Preliminary lessons for modeling from the ALIGO commissioning

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for ALIGO commissioners and modeling team

GWADW, 高山,日本
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Contents

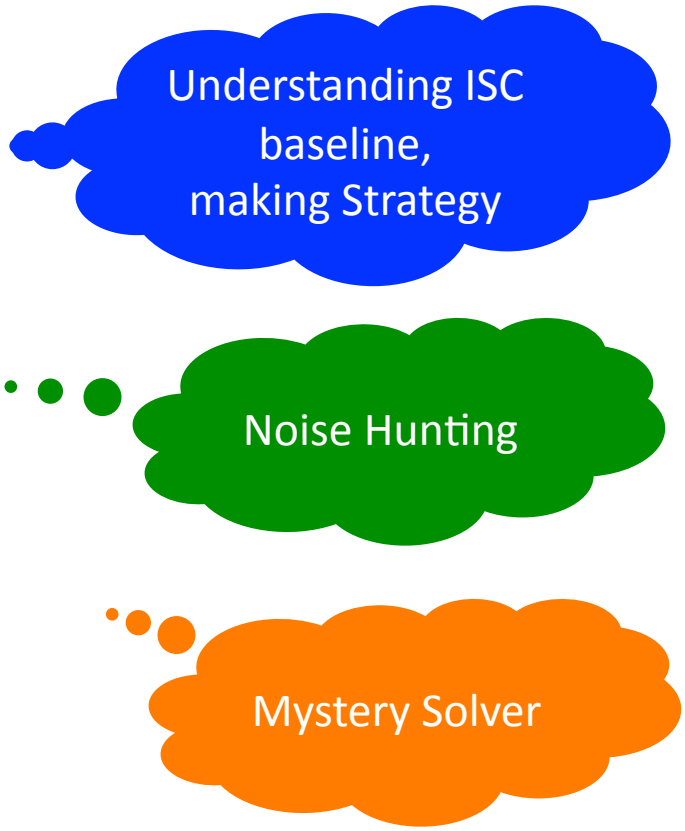
- Challenges in ALIGO commissioning
- 5 successful model examples
- Lessons we learned
- Possibility for future simulation upgrades

Challenges in ALIGO commissioning

- Understanding sensing matrices of the multiple degree of freedom (DoF) for length and angular sensing (LSC and ASC)
- Full IFO Locking strategy
- Noise Coupling
- Effects from higher order modes (HOMs), mirror maps, cavity misalignments

Successful Models for Commissioning

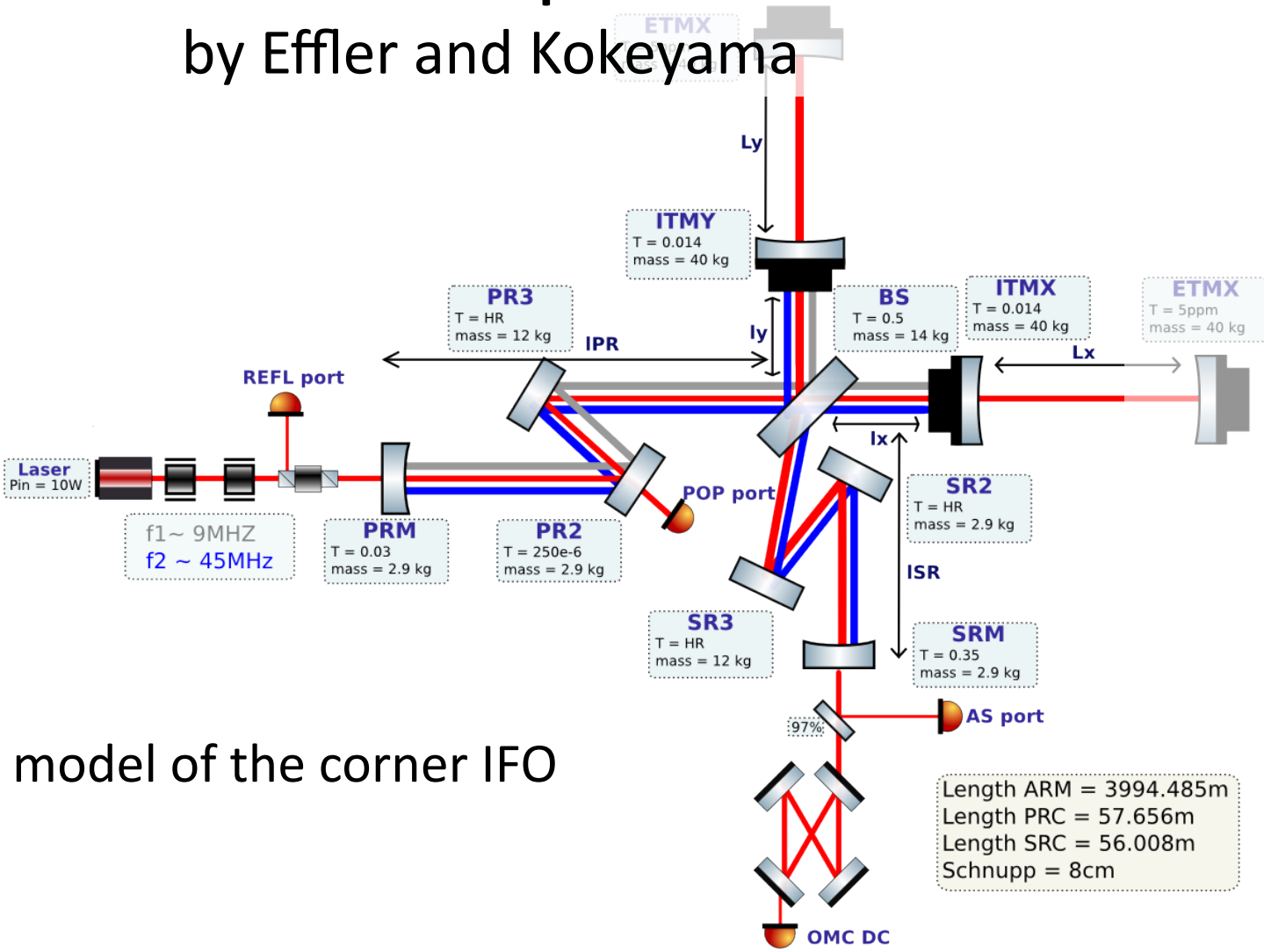
1. LSC & ASC models (Optickle)
2. Lock acquisition (E2E)
3. Noise Budget (Simulink)
4. Mirror Maps (FogPrime 13)
5. Low Finesse Cavity Model
   (Y. Michimura's Model)



ISC: Interferometer Sensing and Control
IMC: Input Mode Cleaner

1. LSC and ASC Optickle models

by Effler and Kokeyama

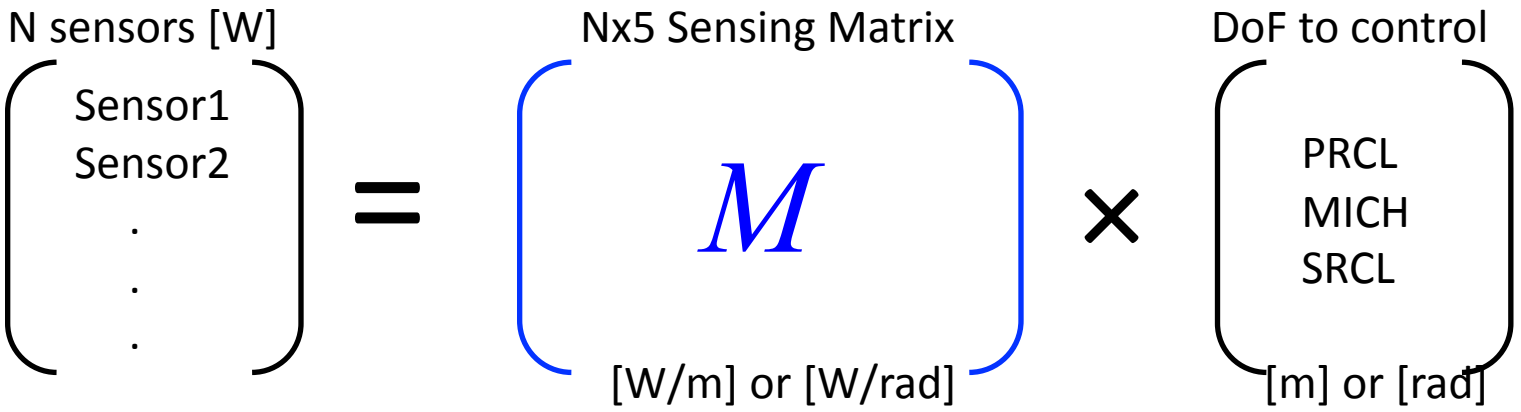


Optickle model of the corner IFO

(*) Full IFO Optickle Model is originally by M. Evans

1. LSC and ASC Optickle models

by Effler and Kokeyama



LSC (~40 sensors)

ASC (~8 sensors)

IFO response

Control DoFs

MICH
SRCL
PRCL

ASC DoFs

PRC1
PRC2
BS

1. LSC and ASC Optickle models

by Effler and Kokeyama

Models vs Measurements matched well (LLO),
but there are some disagreements

LSC Sensing Matrix

contrast defect leakage to AS port

	MICH (meas./model)	PRCL (meas./model)	ΔΦ (MICH-PRCL)
AS AIR 45	0.98	34	86
REFL 9	0.75	0.74	83
REFL 45	1.0	0.91	88
REFL AIR 27	4.3	3.5	81
REFL AIR 135	1.8	1.9	81

3f disagreement not explained ...

1. LSC and ASC Optickle models

by Effler and Kokeyama

Models vs Measurements matched well (LLO), but there are some disagreements

ASC Sensing Matrix

PITCH example	PRC mirror (meas./model/40)	PRC input (meas./model/40)	BS (meas./model/40)
REFL A 9	0.99	-(minus) 1.2	0.95
REFL B 9	1.1	- (minus) 0.80	0.94
AS A 45	(small)	(small)	0.92

Unknown Sign flip
(demodulation phase
i he measurement

Input mode cleaner ASC sensing matrix was also understood by Finesse model, see LIGO-T1300074.

K Izumi's poster
& T1400298-v1

2. E2E Lock Acquisition by K Izumi

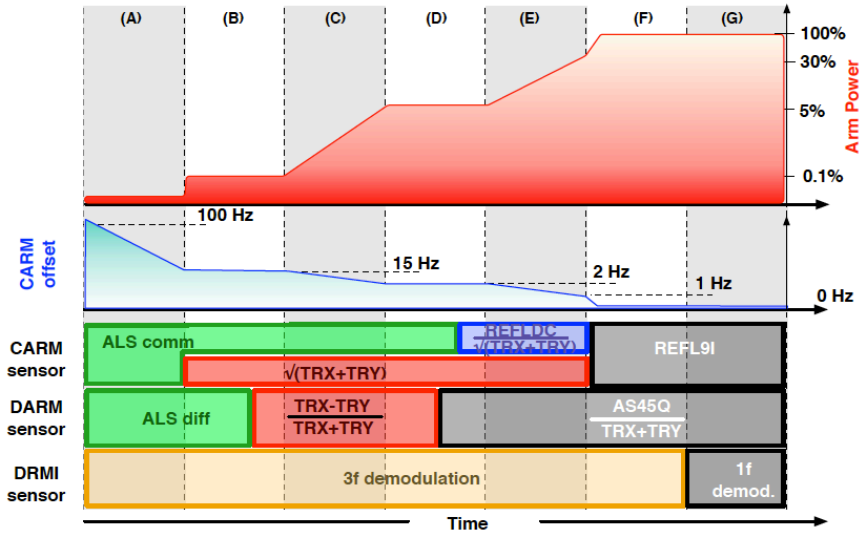
Background:

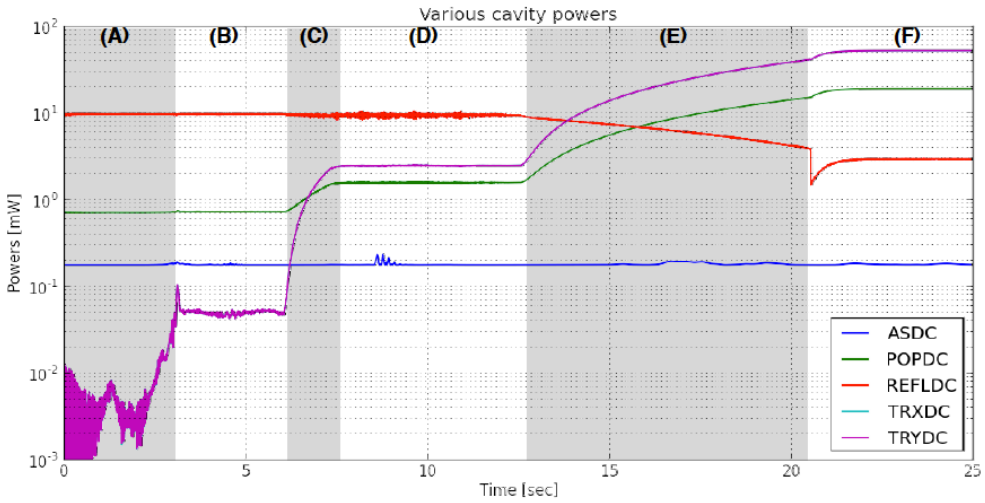
- Generally, lock acquisition for the full IFO is not straightforward, due to the cross couplings between the control DoFs
- Nonlinear signals appear
- Signals drastically change depending on the status of the locking sequence

Tool:

- Time domain simulation, E2E
- It can calculate the field evolution, non-steady state IFO

2. E2E Lock Acquisition by K Izumi





Establish the locking sequence plan for full IFO!

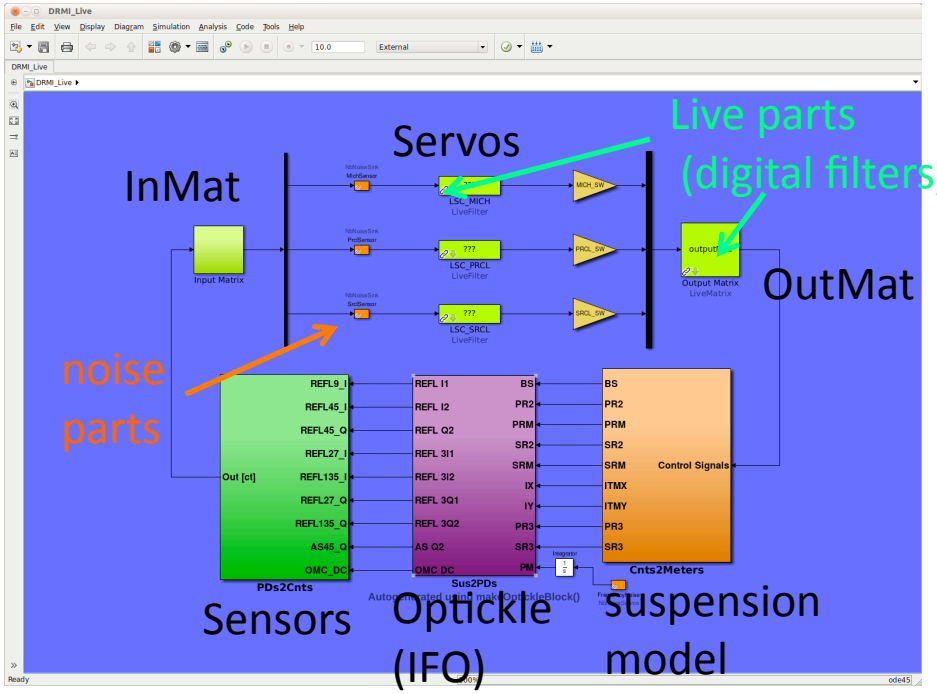
Kiwamu's full IFO package is completed so that anyone can try new locking ideas

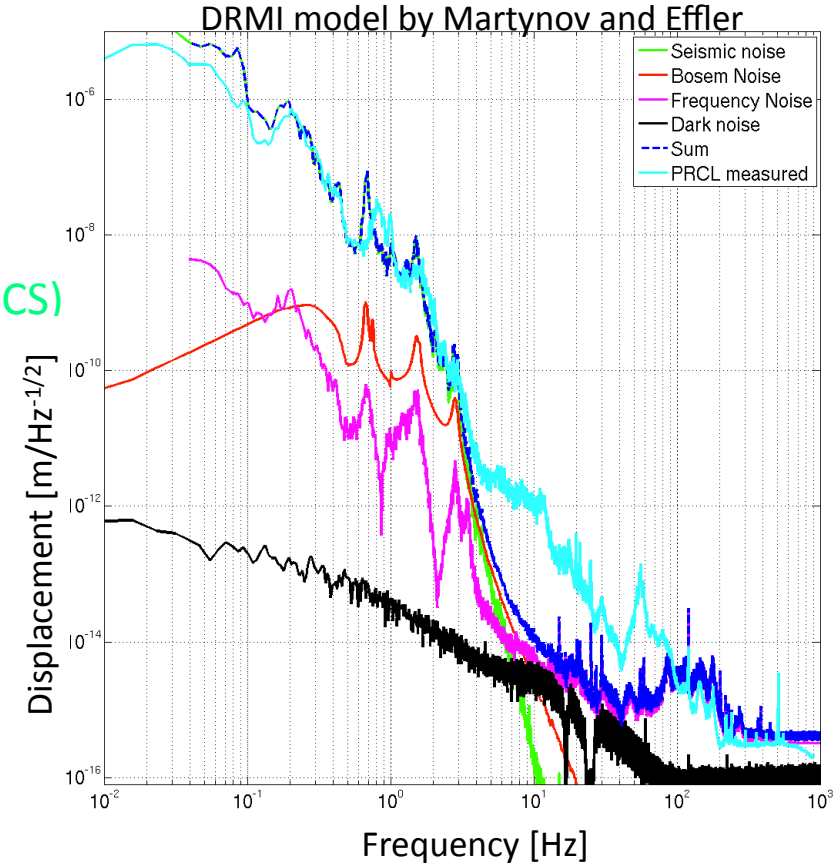
K Izumi's poster will show more detail
Also see his technote, LIGO-T1400298-v1

See C Wipf's talk

3. Noise Budget Simulink by Wipf

NB loads the Optickle model (as IFO response) and live parts





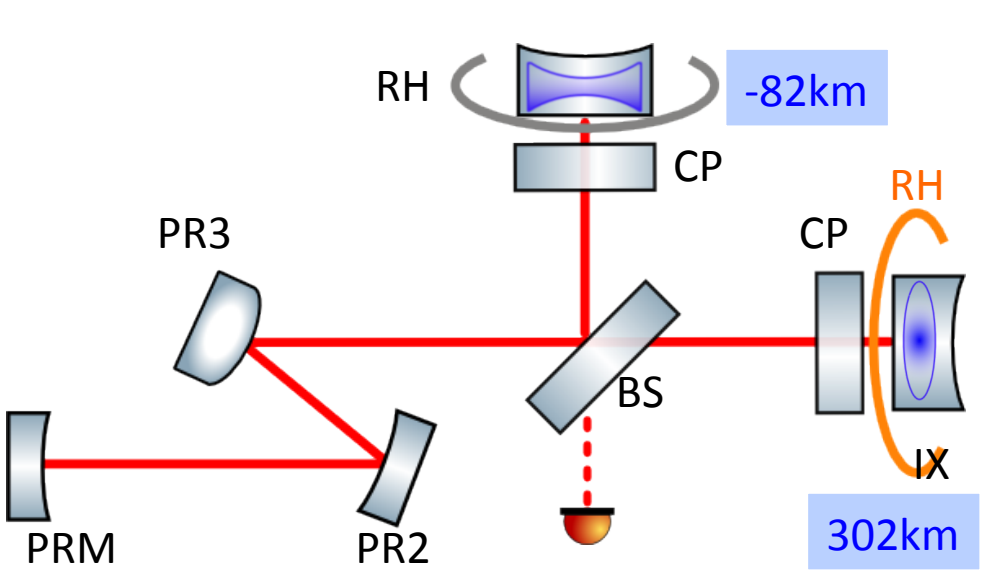
Noise Budget package ready for the noise hunting era!

4. PRMI Contrast Defect (FOGPrime13)

by Yamamoto

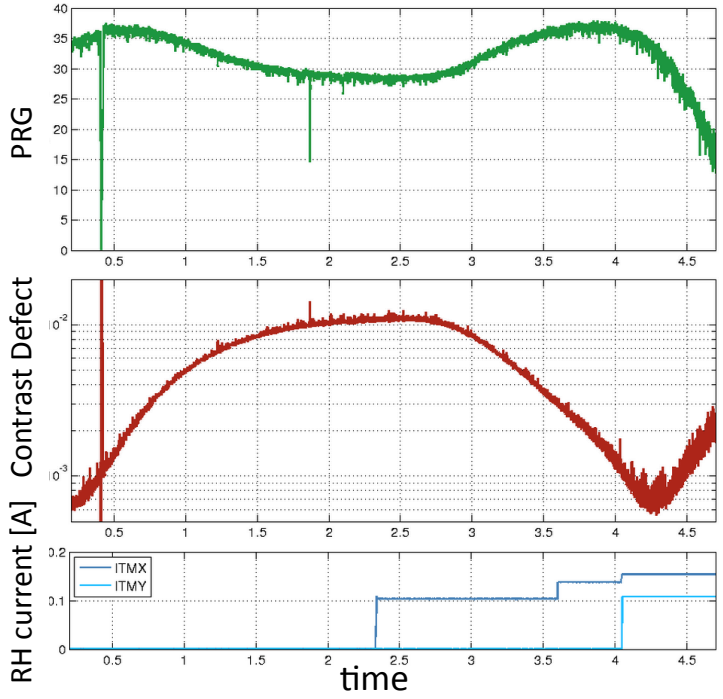
Hiro tried to address the observed PRMI contrast defect (CD)

LLO alog 9733, Martynov *et al*



ITMs have effective RoC due to substrate nonuniformity

Meas. CD With Ring Heater (RH) on IX



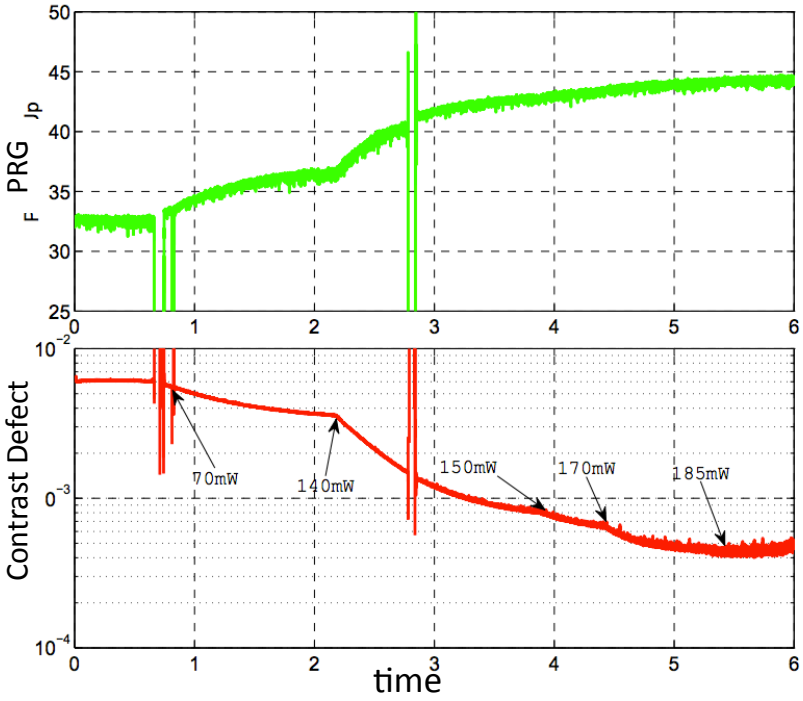
CD~600ppm, PRG~35

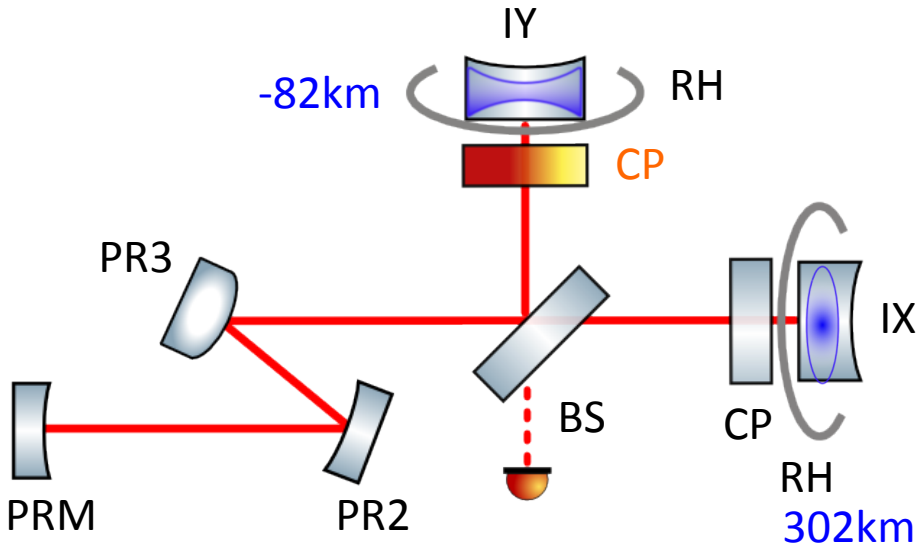
4. PRMI Contrast Defect (FOGPrime13)

by Yamamoto

LLO alog 9333, Martynov *et al*

Meas. CD With TCS on IY



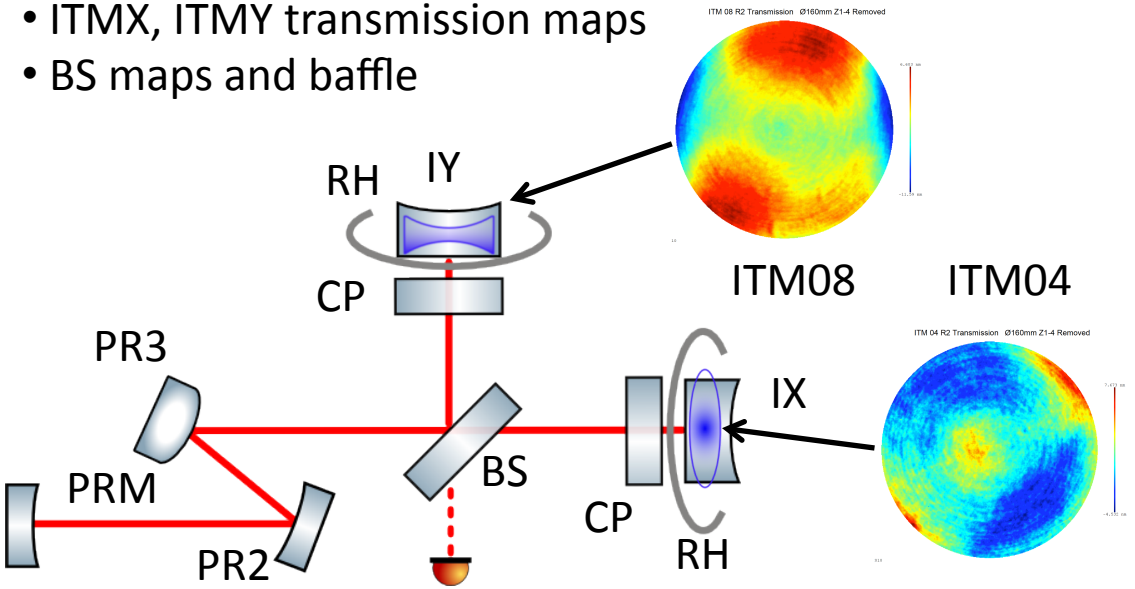


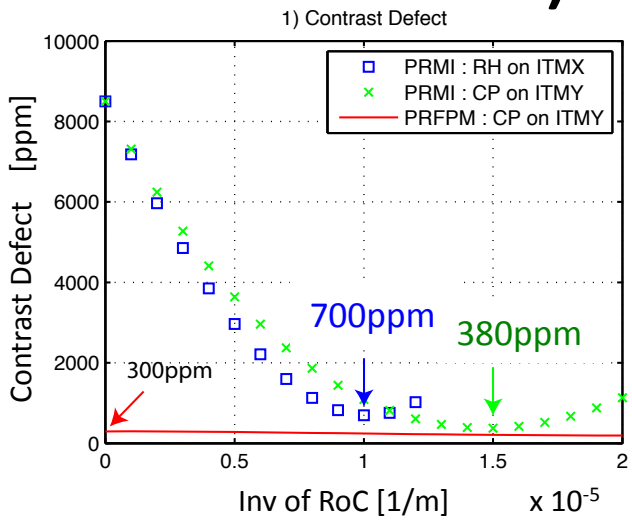
CD~400ppm, PRG~45

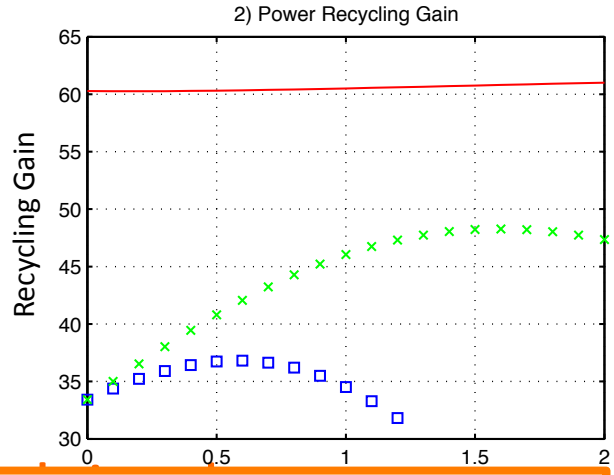
4. PRMI Contrast Defect (FOGPrime13)

by Yamamoto

Simulation:
- ITMX, ITMY transmission maps
- BS maps and baffle







Hiro is showing a poster describing more details and examples about the interferometer performance based on as-built core optics with aberrations.

Measured contrast defec
by the mirror maps and t

Same topic is investigated also by C. Bond and Finesse team. See LIGO-G1400222, T-1300954.

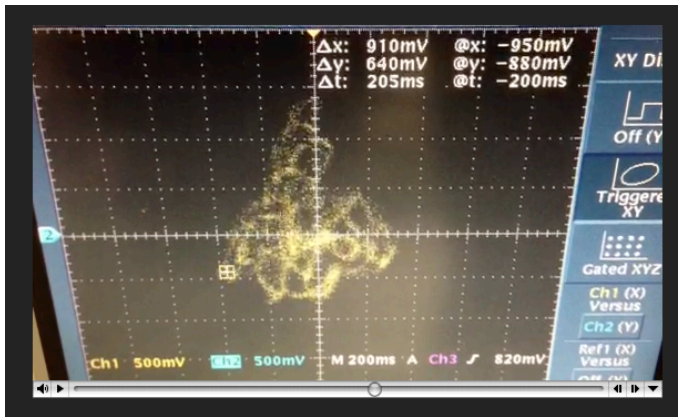
Sheila D's post LHO 9381
Yuta M's post LHO 9384, 9429

5. Low Finesse Cavity Model

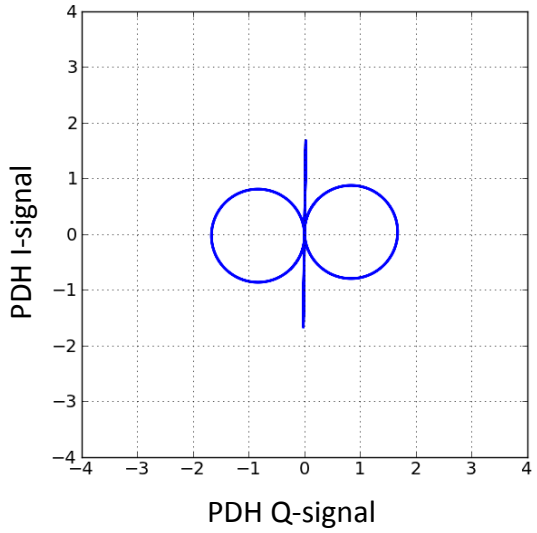
by Michimura and Dwyer

At LHO: they had difficulty to lock the green arm cavity.

Observed I-Q scatter plot of PDH signal



Ideal I-Q scatter plot
(high Finesse, no misalignment)



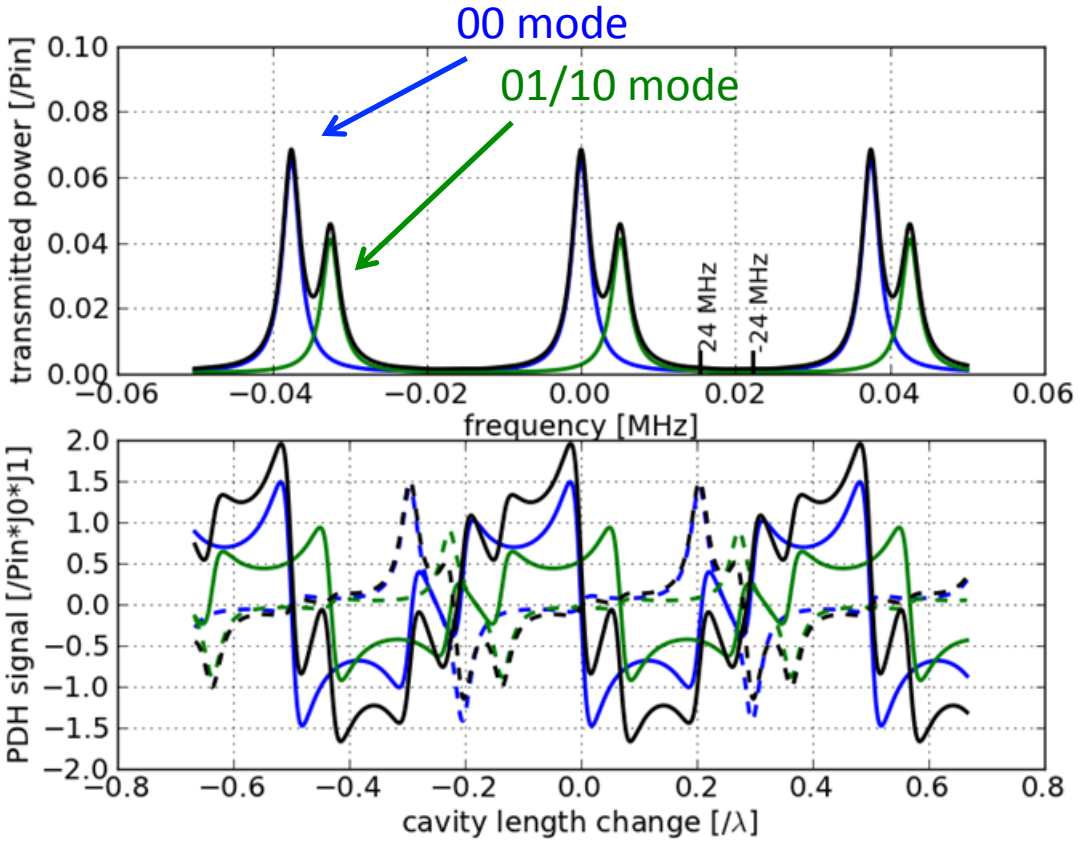
Model: PDH signal in a low finesse green cavity with HOM

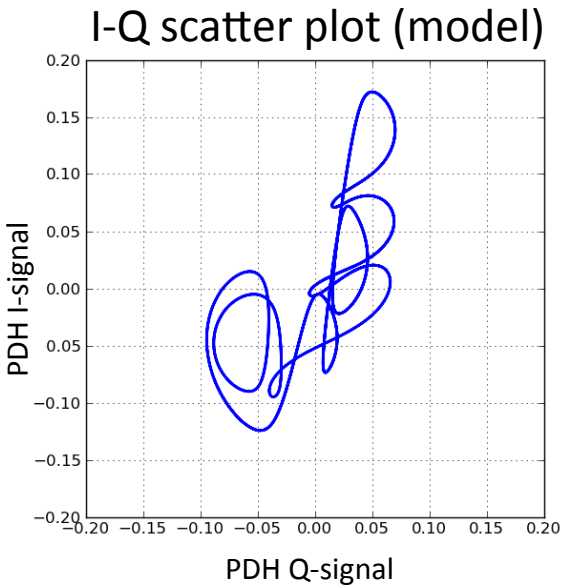
Green transmission was measured as 36% (design 5%)

Sheila D's post LHO 9381
Yuta M's post LHO 9384, 9429

5. Low Finesse Cavity Model

by Michimura





The model explained the distorted PDH signal due to HOM in the low finesse arm cavity for the green beam.

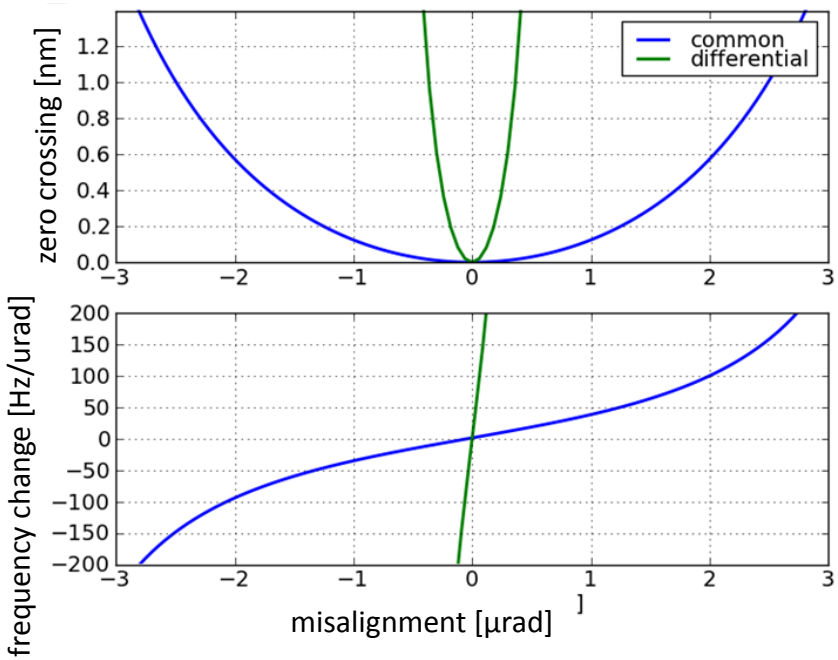
Sheila D's post LHO 9381
Yuta M's post LHO 9384, 9429

5. Low Finesse Cavity Model

by Michimura

Also the model revealed a new mechanism;

cavity misalignment couples to frequency



Misalignments → HOM contents change
→PDH signal gets offsets
→ resonant frequency of the laser is changed

This model showed exactly
what the arm error signals are made of
- not only the length dependence but including both HOM and alignment!

Lessons

- Simulations are important to design/make strategies, to hunt noise and to understand the IFO behaviors

- Sometimes small models without software are enough good as simulation software do not tell the physics
  - There are many small models are used for commissioning; ABCD ray trace, cavity ring down model, cavity length or Gouy phase measurement...and etc

- Simulation software is complimentary depending on the purpose (time domain, frequency domain, FFT ...)

For the next generations...

- Time domain tool which can do angular motion
- Time domain FFT super simulation (Kiwamu's secret)?

- Simulation Tools for the 3rd generation detectors
  - Quantum noise (squeezing and filter cavities)
  - Multi carrier IFO
  - Parametric instability

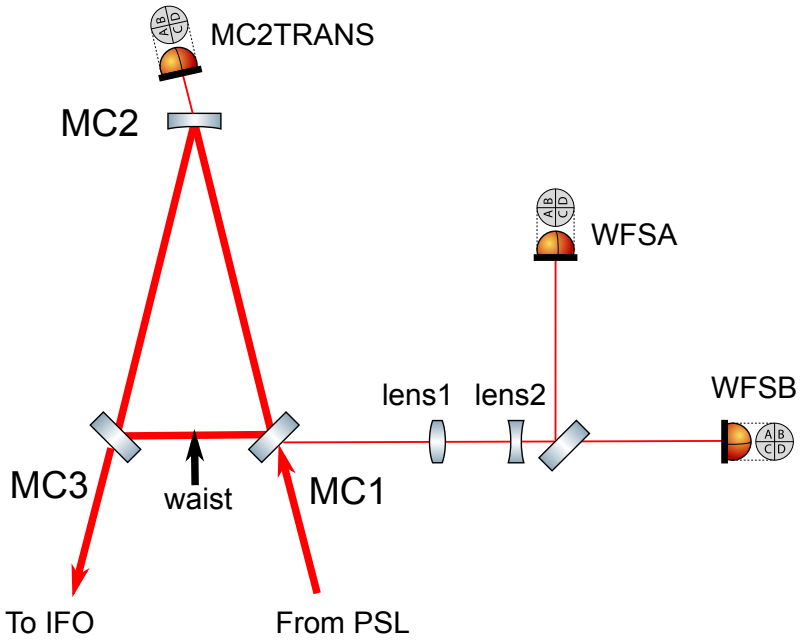
MIST and Finesse upgrade

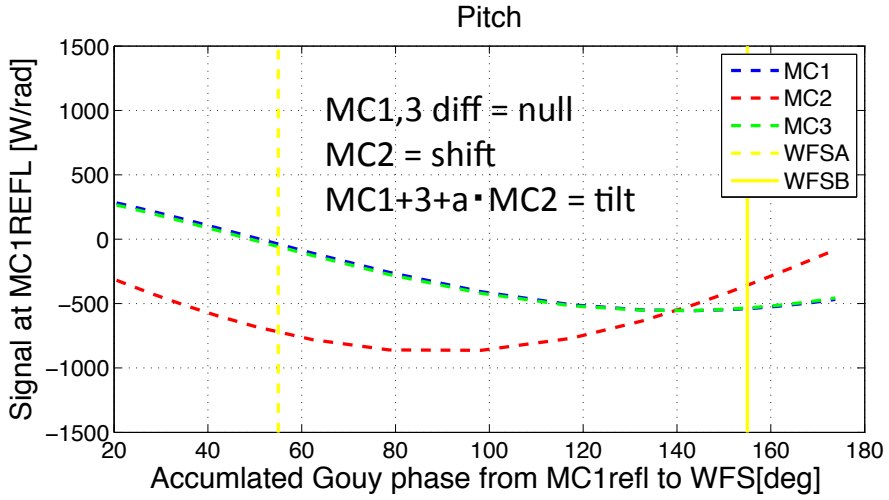
Appendix

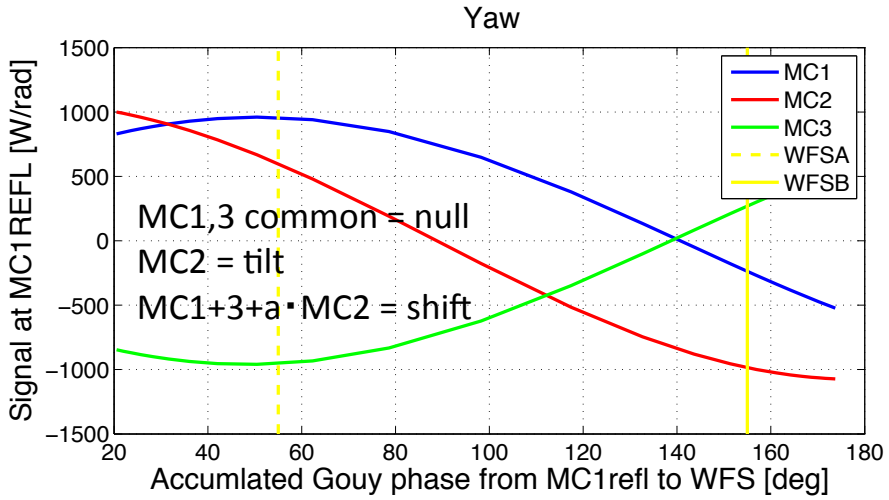
2. IMC ASC Finesse Simulation

by Finesse team

IMC ASC sensing matrix was not understood immediately since it was different from ELIGO







IMC ASC model helped us to understand the ASC signal behavior on Gouy phase domain

omitted page due to time limitation