JGW-T2112594

March 24, 2021
Updated: April 15, 2021

# Summary of Alignment Scheme of KAGRA in O3GK (and RSE commissioning in 2020)

Masayuki Nakano

Yuta Michimura

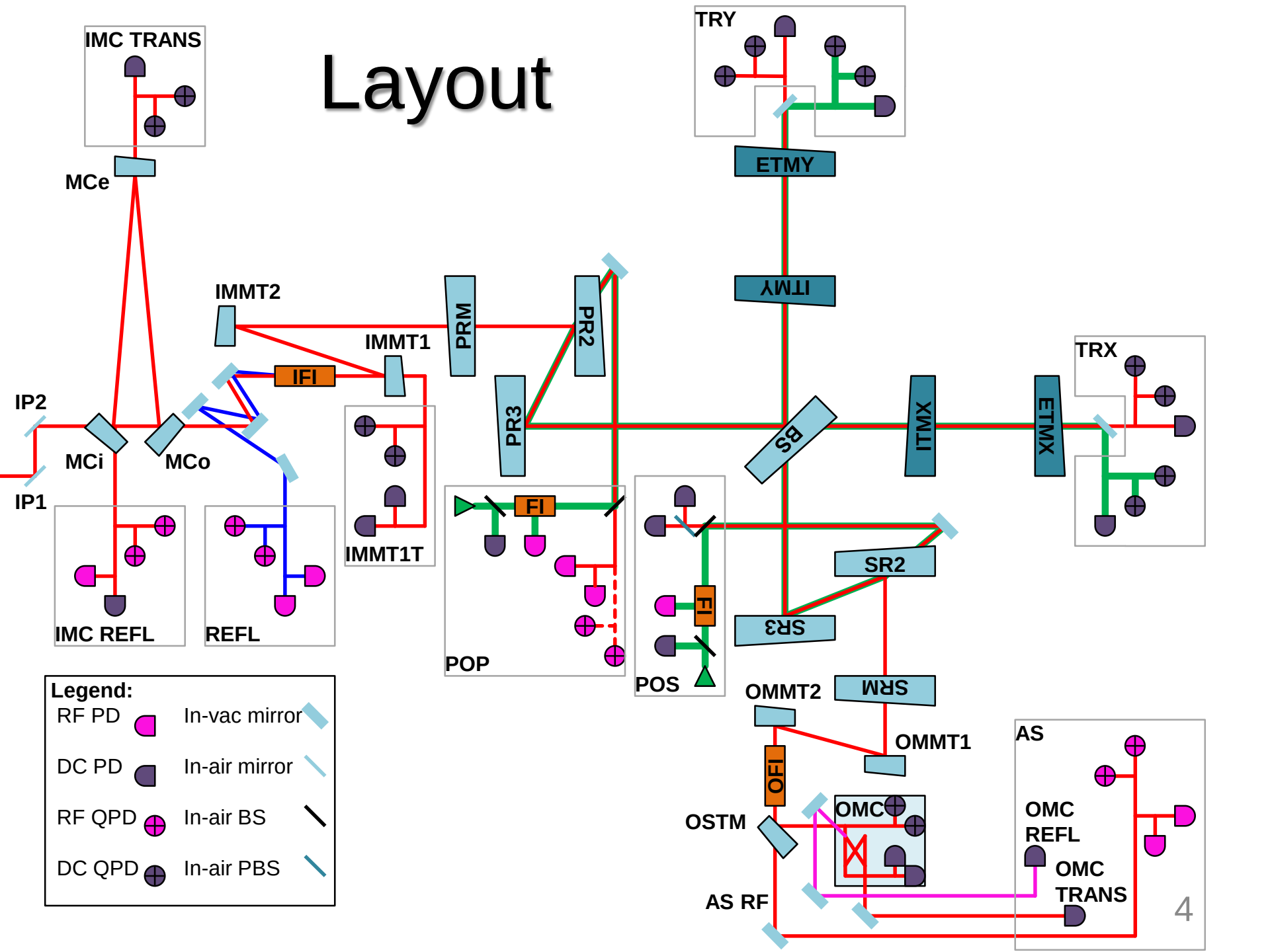
# Scope

- Summarize the alignment scheme used for O3GK and RSE commissioning in 2020
- To discuss if there are better schemes for O4 and beyond
- Here, we only discuss daily alignment (semi-auto alignment; SAL) for locking and ASC after locking
- The initial alignment procedure is not discussed here
  for initial alignment, see, for example, JGW-T1604823 (iKAGRA), JGW-T1605692 (bKAGRA Phase 1), JGW-G1808462 (X&Y arm)
- References
  JGW-G2011544: KAGRA beam alignment manual for beginners in O3
  JGW-G2011687:ASC Status and To-Dos
  JGW-T2112593: Cable diagram (PSL, IOO, IOO1, ALS0, ALS1, LSC0, ASC0)

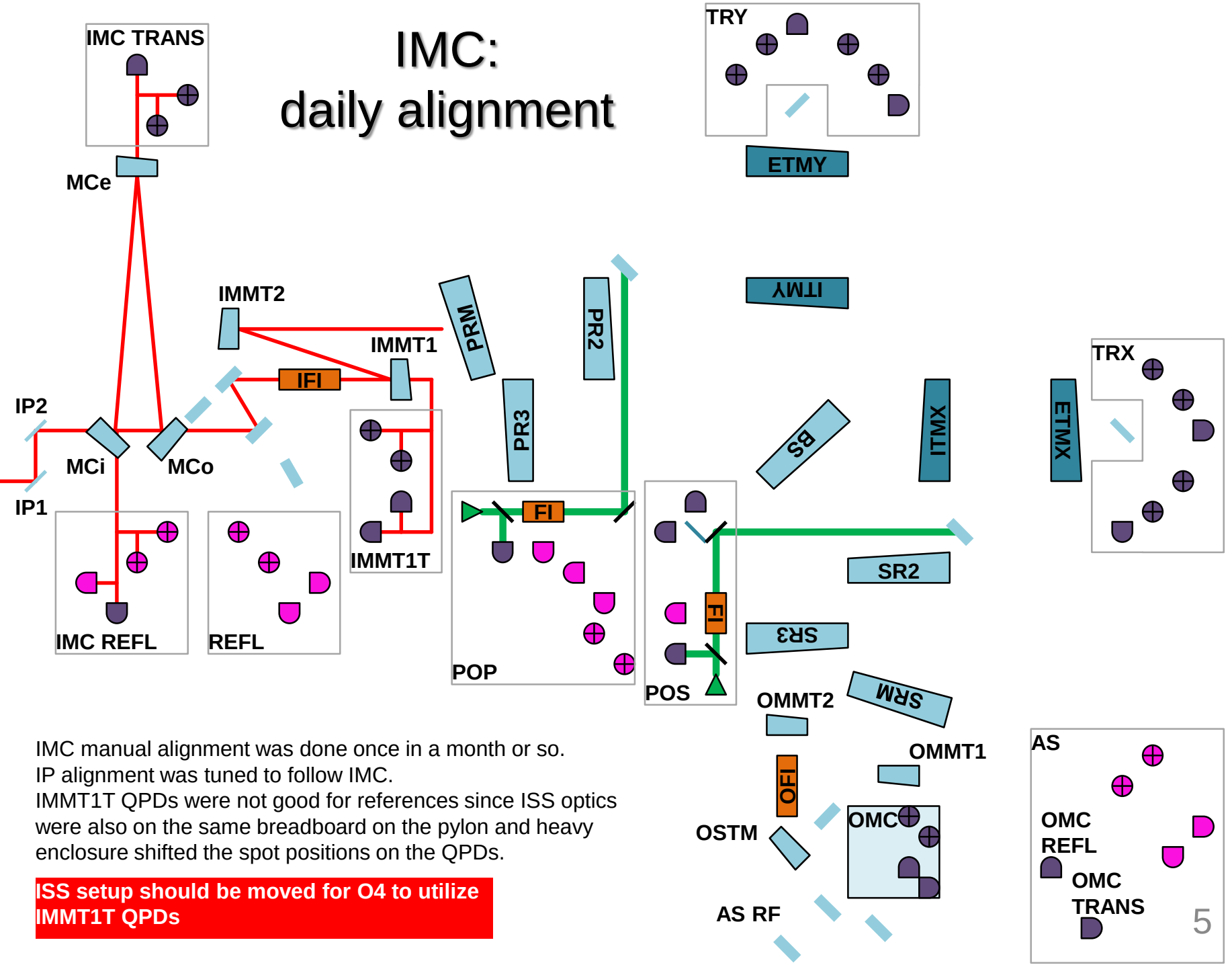
# Acronyms

- **SAL (Semi-Auto Alignment)**
  Guardian based daily alignment where you can click buttons step by step. Manual checkings in-between the steps are necessary.
- **ADS (Alignment Dither System)**
  Dither optics and see the fluctuations in the transmitted power to control the alignment of the optics to maximize the transmitted power.
- **BPC (Beam Pointing Control)**
  Dither optics and see angle-to-length to control the alignment of the optics to control the beam spot positions on the optics.
- **WFS (Wave Front Sensor)**
  Modulation-demodulation scheme to control the alignment of the optics using RF QPDs.
- **IP (Input Pointing)**
  Two steering mirrors at the output of PSL (pre-stabilized laser) table for input pointing to IMC (input-mode cleaner).

# Layout


IMC TRANS
TRY
MCe
ETMY
IMMT2
IMMT1
PRM
PR2
ITMY
IFI
IP2
PR3
TRX
BS
ITMX
ETMX
MCi
MCo
IP1
IMMT1T
FI
SR2
FI
SR3
IMC REFL
REFL
POP
POS
SRM
OMMT2
OMMT1
AS
OFI
OMC
OSTM
OMC REFL
OMC TRANS
AS RF
Legend:
RF PD
DC PD
RF QPD
DC QPD
In-vac mirror
In-air mirror
In-air BS
In-air PBS

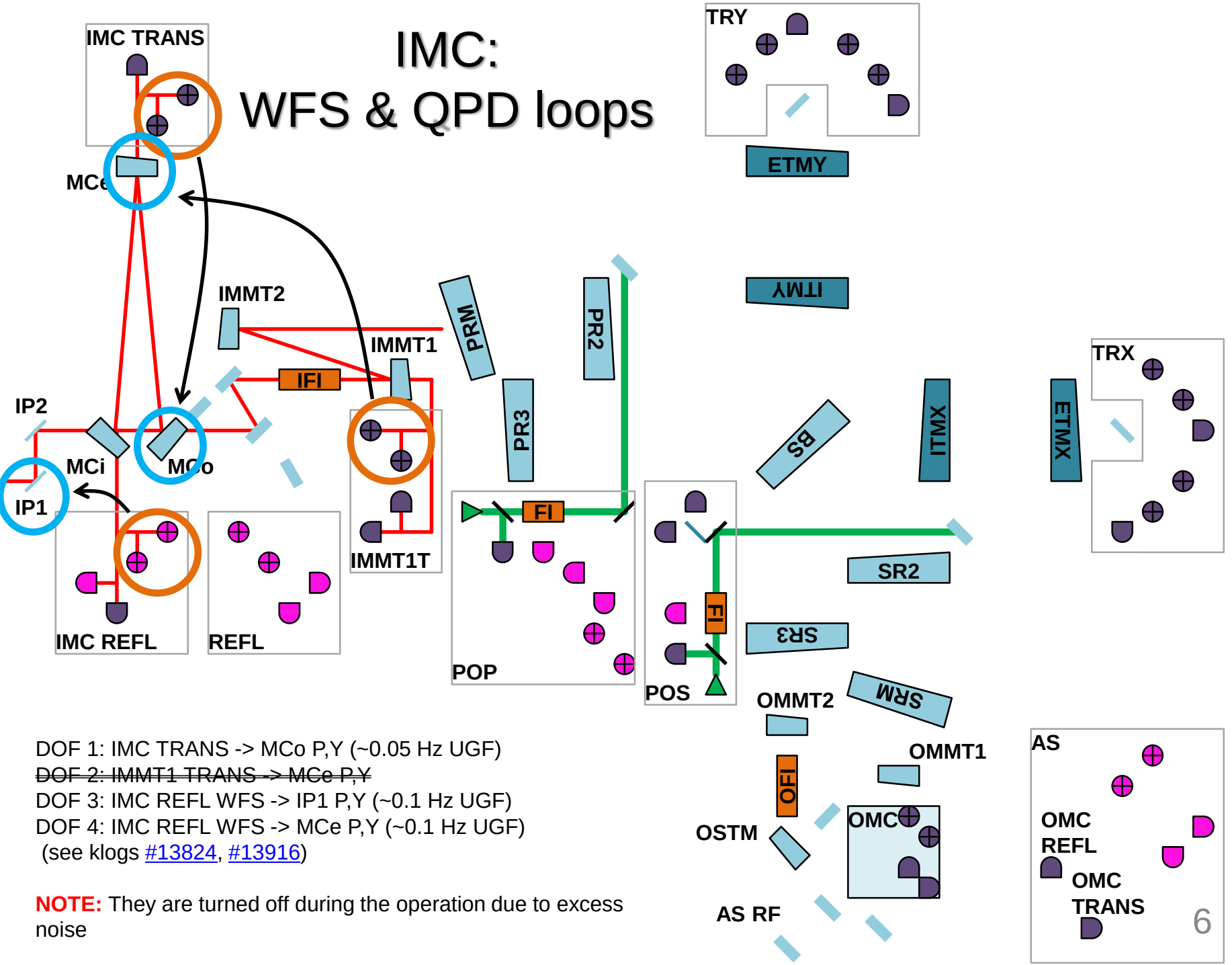
# IMC: daily alignment




IMC manual alignment was done once in a month or so.
IP alignment was tuned to follow IMC.
IMMT1T QPDs were not good for references since ISS optics were also on the same breadboard on the pylon and heavy enclosure shifted the spot positions on the QPDs.

**ISS setup should be moved for O4 to utilize IMMT1T QPDs**

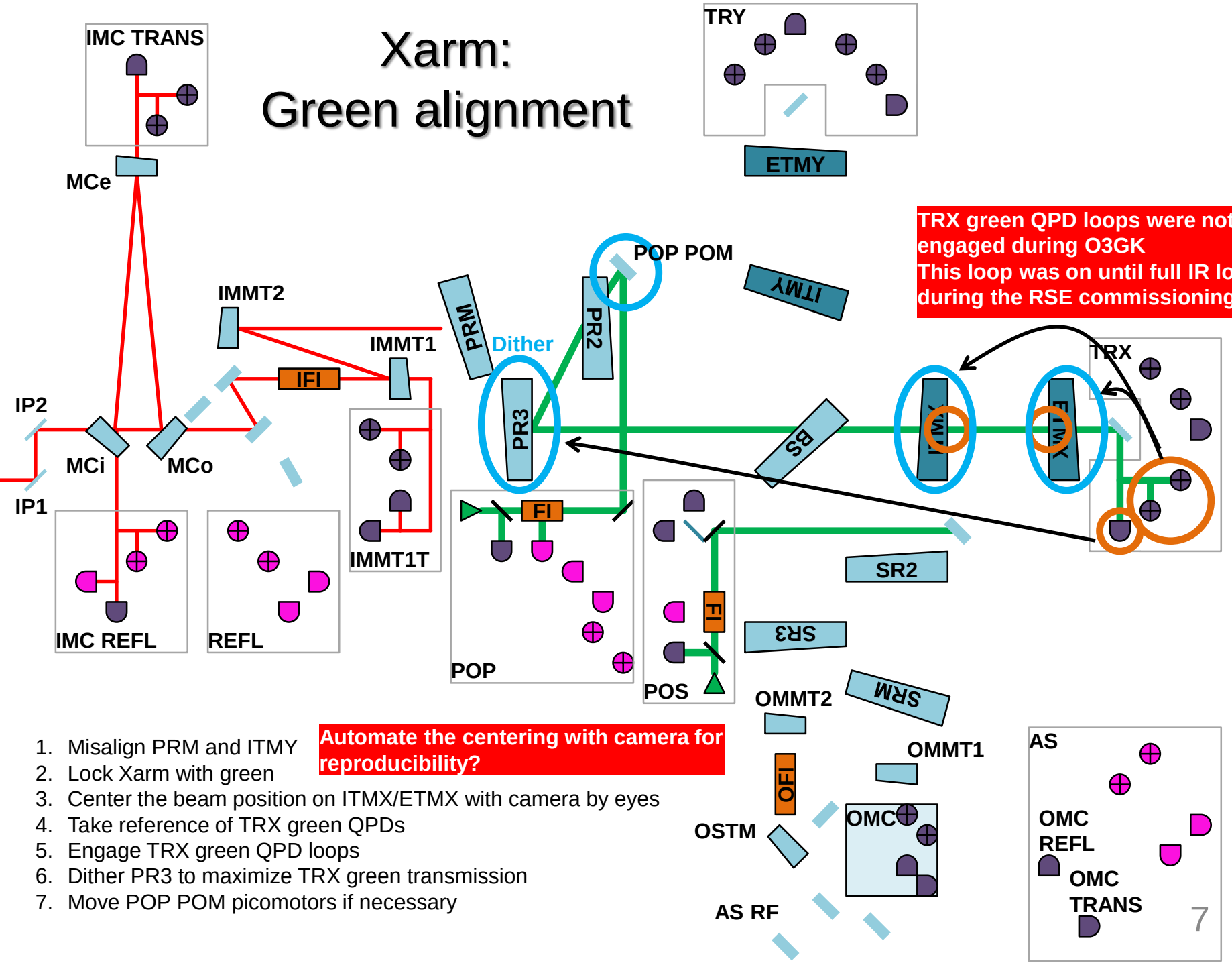
# IMC: WFS & QPD loops




DOF 1: IMC TRANS -> MCo P,Y (~0.05 Hz UGF)
~~DOF 2: IMMT1 TRANS -> MCe P,Y~~
DOF 3: IMC REFL WFS -> IP1 P,Y (~0.1 Hz UGF)
DOF 4: IMC REFL WFS -> MCe P,Y (~0.1 Hz UGF)
(see klogs #13824, #13916)

**NOTE:** They are turned off during the operation due to excess noise

# Xarm: Green alignment

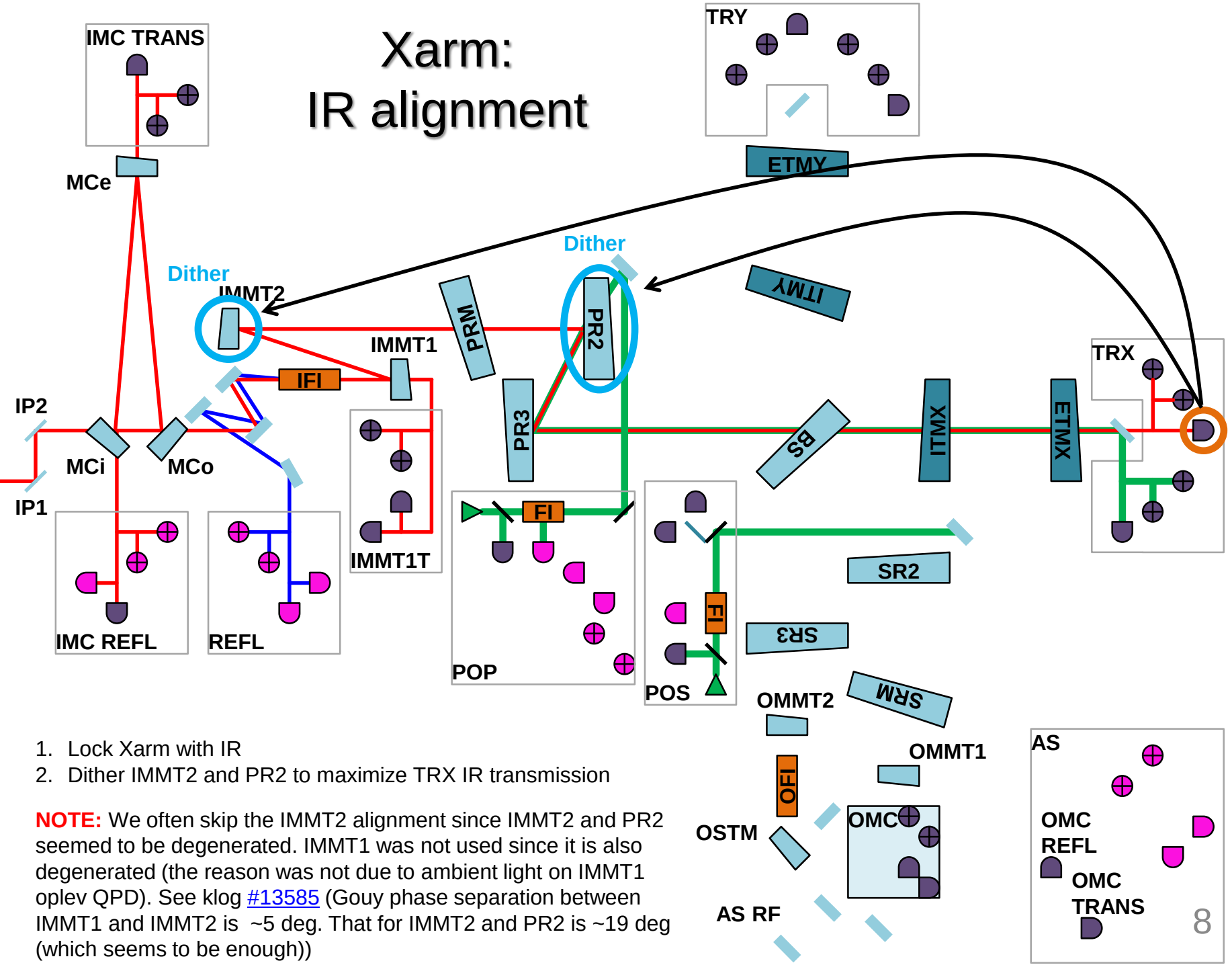



**TRX green QPD loops were not engaged during O3GK**
**This loop was on until full IR lock during the RSE commissioning.**

1. Misalign PRM and ITMY
2. Lock Xarm with green
3. Center the beam position on ITMX/ETMX with camera by eyes
4. Take reference of TRX green QPDs
5. Engage TRX green QPD loops
6. Dither PR3 to maximize TRX green transmission
7. Move POP POM picomotors if necessary

**Automate the centering with camera for reproducibility?**

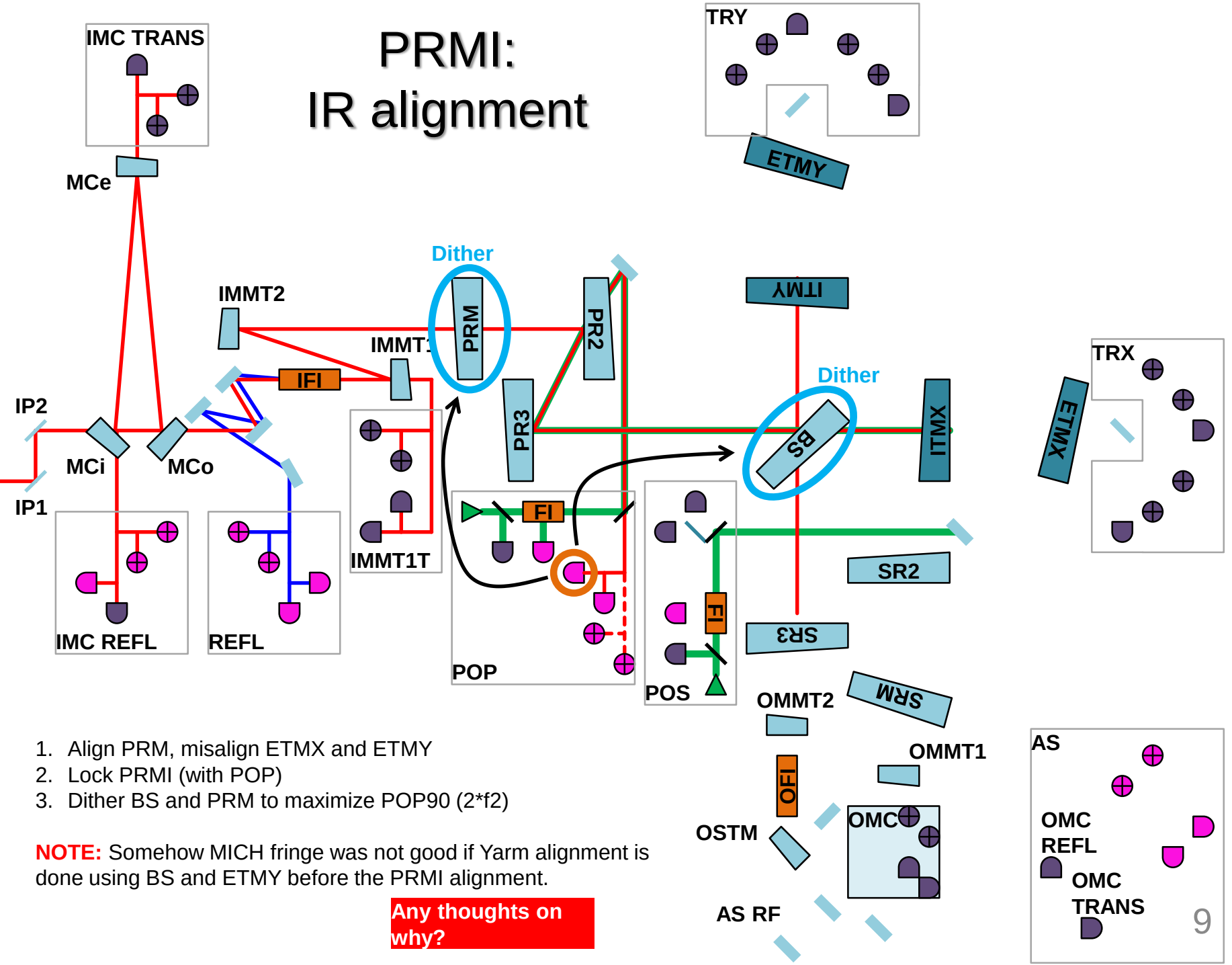
# Xarm: IR alignment




1. Lock Xarm with IR
2. Dither IMMT2 and PR2 to maximize TRX IR transmission

**NOTE:** We often skip the IMMT2 alignment since IMMT2 and PR2 seemed to be degenerated. IMMT1 was not used since it is also degenerated (the reason was not due to ambient light on IMMT1 oplev QPD). See klog #13585 (Gouy phase separation between IMMT1 and IMMT2 is ~5 deg. That for IMMT2 and PR2 is ~19 deg (which seems to be enough))

# PRMI: IR alignment

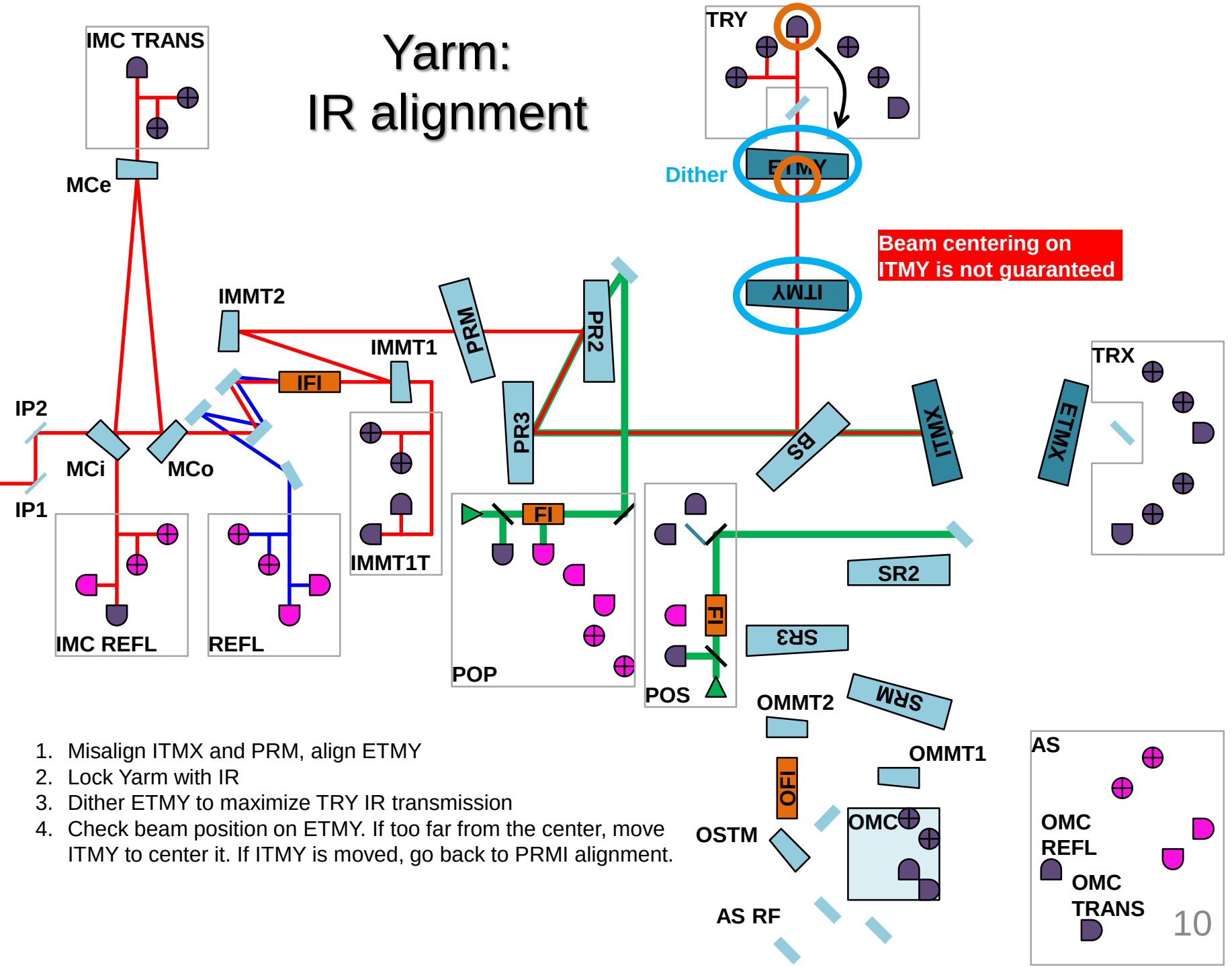



1. Align PRM, misalign ETMX and ETMY
2. Lock PRMI (with POP)
3. Dither BS and PRM to maximize POP90 (2*f2)

**NOTE:** Somehow MICH fringe was not good if Yarm alignment is done using BS and ETMY before the PRMI alignment.

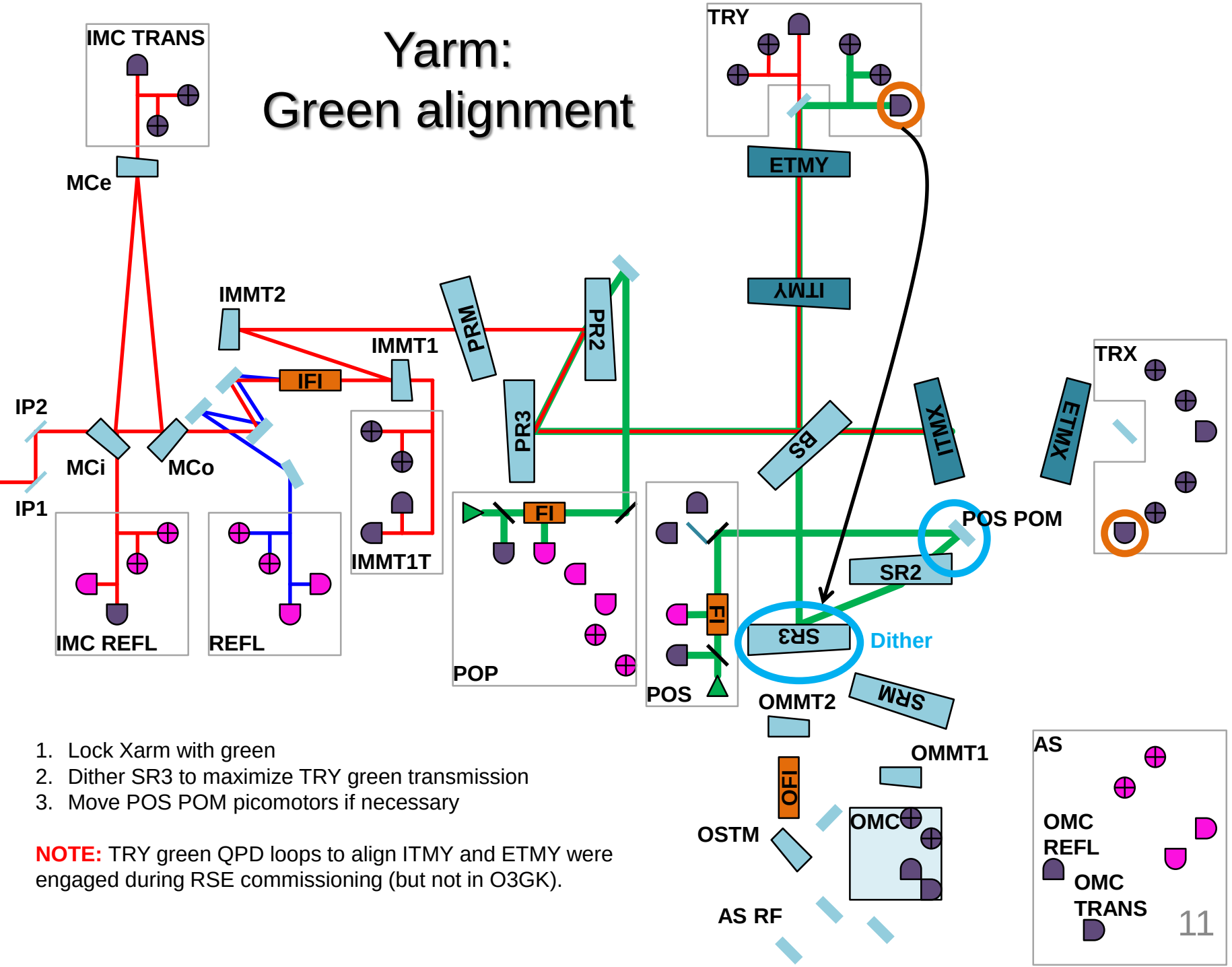
**Any thoughts on why?**

# Yarm: IR alignment




1. Misalign ITMX and PRM, align ETMY
2. Lock Yarm with IR
3. Dither ETMY to maximize TRY IR transmission
4. Check beam position on ETMY. If too far from the center, move ITMY to center it. If ITMY is moved, go back to PRMI alignment.

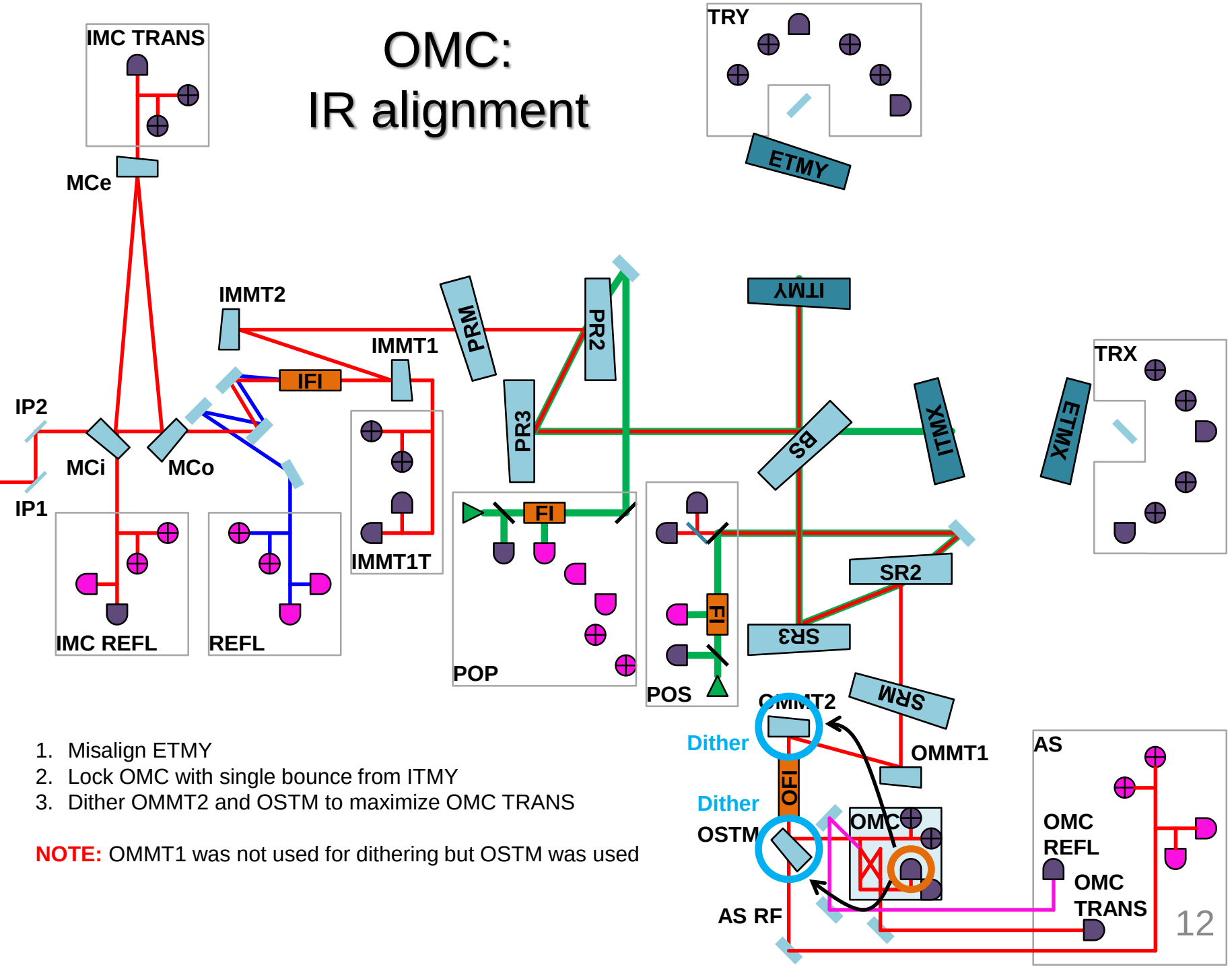
# Yarm: Green alignment




1. Lock Xarm with green
2. Dither SR3 to maximize TRY green transmission
3. Move POS POM picomotors if necessary

**NOTE:** TRY green QPD loops to align ITMY and ETMY were engaged during RSE commissioning (but not in O3GK).

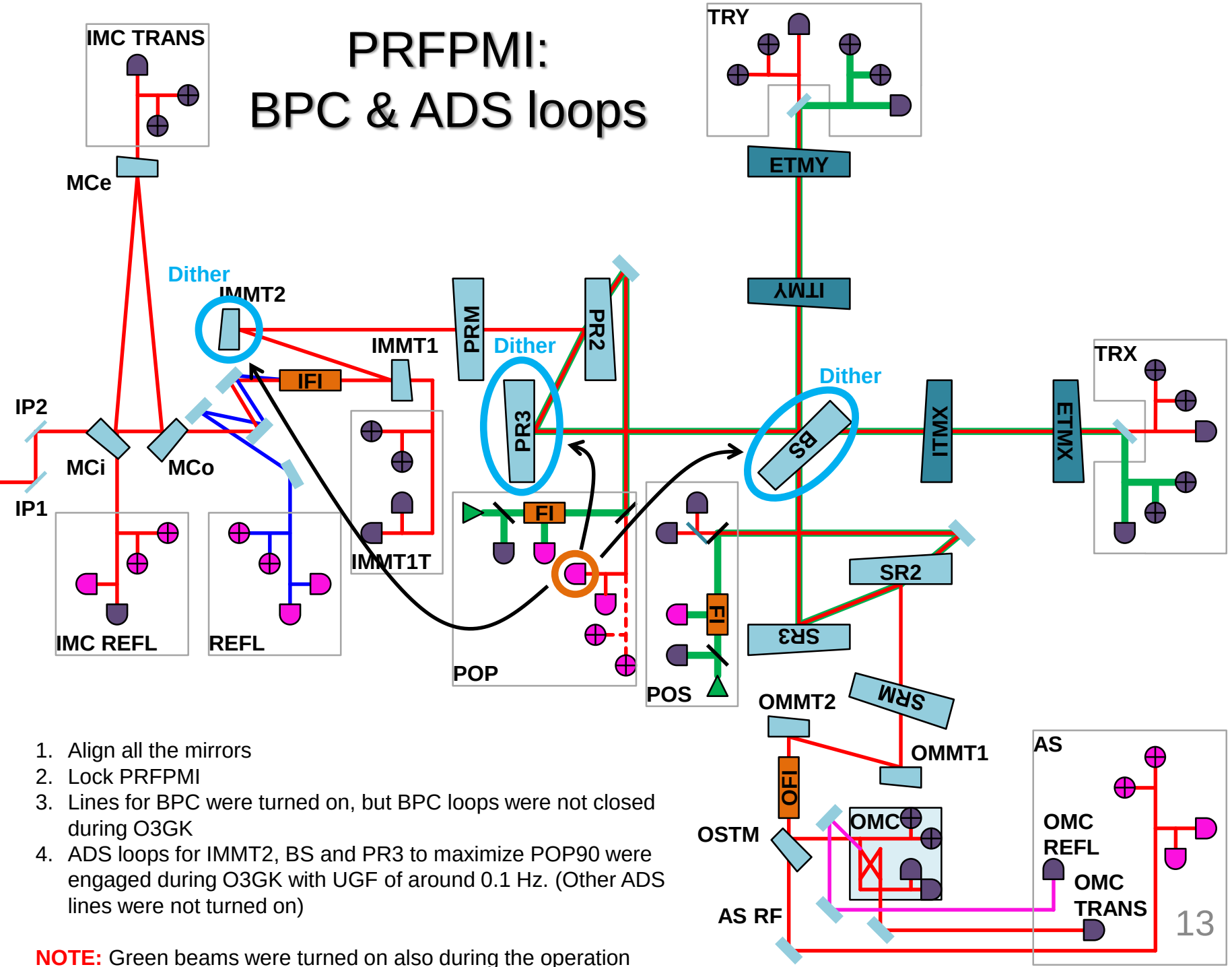
# OMC: IR alignment




1. Misalign ETMY
2. Lock OMC with single bounce from ITMY
3. Dither OMMT2 and OSTM to maximize OMC TRANS

**NOTE:** OMMT1 was not used for dithering but OSTM was used

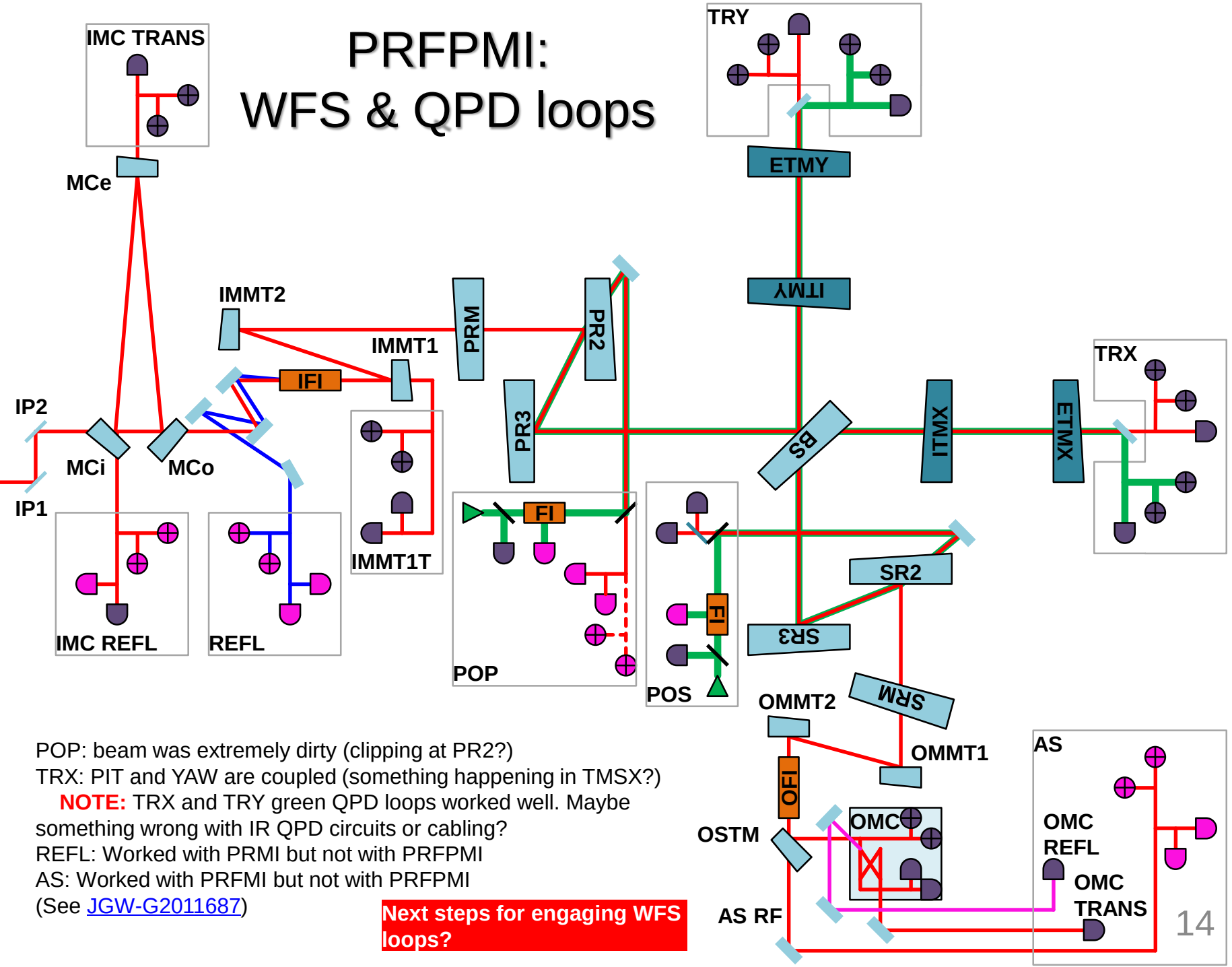
# PRFPMI: BPC & ADS loops




1. Align all the mirrors
2. Lock PRFPMI
3. Lines for BPC were turned on, but BPC loops were not closed during O3GK
4. ADS loops for IMMT2, BS and PR3 to maximize POP90 were engaged during O3GK with UGF of around 0.1 Hz. (Other ADS lines were not turned on)

**NOTE:** Green beams were turned on also during the operation

# PRFPMI: WFS & QPD loops




POP: beam was extremely dirty (clipping at PR2?)
TRX: PIT and YAW are coupled (something happening in TMSX?)
**NOTE:** TRX and TRY green QPD loops worked well. Maybe something wrong with IR QPD circuits or cabling?
REFL: Worked with PRMI but not with PRFPMI
AS: Worked with PRFMI but not with PRFPMI
(See JGW-G2011687)

**Next steps for engaging WFS loops?**