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Optical/Electrical Components Needed for iKAGRA IMC Servo

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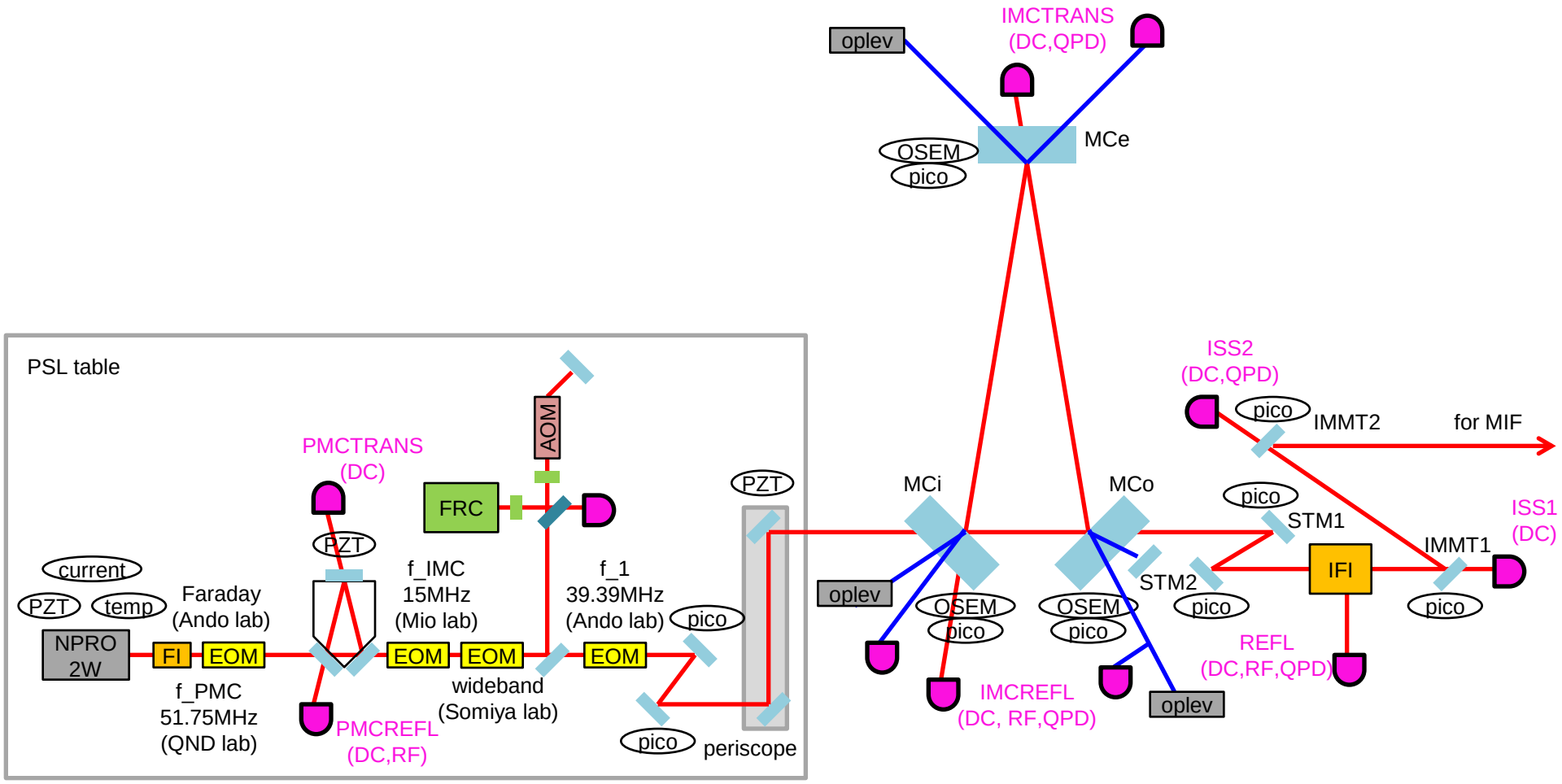
Scope

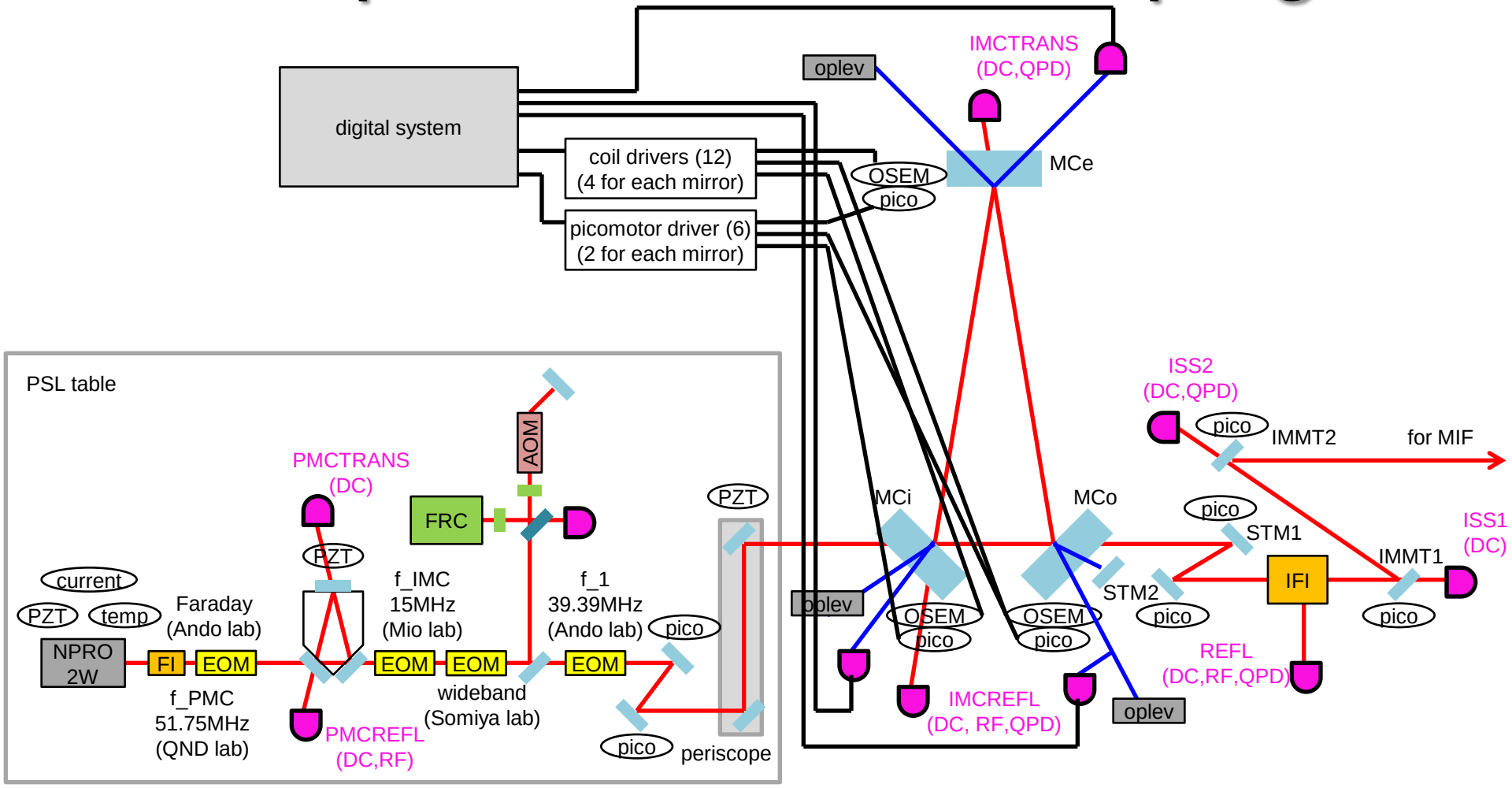
- Start discussion on listing up what we need for iKAGRA IMC (and PSL) servo
- Focus mainly on optical and electrical components

- References:
  - JGW-T1402349 (iKAGRA PMC study)
  - JGW-G1402302 (FSS modeling)
  - JGW-G1402520 (GWADW2014 IOO poster by Nakano)
  - JGW-D1402507 (IOO 3D drawing)
  - JGW-T1302068 (layout around IMMT)
  - JGW-D1402492 (IMC suspension cabling)
  - JGW-D1402516 (anchor, floor mortar, floor cutting lines)
  - Wiki/SmallOptics (list of small optics)
  - Wiki/OutputTables (list of output optical tables)

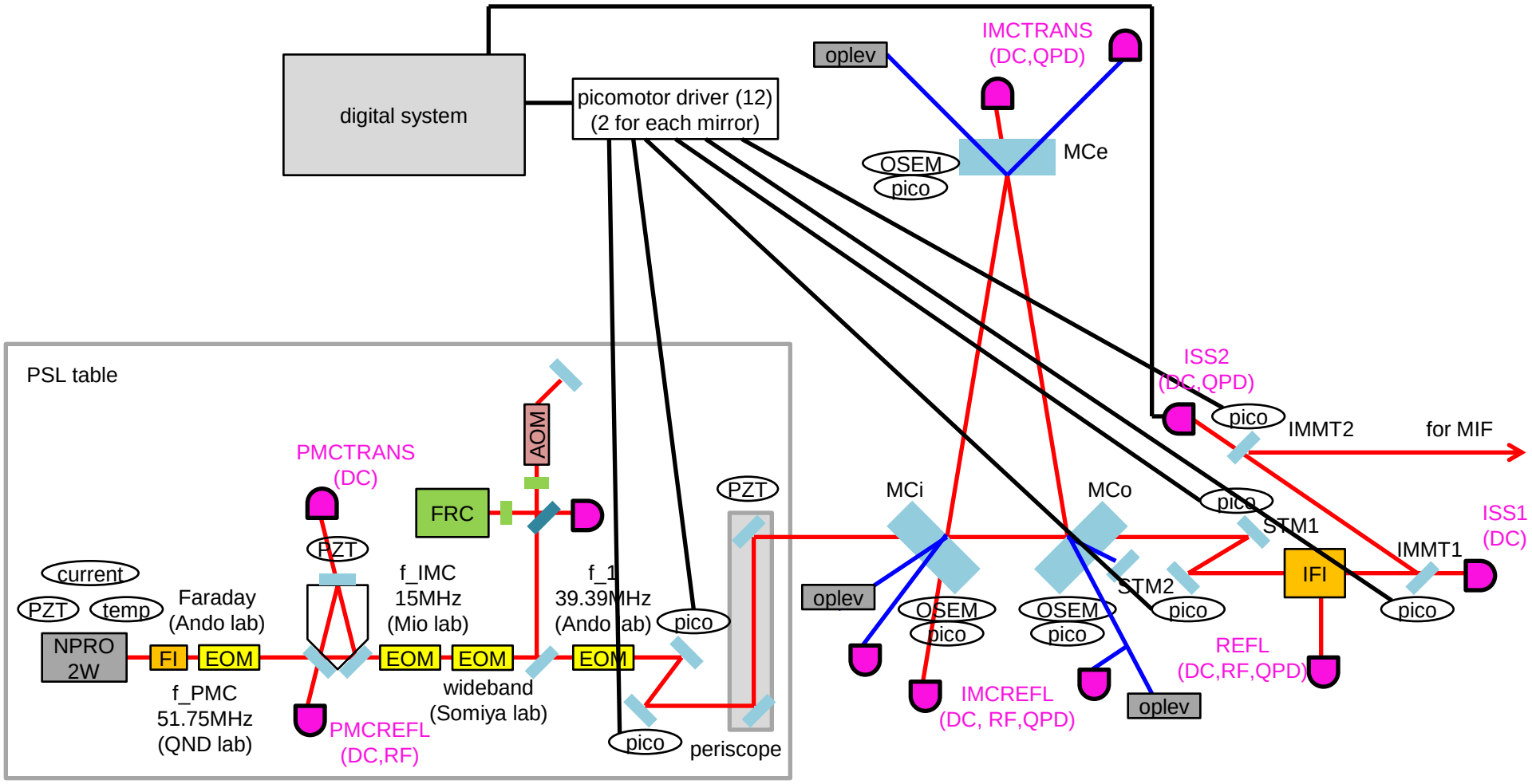
Optical Configuration



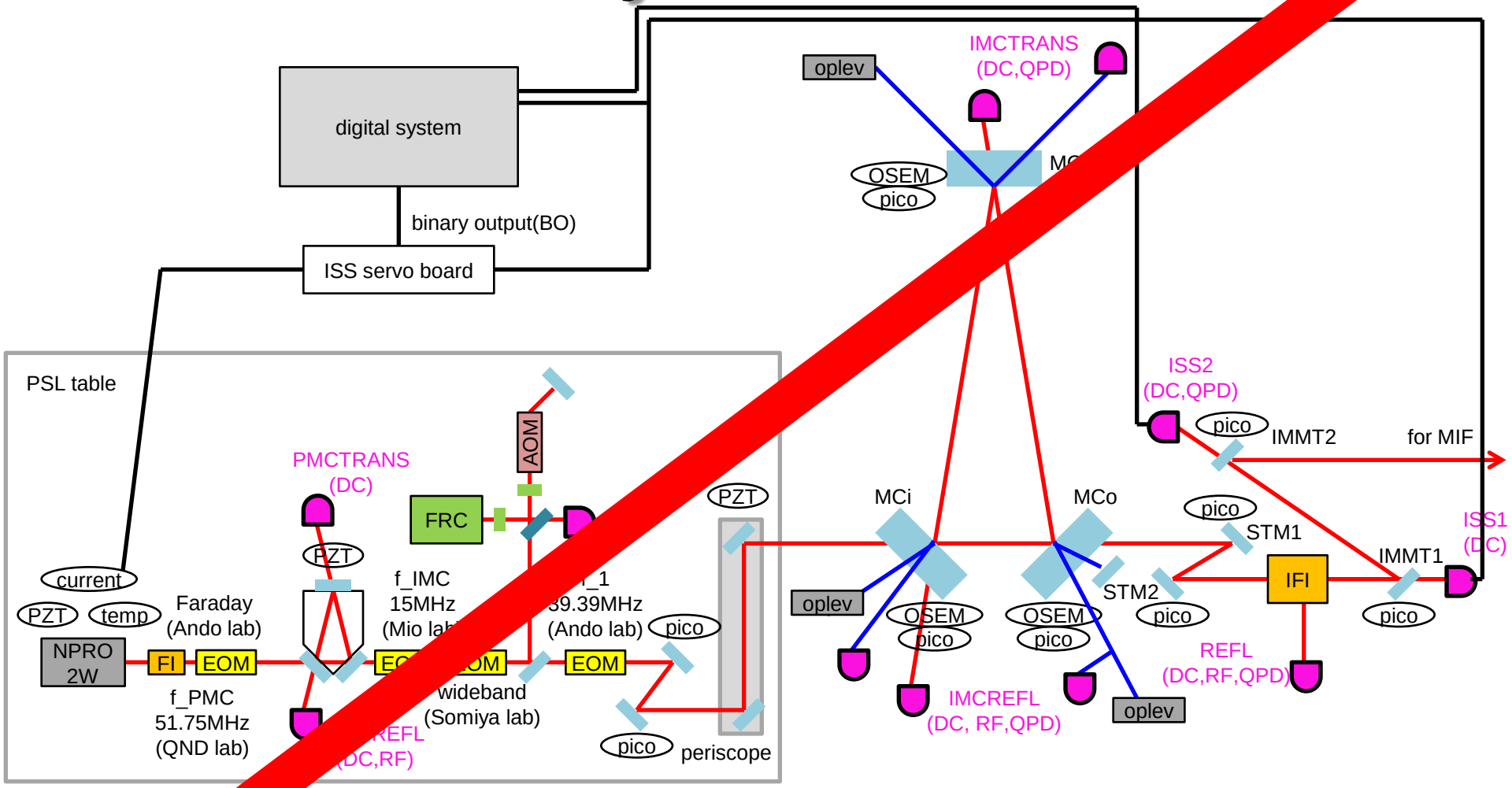
Suspension Local Damping



Initial Alignment

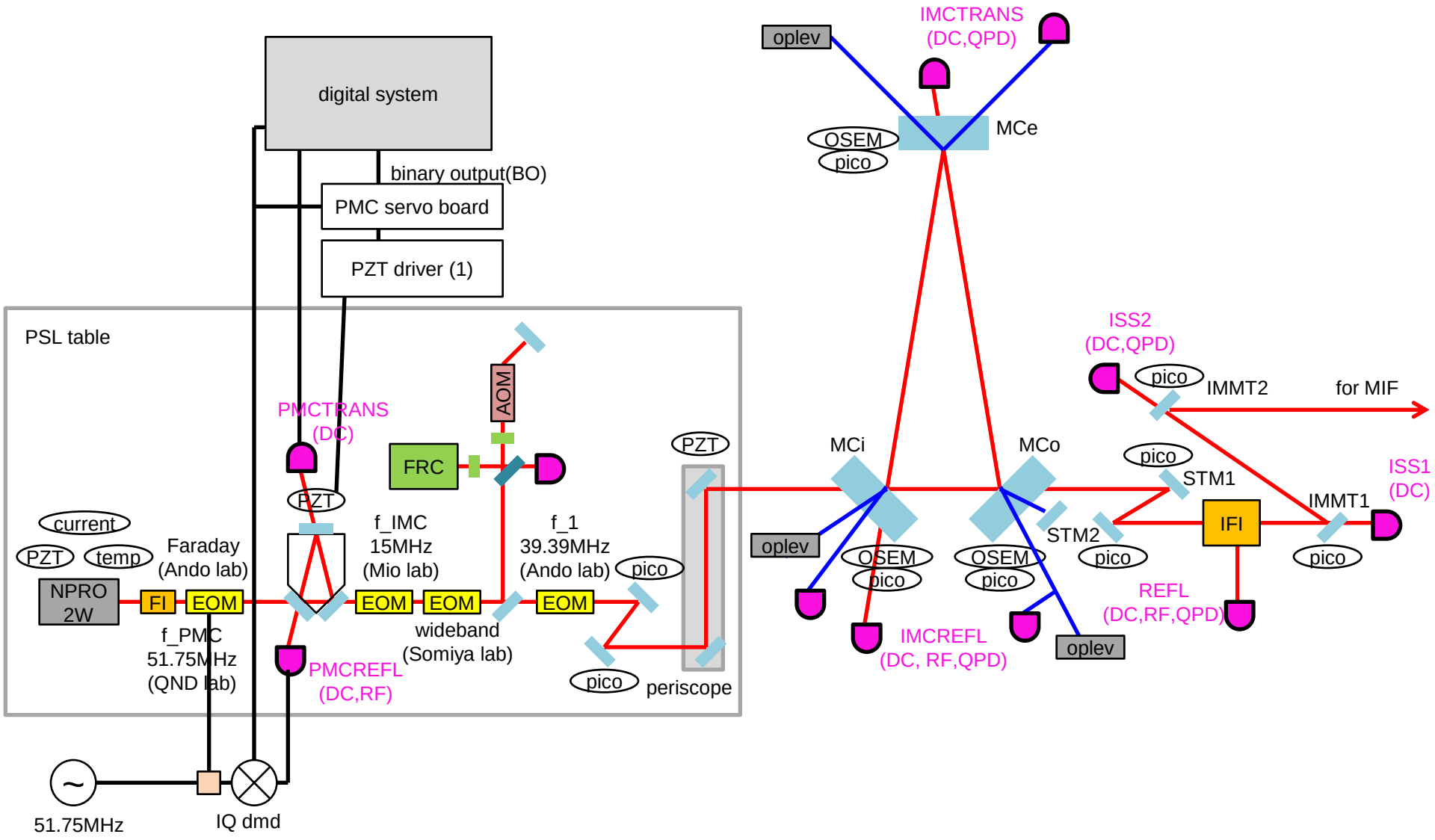


Intensity Stabilization

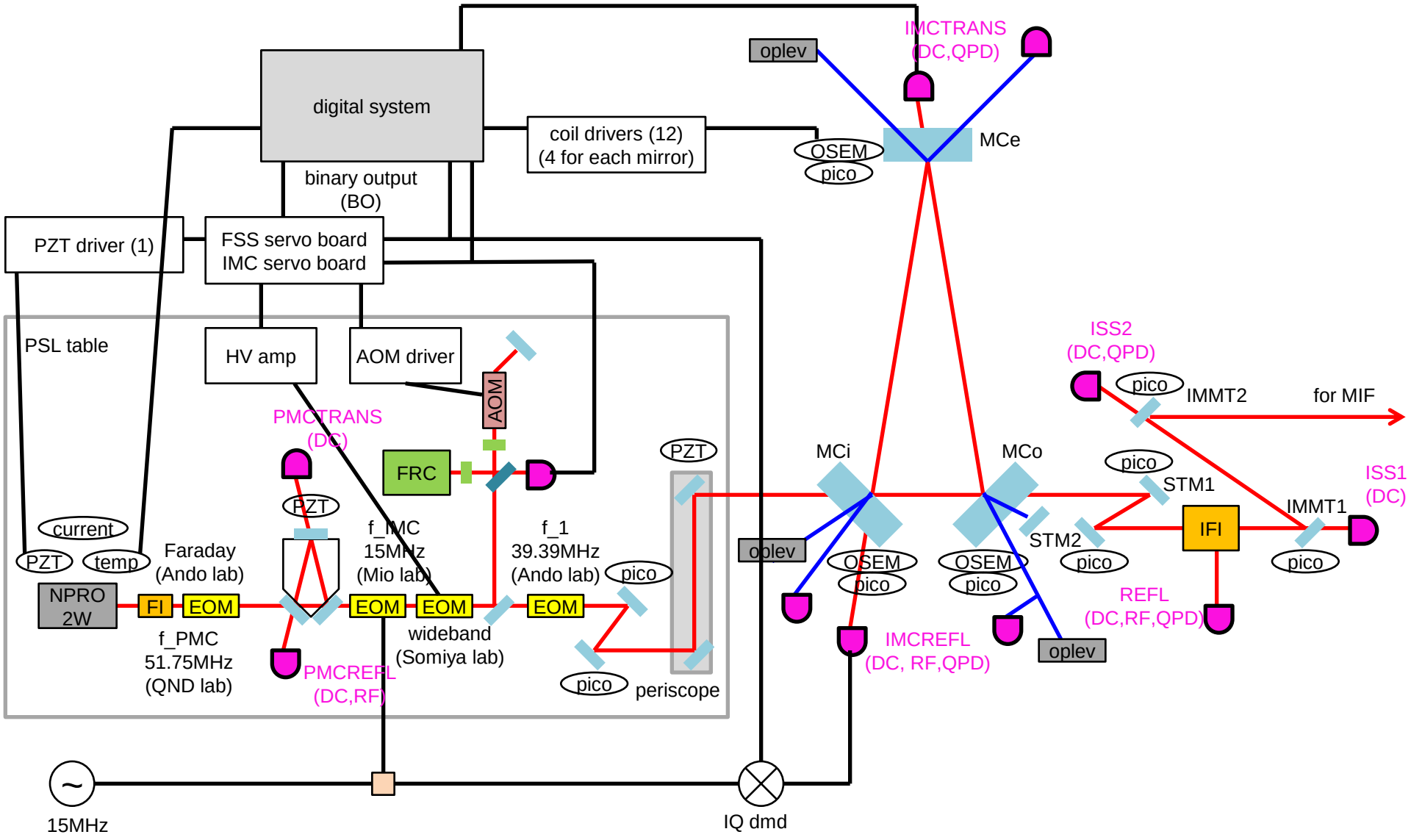


ISS is not a default plan in iKAGRA

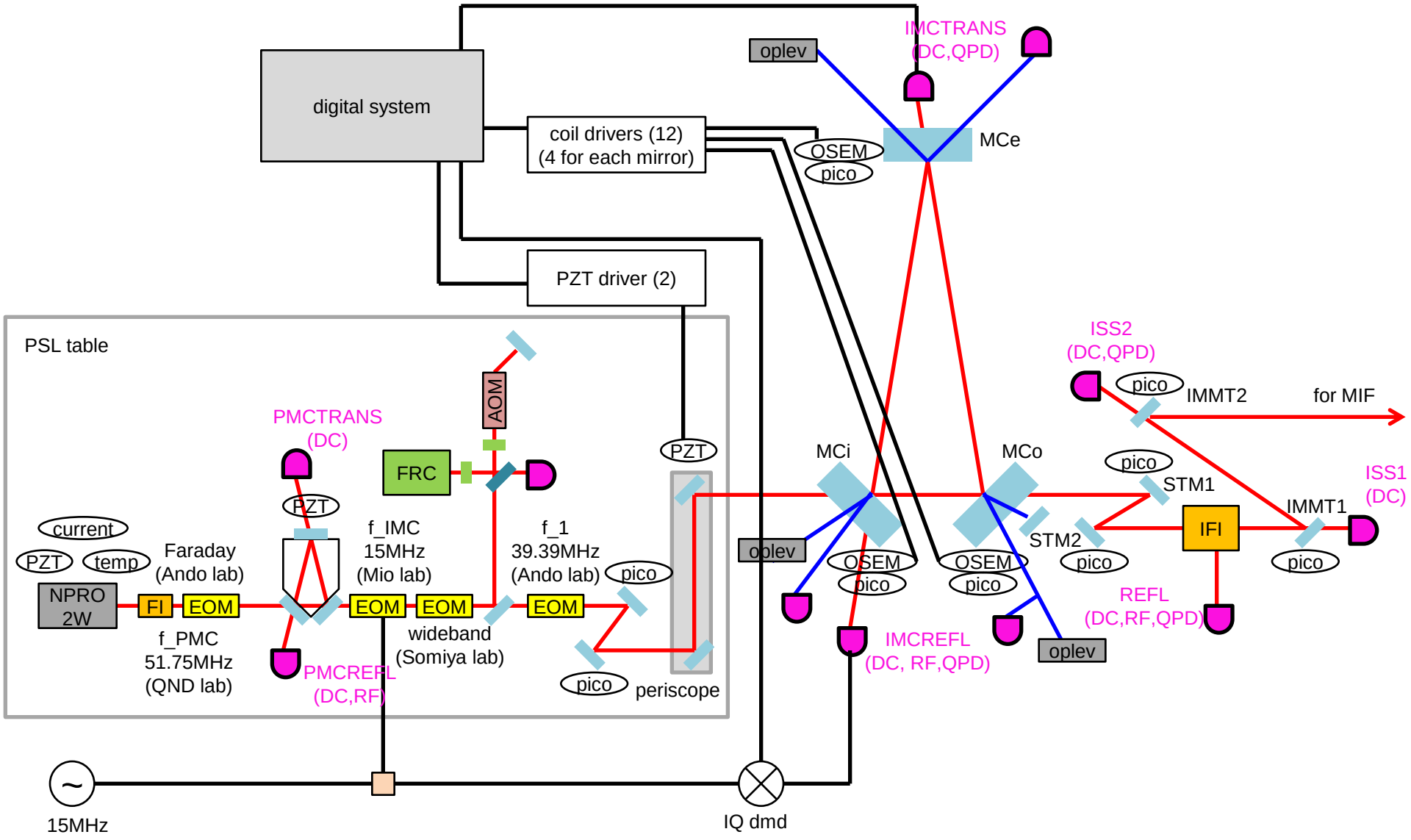
PMC Servo


digital system
binary output(BO)
PMC servo board
PZT driver (1)
PSL table
PMCTRANS
(DC)
AOM
FRC
PZT
current
PZT
temp
Faraday
(Ando lab)
NPRO
2W
FI
EOM
f_PMC
51.75MHz
(QND lab)
PMCREFL
(DC,RF)
f_IMC
15MHz
(Mio lab)
EOM
EOM
wideband
(Somiya lab)
f_1
39.39MHz
(Ando lab)
EOM
PZT
pico
pico
periscope
51.75MHz
IQ dmd
IMCTRANS
(DC,QPD)
oplev
OSEM
pico
MCe
MCi
MCo
oplev
OSEM
pico
OSEM
pico
IMCREFL
(DC, RF,QPD)
oplev
ISS2
(DC,QPD)
pico
IMMT2
for MIF
pico
STM1
ISS1
(DC)
IMMT1
IFI
STM2
pico
pico
REFL
(DC,RF,QPD)

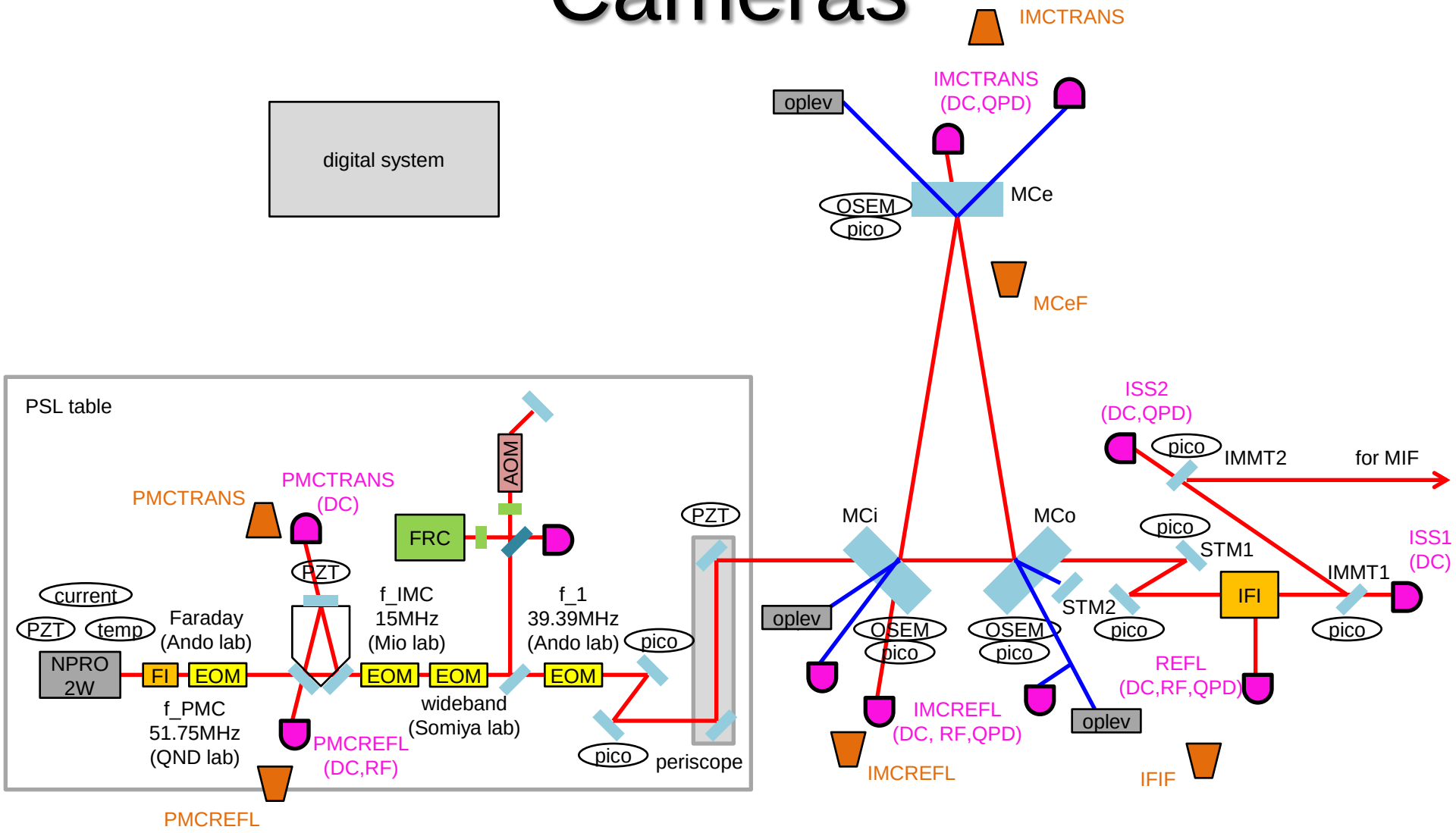
Frequency Stabilization



Alignment Sensing and Control



Cameras



6 cameras?

How do we put their signals in the digital system?

Gouy Phase Telescopes

- We need two QPDs for each port we want to monitor the beam alignment
- It would be nice to have standardized Gouy phase telescopes for each port

- Below is an example aLIGO one (~ 15 cm x 55 cm) LIGO-T1000247

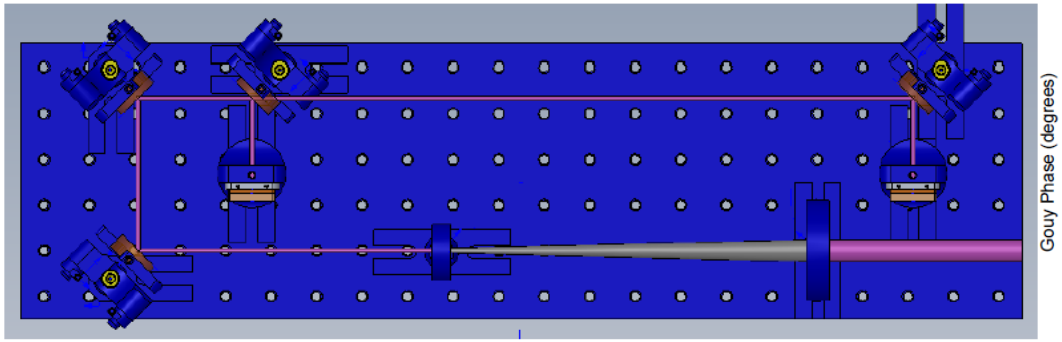


Figure 2: The REFL port QPD layout.

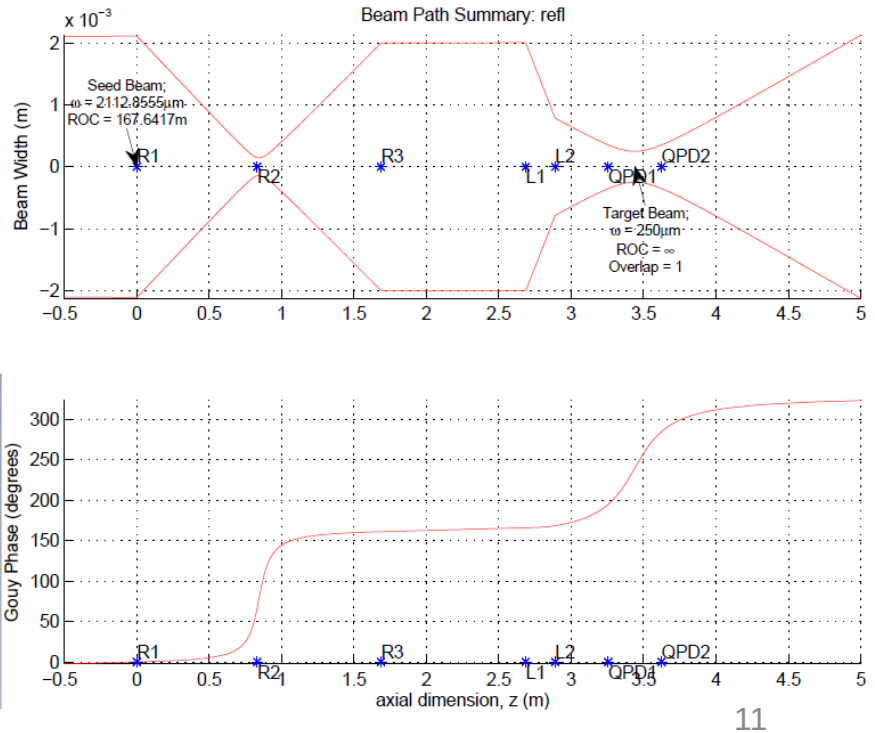


Figure 1: The REFL port telescope beampath.

Optical Components Missing

- PSL periscope
  - we have dumped rods available in Ando Lab
  Newport 45
  Newport M-340-RC already delivered to Ohshima-san
- Gouy phase telescopes and other optical components for each port
  - we can buy flat mirrors and mounts with a rough estimate of numbers, but what do we do for lenses?
- High voltage amplifier for broadband EOM
  Newport 3211 (0.5 MHz bandwidth)
  already included in TTFSS servo board
- AOM for FRC?
  was already there at ICRR (including a driver)

- I suppose there are much more……

FSS Topology (rough idea)

- IMC servo (2 MHz/rtHz @ 0.1 Hz, 0.1 Hz/rtHz @ 10 Hz)
  - AOM (common mode board; DC – 100 kHz)
    efficiency: 5.3 MHz/V, range: 90-130 MHz
  - MCe (digital system; DC – 1 Hz; optional)

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

Actuation efficiency and range?

- FRC servo (with rough estimate, 170 Hz/rtHz @ 1kHz)
  - 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

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

DGS Related

- standalone digital system is needed by Nov 2014
- it is not considered as a baseline DGS schedule
  - full digital system with networks will be available only from Jan 2015
- VIS will also need a standalone for IMC suspensions
  - maybe one standalone will do for VIS & IOO

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)

- 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 (DGS, AEL)

Month	To Do	VIS/AOS	IOO
2014/10	install PSL table		
2014/11	PMC FRC		SR560 RF PD x 2, DC PD x 2 TTFSS servo board RF source x 2 & splitter / mixer PZT driver x 1ch
2014/12	align beam to IMC install IMC sus	oplev QPD x 3	picomotor driver x 4 ch
2015/1	digital system installed IMC LSC	coil drivers x 12ch picomotor driver x 6 ch	SR560 RF PD, DC PD x 2 RF source x 1 & splitter / mixer
2015/2	IMC ASC		RF QPD x 2, DC QPD x 2 IQ demod x 8ch (in fabrication) RF distributors PZT driver x 1ch
2015/3	improve IMC install REFL/AS table		PMC servo board IMC servo board DC PD x 2, DC QPD x 2

- Blue things are already there (might need modification or soldering)
- Red things are temporary

Oplev QPD: JGW-D1402411 (S5981)

Picomotor Driver

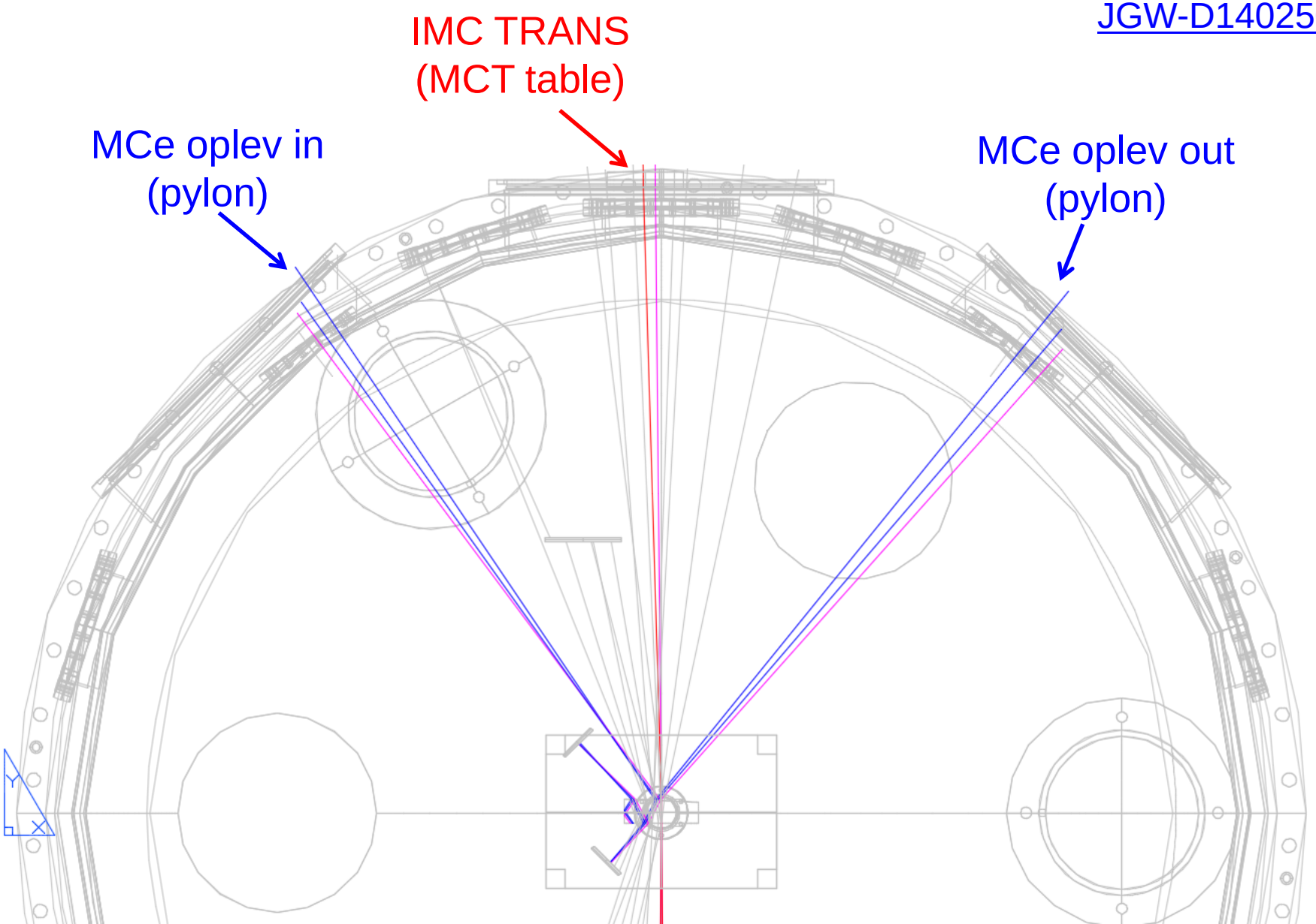
- For CLIO, NewFocus drivers below were used
  PICOMOTOR EHTERNET CONTROLLER 8752
  INTELLIGENT PICOMOTOR DRIVER 8753
  Now, they are discontinued and replaced with
  Four-Axis Picomotor Controller/Driver Kit 8742-4-KIT
- Picomotor control with EPICS and Python
  http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/CLIO/Technicals/PMEPICS
  http://gwclio.icrr.u-tokyo.ac.jp/lcgtsubgroup/digitalsystem/2012/03/new-focus-picomotor-controlled-at-stda.html
- No special interface circuit is needed for controlling picomotor from digital system

Cables

- TBD
- JGW-D1402492 (IMC suspension cabling)

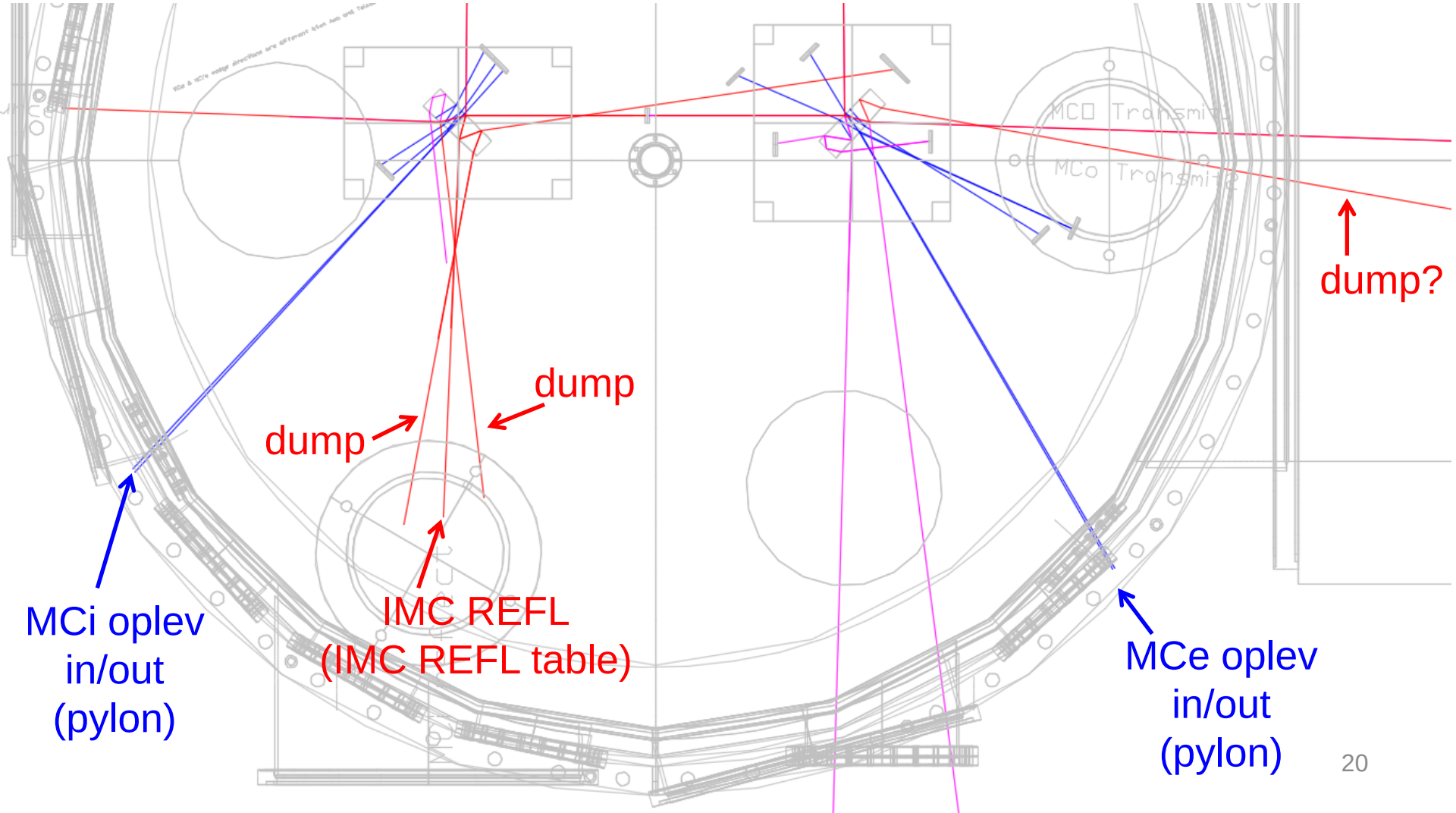
Beams around MCe

JGW-D1402507



Beams around MCi and MCo

JGW-D1402507

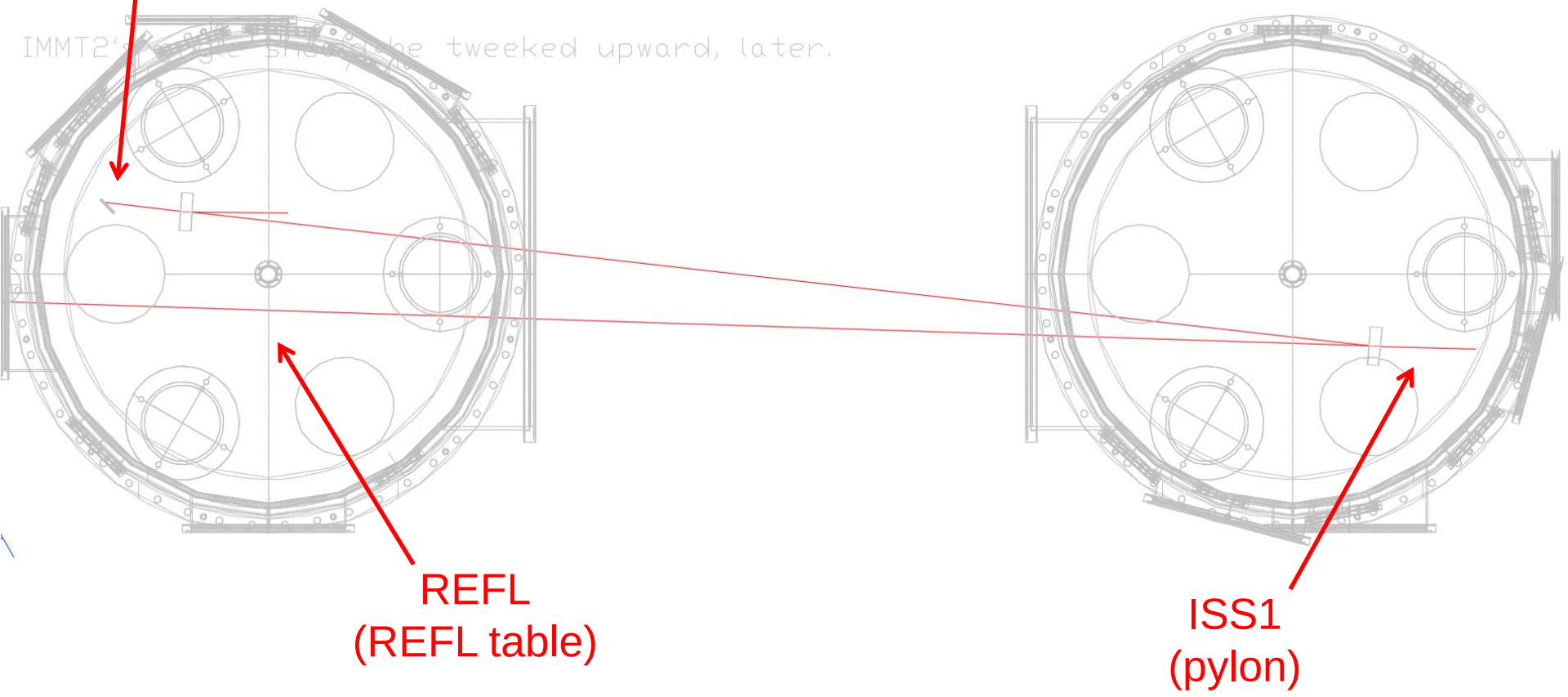


Beams around IMMT1/2

JGW-D1402507

ISS2
(pylon->IMMT2 table)

IFI not included in the drawing yet



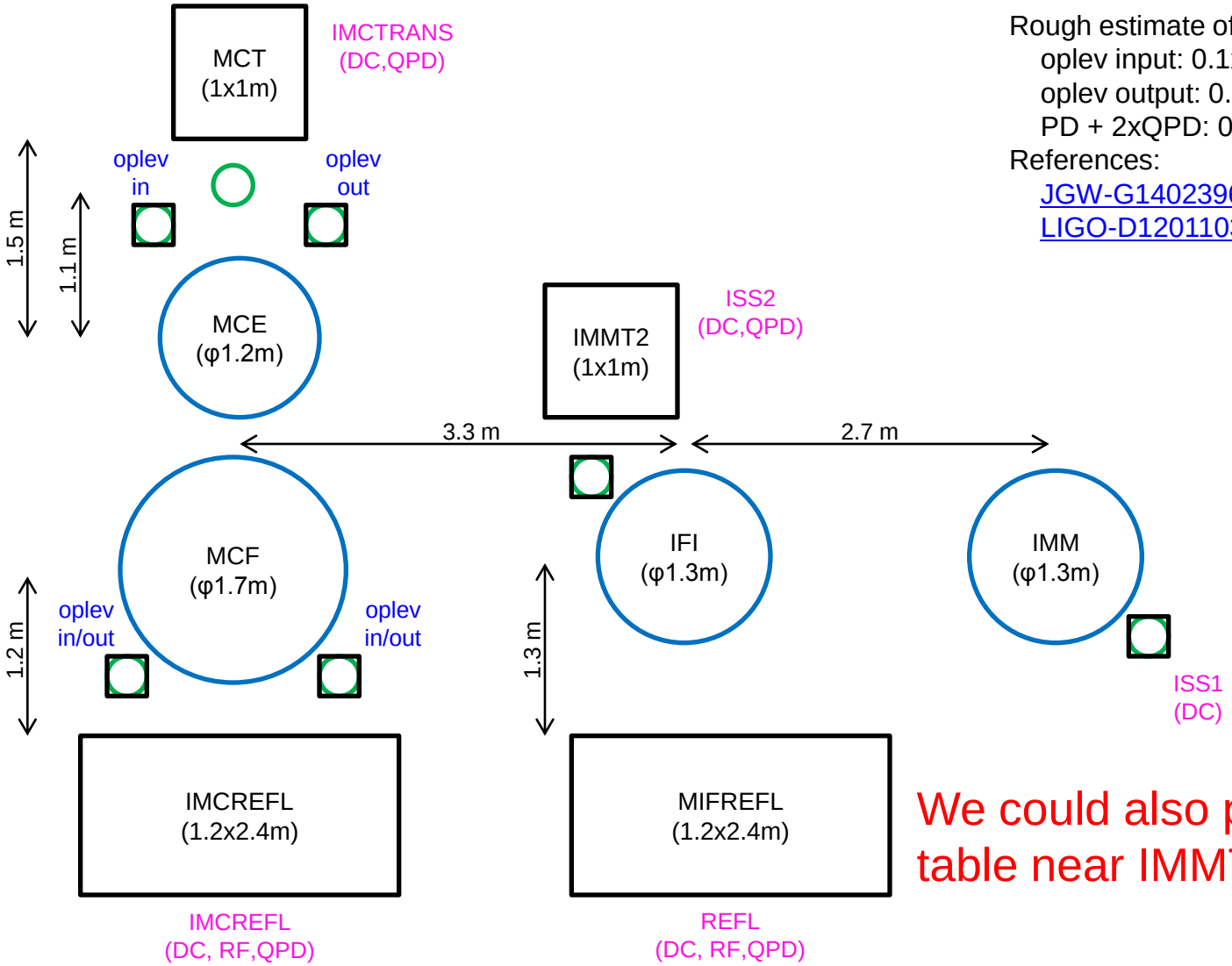
REFL
(REFL table)

ISS1
(pylon)

Optical Tables / Pylons Layout

- chamber: ◯ pylon: ○ table: □

Wiki/OutputTables



Rough estimate of space required
- oplev input: 0.1x0.1 m
- oplev output: 0.1x0.1 m
- PD + 2xQPD: 0.8x0.8 m

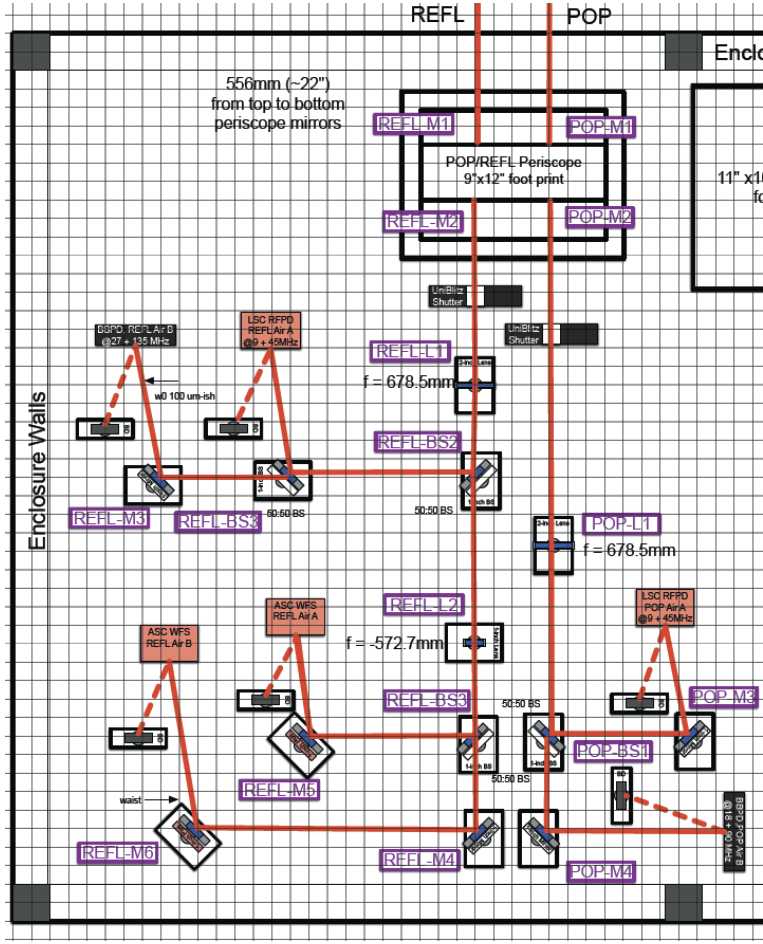
References:
- JGW-G1402396 (oplev)
- LIGO-D1201103 (aLIGO ISCT1 table)

We could also place a 1 m x 1 m table near IMMT1

Small Optics for whole IOO

Wiki/SmallOptics

- port with DC PD + RF PD + 2 x QPD needs at least
  periscope, beam shutter, 2 x lens, 4 x mirror, 3 x BS, 4 x beam dump
- optionally
  HWP, PBS, CCD, +1 x BS
- some ports needs more cf. LIGO-D1201210 (aLIGO ISCT6 table)
  +2 x mirror, +4 x lens
- 2 picomotors/QPD for beam centering
- there are
  [before IMMT]
  IMCREFL: DC PD + RF PD + 2 x QPD
  IMCTRANS: DC PD + 2 x QPD
  REFL: DC PD + RF PD + 2 x QPD
  ISS1: DC PD
  ISS2: DC PD + 2 x QPD
  [after IMMT]
  AS(SR2): DC PD + RF PD + 2 x QPD
  ETMX: DC PD + 2 x QPD
  ETMY: DC PD + 2 x QPD



LIGO-D1201103 (aLIGO ISCT1 table)

* one grid is 1inch x 1 inch

Small Optics for whole IOO

Wiki/SmallOptics

- My estimation for iKAGRA is;

- 8 periscope: for adjusting the height
  including 2 mirrors (may have to be 2 inch) and a post
  mirrors on periscopes are not included in numbers below
- 8 beam shutter: for zeroing the PD offsets and so
- 8 lens (2 inch): for reducing the beam size
- 8-40 lens (1 inch): for Gouy phase telescope, focusing on RF PD
- 16 mirror (2 inch): for steering before reducing the beam size
- 32-48 mirror (1 inch): for steering, folding
- 8 PBS (1inch): for adjusting power
- 24-32 NPBS (1inch): for splitting the beam to PDs, cameras
- 8 HWP (1inch): for adjusting power
- 32 beam dump: for dumping PD reflection
- 8 CCD: for monitoring the beam
- 28 picomotors: for centering the beam on QPDs

Some Important Info (for iKAGRA)

- Suspended optics from laser to PRM chamber are just IMC mirrors
  - we don’t suspend IFI nor IMMTs
  - oplevs only for IMC mirrors (no oplevs for IMMTs)
- IMMTs are flat and have picomotors
- we don’t need hardware interface between picomotor drivers and digital system

Questions

- Are we going to use IMMTs as actuators for ASC of FPMI?
- Are there PDs/QPDs which should be in vacuum?
  - only MIF REFL? maybe none for iKAGRA
- What are we going to do with MCo AR reflected beam?
  - I don't think it is essential for ISC point of view
    Miyoki-san says it was in CLIO since IMC TRANS was low power
- How many standalone digital system will be needed by Nov 2014?
- What's the situation about FRC servo circuit? Nakano has it
  - Miyakawa-san said he delivered to IOO on Sep 2013
- Are we really going to use FRC? Is it a default plan?
- How many picomotors for a MC mirror? 2
- What do we need for digital system to picomotor driver interfaces? Do we need some interface circuits? no
- What's the camera situation? How do we put them in the digital system?
- Where and how many do we have optical tables and pylons? What are the sizes of them? Do we need periscopes for them?