IMC Servo Topology

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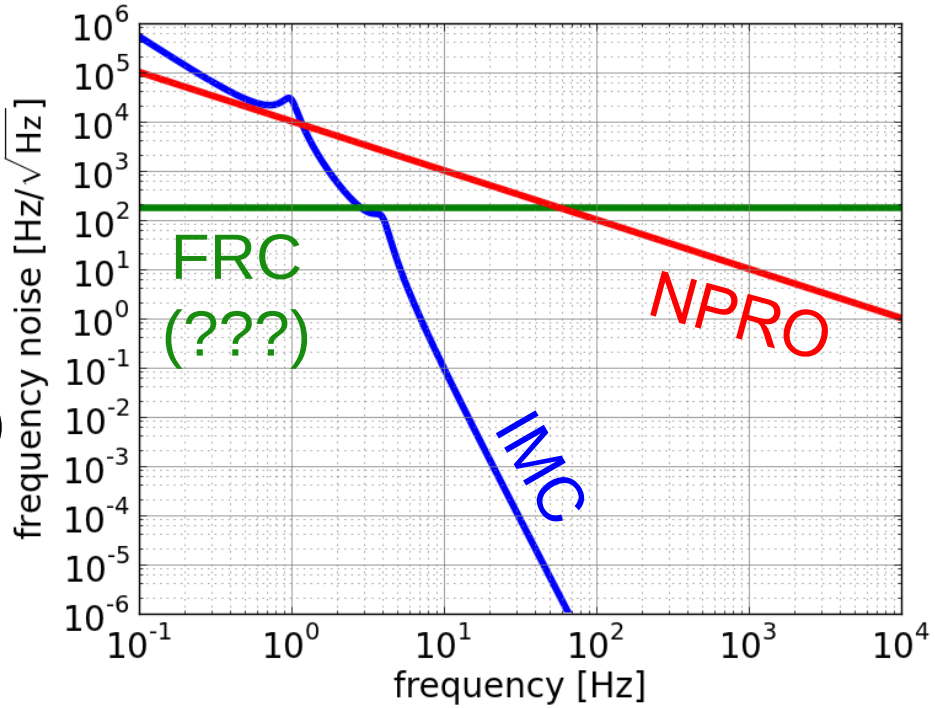
Scope

- 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)

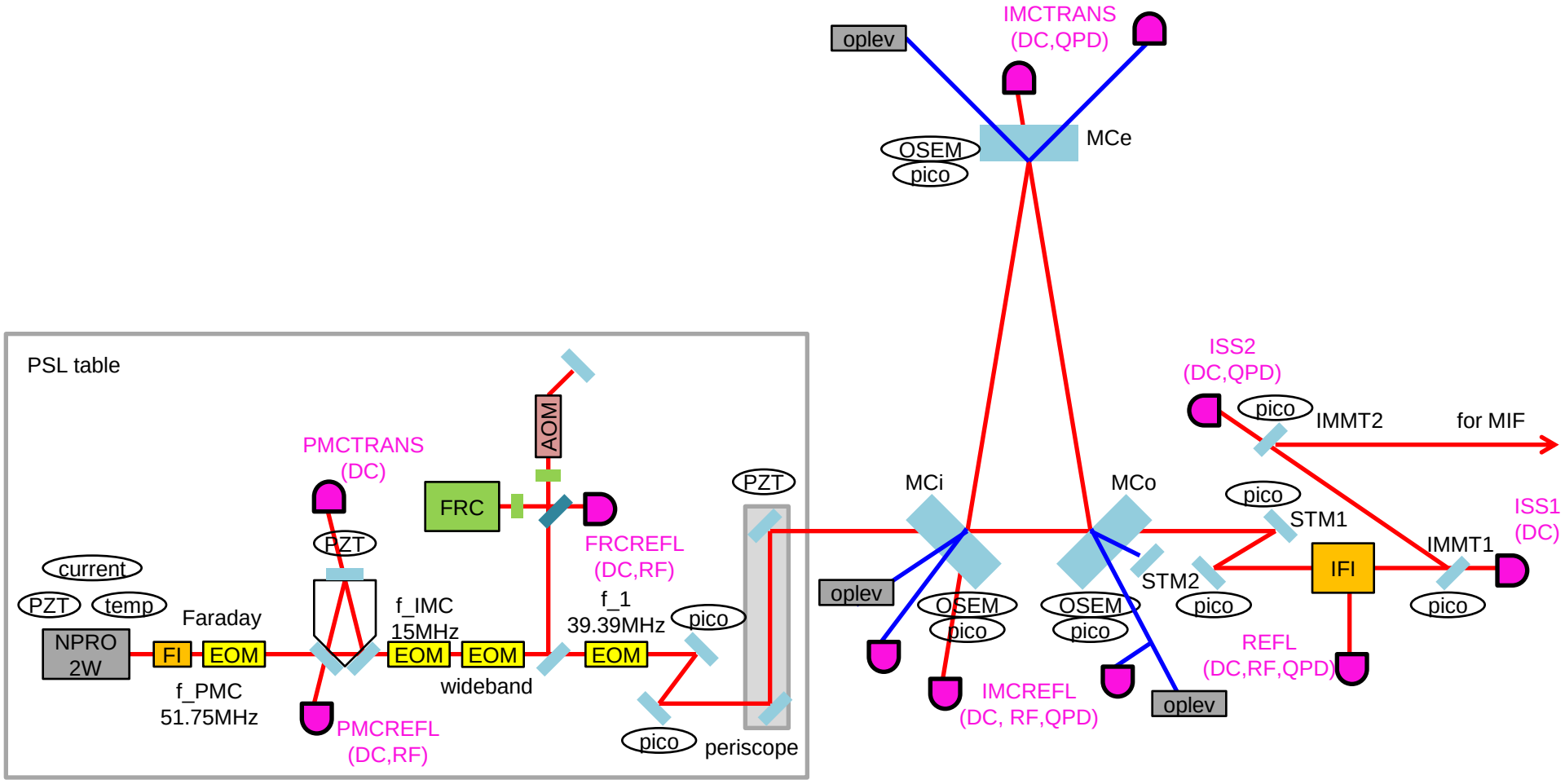
Frequency Stabilization Servo

- 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)

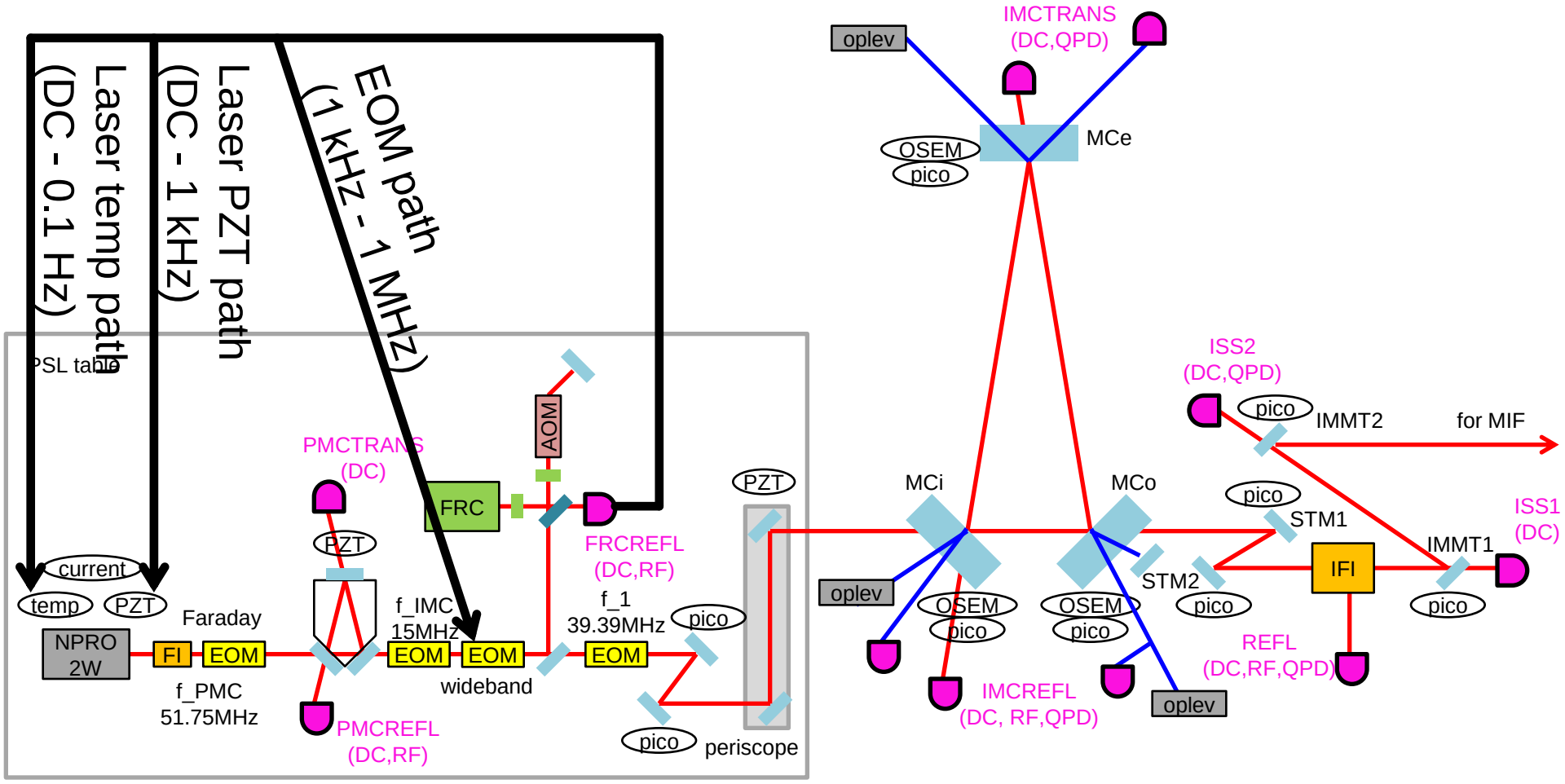


Numbers to remember:
- Kamioka seismic noise 2e-7 m/rtHz @ 0.1 Hz, 1e-11 m/rtHz @ 10 Hz, 1e-13 m/rtHz @ 100 Hz
- IMC suspension vibration isolation ratio: 0 dB @ 0.1 Hz, -60 dB @ 10 Hz, -140 dB @ 100 Hz
- IMC round-trip length: 2*26.65 m
- laser frequency: 2.8e14 Hz
- NPRO free-run frequency noise: 10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

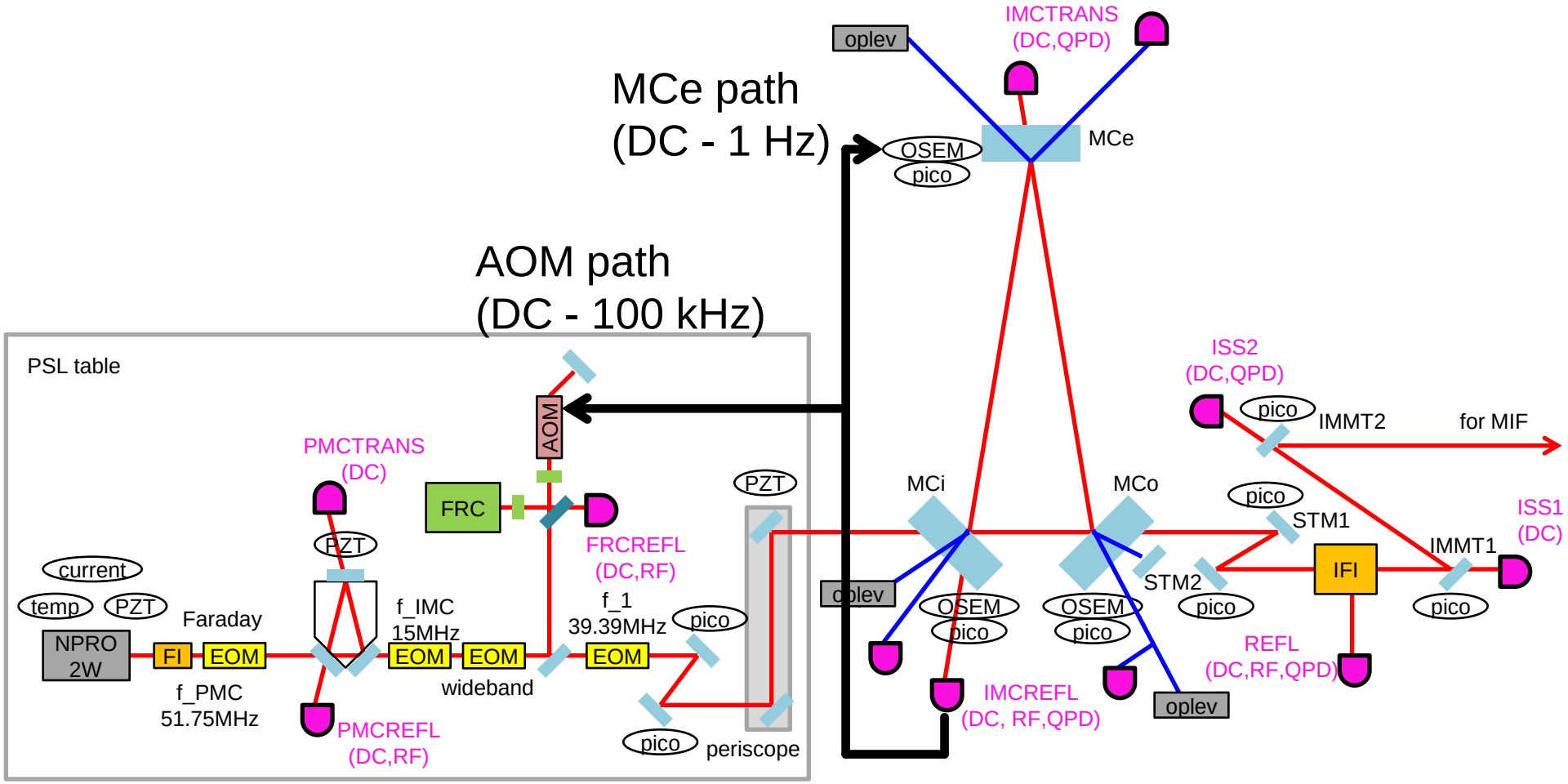
Optical Configuration



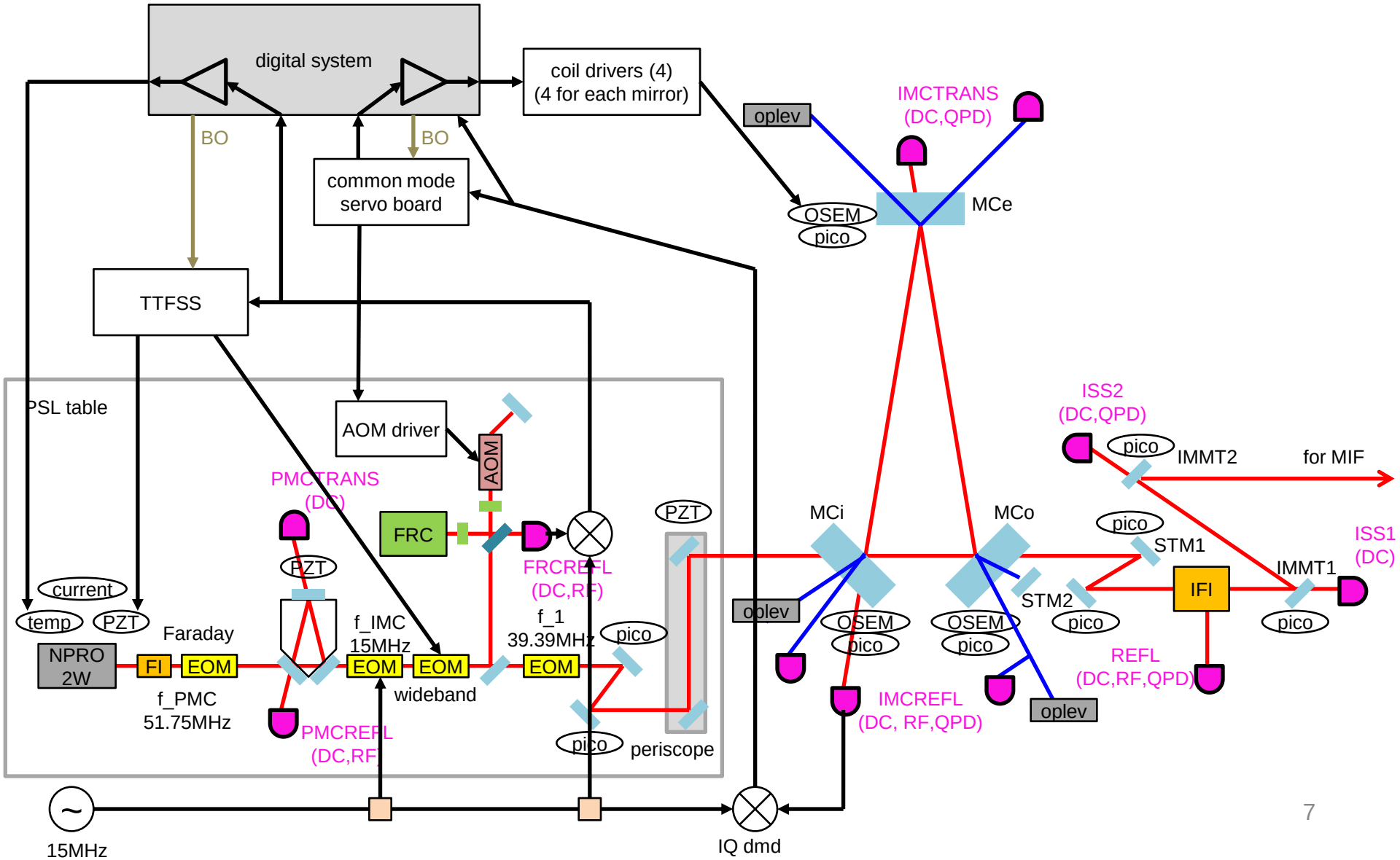
FRC REFL Loop



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
  - MCe coils (digital system; DC – 1 Hz)
    efficiency: 280 MHz/V (25 um/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 Hz) Hz/V, range: 0.6 MHz

AOM: 3110-197
driver: 1110AF-AEFO-1.5
(Crystal Technology)

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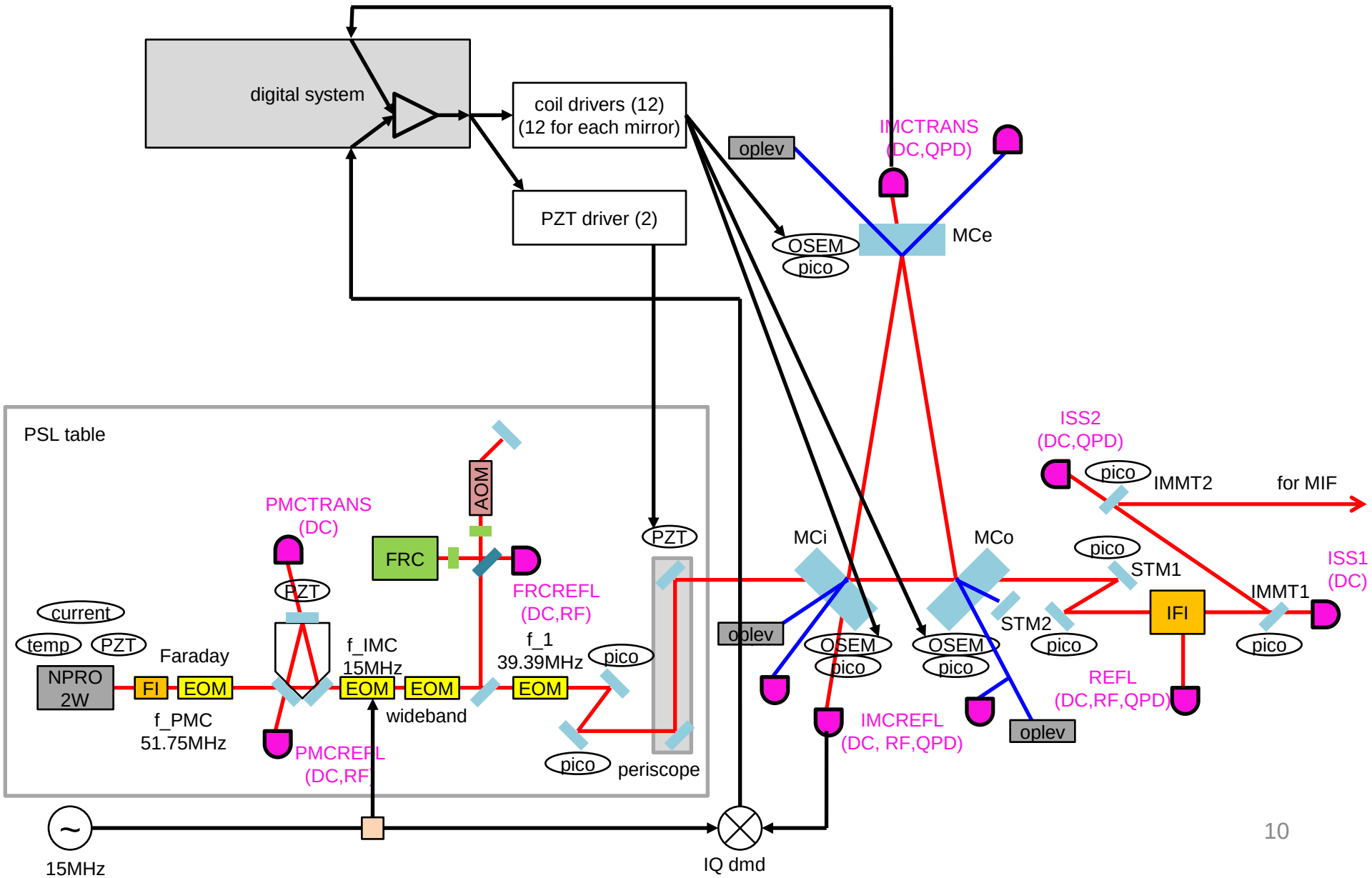
Alignment Control

- 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



copied from JGW-G1402519

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
  REFL
  FRCREFL

  IMCREFL A/B
  REFL A/B

  PMCREFL
  PMCTRANS
  IMCREFL
  IMCTRANS
  REFL
  ISS1
  ISS2

  IMCTRANS A/B
  ISS1 A/B
  (it would be nice to have 2 more at PSL table for incident beam monitor)

  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)
  f_1: split into 21? (EOM, REFL, 4xREFLA/B, AS, 4xASA/B, POX?, POY?)

- RF source(3)

- 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