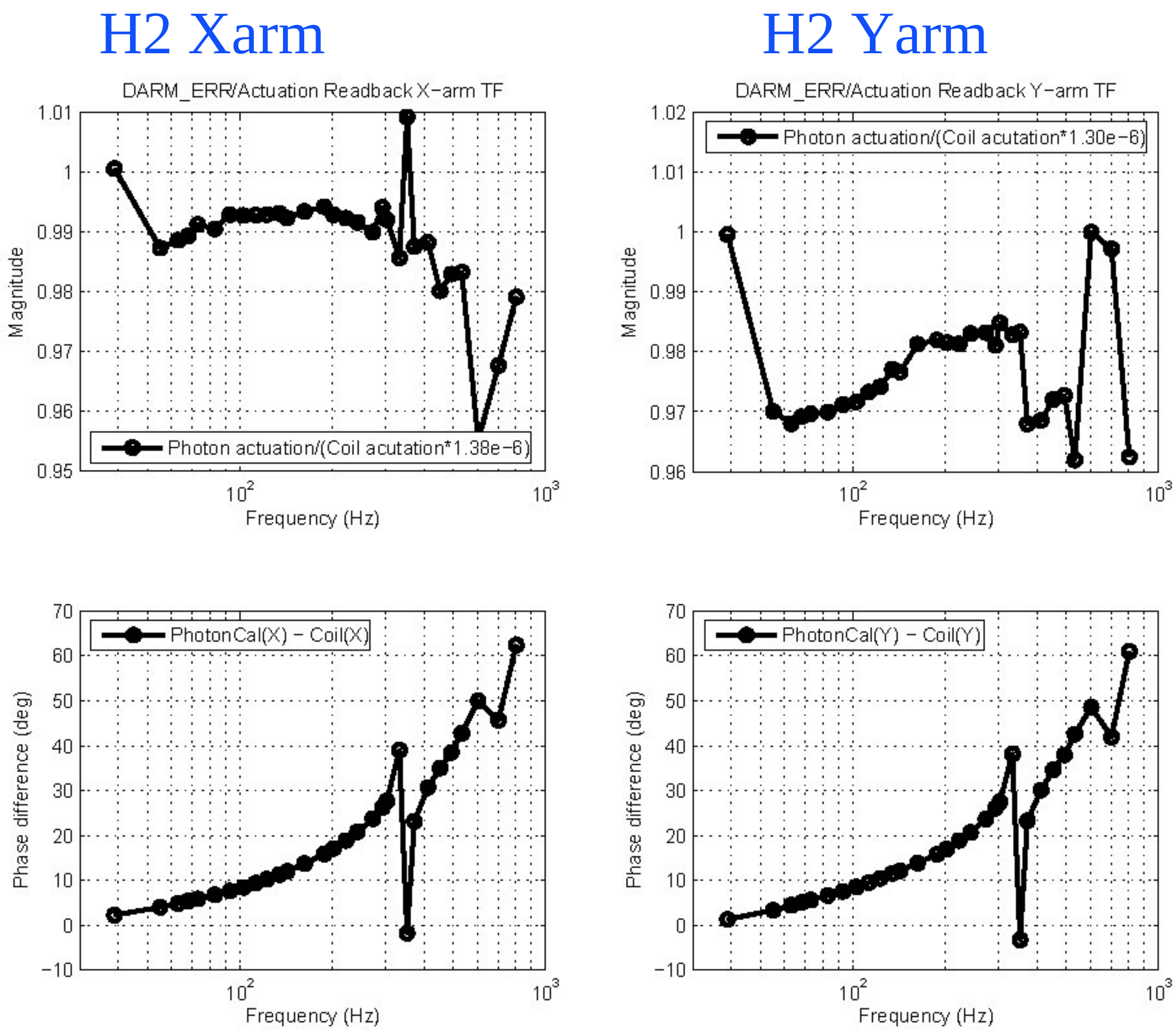
Coils



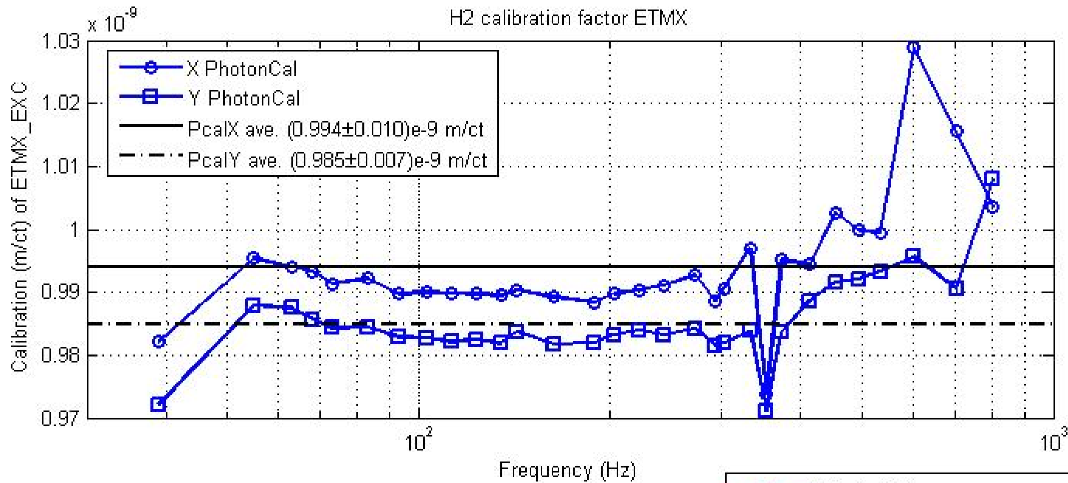
Pcals



TF ratios (normalized to first data point)

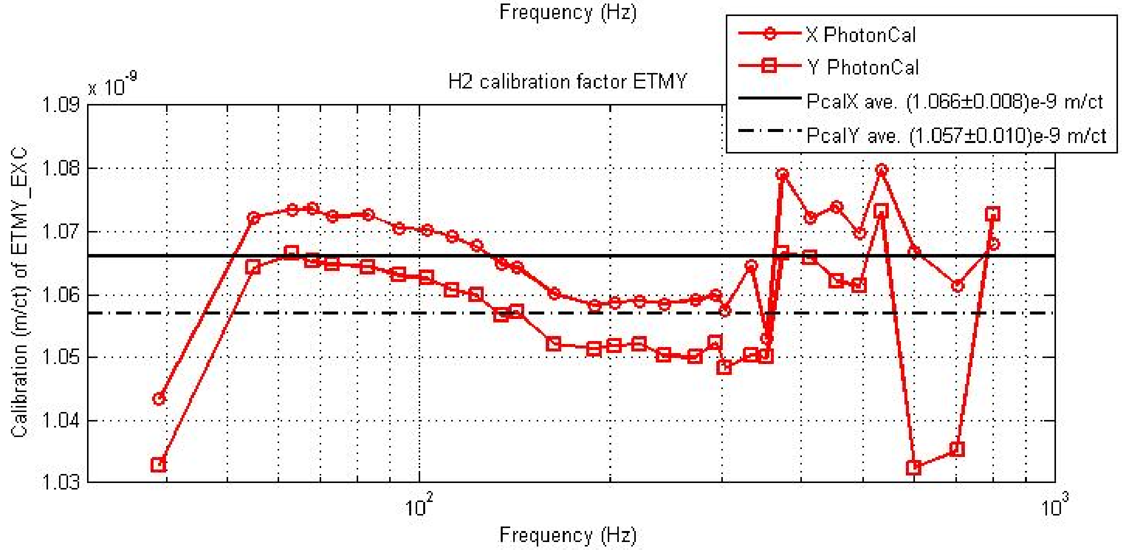


H2 ETM drives calibrated with Pcals



Official cal: 0.860e-9 m/ct

Photon cal: 0.900e-9 m/ct



Official cal: 0.896e-9 m/ct

Photon cal: 1.062e-9 m/ct

Results for H1 and H2

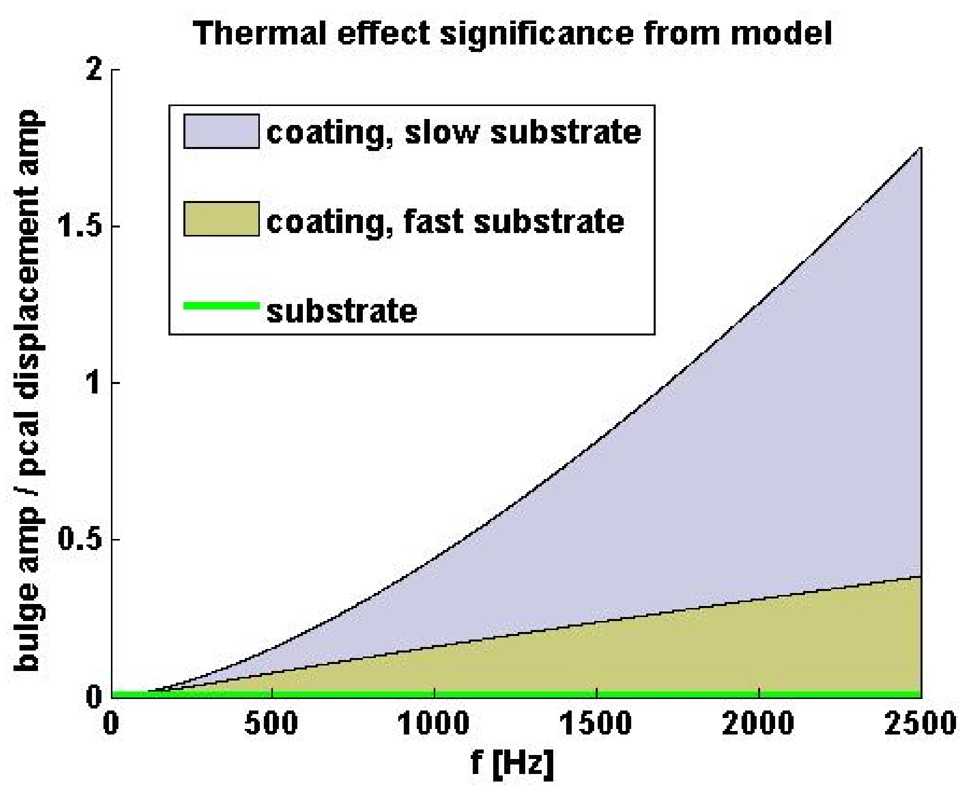
Optic	Calibrator	Average Photon Calibration	Ratio to Off. Cal.
H1X	H1Y PhotonCal	$0.963 \pm 0.013 \times 10^{-9}$ m/ct	1.186 ± 0.016
H1Y	H1Y PhotonCal	$0.982 \pm 0.017 \times 10^{-9}$ m/ct	1.182 ± 0.020
H2X	H2X PhotonCal	$0.994 \pm 0.010 \times 10^{-9}$ m/ct	1.156 ± 0.012
	H2Y PhotonCal	$0.985 \pm 0.007 \times 10^{-9}$ m/ct	1.145 ± 0.008
H2Y	H2X PhotonCal	$1.066 \pm 0.008 \times 10^{-9}$ m/ct	1.190 ± 0.009
	H2Y PhotonCal	$1.057 \pm 0.010 \times 10^{-9}$ m/ct	1.180 ± 0.011

- Consistent 15 - 20% ratio with Pcal predicting lower sensitivity than official calibration
- Two Pcals on same interferometer agree within ~1%
- At higher frequencies ratio grows – thermal or mechanical deformation?
- Two-beam or spot size variations planned to test these hypotheses.

Thermal Effects

- A. Bullington, P. Kalmus, D. Ottaway, M. Rakhmanov
- Substrate bulge modeled with formalism in Winkler et al. (1991)
  - model predicts substrate bulging to be negligible
- Coating bulge modeled with formalism in S. Rao's thesis
  - coating with slow substrate (e.g. fused silica)
  - coating with fast substrate (e.g. sapphire)

- effect from HR coating bulge not ruled out by model
  - grey range in plot due to uncertainty in coating params
  - plot shows effects if 180° phase relative to TM
- If phase not 180°, effect will be less or even contrary
- Experimental tests:
  - High frequency measurements
  - aim spot away from IFO beam



Pcal transmission efficiency test

- Pcal ports don't allow reflected spot to exit vacuum system
- On 10/10/06 pcal beam injected via optical lever port
- Power reflected from ETM plus window reflections account for all of incident power (within few percent)

- Still looking for source of 15-20% discrepancy – suspension cage recoil?