

LHO TCS commissioning for O3

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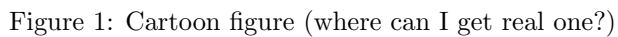
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Abstract

The primary role of the currently existing thermal compensation system (TCS) is to probe (via Hartmann wavefront sensors (HWS)) and compensate for (via CO2 lasers and ring heaters) thermo-optic distortions of low spatial frequency that can have potentially adverse affects on mirror geometry which in turn affect interferometer contrast, cavity mode mismatch, reduced cavity buildups, etc. especially when operating at high power. The primary probing is done with Hartmann wavefront sensors placed at each test mass of the dual recycled Fabry-Perot Michelson interferometer and in preparation for O3 we discovered other useful metrics while making final adjustments to TCS actuators. Actuation by negative lensing is performed by a series of installed ring heaters on each of the test masses that form the Fabry Perot cavities while actuation by positive lensing is induced by firing a CO2 laser onto a compensation plate immediately prior to the carrier entering the arm cavity. Relevant measurements and techniques that directly apply to the optimal operation of TCS at the aLIGO Hanford observatory for O3 are detailed. Also discussed are the measurements and effects of point absorbers on input/end test masses. As suggested by models discussed, some of the modeled affects are: higher order mode mismatch from the power recycling cavity to the Y-arm cavity, reduced buildup of RF sidebands in the recycling cavities, and light scatter into higher order modes in the LIGO arm cavities. Keeping the interferometer locked above 30 W input power with the

1 Thermal compensation schema for O3



2.1 Differential Lens tuning

When handling and preparing your interferometer in a cold state you want to make sure you are minimizing your contrast. We define contrast as the following:

$$CD = \frac{|E_{ITMX} - E_{ITMY}|^2}{|E_{ITMX} + E_{ITMY}|^2}$$

Where E_{ITMX} and E_{ITMY} are the fields coming from ITMX and ITMY respectively.

We measured this early to be ? With the current TCS settings we measure it to be:

2.1.2 Locked DRFPMI

Ideally, at lower arm power you would expect nearly the same mode shapes impinging from the arms onto the beamsplitter after the carrier has traveled through the arms. This is not the case with the finite absorption of the ITMs (bulk and surface) and ETMs (surface) which is guaranteed to introduce contrast with different absorption. Can tune your DARM offset so that you can understand what your contrast is in this configuration?

2.2 Absorption estimates

ITMX	ETMX*	ITMY*	ETMY
$.344 \cdot 10^{-6}$	$.4 \cdot 10^{-6}$	$.804 \cdot 10^{-6}$	$.4 \cdot 10^{-6}$

- The arm gain
 - Use result from [Craig's SRCL dither measurement](#)
- Follow up with notes (uncertainties, potential point absorber issues.. maybe mention later)
- Dan's idea of quantifying the absorption from integrating the OPD. Can we convert into an absorbed power?

2.3 Mode-matching

2.4 RCs to arms

- Monitoring PRG and arm cavity buildups

2.4.1 Arms to OMC

- Testing SR3 heating
 - [alog 46540](#)
 - NEEDS ANOTHER TEST

2.5 LHO locking with TCS

- TCS actuation from 2 W to 50 W (what the models suggest), TVo model

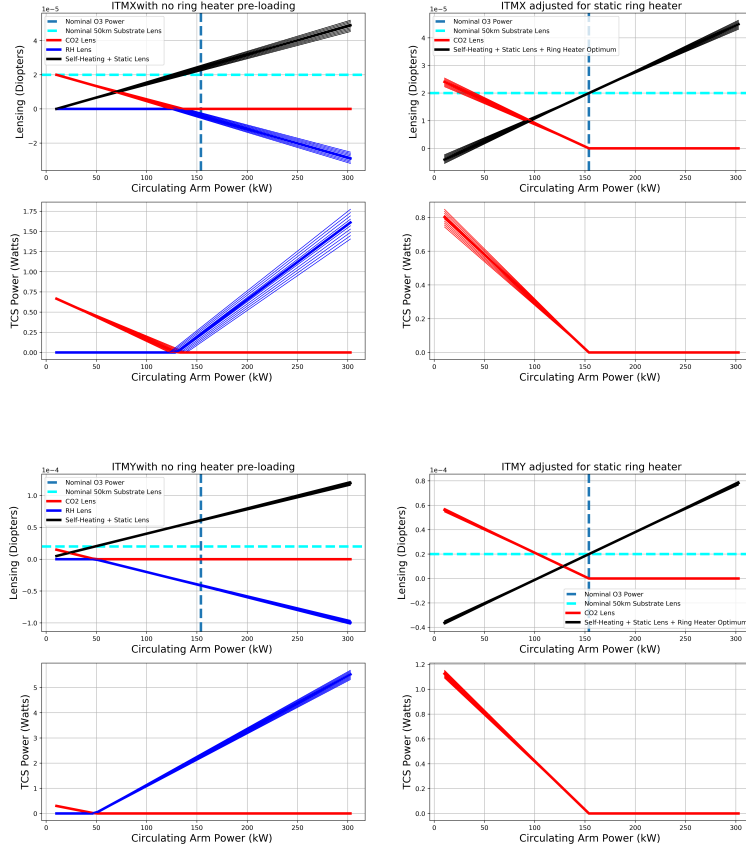


Figure 2: These plots assume that there are no high frequency spatial defects. PRG = 45, Arm gain = 228. Absorbed power for each test mass (in measurements) section. PC: Thomas Vo

- We separate TCS into two different states in the locking scheme while we attempt to achieve high power (assume we mean $P_{in} > 2W$): Preloading and High power operation.
- Preloading

The principle behind this state is to replicate the positive lens thermal distortions induced by a high power buildup within the interferometer

arms and to properly compensate with the ring heaters to achieve an overall 50 km nominal lens.

Positive lens thermal distortions are replicated with CO2 lasers on the ITMX and ITMY compensation plates.

Allows for realistic commissioning of the interferometer controls in a "high power" thermal state.

- High power operation

This state is achieved when increasing the input laser power (above 2 W) to a locked interferometer.

2.6 Effects of high frequency spatial defects on test masses (Point absorbers)

- ITM point absorbers

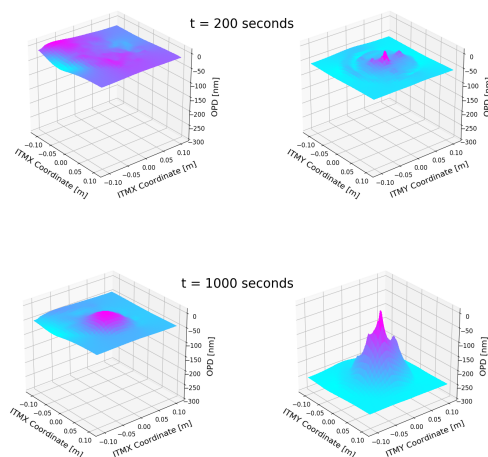


Figure 3: Comparison between the ITMX and ITMY HWS. PC: Thomas Vo

- ETM point absorbers
 - * [alog 45727](#)
 - * [first post](#)
- Hurts contrast see Figure 3
- Fast reduction in PRG and sideband buildup when increasing power to ifo
 - * Time constant measurements
 - * Dan's finesse simulation ([G1900090](#))

- Scattering of the carrier into higher order modes in the arm cavities
 - * Hiro's model
 - Scattering of arm power to $(n+m) = 7$
- Mode matching of the carrier from the Power Recycling cavities to the arms
 - Gabriele's models
 - * 9 MHz $(n+m)=9$ transmission
 - Hiro's model

3 TCS settings going into O3

- Preloading:
 - Lenses in cold state:
 - * ITMX
 - Nominal substrate lens: -1.712 microdiopeters
 - CO2: .65 W
 - RH: 0.8 W (-14.4 μ diopeters from double pass lens)
 - Overall induced lensing:
 - * ITMY
 - Nominal substrate lens: -23.81 microdiopeters
 - CO2: .83 W
 - RH: 2.6 W (-46.8 μ diopeters from double pass lens)
 - Overall induced lensing:
 - * ETMX
 - Nominal "lens":
 - RH: 0.4 W (-7.2 μ diopeters from double pass lens)
 - Overall induced lensing*:
 - * ETMY
 - Nominal "lens":
 - RH: 0.4 W
 - Overall induced lensing*: (-7.2 μ diopeters from double pass lens)

* as seen by the carrier

4 Future tests/measurements/analysis

- SR3 heating
 - [Short-ish SR3 measurement](#)
- SRM heating
 - Issues aligning when interferometer is locked? ([alog 47342](#))
 - To improve mode-matching from the ifo to the OMC.
 - This reduction in optical loss would allow optimal squeezing
- SR3 and SRM
 - Might be worth exploring this actuation space when assuming two nearly optimal actuators.
- ITMY CO2 mask
 - Potential increase in sideband buildup as we are increasing power
 - Increased optical gain for length and angular control loops
 - Aidan's pitch [alog 46127](#)
 - Aidan's mask design [alog 46738](#)
 - Aidan's mask model [alog 46976](#)
 - Mask test [alog 47081](#)
 - Improves 9MHz RIN coupling. Is this limiting us though?
 - Projecting this 9MHz RIN coupling in the noise budget
- Moving spot position (Jenne and Dan moves)
 - Moving away from the ITMY and ETMX point absorbers? [alog 47101](#)
 - [alog 47117](#)