Modeling of the Effects of Beam Fluctuations from LIGO's Input Optics

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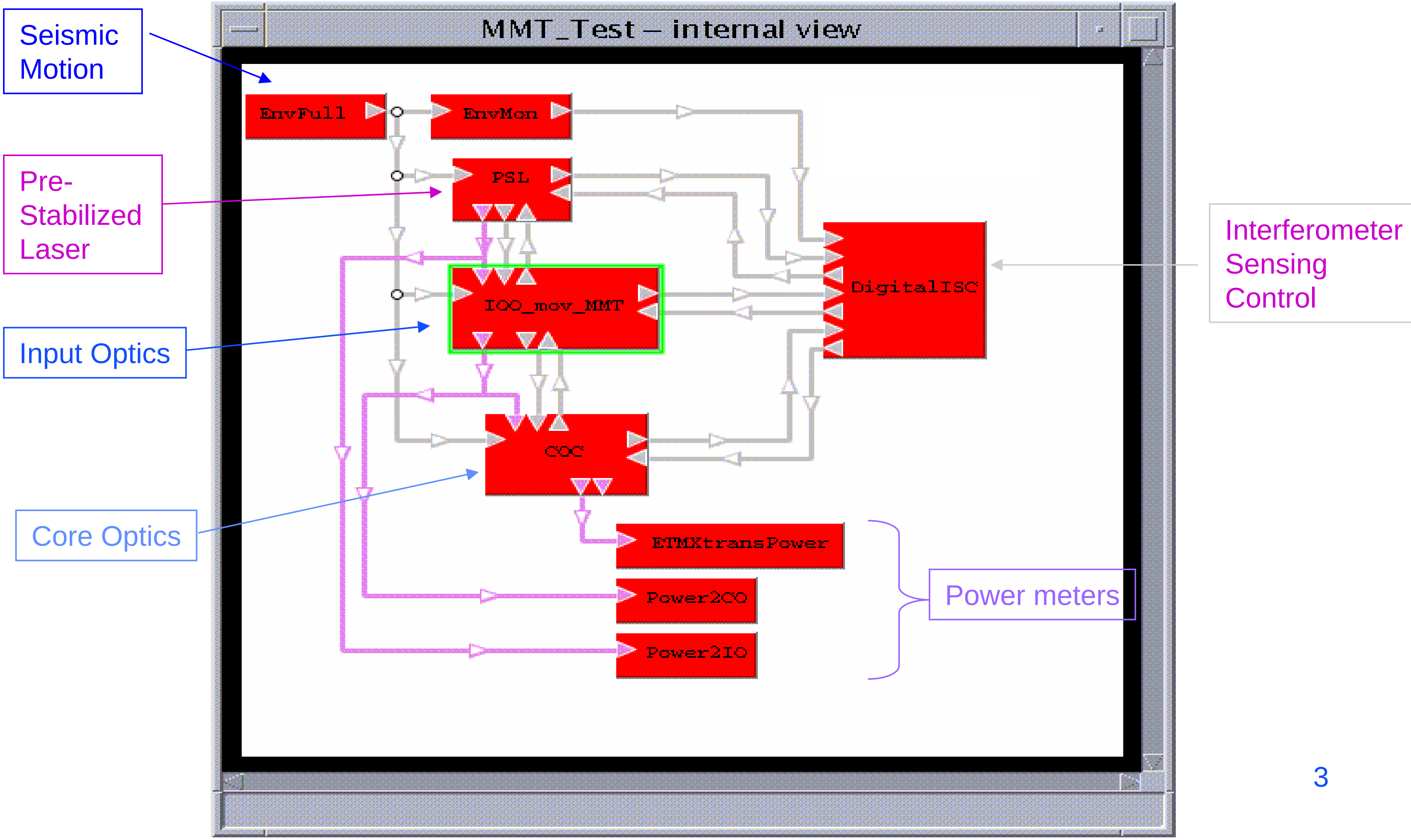
PART I:

Modeling MMT's motion and effect on power in the arm cavity

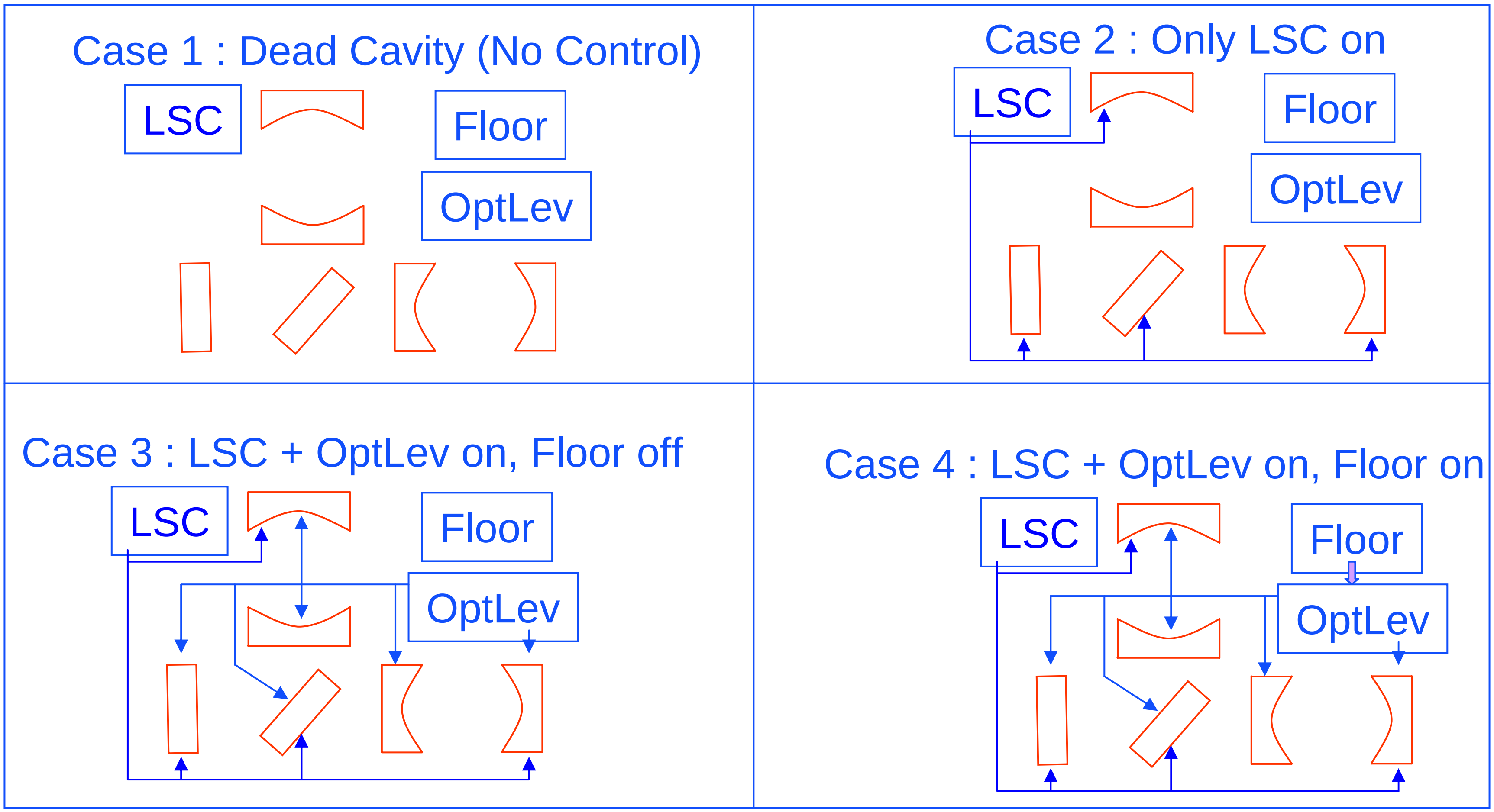
The SimLIGO model



Objective

- Study the effect of the fluctuation of the input beam
  - Provide seismic noise to input optics
  - No seismic influence on core optics
  - Study the effect of input beam's fluctuations under the following conditions:

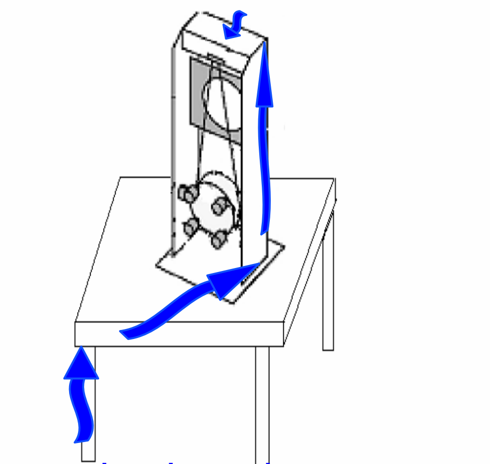
Conditions on Core Optics (Cases)



Note : There is no suspension point motion to any of these mirrors

Conditions on the Input Optics (Runs)

- The following table shows the state of different input optics, that has been used to study the four cases mentioned in the last slide

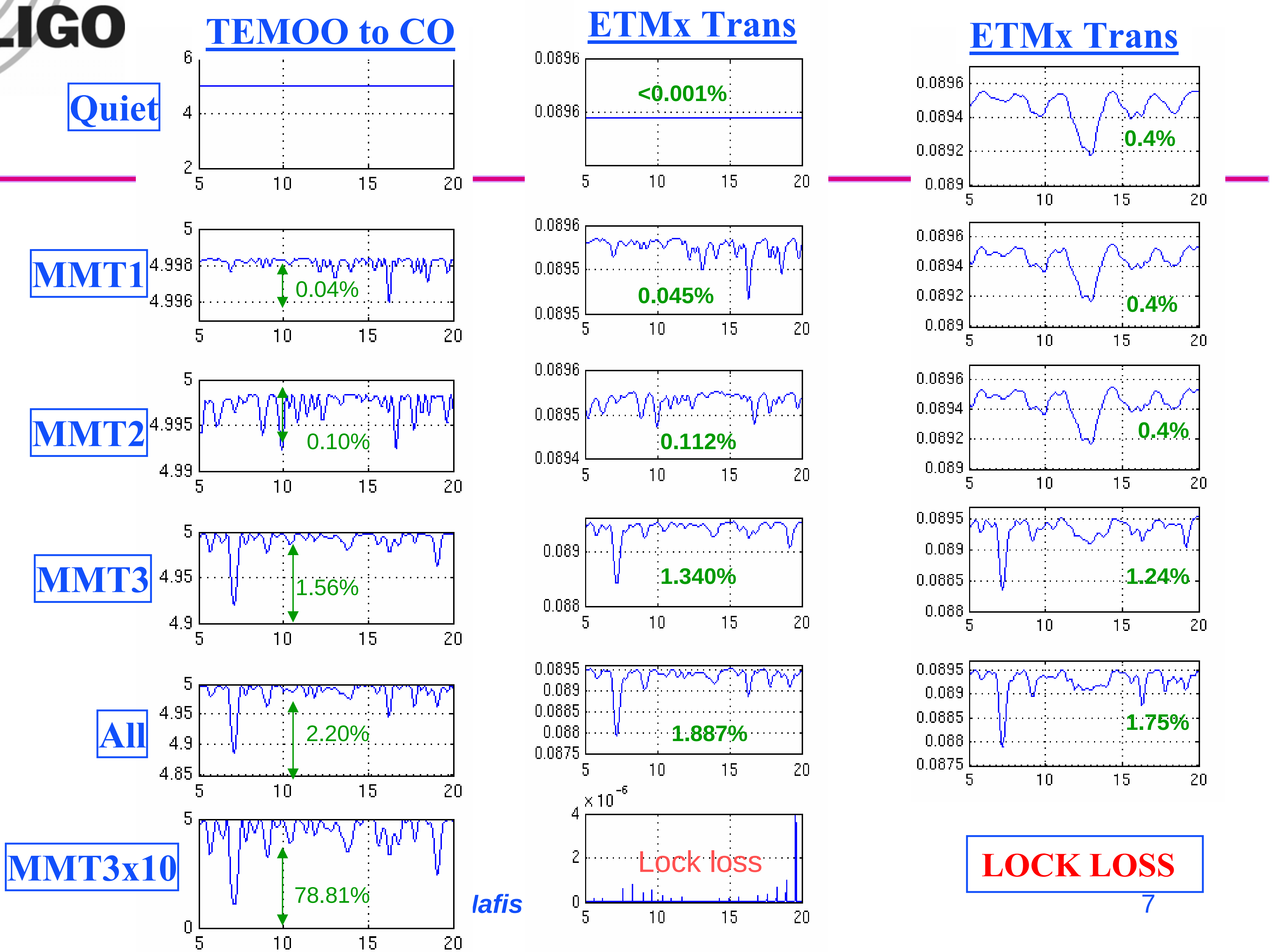


runs	MMT1	MMT2	MMT3
1	0	0	0
2	1	0	0
3	0	1	0
4	0	0	1
5	1	1	1
6	0	0	10

→ All Quiet
→ Only MMT1 moving
→ Only MMT2 moving
→ Only MMT3 moving
→ All IO moving
→ Only MMT3 moving but 10 times larger motion

0 – no suspension point motion
1 – suspension point motion turned on at 0.7s
10 – optic has 10 times larger motion

Figure 1: Time series

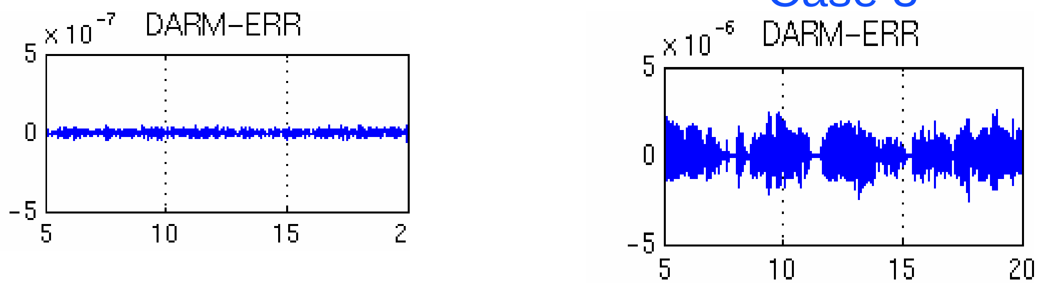


Findings from Case 3
LSC + OptLev

- OptLev on
  - » same power in arms as OptLev off
  - » extra noise in DARM error signal
- 20Hz, 40Hz peaks in both DARM and Opt Lev signals when quiet case subtracted

DARM_ERR for Run 1

Case 2 | Case 3



Run 3

d-DARM | d-Opt Lev Pitch

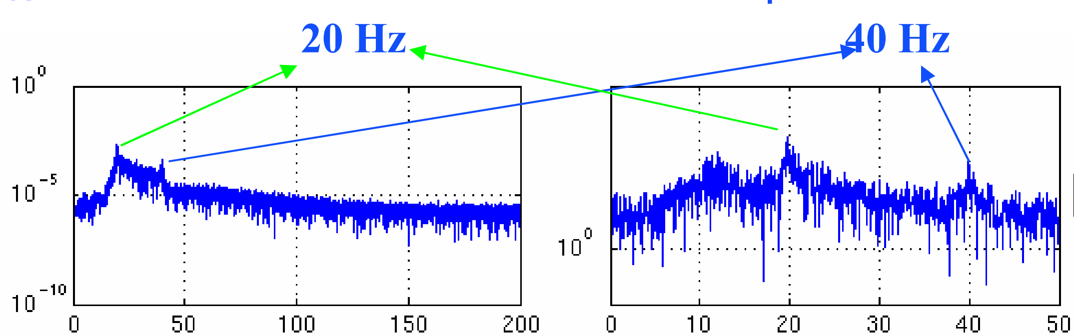
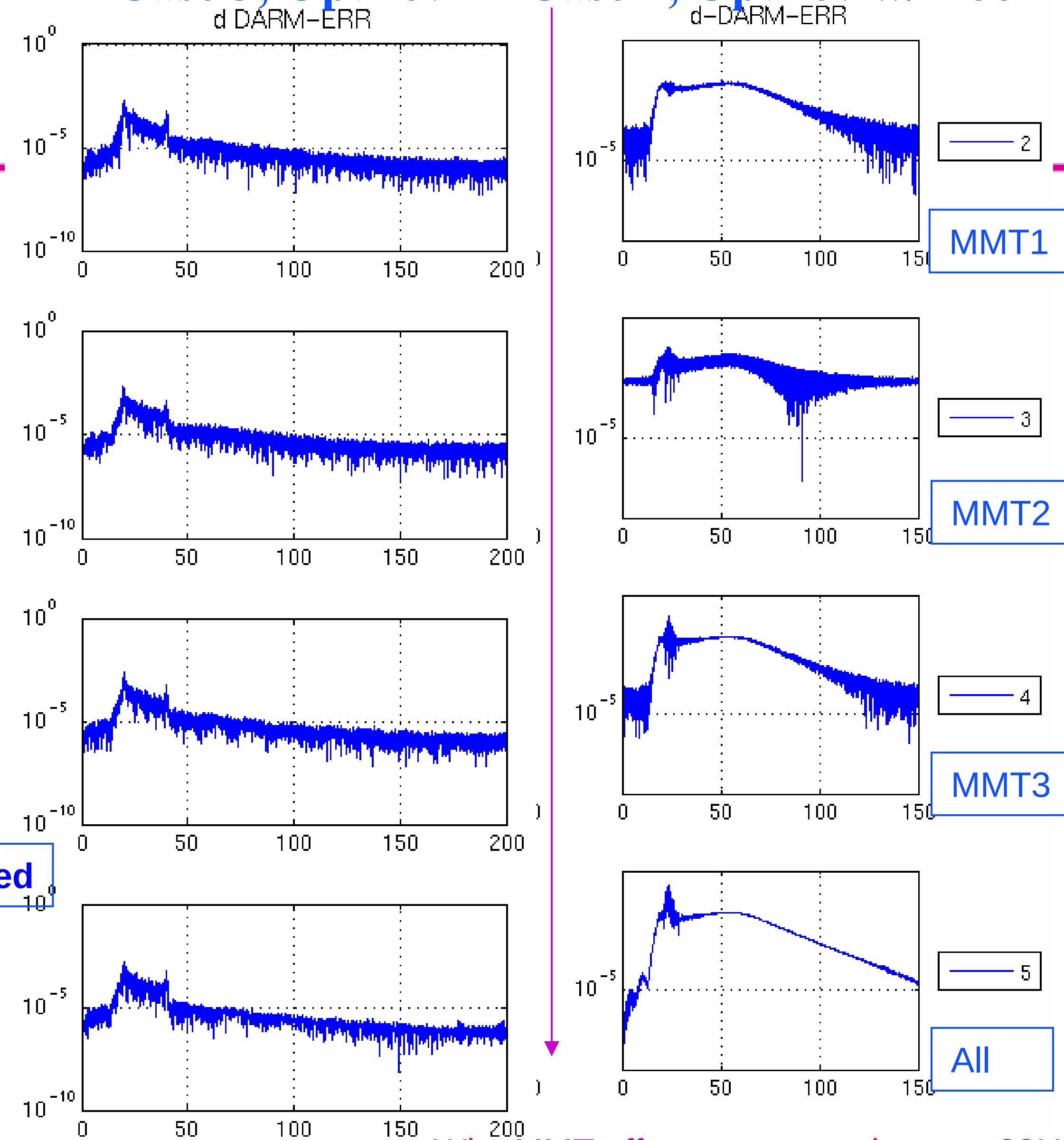


Figure 7: The frequency spectrum of results of Case 3, 4

Case 3, OptLev **Case 4, OptLev w/Floor**



****Quiet MMT run subtracted**

Why MMT effect more prominent at 23Hz with floor motion?
(Compared to quiet floor case)

Conclusion (Part I)

- When MMT3 experiences 10 times larger suspension point motion, the fluctuation in the input beam increases by about 77% and the LSC fails to keep the arm cavities locked.
- Even when LSC works at its best, the maximum mode mismatch due to the input beam fluctuation is directly proportional to the fluctuations in the TEM00 mode from MMT. A different mechanism is needed to correct this (ASC control to MMT3).

PART II:

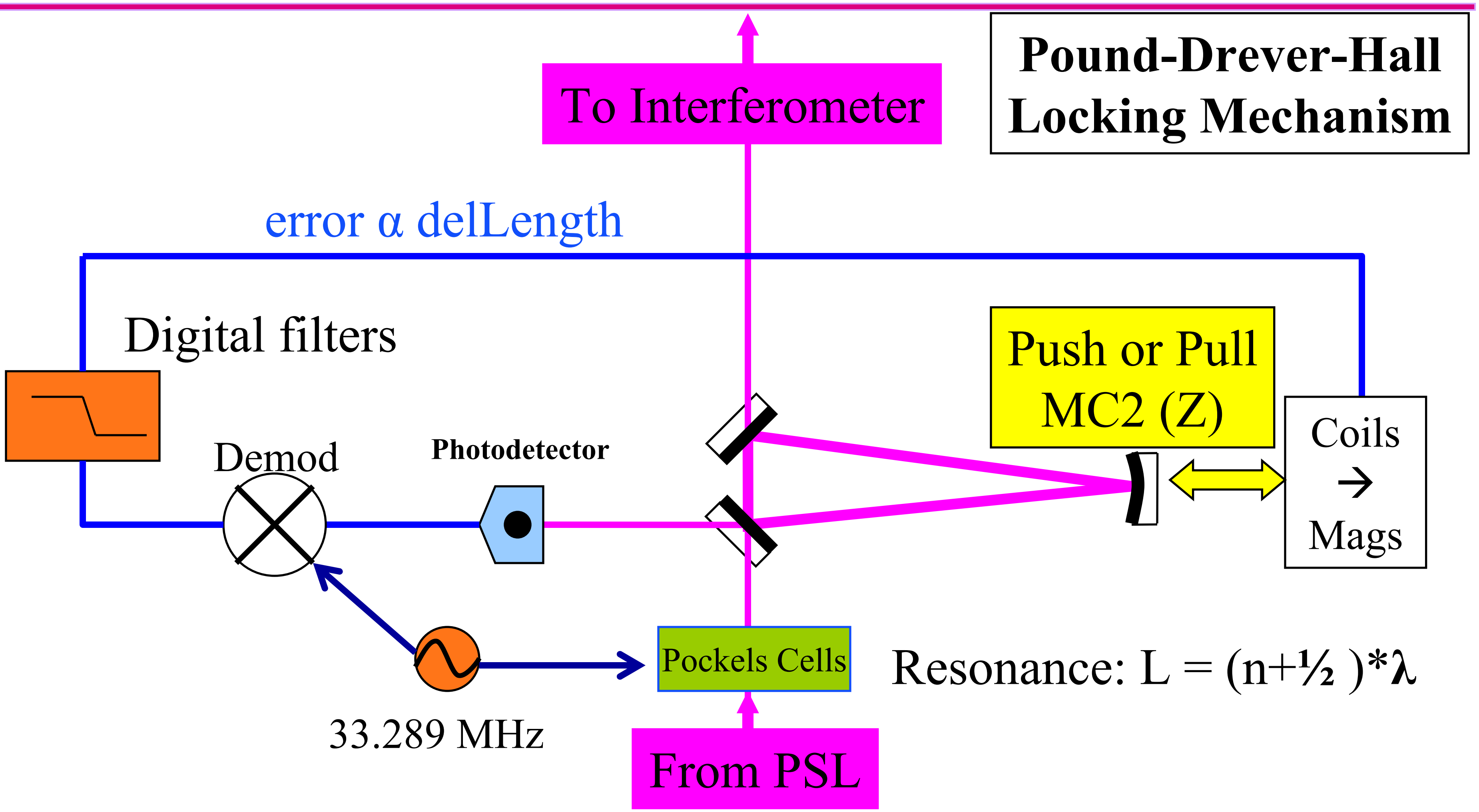
Modeling LIGO’s Input Mode Cleaner (MC)

Objectives

1. Create a complete, dynamic model of LIGO's input mode cleaner.

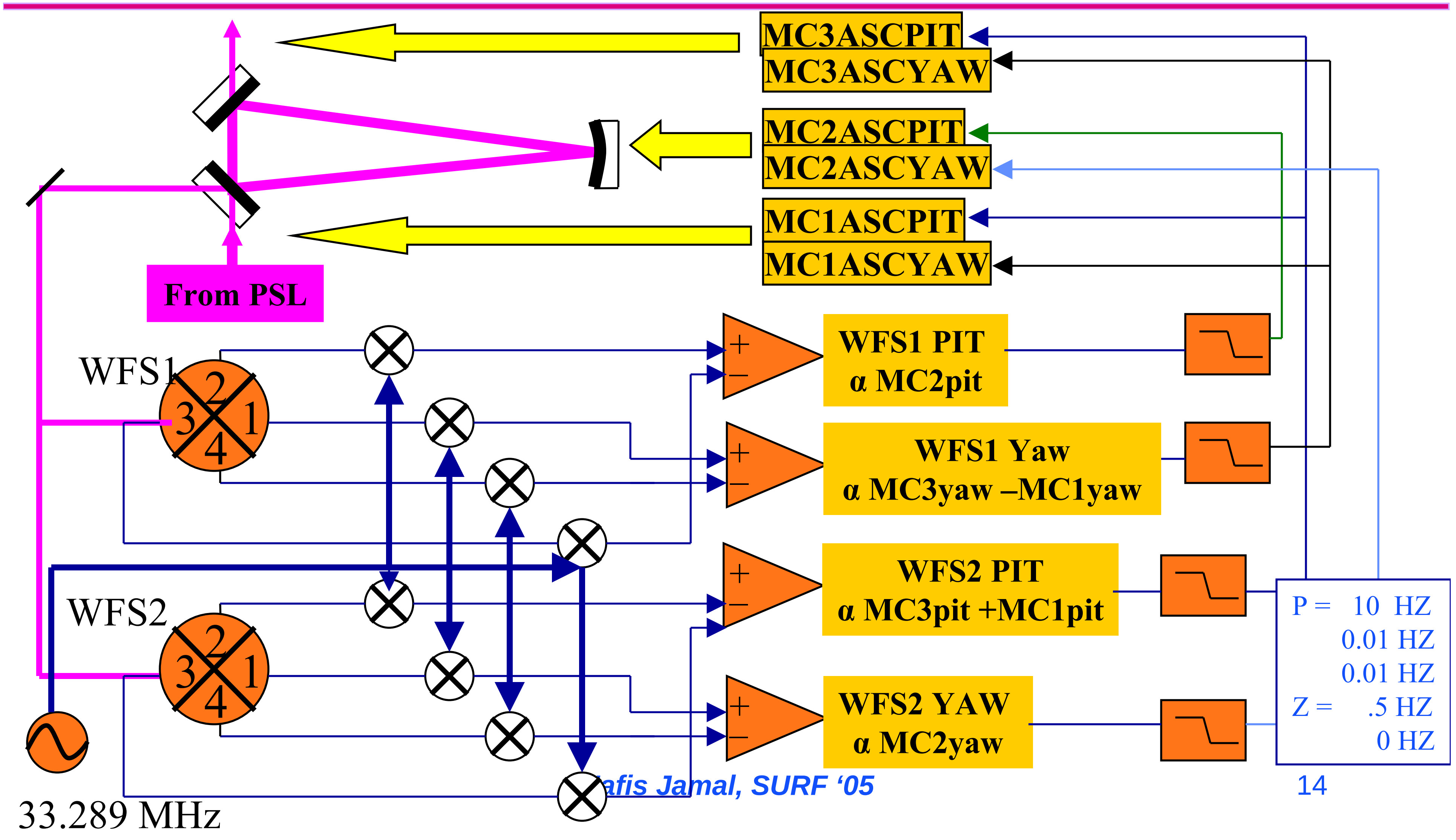
2. Incorporate this model into SimLIGO and study the how the mode cleaner's performance affects LIGO's sensitivity.

LIGO's Mode Cleaner:
Length Sensing Servo

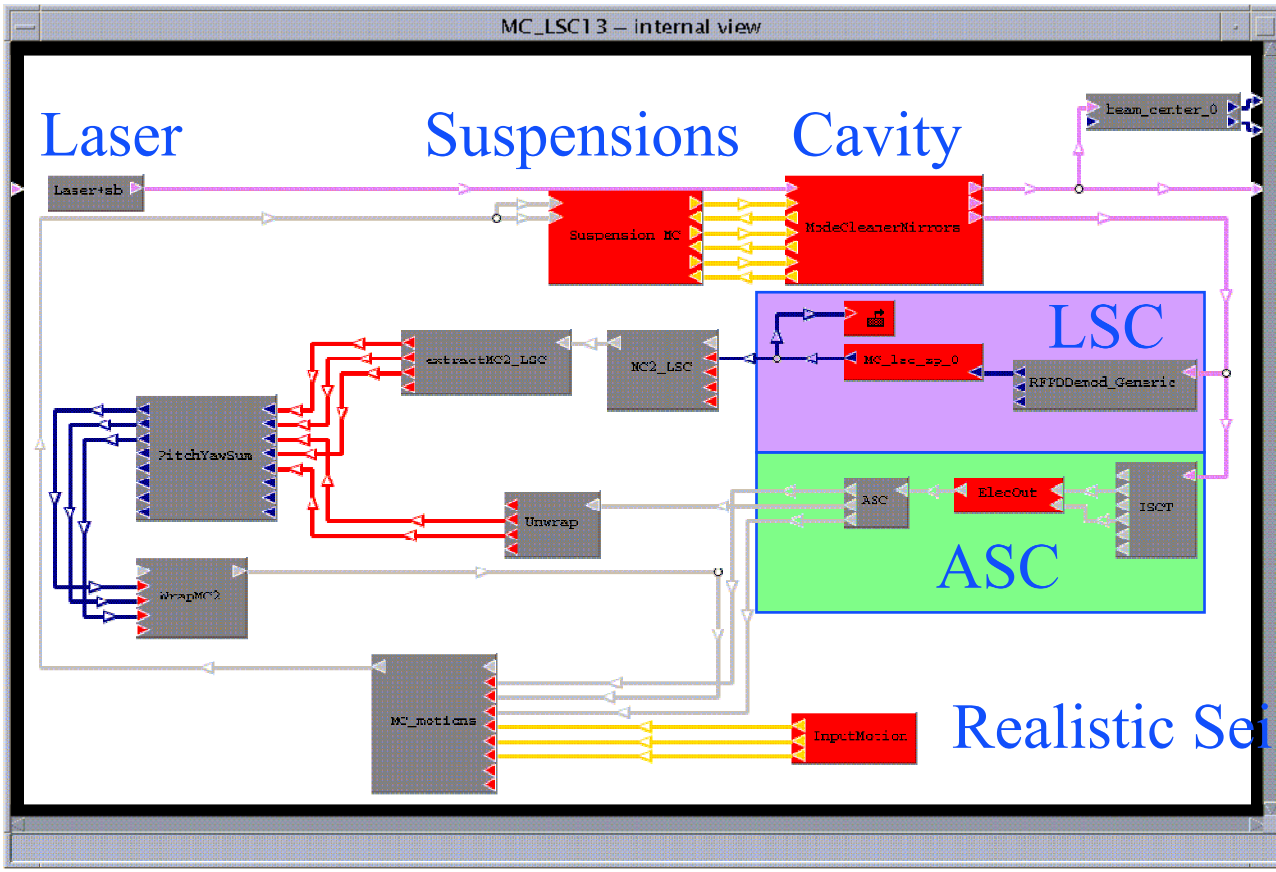


LIGO's Mode Cleaner:

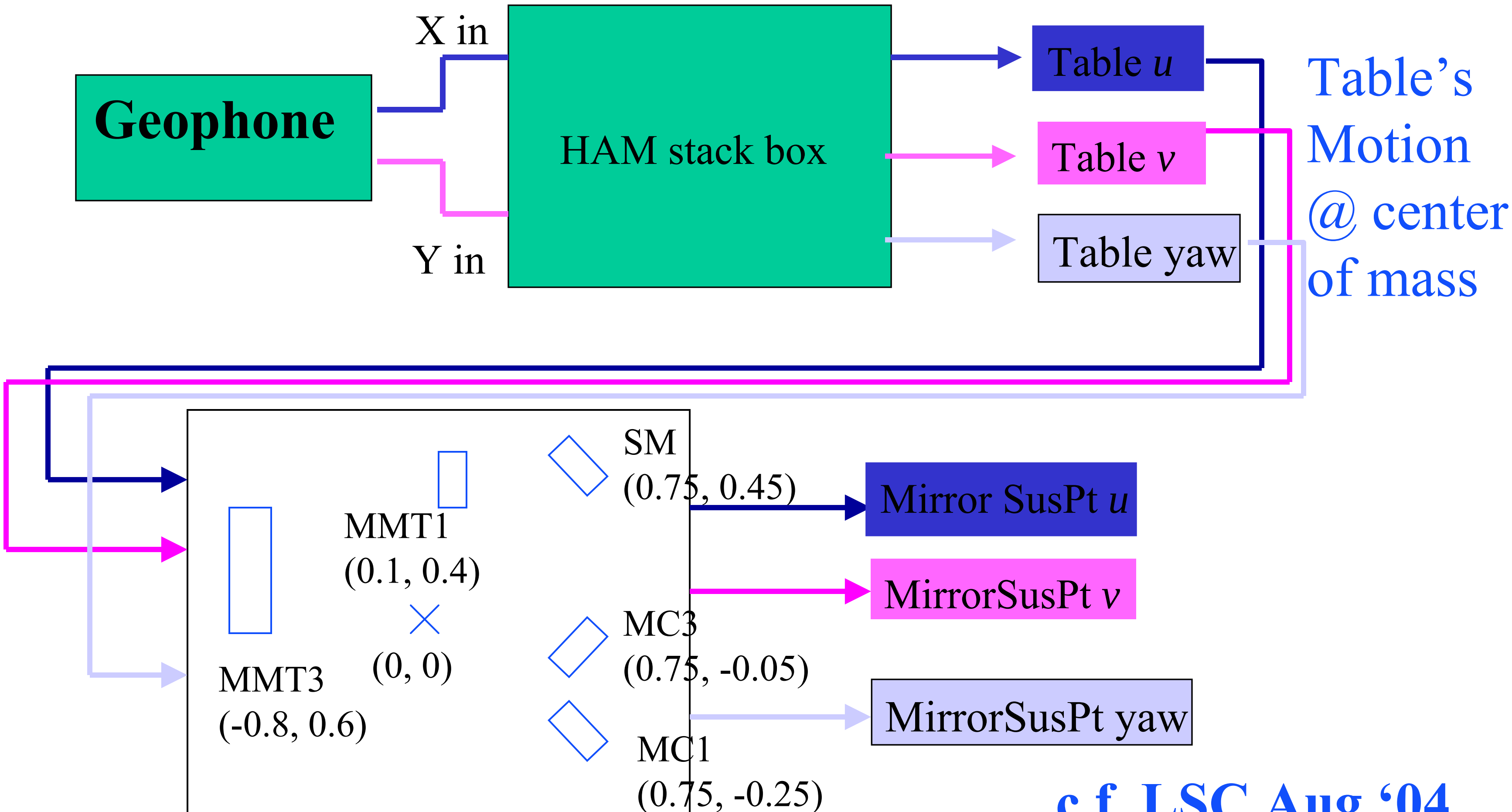
Alignment/Wavefront Sensing Servo



Modeling LIGO's Mode Cleaner



Calculation of SusPt Motion

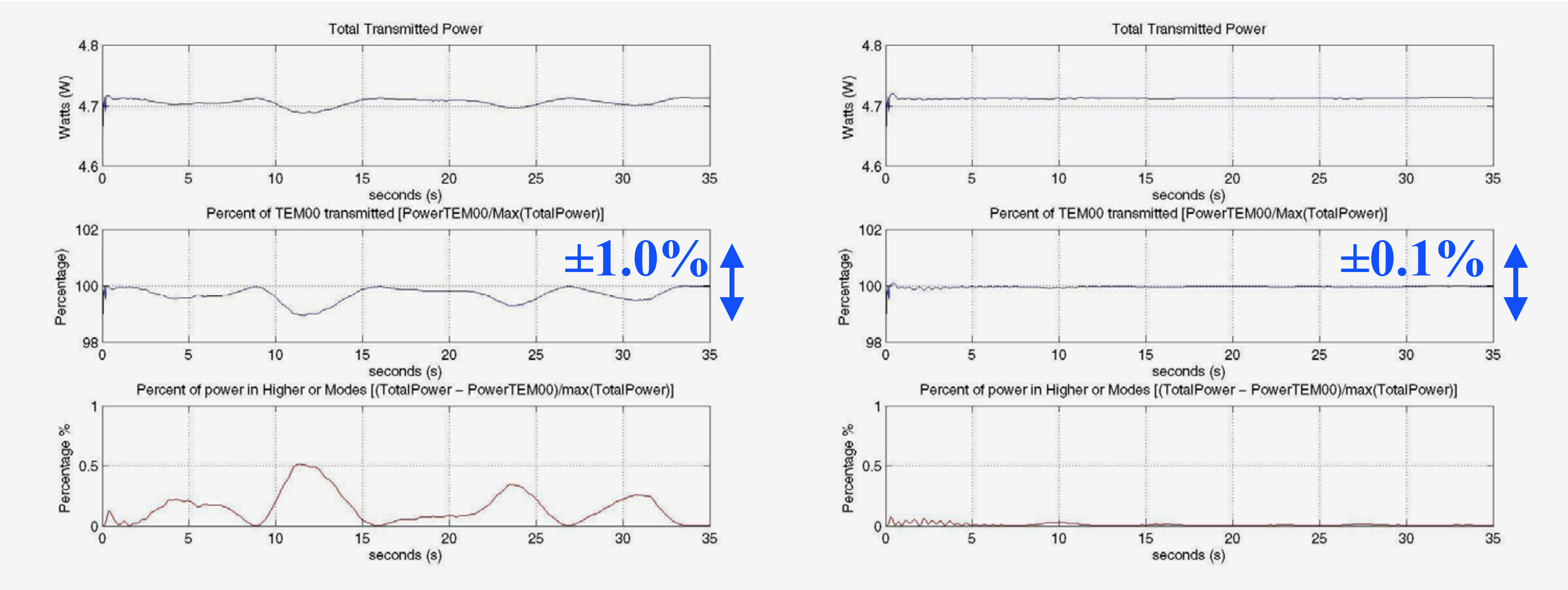


c.f. LSC Aug '04

Results:
MC Transmitted Power

ASC OFF

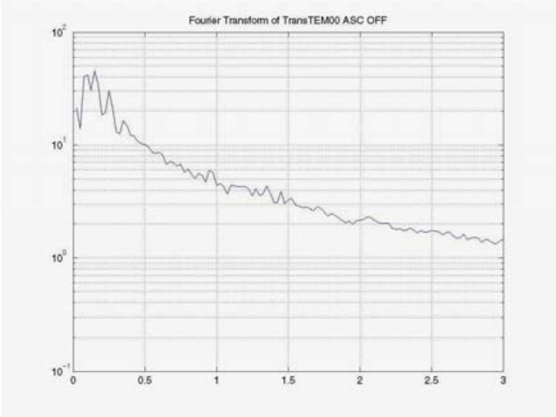
ASC ON

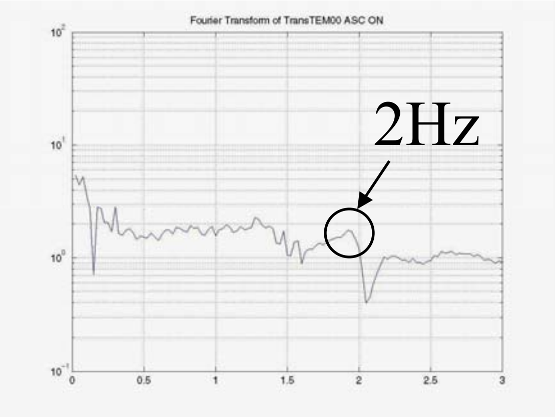


Results:
Fourier of Transmitted Power (TEM00)

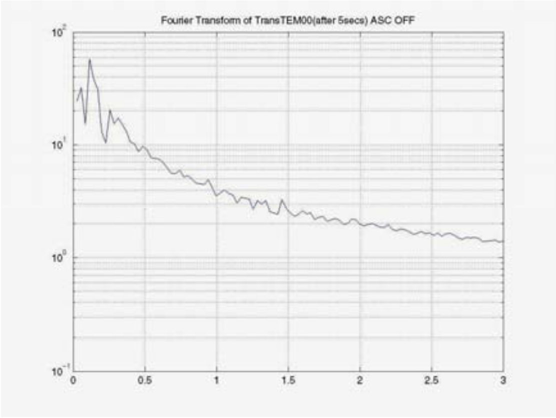
ASC OFF | ASC ON

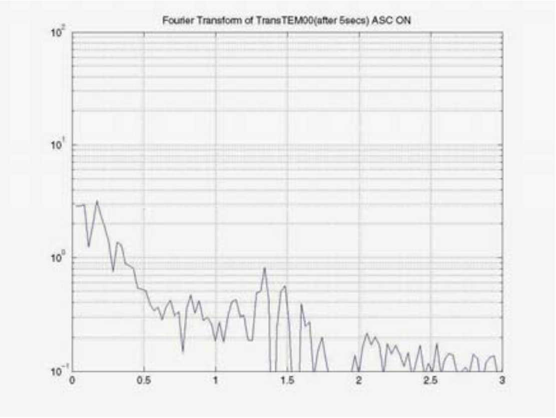
FULL





After 5secs



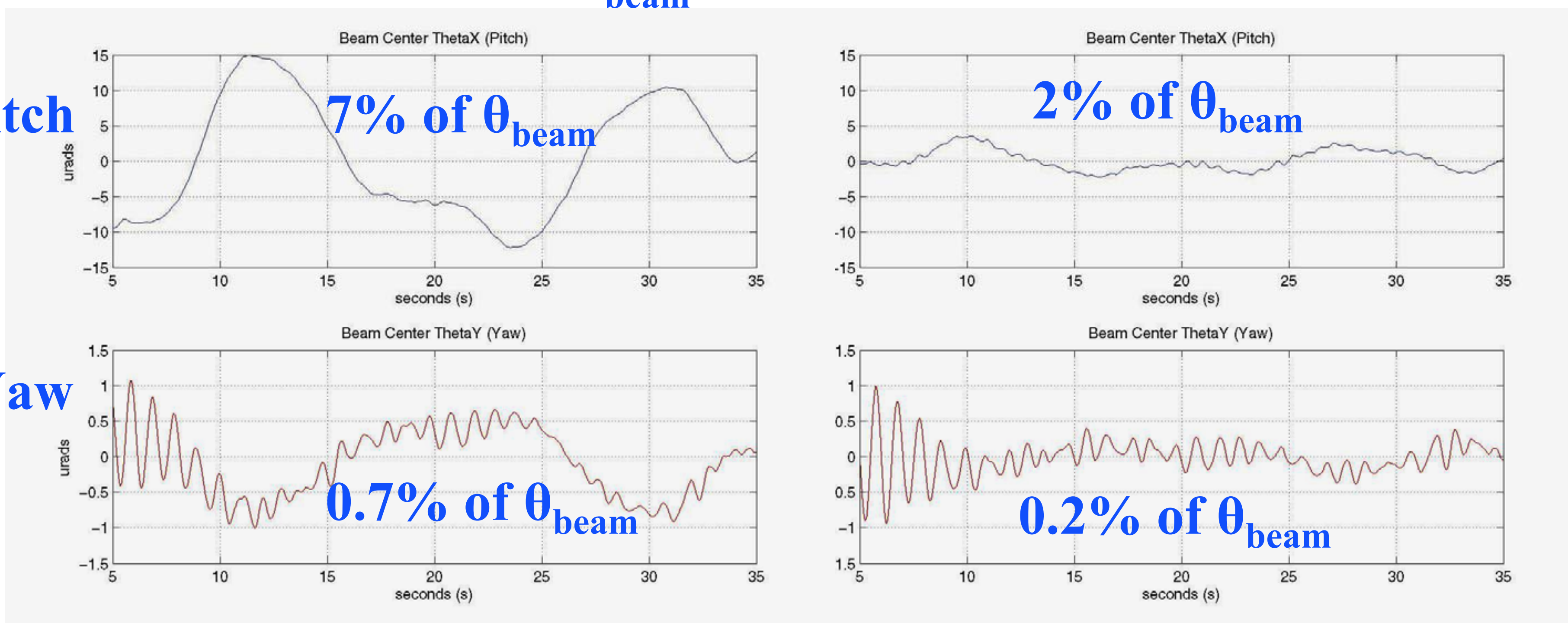


Results:
MC Transmitted Beam Pointing

ASC OFF θ_{beam} = 208 urad ASC ON

Pitch

Yaw



Pitch = 10*Yaw **ASCon = (1/3)ASCoff**

Findings

	ASC OFF	**ASC ON**
% Fluctuation in TEM00	~1.0%	~0.1%
Beam Pointing Angle (max)	Pitch: 15 μrad Yaw: 1.5 μrad	Pitch: 4 μrad Yaw: 0.5 μrad
Fourier Spectrum	High Low-Frequency Component	Low-Frequency Suppressed
Time Series	Low-Frequency oscillation	Noticeable 2 Hz oscillation

Conclusion (Part II)

- Alignment Sensing serves a vital role in the Mode Cleaner's stability. This servo reduces the beam pointing angle and helps to maximize the power coupled into the cavity, resulting in increased power in the laser's TEM00 mode.
- Model Complete

Future Work:

- Now that the Mode Cleaner has been completely modeled, I have begun to incorporate this box in SimLIGO. We will study the affect of mode cleaner on the power coupled into the cavities as well as its affect on the differential arm signal.
- Update current model to study Advanced LIGO's input mode cleaner
- Study the effect of the input beam's fluctuations when all of the core optics receive seismic noise
- Activate the arm cavities' ASC to act upon MMT3, stabilize the input beam to the RM.

Thanks SURF!