Status of the input optics for the O3

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University of Toyama

Objectives of the input optics

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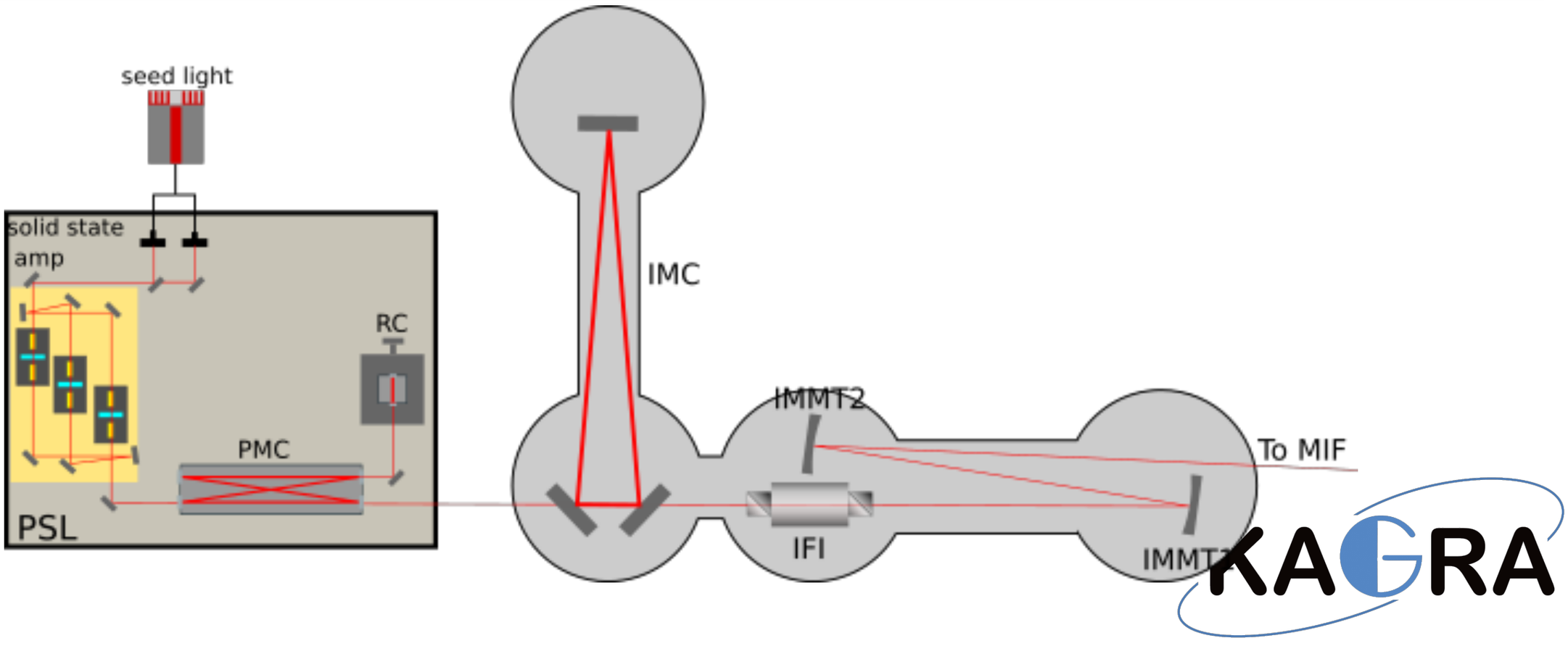
Provide the stable laser to the main interferometer.

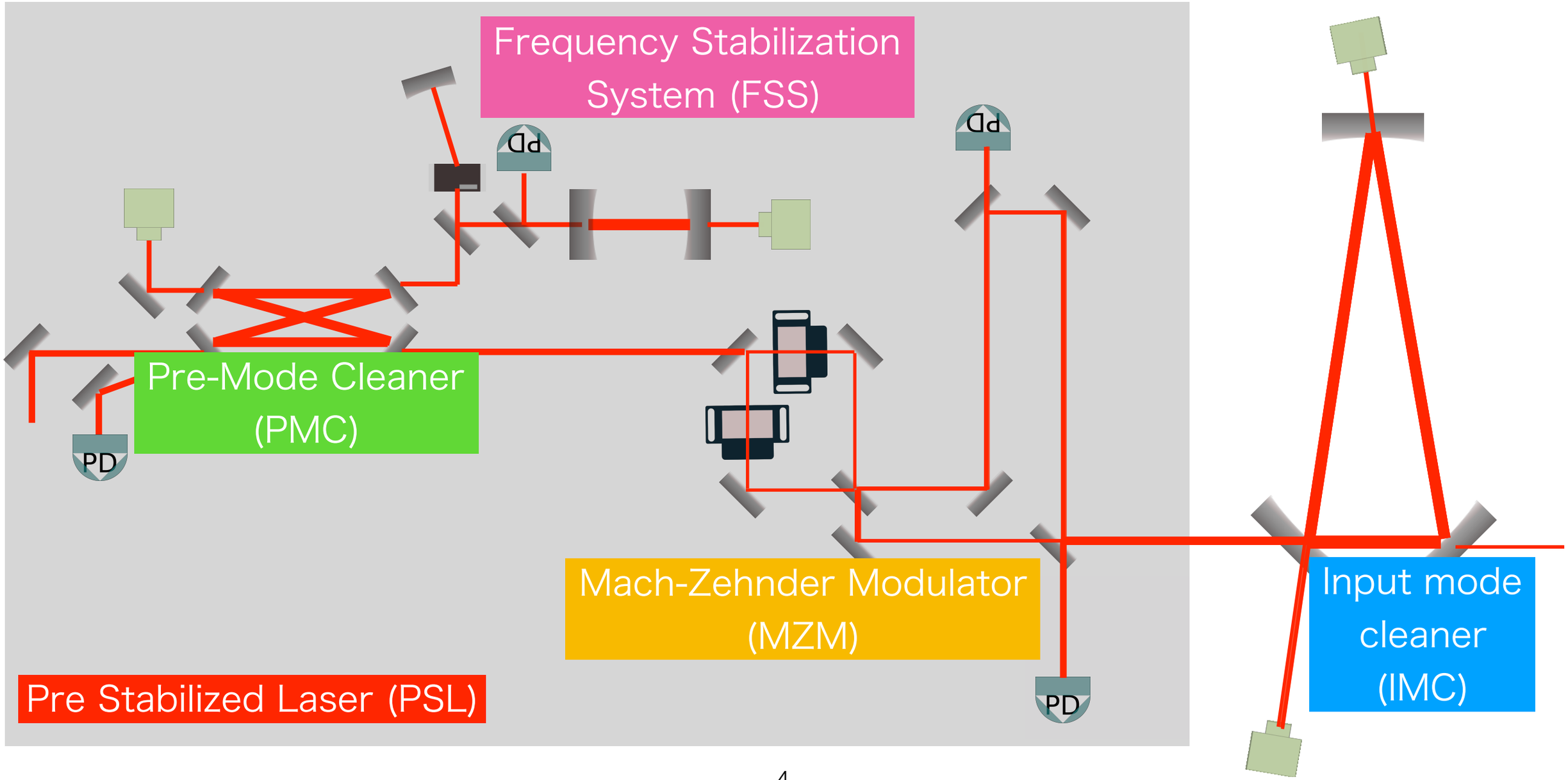
- ✓ The frequency stabilization
- ✓ The intensity stabilization
- ✓ The reduction of the beam jitter
- ✓ The cleaning of the spacial mode of the laser



Status of the input optics

- Almost all system has installed.
- The maximum power from the IMC is 4 W so far, with the fiber amplifier output of 10 W
- The alignment control for the input mode cleaner is not finalized yet.
- Although the modulation system using the Mach-Zehnder interferometer has been installed, the displacement noise does not meet the requirement for the O3.
  - ✓ We decided not to use the MZM.

Overview of the input optics



Pre-Stabilized Laser (PSL)

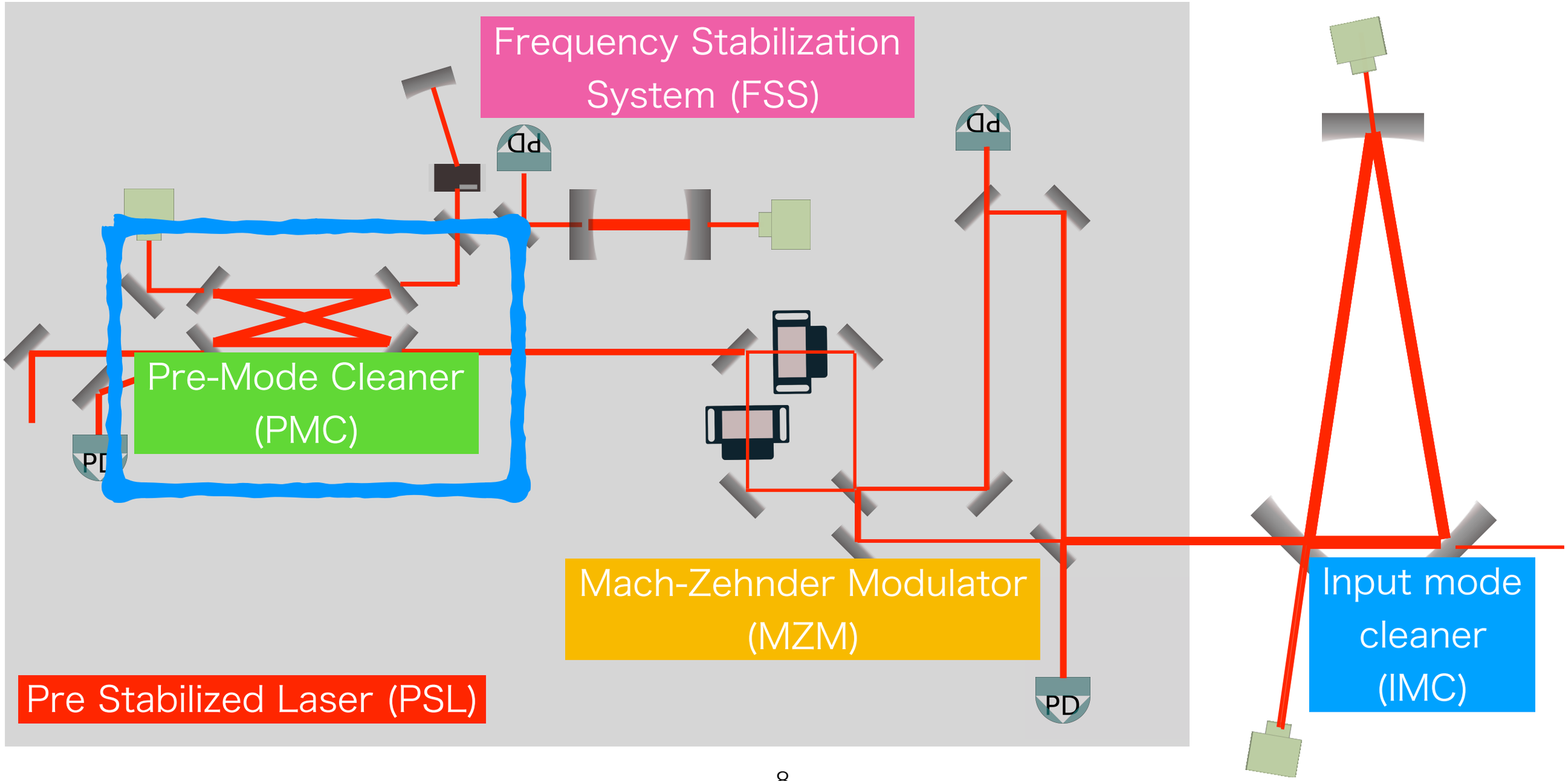
MZM

FSS

PMC

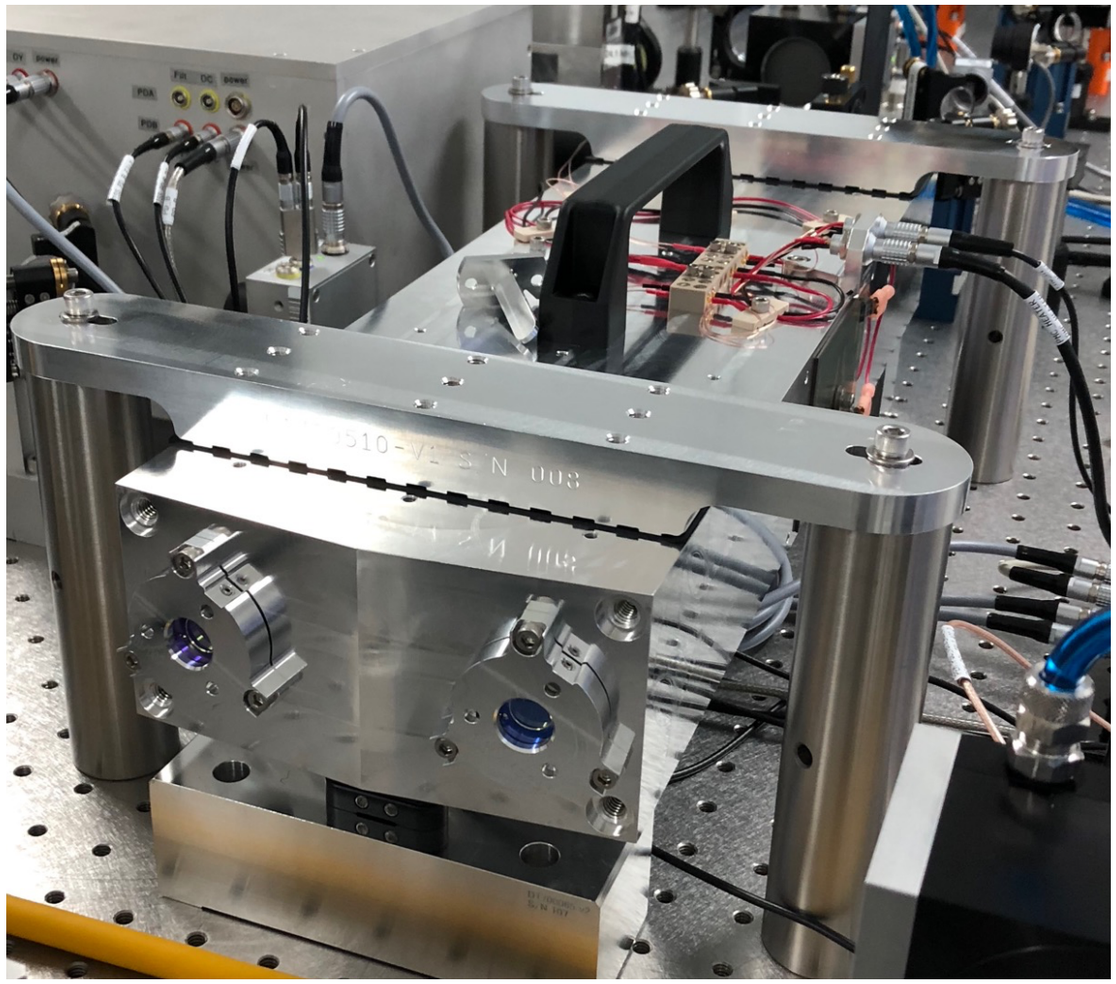
Pre-Mode Cleaner (PMC)

Pre-Mode Cleaner



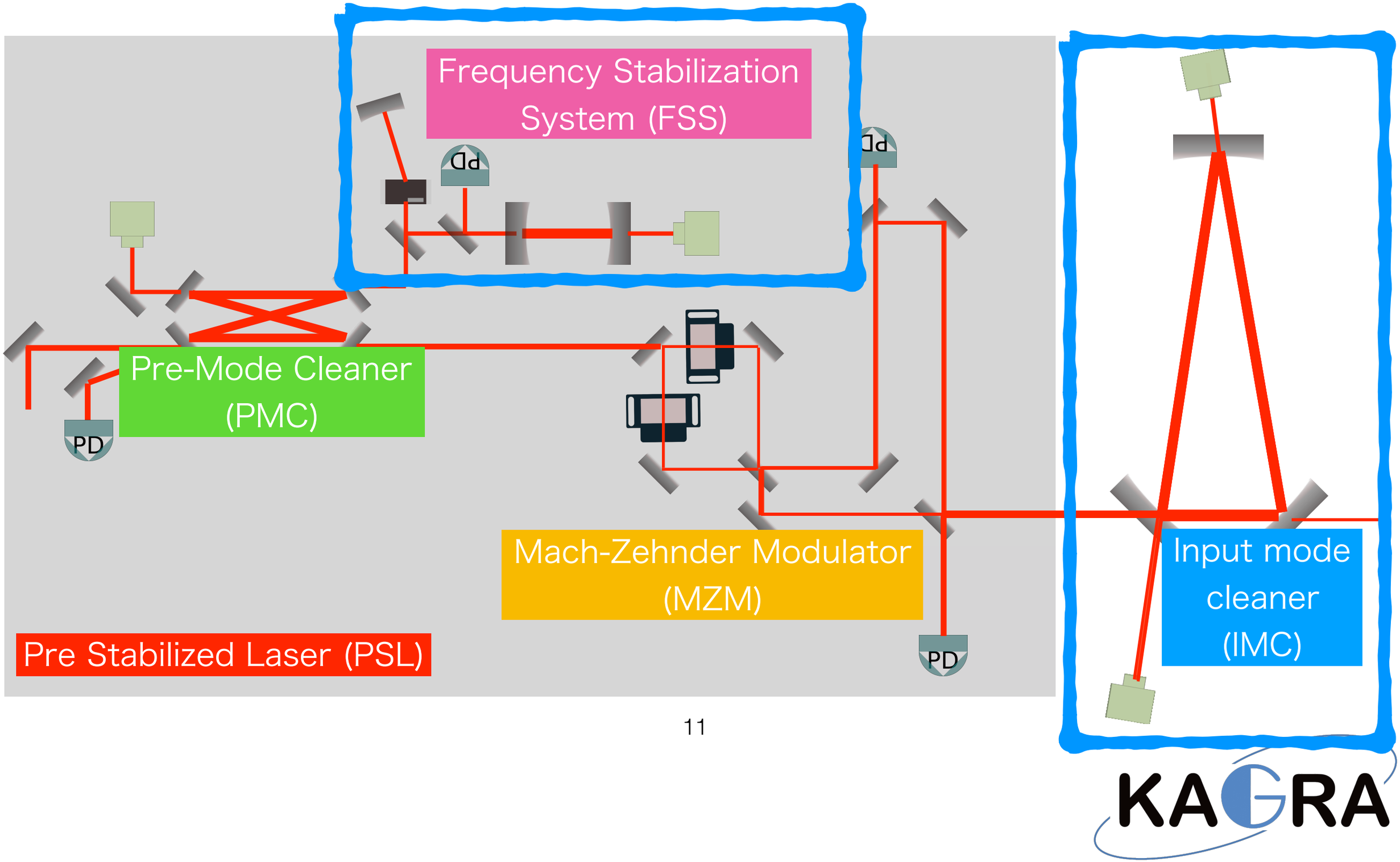
Pre-Mode Cleaner (PMC)

- 2-m long bow-tie shaped cavity.
- Objectives:
  - ✓ Spacial mode cleaning
  - ✓ Beam jitter reduction
  - ✓ RF RAM noise suppression
- Control the Cavity length to follow the laser frequency.

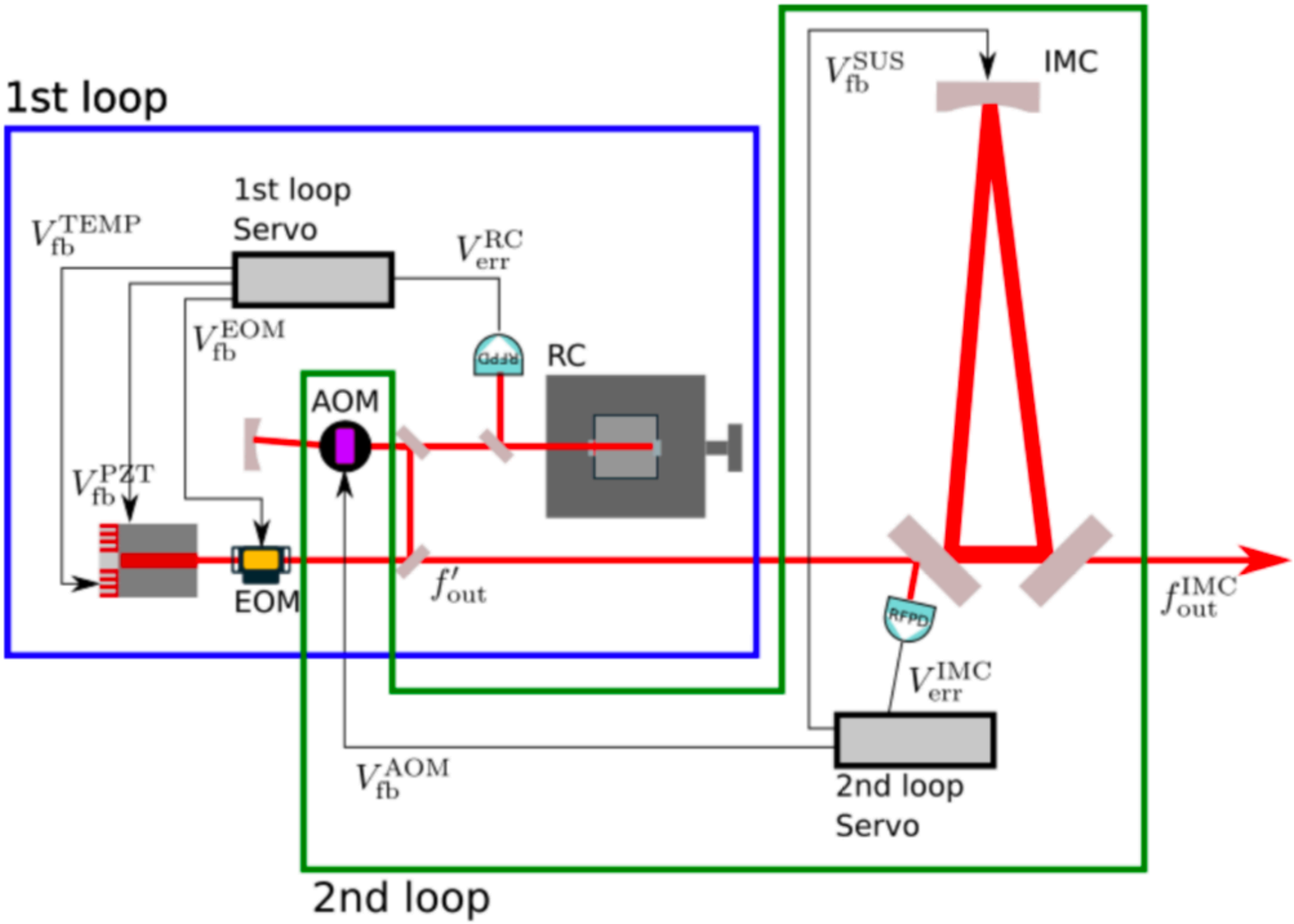


Input Mode Cleaner (IMC)
And
Frequency Stabilization System(FSS)

IMC and FSS

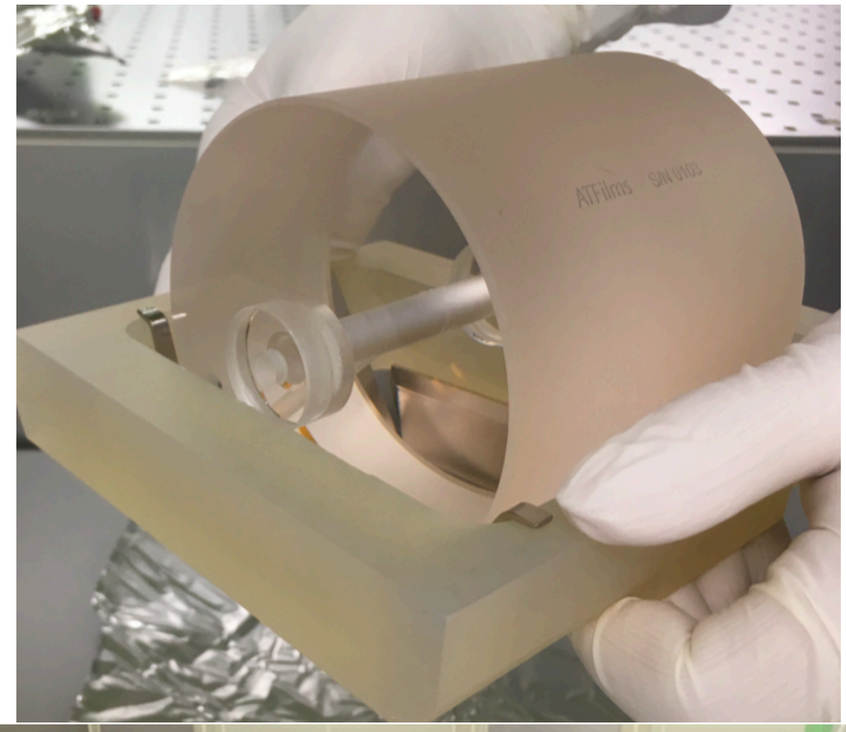

Frequency Stabilization System (FSS)
PD
Pre-Mode Cleaner (PMC)
PD
Mach-Zehnder Modulator (MZM)
Pre Stabilized Laser (PSL)
PD
Input mode cleaner (IMC)

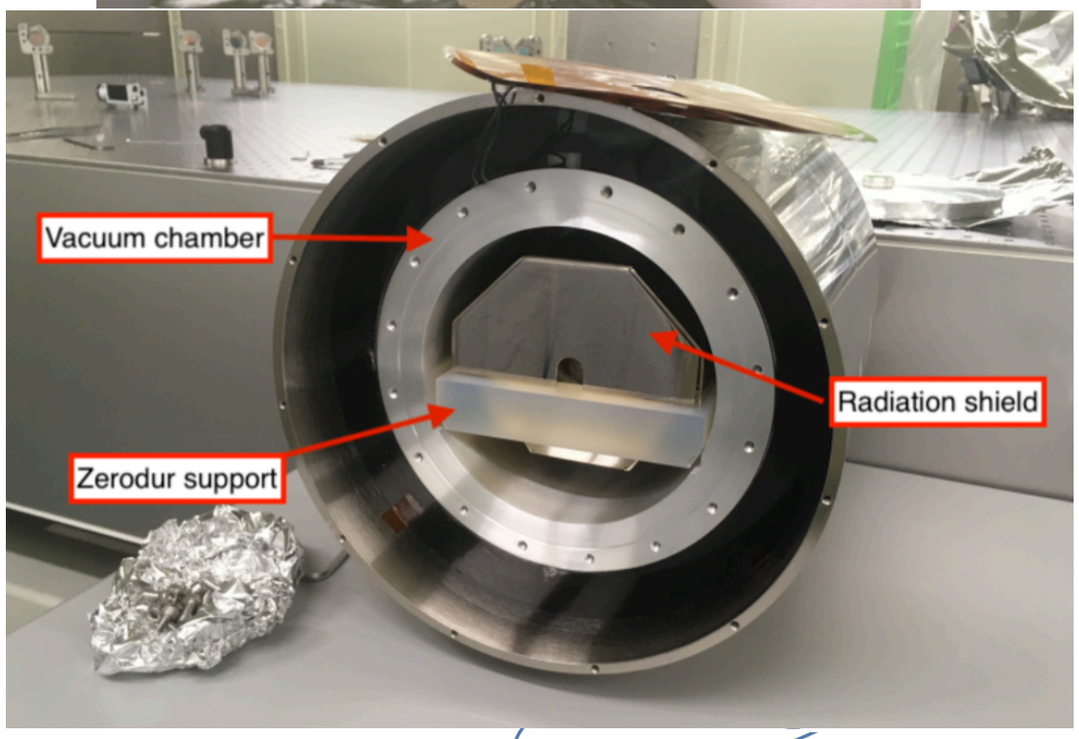
Frequency Stabilization



Reference Cavity

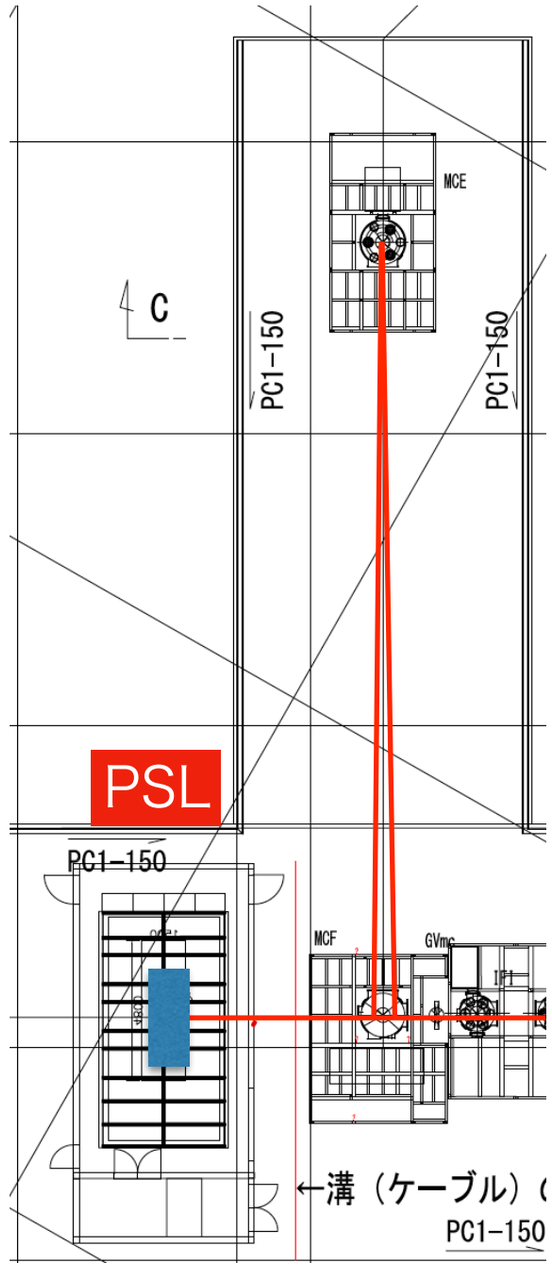
- Use the ULE glass linear cavity as the frequency reference for the 1st loop.
  - ✓ The resonance frequency of the cavity is more stable than the laser frequency.
- Control the laser frequency to follow the resonance frequency of the reference cavity.
  - ✓ Slow actuator: Laser temperature
  - ✓ Mid actuator: Laser PZT
  - ✓ Fast actuator: Broadband EOM

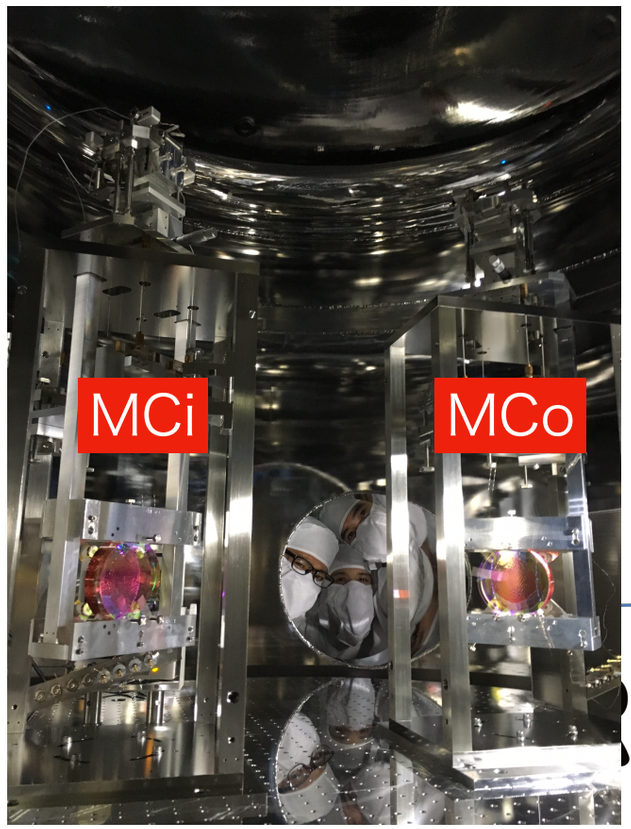




Input Mode Cleaner (IMC)

- Suspended triangular cavity
  - ✓ Cavity length: 25 m
- Objectives
  - ✓ The spacial mode cleaning.
  - ✓ The frequency reference for the FSS.
  - ✓ The beam jitter reduction
- The laser frequency is controlled to follow the resonance frequency of the IMC.
- At low frequencies, the cavity length is controled.

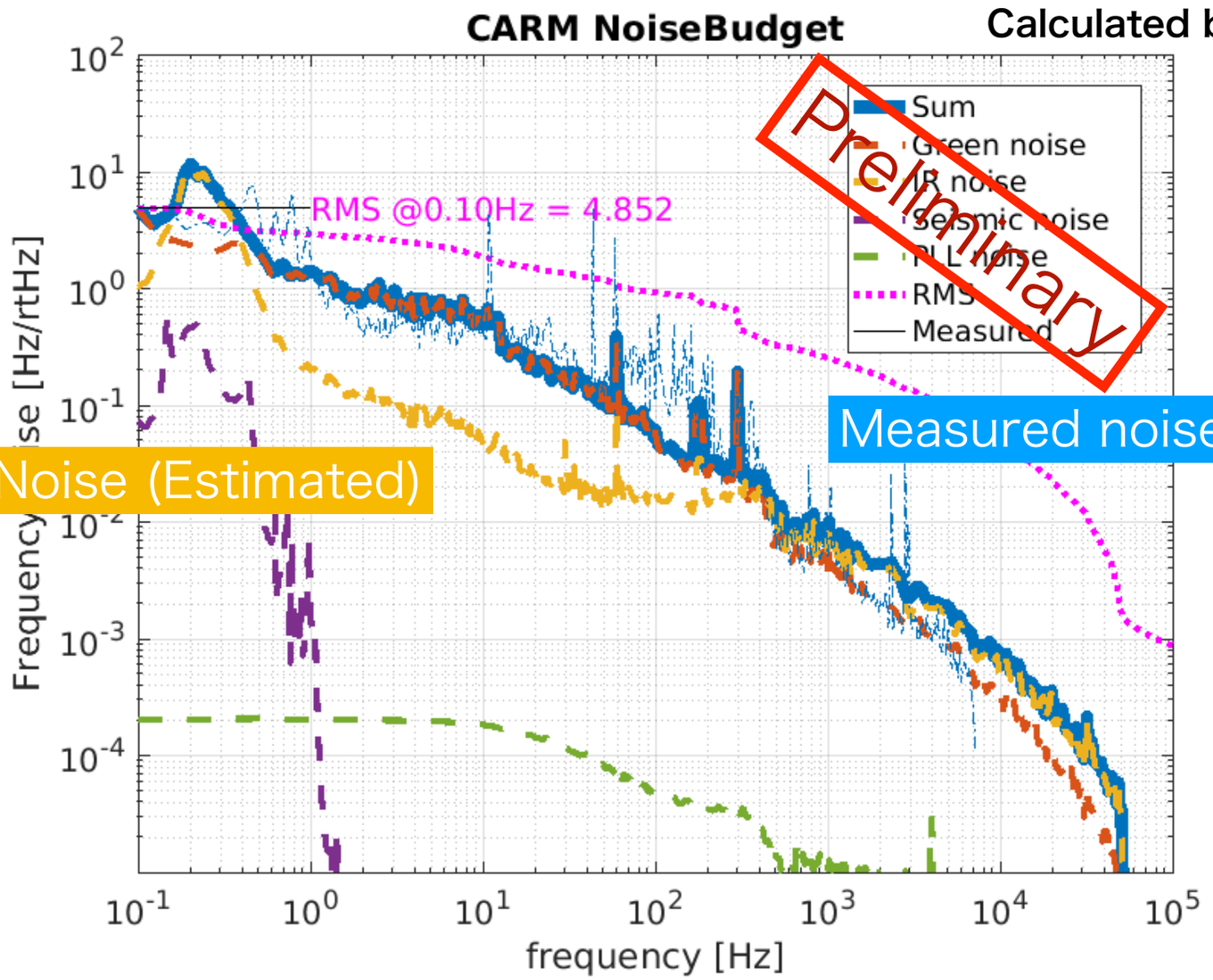




Frequency Noise

- The frequency noise was measured by using the Xarm at the frequencies above ~400 Hz
  - ✓ It is consistent with the estimated frequency noise by using the in-loop signals

klog 7562
Calculated by Y. Enomoto, K. Yokogawa



Frequency Noise (Estimated)

Measured noise in Xarm control

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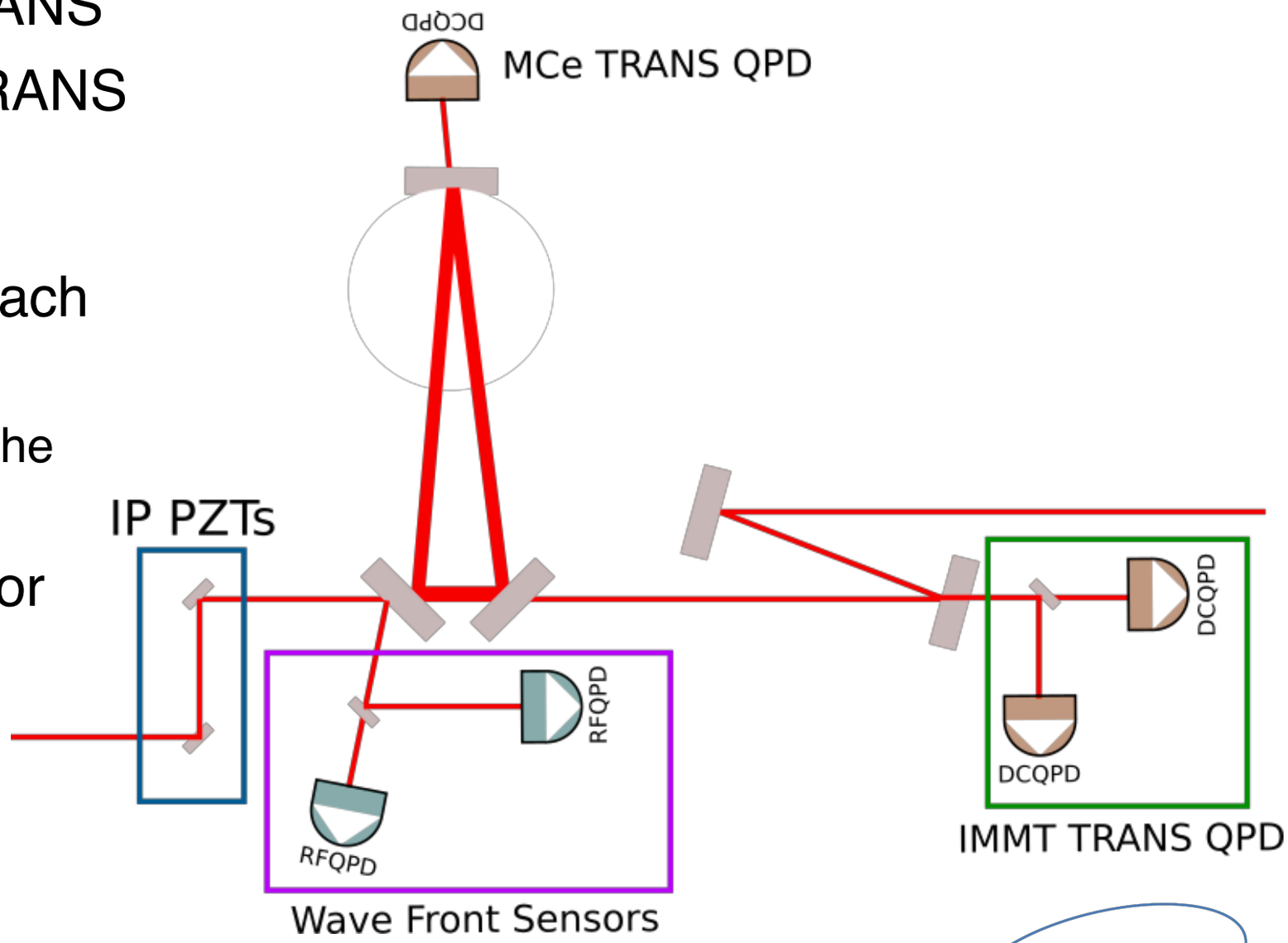
IMC Alignment Sensing and Control (ASC)

IMC alignment sensing & control (ASC)

- 5 sensors
  - ✓ WFS on the IMC REFL table
  - ✓ DC QPD for the MCe TRANS
  - ✓ DC QPD for the IMMT TRANS
- 5 DOFs to be controlled
  - ✓ Cavity axis (3 DOFs for each direction)
    - ➡The cavity axis determines the output beam axis.
  - ✓ Injection beam (2 DOFs for each direction)
- 5 actuators
  - ✓ Input pointing PZTs.
    - ➡In the PSL room.
  - ✓ IMC suspended mirrors.



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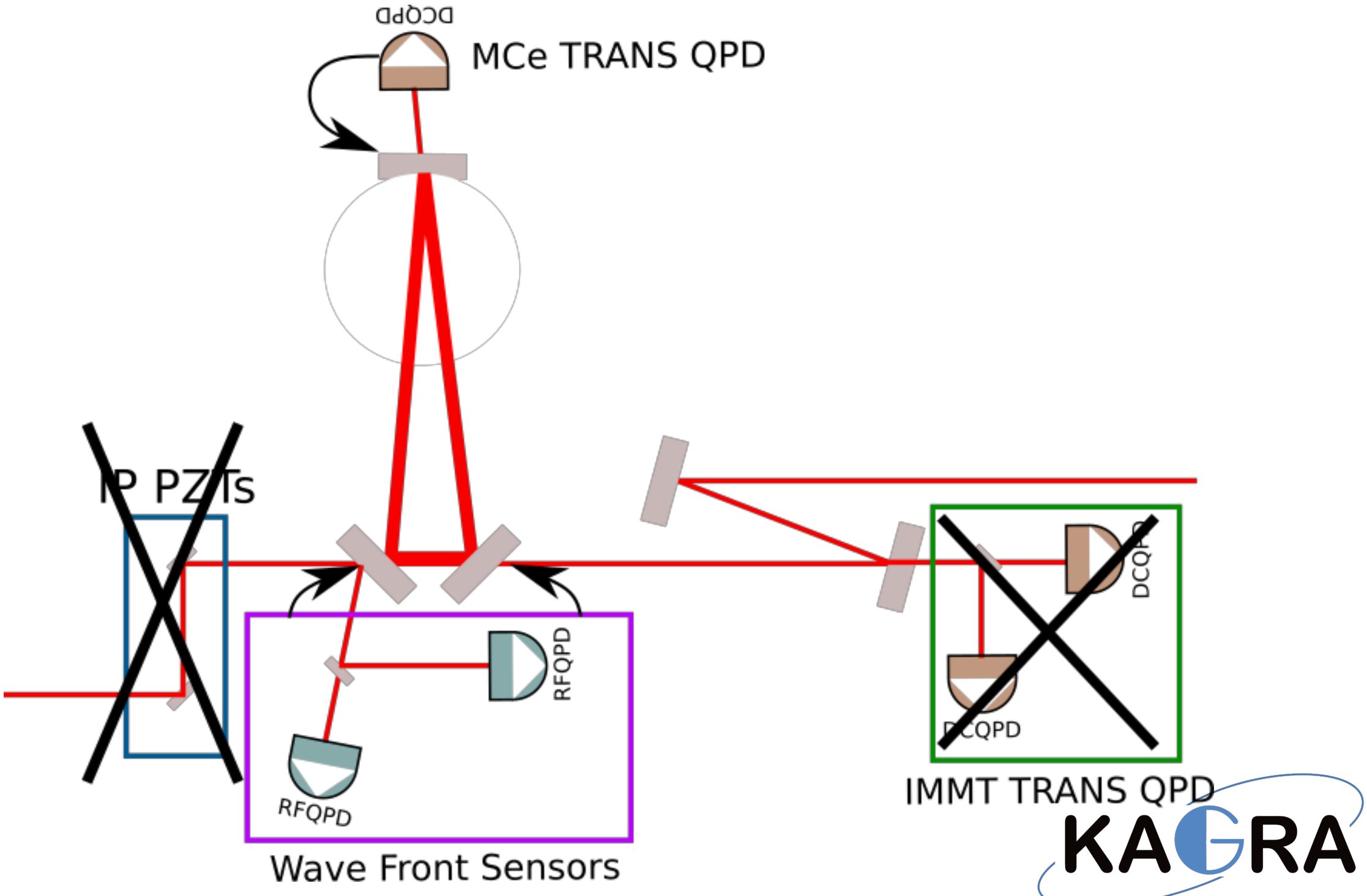
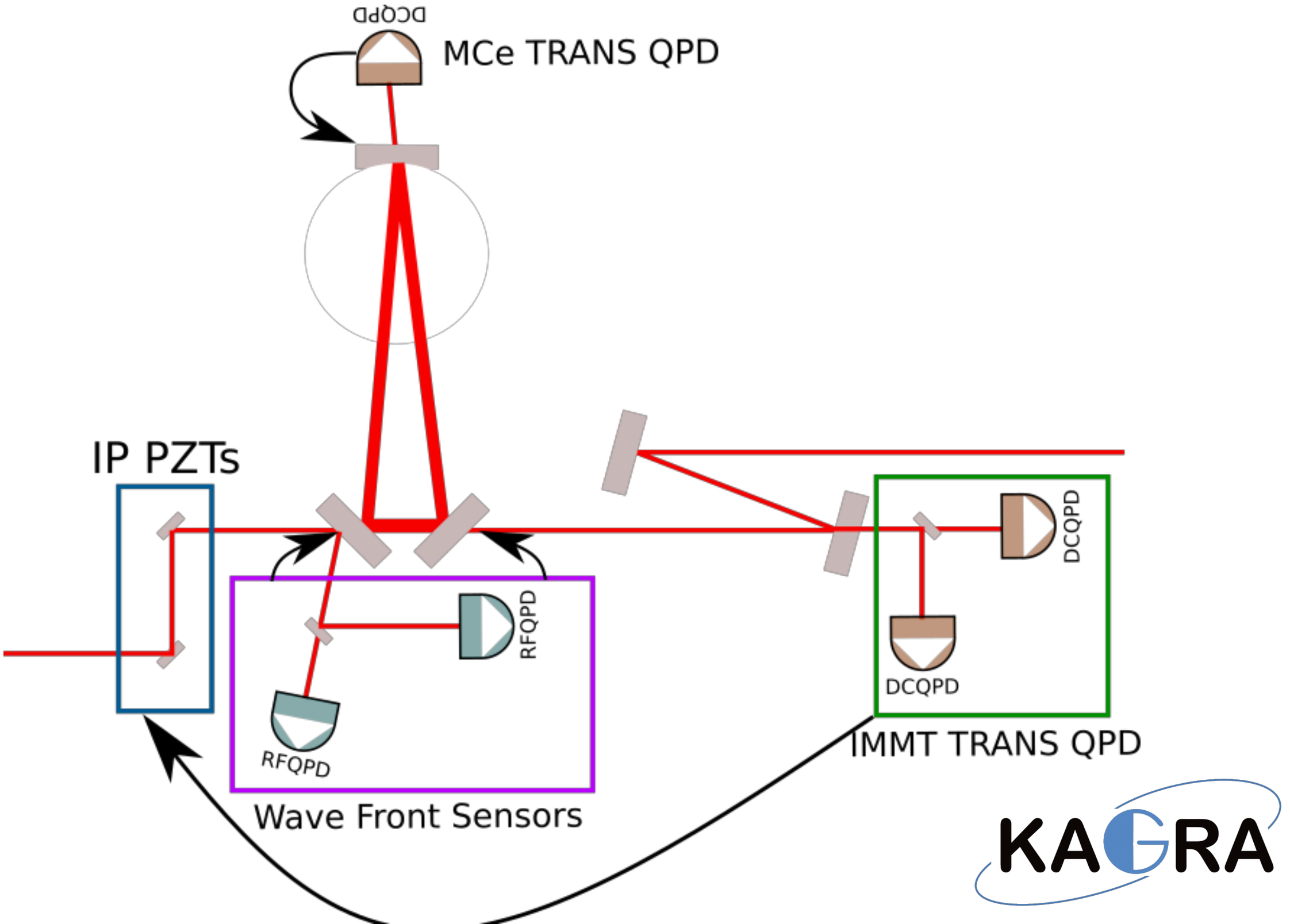
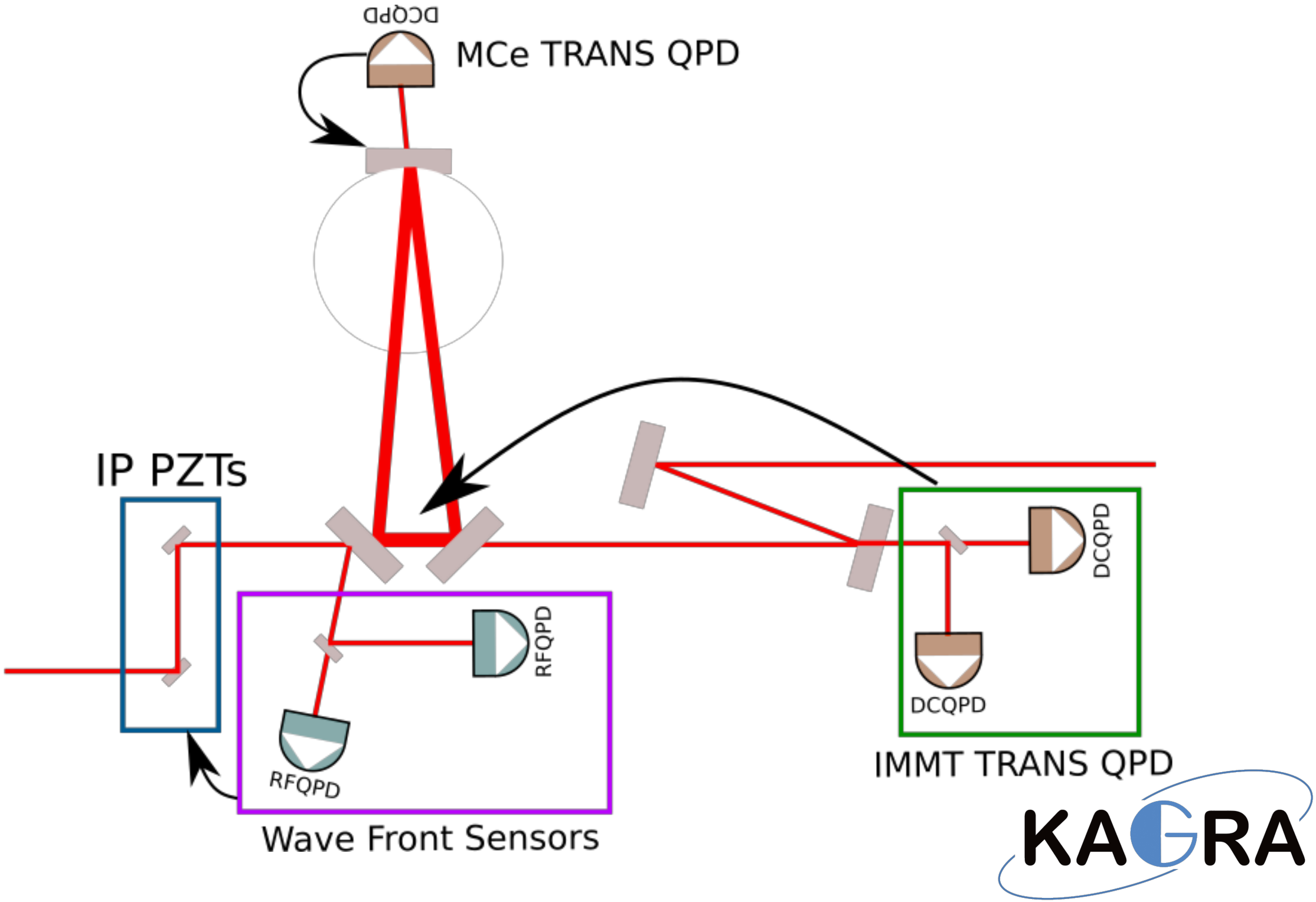
IMC ASC (current configuration)



IMC ASC (final configuration 1)



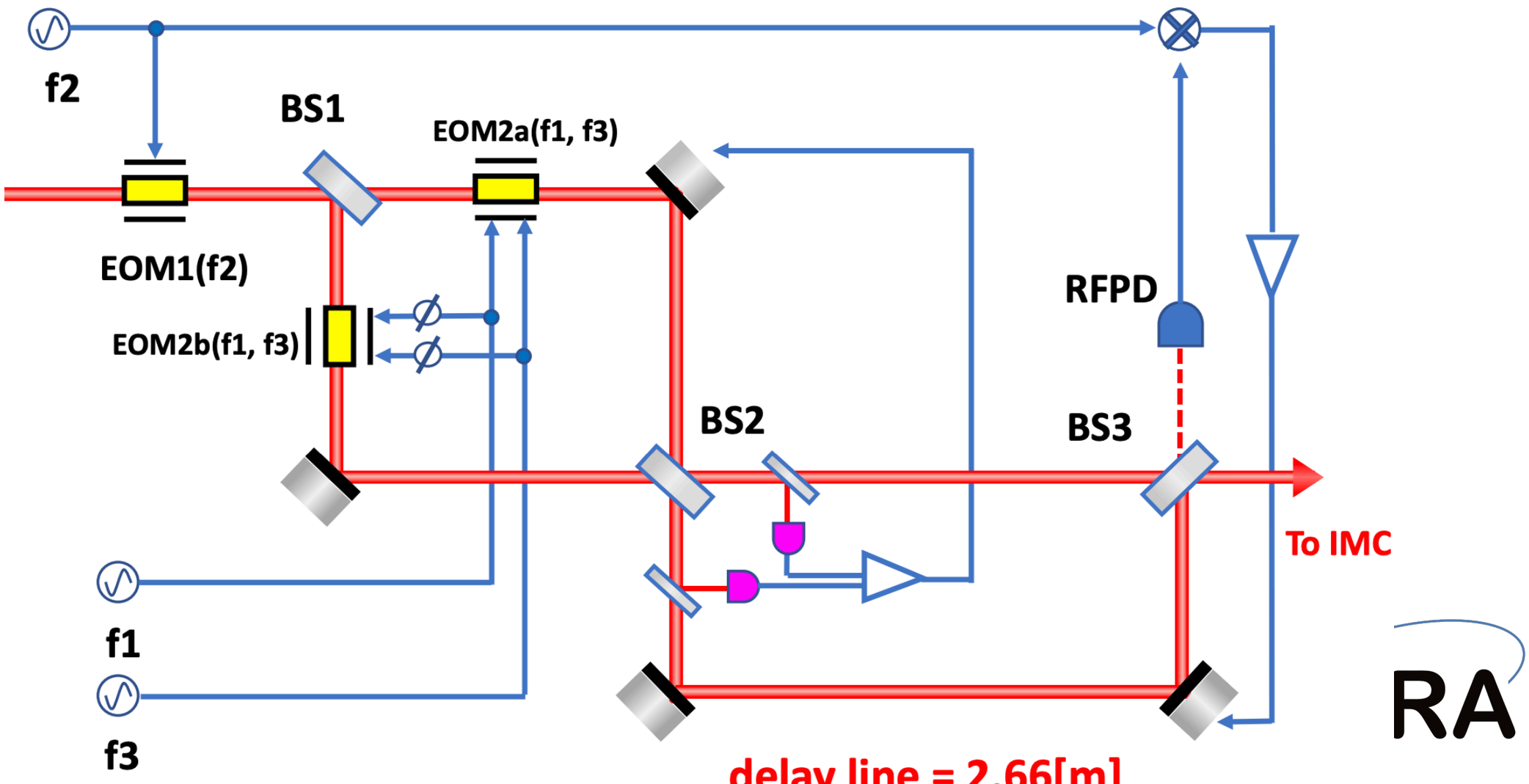
IMC ASC (final configuration 2)



Mach-Zehnder Modulator (MZM)

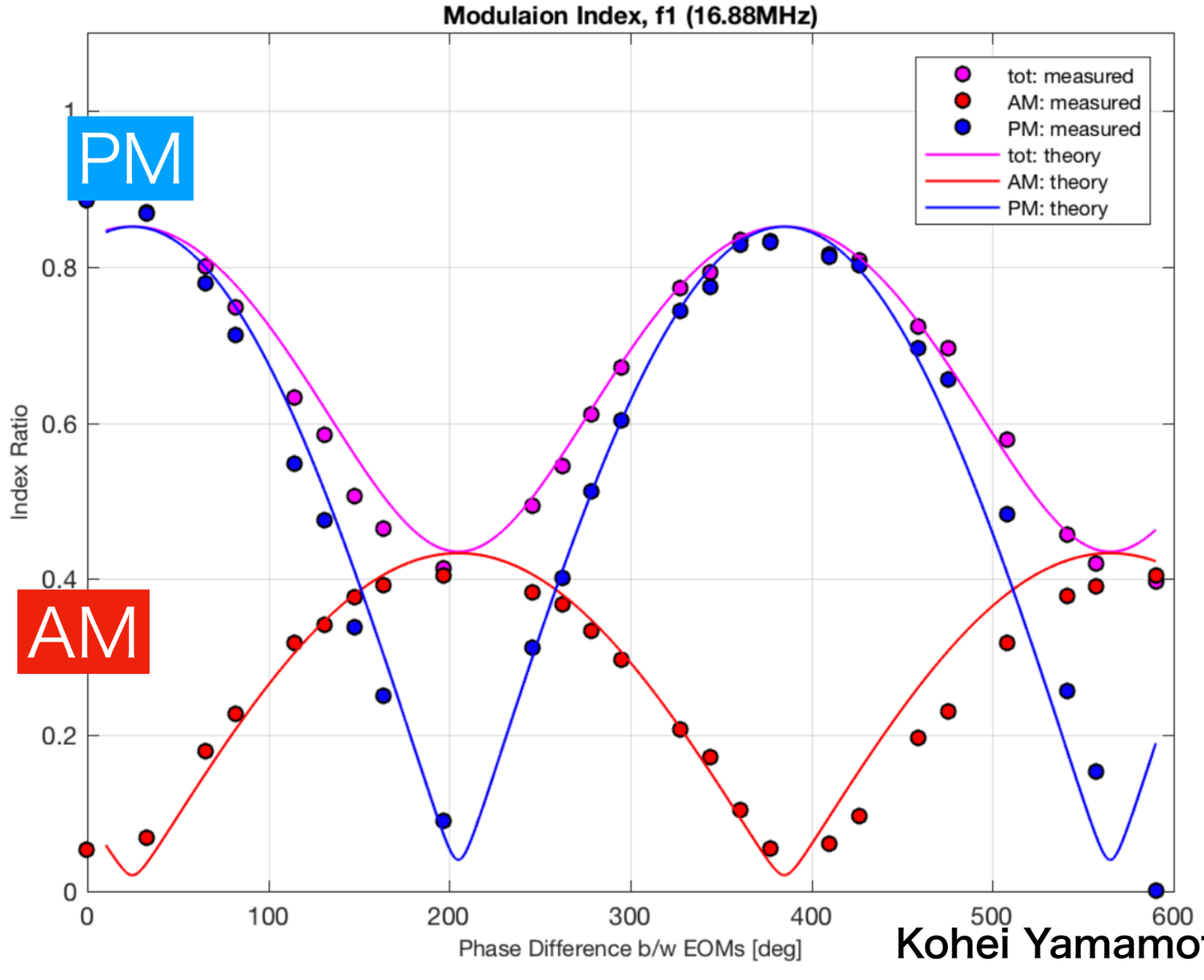
Mach-Zehnder Modulator (MZM)

- MZM can generate the tunable AM
  - ✓ To cancel the AM generated by the detuning of the RSE interferometer
  - ✓ To generate the AM for the lock acquisition
-



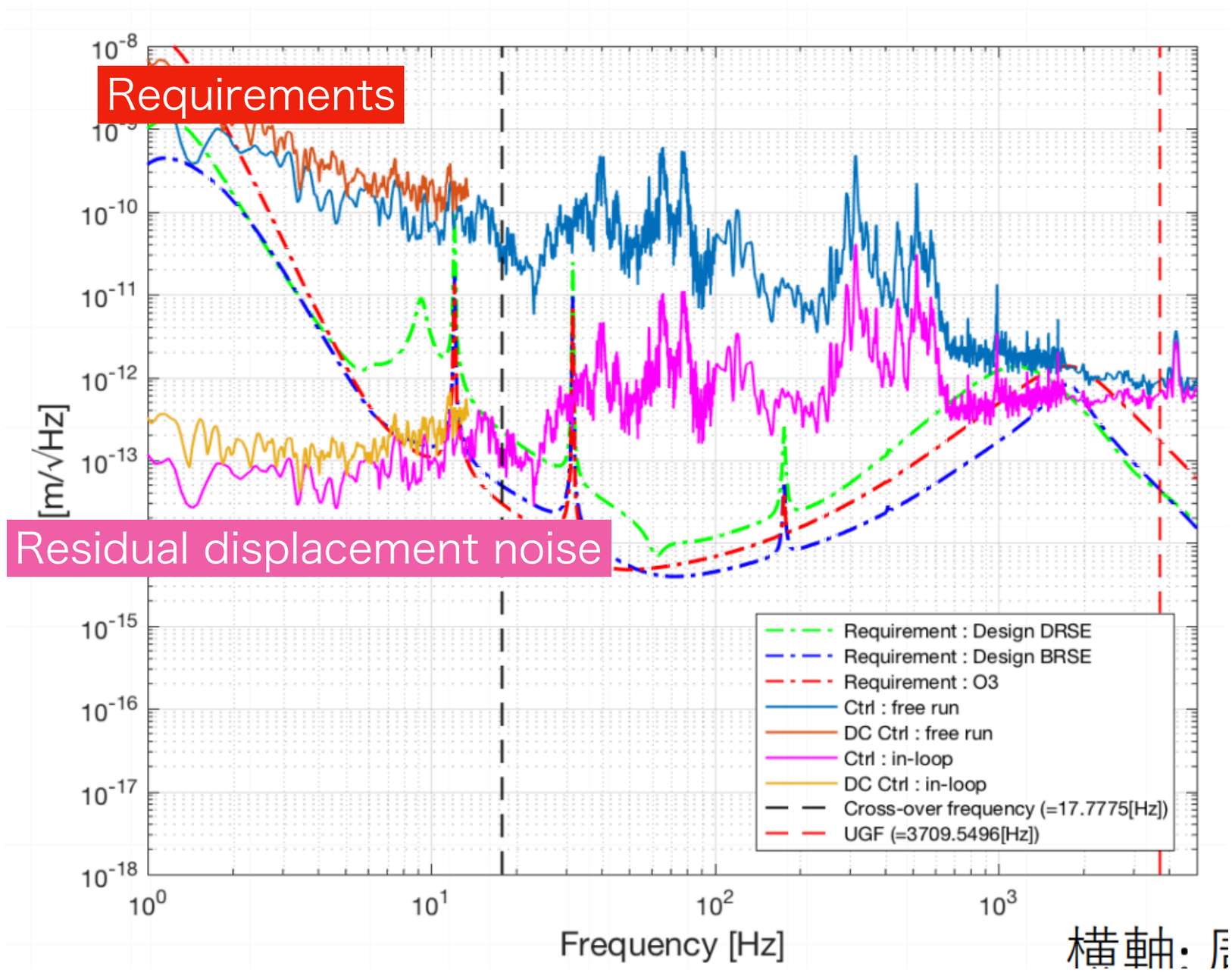
Mach-Zehnder Modulator (MZM)

- The AM can be tuned by tuning the phase difference between the EOMs
  - ✓ Demonstrated by the experiment



Displacement noise of the MZM

- The displacement noise has not met the requirement



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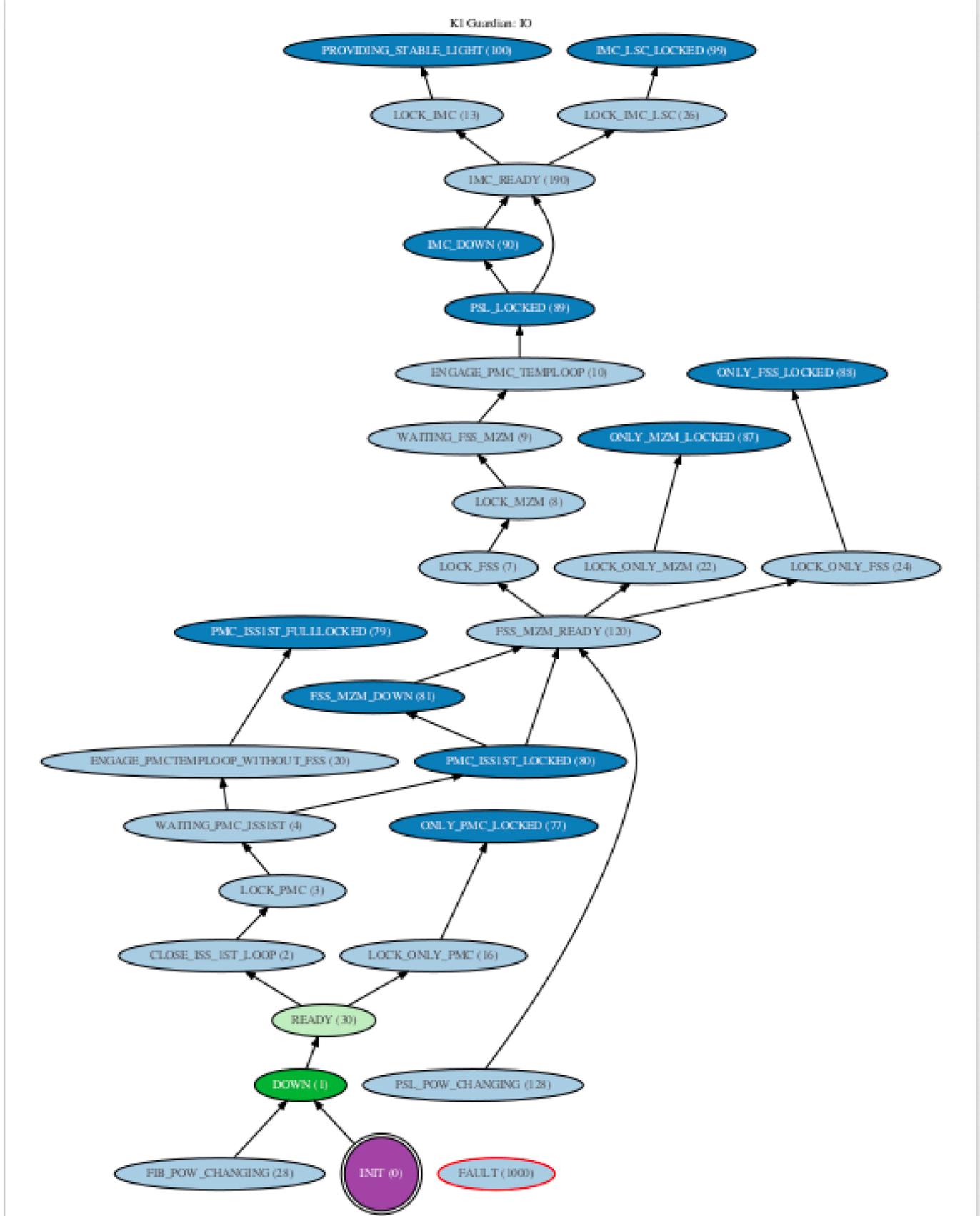
Guardian

KAGRA

Guardian

- All system has been operated automatically by using the guardian.



Summary

Summary and future plan

- Almost all system has been installed.
- All system are operated automatically with the guardian.
- The frequency noise has been measured by using the Xarm control signal
  - ✓ It was consistent with the estimation with the in-loop signal.
- IMC ASC is using limited sensors so far.
  - ✓ It will be finalized in a couple of weeks.
- MZM has been installed and demonstrated to generate the tunable AM.
  - ✓ The displacement noise has not met the requirement.
    - Use the monolithic MZI?
    - Use the rigid mirror mounts?
- High power test is on going.

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Appendix

Control Bandwidth of the PMC

- UGF: ~6 kHz -> Is enough?