

# IMC Servo Topology

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Ando Group

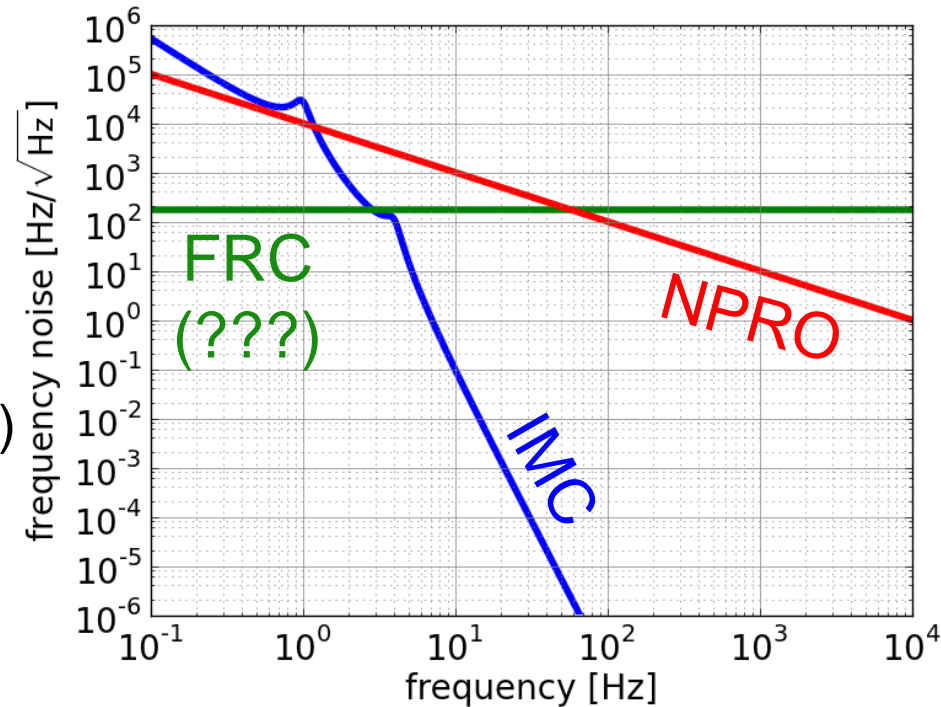
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# Scope

- Make consensus on IMC servo topology
  - frequency stabilization servo (FSS)  
IMC, FRC, wideband EOM, laser PZT  
(forget about about CARM and green for now)
  - angular control of IMC mirrors (DC/RF WFS)
- List up what do we have now and what we don't
- References:
  - [JGW-G1402519](#) (grasp of current situation by Michimura)
  - [JGW-G1402302](#) (FSS modeling by Aso)
  - [JGW-G1402520](#) (GWADW2014 IOO poster by Nakano)
  
  - Ph. D. Thesis by Ohmae (Chapter 3)
  - [Ph. D. Thesis by Rana](#) (Chapter 5)
  - Emails from Ohmae
  - [LIGO-G1300126](#) (aLIGO IMC commissioning report)

# Frequency Stabilization Servo

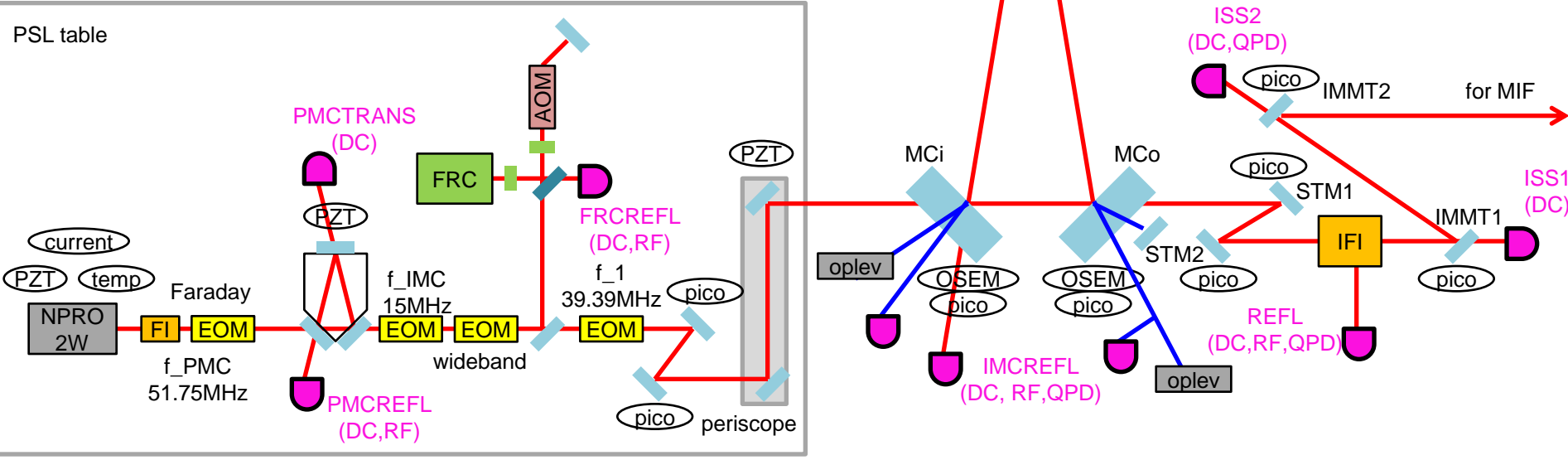
- Error signals
  - IMC REFL  
double-pendulum
  - FRC REFL  
(170Hz/rtHz@1kHz;  
according to Tai Hyun Yoon)
- Feedback actuators
  - laser temp (DC – 0.1 Hz)
  - MCE coils (DC – 1 Hz)
  - laser PZT (DC – 1 kHz)
  - FRC AOM (DC – 100 kHz)
  - wideband EOM (1 kHz – 1 MHz)



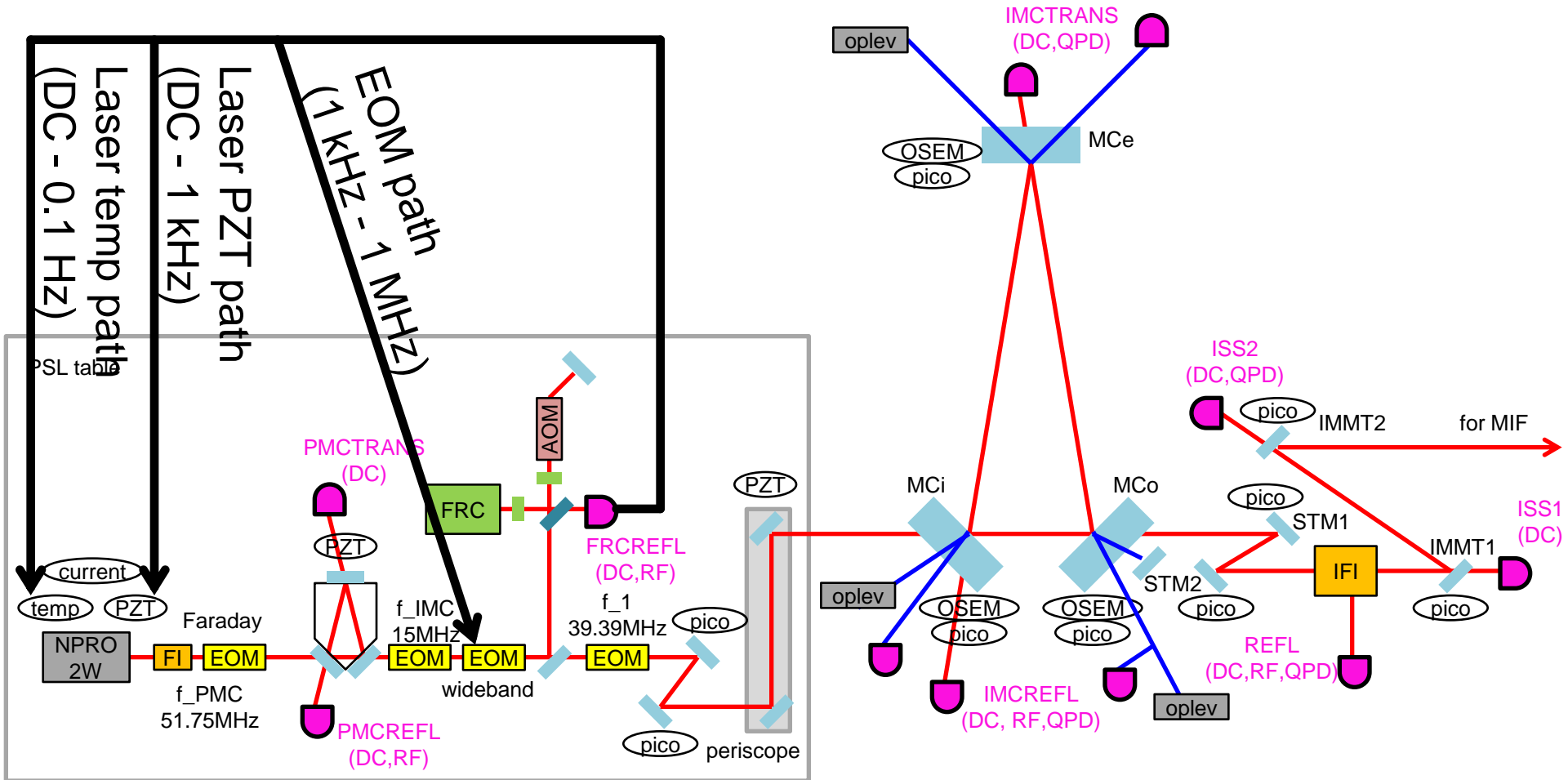
Numbers to remember:

- Kamioka seismic noise 2e-7 m/rtHz @ 0.1 Hz, 1e-11 m/rtHz @ 10 Hz, 1e-13 m/rtHz @ 100 Hz
- IMC suspension vibration isolation ratio: 0 dB @ 0.1 Hz, -60 dB @ 10 Hz, -140 dB @ 100 Hz
- IMC round-trip length: 2\*26.65 m
- laser frequency: 2.8e14 Hz
- NPRO free-run frequency noise: 10 kHz/f Hz/rtHz

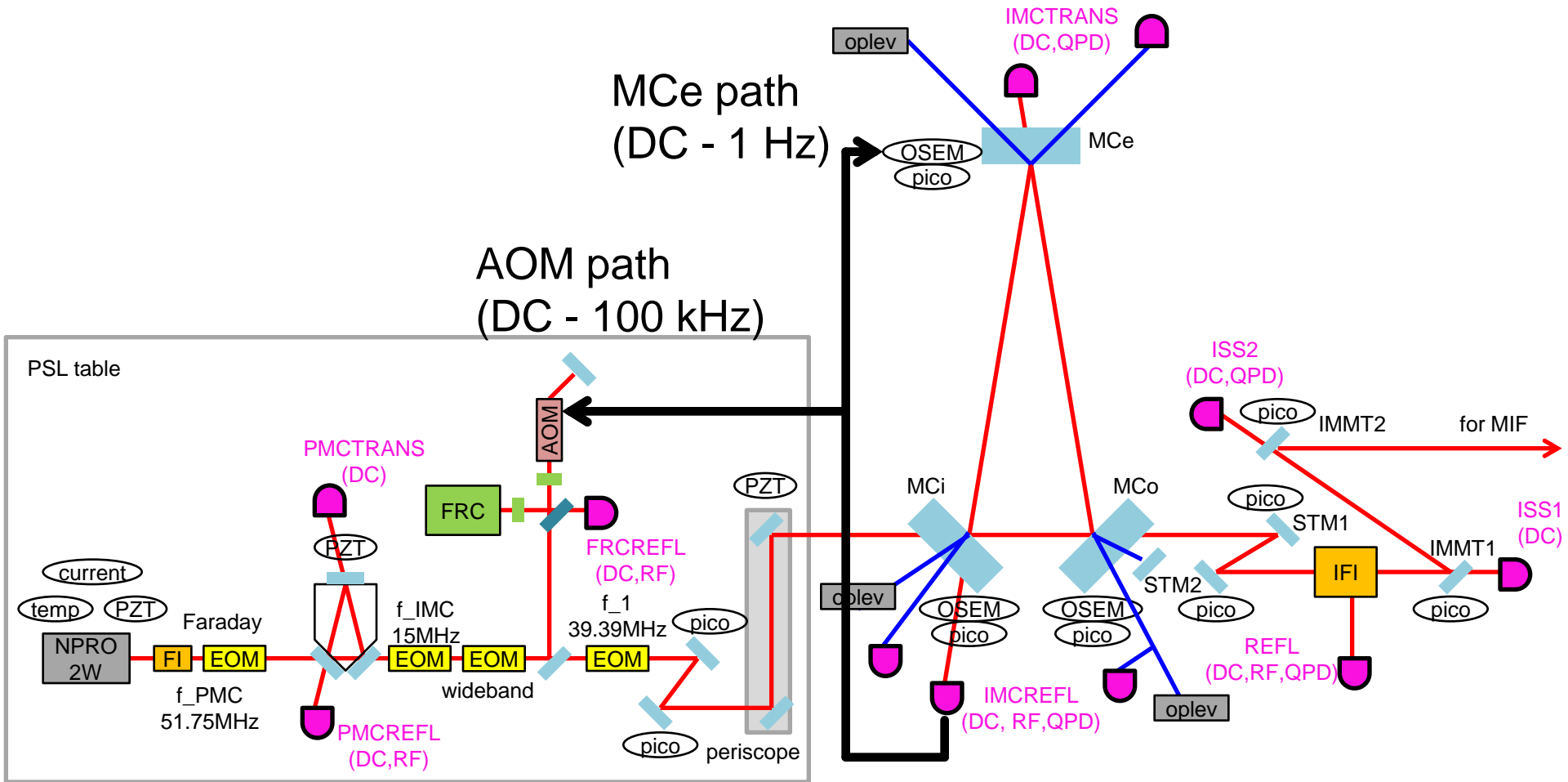
# Optical Configuration



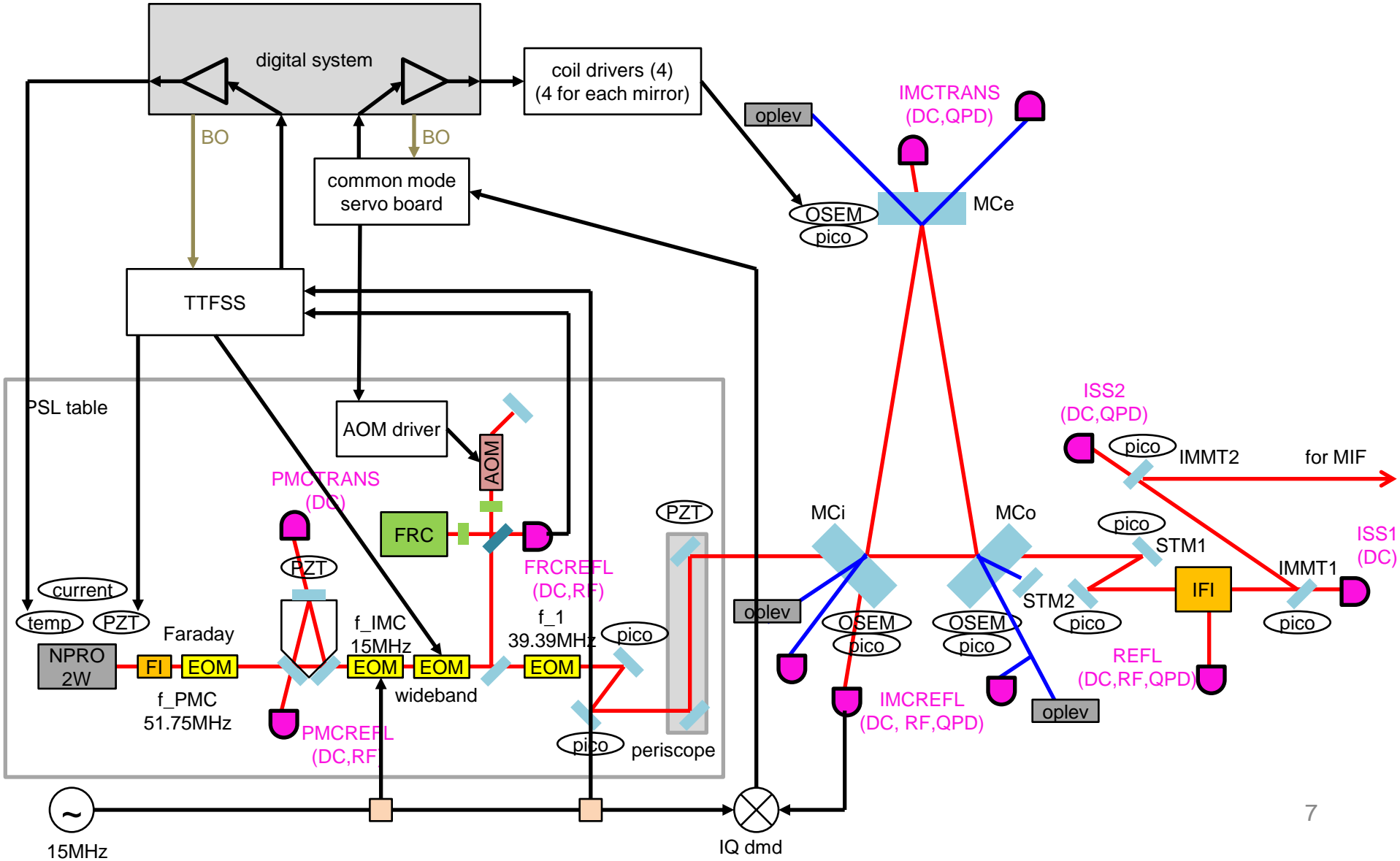
# FRC REFL Loop



# IMC REFL Loop



# Frequency Stabilization



# Actuation Efficiency/Range

- IMC servo
  - AOM (common mode board; DC – 100 kHz) efficiency: 5.3 MHz/V, range: 90-130 MHz AOM: 3110-197 driver: 1110AF-AEFO-1.5 (Crystal Technology )
  - MCE coils (digital system; DC – 1 Hz) efficiency: 280 MHz/V (25  $\mu\text{m}/\text{V}$ ) @ DC
- FRC servo
  - laser temp (digital system; DC – 0.1 Hz) efficiency: 3 GHz/V, range: 30 GHz
  - laser PZT (FSS board; DC – 1 kHz) efficiency: 1 MHz/V, range: 100 MHz
  - EOM (FSS board; 1 kHz – 1 MHz) efficiency:  $0.01 * (f/1 \text{ Hz}) \text{ Hz}/\text{V}$ , range: 0.6 MHz

## Numbers to remember:

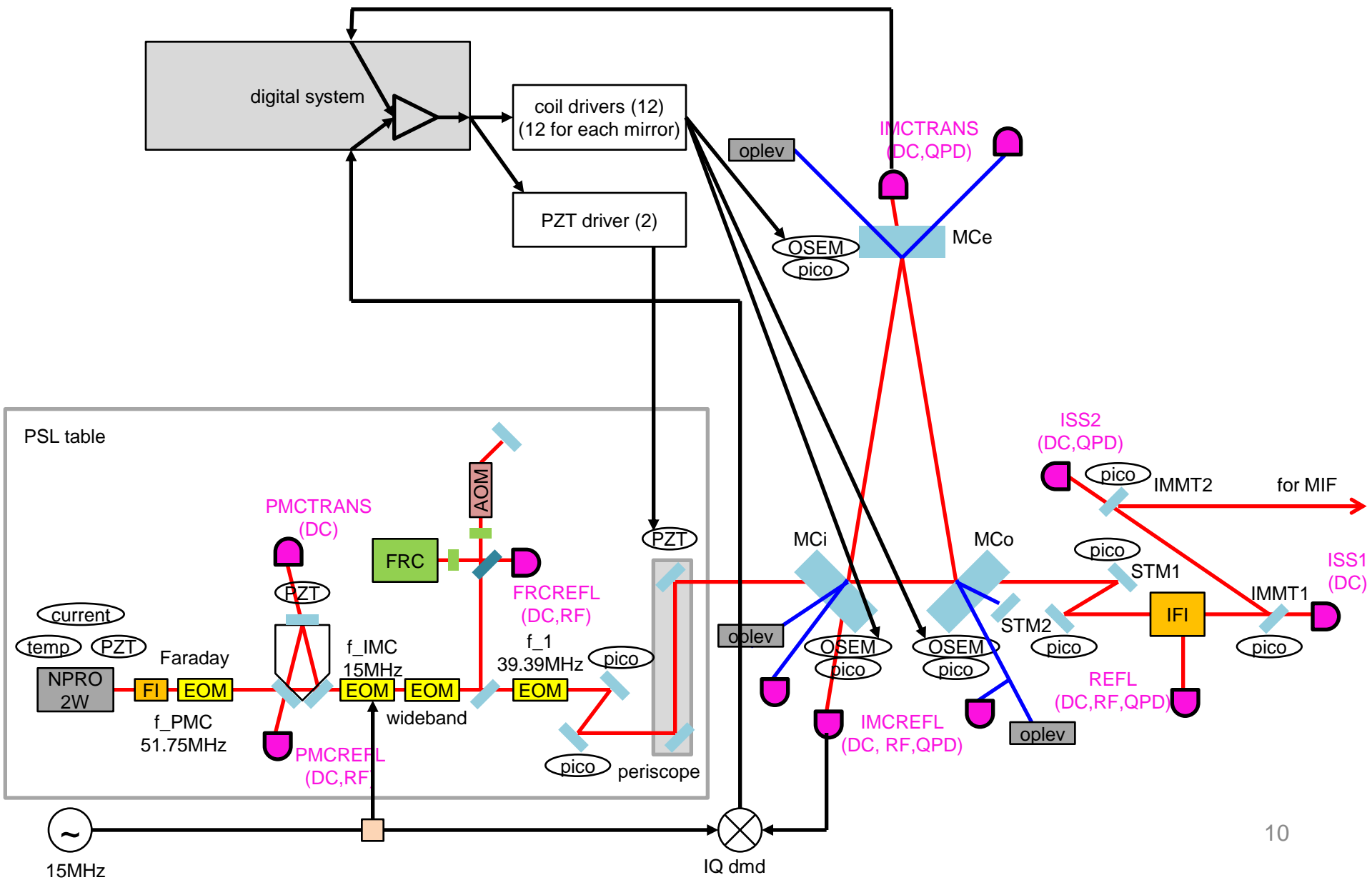
- Kamioka seismic noise  $2\text{e-}7 \text{ m}/\text{rtHz}$  @ 0.1 Hz,  $1\text{e-}11 \text{ m}/\text{rtHz}$  @ 10 Hz,  $1\text{e-}13 \text{ m}/\text{rtHz}$  @ 100 Hz
- IMC suspension vibration isolation ratio: 0 dB @ 0.1 Hz, -60 dB @ 10 Hz, -140 dB @ 100 Hz
- IMC round-trip length:  $2*26.65 \text{ m}$
- laser frequency:  $2.8\text{e}14 \text{ Hz}$
- NPRO free-run frequency noise:  $10 \text{ kHz}/f \text{ Hz}/\text{rtHz}$



# Alignment Control

- Error signals
  - IMC REFL (RF WFS)
  - IMC TRANS (DC WFS)
- Feedback actuators
  - MCi/o/e coils (DC – 10 Hz)
  - periscope PZTs (DC – 10 Hz)
- IMC ASC study
  - [JGW-T1402481](#) (calculation by T. Saito)
  - [LIGO-T1300074](#) (Finesse vs measurement)
  - [LIGO-G1301131](#) (DOF)

# Alignment Sensing and Control



# AEL Related

- **PMC(1) / FSS(1) / IMC(1) servo circuits**  
IMC servo board is not there yet ([LIGO-D040180](#) aLIGO common mode servo board)  
TTFSS servo board is already there at ICRR  
[JGW-D1301823](#) TTFSS board is for EOM path and PZT path (copy of [LIGO-D040105](#))
- **RF PD(4) / RF QPD(4) / DC PD(7) / DC QPD(4) (at least!)**

PMCREFL	IMCREFL A/B	PMCREFL	IMCTrans A/B
IMCREFL	REFL A/B	PMCTrans	ISS1 A/B
REFL		IMCREFL	(it would be nice to have
FRCREFL		IMCTrans	2 more at PSL table for
		REFL	incident beam monitor)
		ISS1	
		ISS2	

LSC RF PD: [JGW-D1201280](#) Oplev QPD: [JGW-D1402411](#) (S5981)
- **IQ demodulators(17ch)**  
1 for each RF PD, 4 for each RF QPD  
(for RF PDs, we use phase shifters because we do fast servo in IOO)
- **RF distributors** f\_PMC: split into 2 (EOM, PMCREFL)  
f\_IMC: split into 11 (EOM, IMCREFL, 4xIMCREFLA/B, FRCREFL)
- **RF source(3)** f\_1: split into 21? (EOM, REFL, 4xREFLA/B, AS, 4xASA/B, POX?, POY?)
- **picomotor drivers(18ch, at least!)**  
2 for each mirror  
PSLSTM1/2  
STM1/2  
IMMT1/2  
MCi/e/o (top stage)  
(it would be nice to have 2 for each PD/QPD for aligning the beam into them)
- **PZT drivers(3ch)** 2 for periscope mirror  
1 for PMC  
(1 for laser is included in TTFSS)
- **coil drivers(12ch)** 4 for each MC mirror

# By Schedule

Month	Tables / DGS	PMC	FRC	IMC sus	IMC
2014/10	PSL table				
2014/11 (PMC/ FRC)	IMC REFL table(?) IMC TRANS table(?)	DC PD x 1 RF PD x 1 camera x 1 or 2 51.75 MHz source RF splitter x 1ch IQ demod x 1ch (cable/mixer/LPF) PMC servo board (SR560) PZT driver x 1ch	RF PD x 1 15 MHz source RF splitter x 1ch IQ demod x 1ch (cable/mixer/LPF) TTFSS		
2014/12				oplev QPD x 3	picomotor driver x 4ch
2015/01 (IMC LSC)	digital system 1 for PSL 1 for IMC			coil drivers x 12ch picomotor driver x 12ch	DC PD x 1 RF PD x 1 camera x 1 or more (15 MHz source) RF splitter x 1ch IQ demod x 1ch (cable/mixer/LPF) IMC servo board (SR560)
2015/02 (IMC ASC)					DC QPD x 2 RF QPD x 2 RF splitter x 8ch IQ demod x 8ch PZT driver x 2ch

•Blue things are already there (might need modification or soldering)

•Red things are temporary

# Forgetful Considerations

- Initial alignment
- Cameras
- Gouy phase telescopes