A Short Overview of Pcal Calibration (v2)

D. Tuyenbayev, S. Karki, S. Kandhasamy, T. Abbott, R. Savage
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The force applied to ETM due to photon radiation pressure, in N, is:

$$F_{\mathtt{ETM}} = \frac{2cos\theta}{c} \cdot P_{\mathtt{ETM}} = \alpha_{\mathtt{Tx}} \cdot \mathtt{Tx\_ct} = \alpha_{\mathtt{Rx}} \cdot \mathtt{Rx\_ct}$$

Force coefficients, $\alpha_{\mathtt{Tx}}$ and $\alpha_{\mathtt{Rx}}$ (in N/ct), are determined in two major steps:

- measuring *responsivities* of the Rx and Tx photodetectors in W/ct, $\eta_{\mathtt{Tx}}$ and $\eta_{\mathtt{Rx}}$.
- accounting for the *optical efficiency*, i.e. the losses between the input viewport and the output viewport.

Responsivities of the Rx and Tx photodetectors are determined by: *a*) calibrating Gold Standard photodetector assembly (GS) at NIST; *b*) WSn/GS response ratio measurement in LSB lab at LHO; *c*) end-station measurements with WSn.

WSn is used to measure optical efficiency, $e = \dfrac{P_{\mathtt{Rx}}}{P_{\mathtt{Tx}}}$; where $P_{\mathtt{Rx}}$ is power measured at the receiver module (output window), $P_{\mathtt{Tx}}$ is power measured at the transmitter module (input window). A mean value between these two quantities is taken for power on ETM, here the assumption is made that approximate power losses at the input and output viewports are the same. Then power on ETM can be expressed in terms of $P_{\mathtt{Rx}}$ or $P_{\mathtt{Tx}}$:

$$P_{\mathtt{ETM}} = \frac{P_{\mathtt{Tx}} + P_{\mathtt{Rx}}}{2} = \left(\frac{1+e}{2}\right) P_{\mathtt{Tx}} = \left(\frac{1+e}{2e}\right) P_{\mathtt{Rx}}$$

$\alpha_{\mathtt{Tx}}$ and $\alpha_{\mathtt{Rx}}$ are calculated by combining responsivities of the Rx and Tx photodetectors and the optical efficiency as shown below:

$$\alpha_{\mathtt{Tx}} = \frac{F_{\mathtt{ETM}}}{\mathtt{Tx\_ct}} = \left(\frac{1+e}{2}\right) \frac{2cos\theta}{c \cdot \eta_{\mathtt{Tx}}}$$
$$\alpha_{\mathtt{Rx}} = \frac{F_{\mathtt{ETM}}}{\mathtt{Rx\_ct}} = \left(\frac{1+e}{2e}\right) \frac{2cos\theta}{c \cdot \eta_{\mathtt{Rx}}}$$

Table 1. Force Factors (ref. [1])

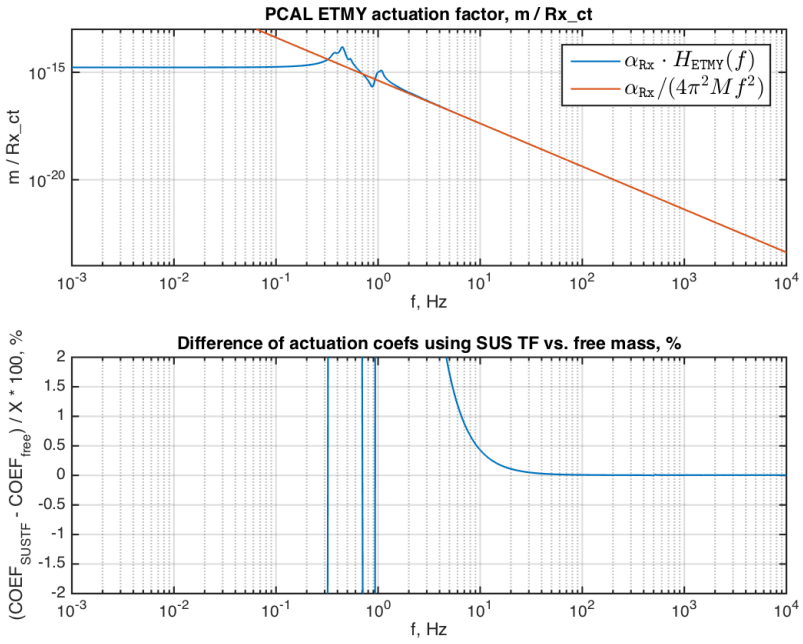
End Station	**Date**	$\boldsymbol{\alpha_{\mathtt{Tx}}}$ (N/ct)	$\boldsymbol{\alpha_{\mathtt{Rx}}}$ (N/ct)
LHOX	D20150520	8.0861×10^{-13}	6.4222×10^{-13}
LHOY	D20150522	9.2367×10^{-13}	6.4962×10^{-13}
LLOX	D20150521	1.0302×10^{-12}	6.5415×10^{-13}
LLOY	D20150521	9.7044×10^{-13}	6.4034×10^{-13}

To determine the *displacement of the ETM* induced by Pcal beams at a given frequency, $X(f)$, we use the ETM suspension transfer function, $H_{\mathtt{ETM}}(f)$ given in m/N.

$$X(f) = \alpha_{\mathtt{Rx}} \cdot |H_{\mathtt{ETM}}(f)| \cdot |\widehat{\mathtt{Rx\_ct}}(f)|$$

where $|\widehat{\mathtt{Rx\_ct}}(f)|$ is the amplitude of the Pcal excitation readout in RxPD at f Hz.

At the high frequencies the displacement of the ETM can be approximated by a displacement of a free mass, $X_{free}(f) \approx (\alpha \cdot |\widehat{\texttt{Rx\_ct}}(f)|)/(4\pi^2 M f^2)$. For comparison, the approximated, free mass actuation and the calculated actuation functions for RxPD readings using ETMY suspension transfer function (ref. [2]) is plotted on the figure below.



The calibration group prefers to state actuator strength coefficients in m/cts at 1 mHz. Using $H_{\texttt{ETM}}(f)$ measured on [date] and evaluated at 1 mHz, the Pcal strength coefficients are given in Table 2.

Table 2. Actuation Coefficients (at 1mHz)

End Station	m/`Tx_ct` at 1mHz	m/`Rx_ct` at 1mHz
LHOX	N / A	N / A
LHOY	2.4015×10^{-15}	1.689×10^{-15}
LLOX	N / A	N / A
LLOY	N / A	N / A

Data sources

1. End station calibrations on May 20 - 22, 2015 listed in
   `"aligocalibration/trunk/Projects/PhotonCalibrator/report/full_report/full_report_output.pdf" (@ r623)`.

2. $H_{\texttt{ETM}}(f)$ - LHO SUS ETMY model, the output of the script
   `aligocalibration/trunk/Runs/PreER7/H1/Scripts/PcalETMs/2015-06-06_SUS_ETMY_f_mpN/loadSaveSUSL3_f_mpN.m (@ r725)`
   which is the same as taking the vector `par.A.plant(1,4).f_mpN`) that was generated in
   `"H1DARMOLGTFmodel_ER7(eval('H1DARMparams_1117124229'))"`.