Input/Output Optics subgroup

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General definition

- Make the input optics system from laser to power recycling mirror and make the all of output optics systems* including output mode-cleaner.
- Prepare all of optics and facilities for them.

output optics system* AOS prepares too.

Item Lists [1/2]

Items	iLCGT	bLCGT	Presen-tation
(a) Laser Room	◎	○	Yes
(b) Input Optics	◎	◎	Yes
(c) Mode Cleaner	◎	○	Yes
(d) Mode Matching Telescope	◎	○	Yes
(e) Isolator	◎	○	Yes
(f) Output Optics*	◎	◎	No
(g) Output Mode Cleaner	−	◎	Yes
(h) Photo Detector	◎	◎	No
(i) Beam Shutter	◎	○	Yes
(j) Green Laser	◎	○	Yes

◎ develop or modify ○ same as iLCGT − none

Output Optics* AOS prepares too.

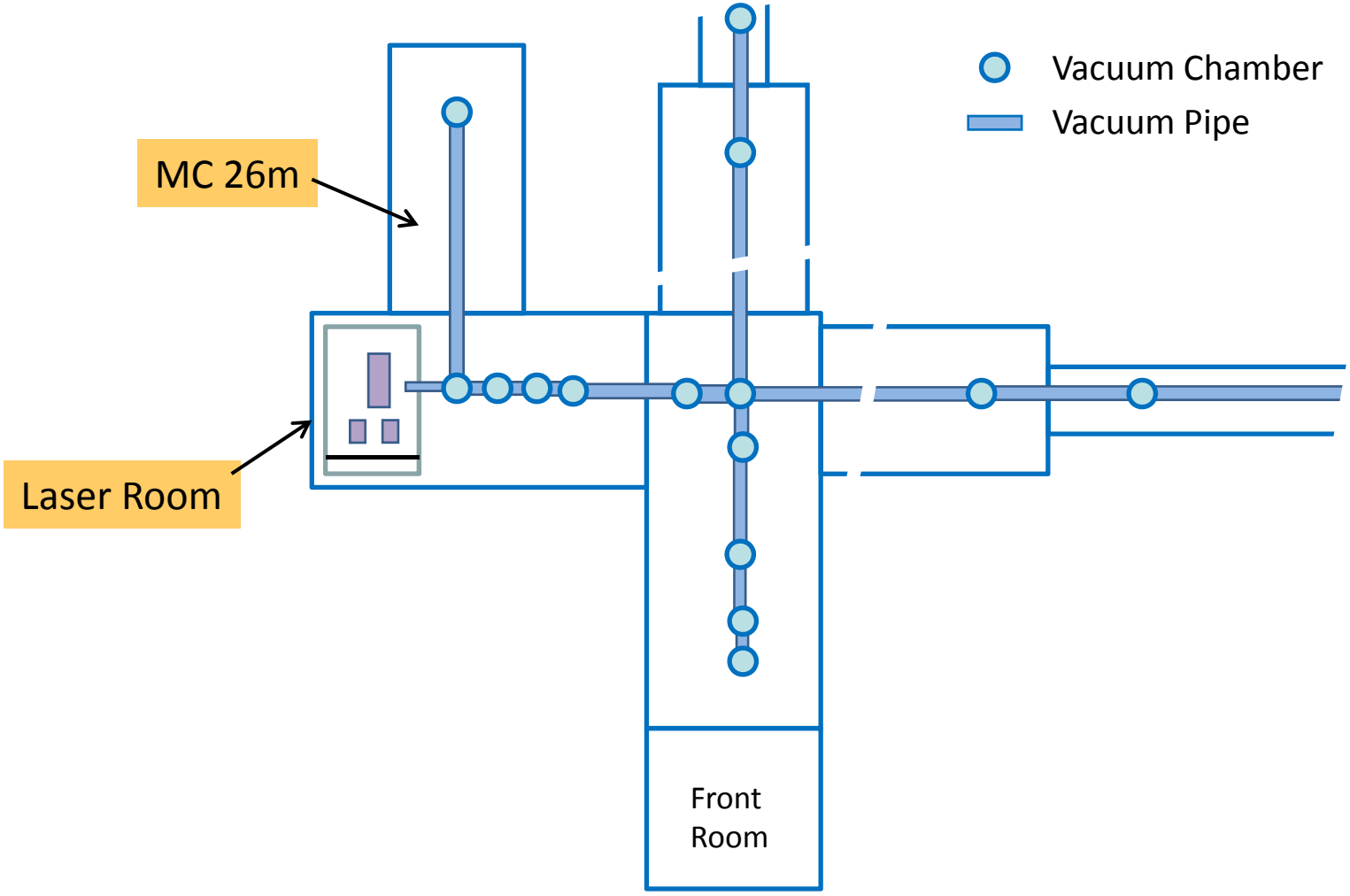
Item Lists [2/2]

(b) Input Optics

Sub Items	iLCGT	bLCGT	Presen-tation
(b-1) Pre Mode Cleaner	◎	○	Yes
(b-2) Reference Cavity	◎	○	Yes
(b-3) Intensity stabilization	◎	◎	Yes
(b-4) Frequency stabilization	◎	◎	Yes
(b-5) Modulator	◎	◎	Yes
(b-6) Alignment control of incident beam	◎	○	No
(b-7) Other optics	◎	◎	No

◎ develop or modify ○ same as iLCGT

(a) Laser Room [1/2]



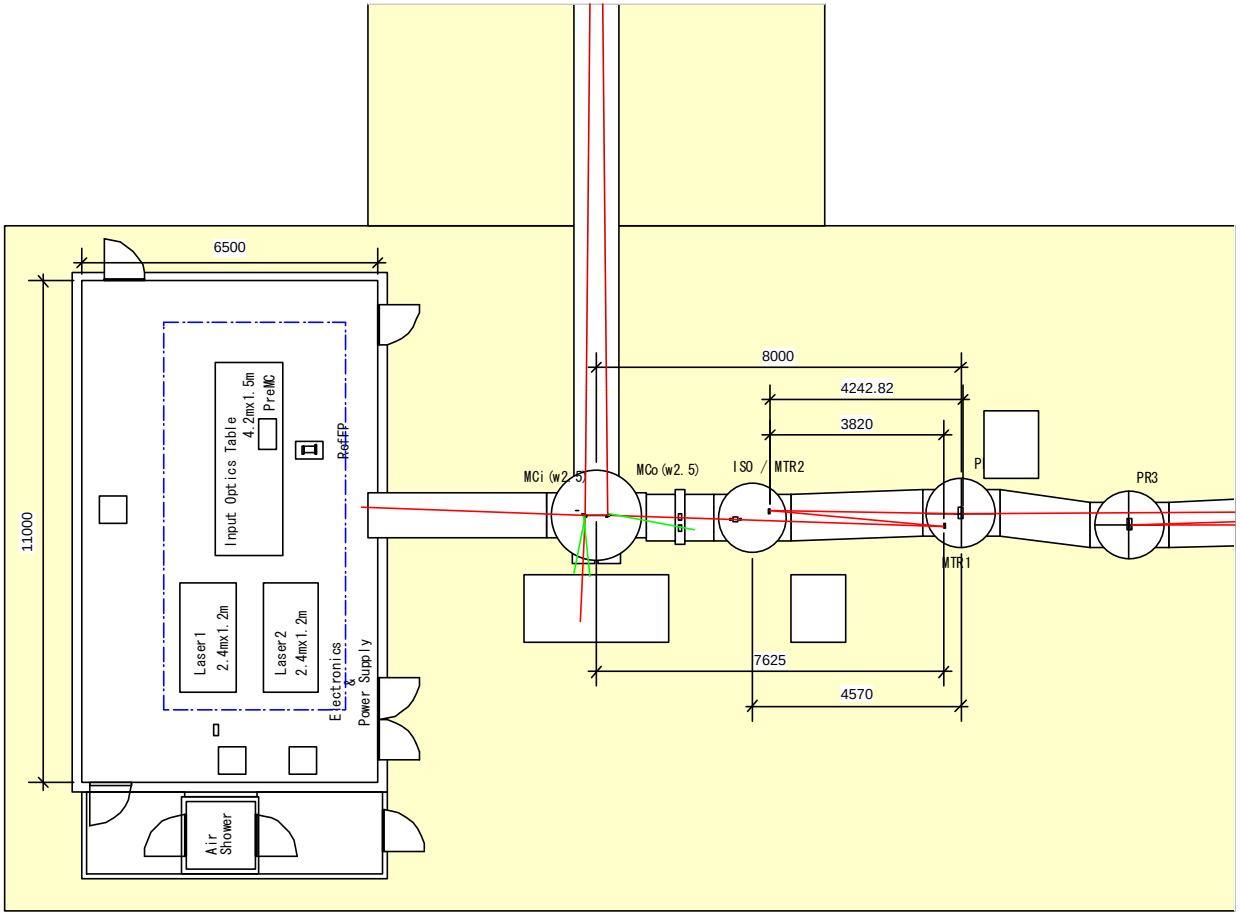
(a) Laser Room [2/2]

iLCGT ◎
bLCGT ○

Specifications

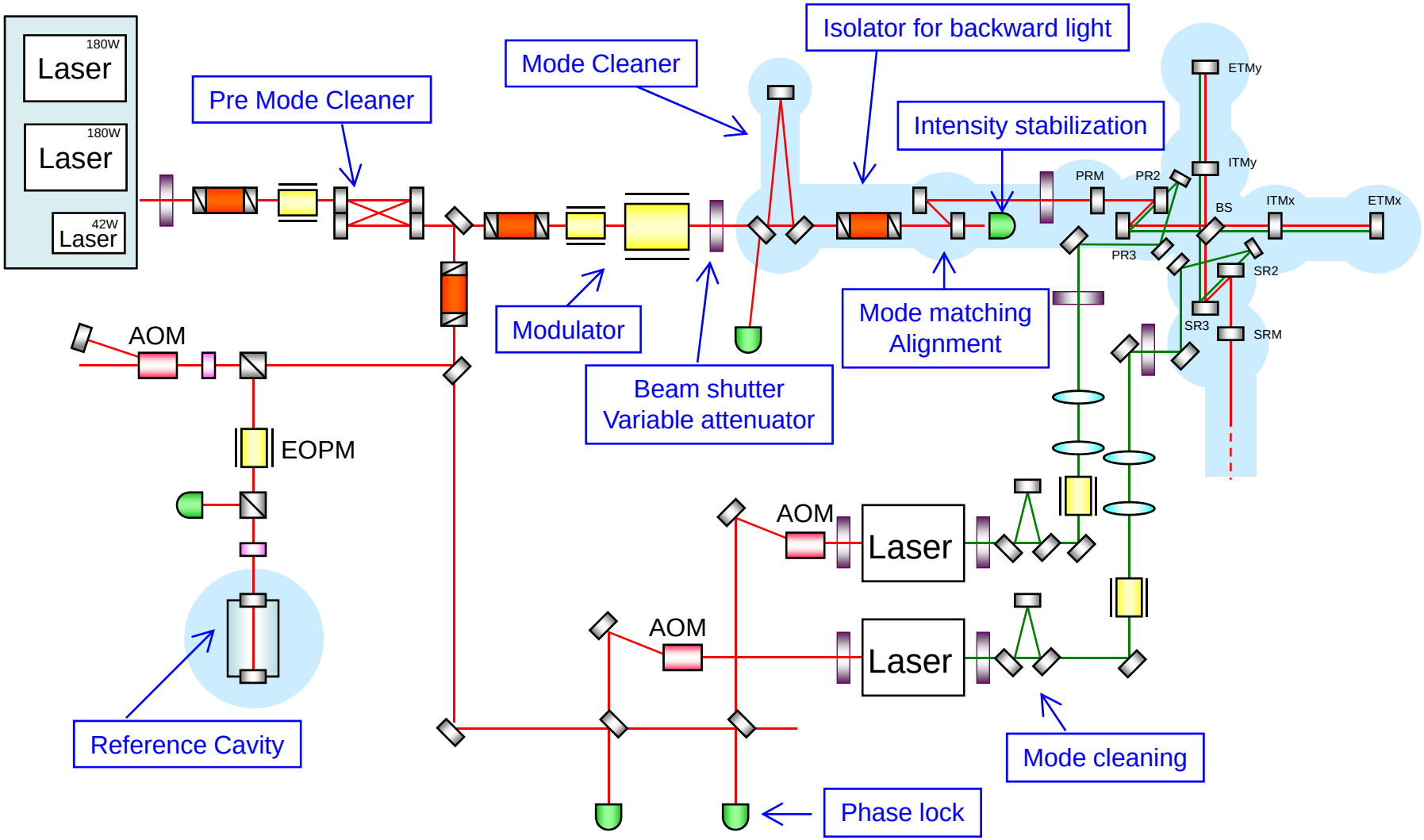
- Higher class clean room than center room (class ???).
- Better temperature stability with air conditioner (+/- 1K).
- Soundproof room.
- The floor is separated from center room floor (blue broken line).
- Lasers and input optics table are surrounded by Enclosers.

Inter-face	->	TUN, FCL and VAC
	<->	LAS



(b) Input Optics [1/3]

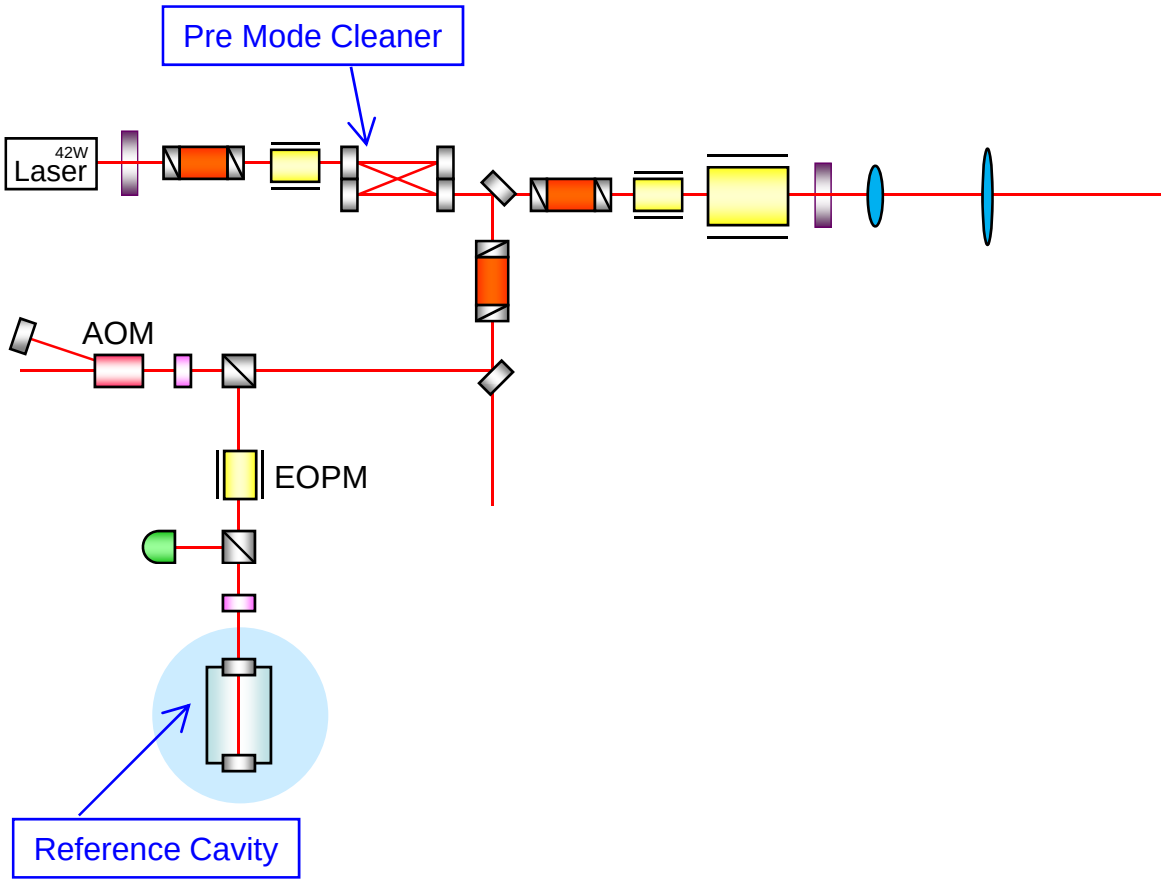
iLCGT ◎
bLCGT ◎



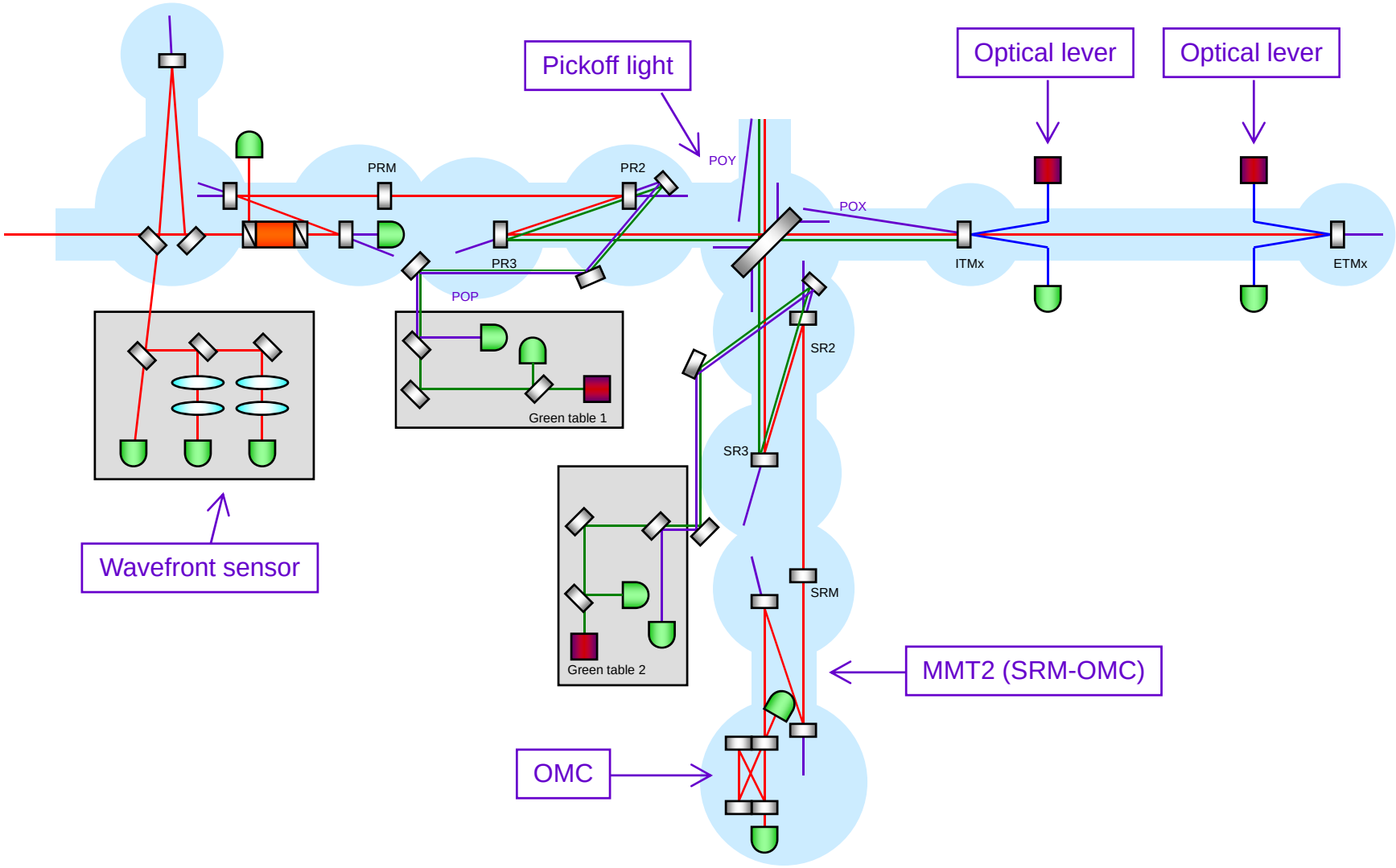
(b) Input Optics [2/3]

First Step
(*before tunnel*)

- Using commercial product laser.
- Development pre-MC and RefCav.
- Test of mode matching.



(b) Input Optics [3/3]



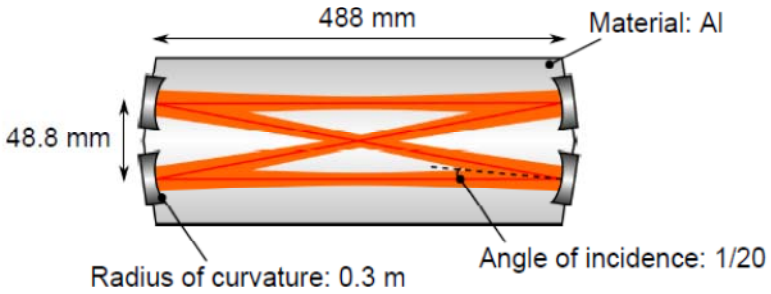
(b-1) Pre Mode Cleaner [1/2]

iLCGT ◎
bLCGT ○

- RF noise reduction.
  Suppress the intensity noise of the laser below shot noise level around the RF modulation frequency with passive effect of a cavity, because the Mode-cleaner transmits the RF modulations which are used for control of the main interferometer. If insufficient the RF noise reduction with one pre-mode-cleaner, then two or three pre-mode-cleaners will be used in series.

  Requirement: < 1 x 10-8 /sqrt(Hz) (>10 MHz) for bLCGT

- Spatial pre mode cleaning.
  As the additional function, spatial mode of the laser beam is made clean.



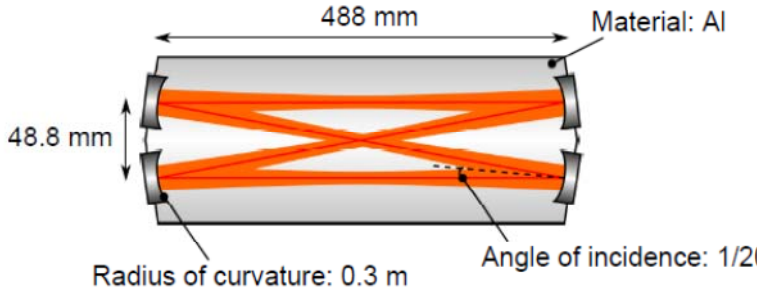
(b-1) Pre Mode Cleaner [2/2]

iLCGT ◎
bLCGT ○

Design of Pre Mode Cleaner

FSR	154MHz
Finesse	155
Cutoff frequency	495kHz
Beam waist radius	199mm
Beam radius on mirrors	460mm

Round-trip length	1.95m
R (Coupler)	98%
ROC	0.3m



This cavity is put in air tight case, not in vacuum.

Error signal acquisition	PDH method
Actuator	Heating the spacer or Piezo stage (DC-0.1Hz)
	Piezo (0.1Hz-1kHz)

Interface	<-> LAS, AEL and DGS

(b-2) Reference Cavity [1/1]

iLCGT ◎
bLCGT ○

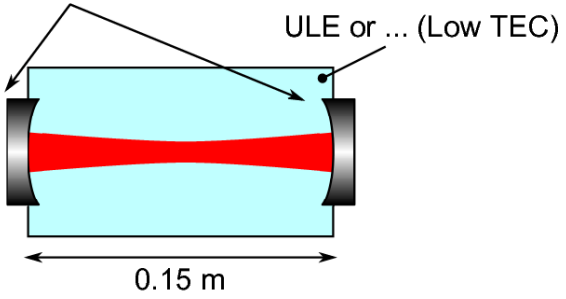
- Lower frequency stabilization
  The laser frequency is stabilized as the reference of the 'Reference cavity' at the lower frequency (DC – 10 Hz). The 'Reference cavity' is rigid Fabry-Perot cavity placed in vacuum with vibration isolation.

Design of Pre Mode Cleaner

Length	0.15m
R (Coupler)	99.97%
ROC	0.1m
Substrate	ULE or Silica

FSR	1GHz
Finesse	10000
Cutoff frequency	50kHz

Substrate: Silica
Φ = 1 inch
S1: ROC = 0.1 m, R = 99.97 %@1064nm
S2: Flat, Wedge = 1 deg, AR@1064nm



FSR = 1 GHz
Finesse = 10000
=> Cutoff freq. = 50 kHz

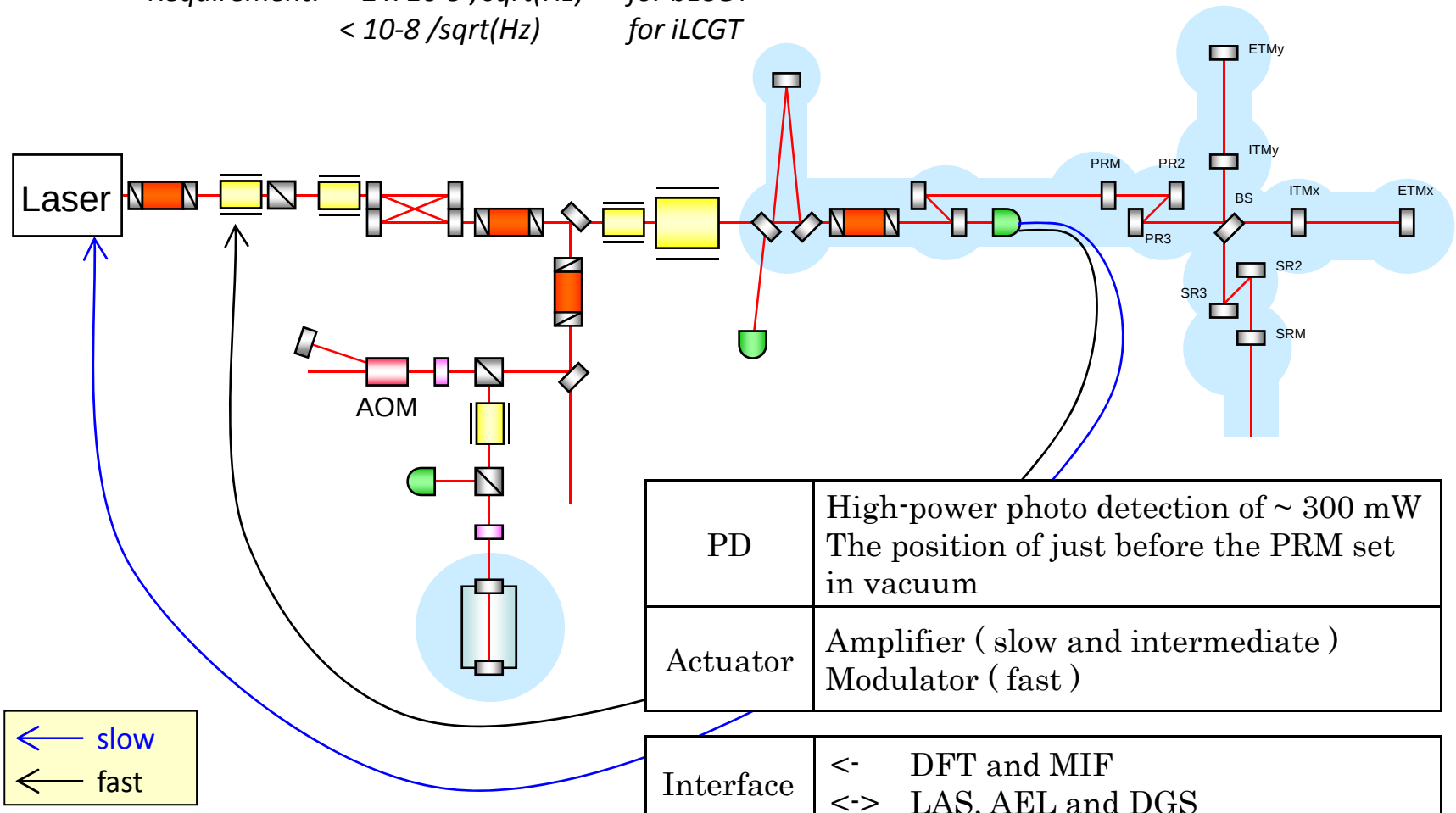
Interface	<-> LAS, AEL and DGS

(b-3) Intensity stabilization [1/1]

iLCGT ◎
bLCGT ◎

Intensity stabilization

Requirement: < 2 x 10-9 /sqrt(Hz) for bLCGT
< 10-8 /sqrt(Hz) for iLCGT



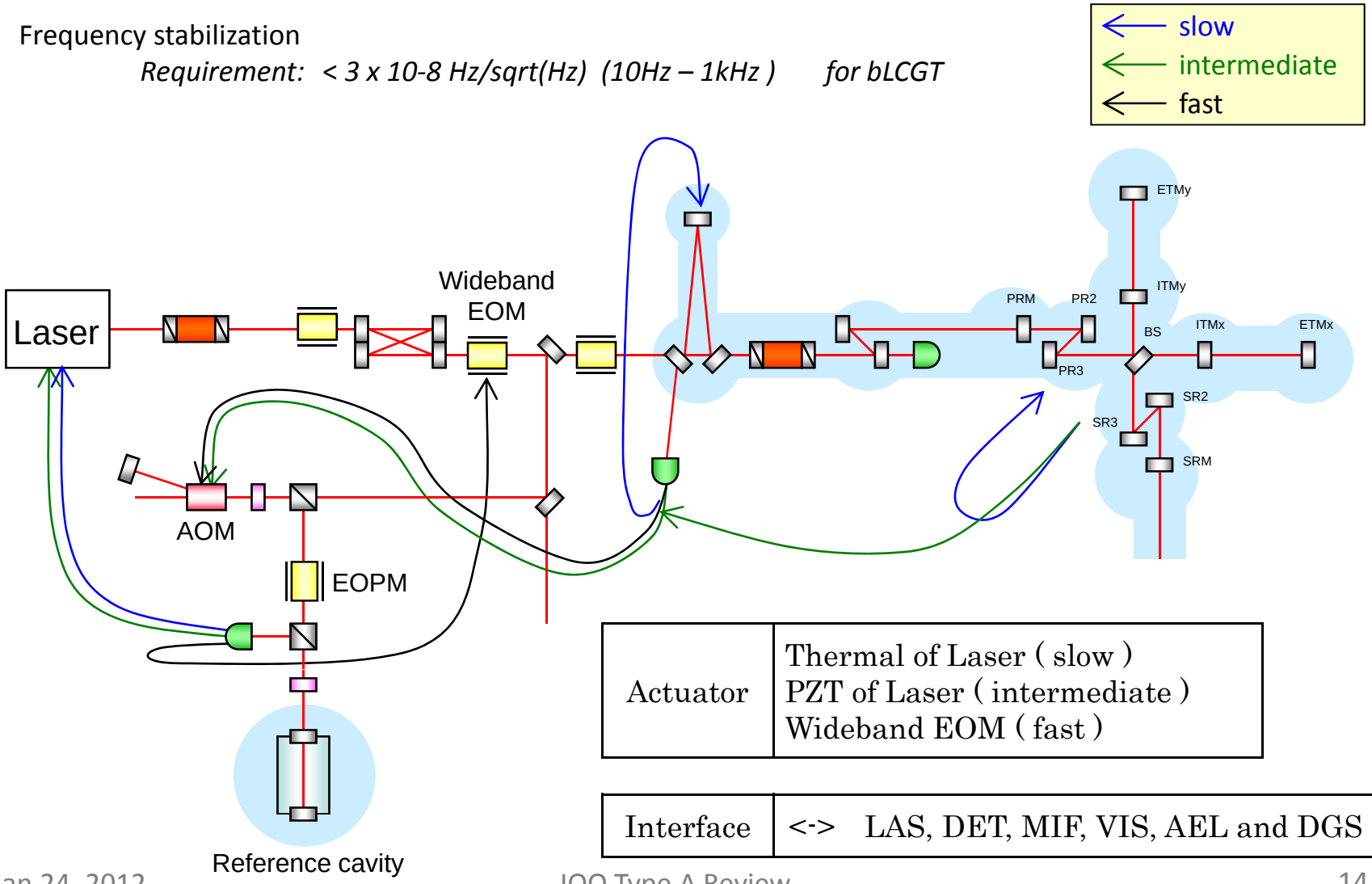
PD	High-power photo detection of ~ 300 mW The position of just before the PRM set in vacuum
Actuator	Amplifier (slow and intermediate) Modulator (fast)
Interface	<- DFT and MIF <-> LAS, AEL and DGS

(b-4) Frequency stabilization [1/1]

iLCGT ◎
bLCGT ◎

Frequency stabilization

Requirement: < 3 x 10-8 Hz/sqrt(Hz) (10Hz – 1kHz) for bLCGT



Actuator	Thermal of Laser (slow) PZT of Laser (intermediate) Wideband EOM (fast)

Interface	<-> LAS, DET, MIF, VIS, AEL and DGS

(b-5) Modulator [1/3]

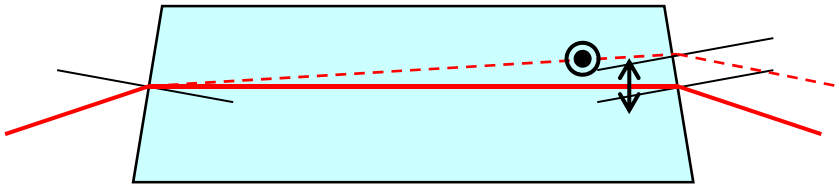
iLCGT ◎
bLCGT ◎

Parameters

EO crystal		RTP ($RbTiOPO_4$) MgO:SLN (MgO-doped $LiNbO_3$)
Aperture size	RF modulation	4 x 4 mm^2 or 5 x 5 mm^2
	Wideband control ~1MHz	2 x 2 mm^2
	Wideband control >100kHz	4 x 4 mm^2
Length		20 – 40 mm

Wedged crystal

Polarization selectivity due to the birefringence of EO crystal.
e-LIGO has already used.
Detail design for LCGT is not fixed.



(b-5) Modulator [2/3]

iLCGT ◎
bLCGT ◎

Modulation Frequencies for Main Interferometer

bLCGT	16.875 MHz (PM) 45 MHz (PM) 39.375 MHz (AM) [if any]
iLCGT	16.875 MHz (PM) or 45 MHz (PM)

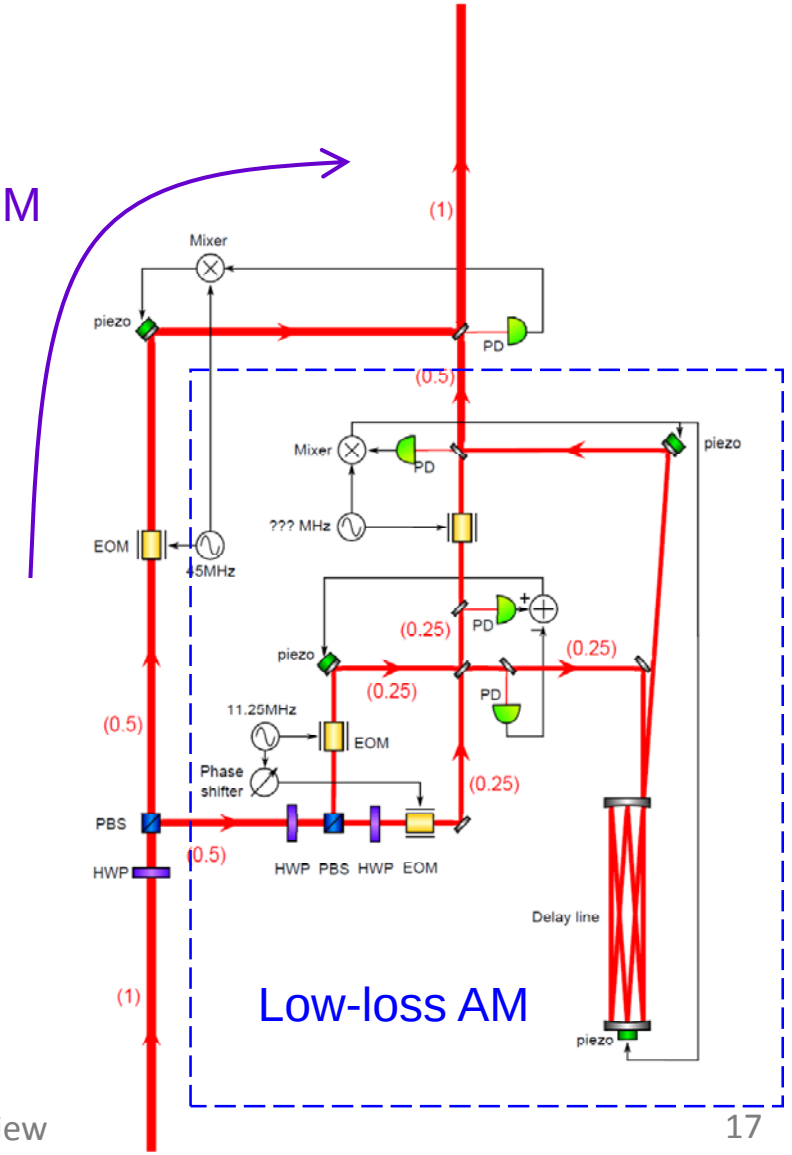
Interface	<- DFT and MIF <-> AEL and DGS

(b-5) Modulator [3/3]

PM + AM Generation Scheme

Dr. Ohmae has been performed in his doctor thesis.

- PM: simple configuration
  - Amplitude ratio (CR : 1st SB : 2nd SB)
    - |J0(m)| : |J1(m)| : |J2(m)|
- AM: complex configuration
  - Amplitude ratio (CR : 1st SB : 2nd SB)
    - |J0(m)| : |J1(m)| : |J2(m)|
      - Possible solution
    - (Ideal AM) = 1 : m/2 : 0
      - Impossible



(b-6) Alignment Control of Incident Beam [1/1]

iLCGT ◎
bLCGT ○

The alignment of the incident beam at lower frequency like a drift will be controlled with the last two folding mirrors on the input optical table.

Actuator	PZT(?) on mirror mount.
Sensing at	Before PRM. End of 3km inline arm.

Interface	<- DFT and MIF <-> AEL and DGS

(b-7) Other Optics [1/1]

We will prepare all of optics;
mirrors, lenses, BSs, PBSs, isolators, mirror mounts, …. , optical tables, and so on.

Interface	<-> DFT and MIF

(c) Mode Cleaner [1/6]

iLCGT ◎
bLCGT ○

- Spatial mode cleaning.

  Main function of the mode-cleaner is a spatial mode cleaning of laser beam and a reduce beam jitter for the main interferometer.
  The mirrors are suspended independently for vibration isolation and placed in vacuum tanks.

- Transmission sideband.

  It must transmit the modulation sidebands for the main interferometer.
  The current design of the modulation frequencies are 16.875 MHz and 45 MHz (optional 56.25 MHz).
  The FSR of MC is 5.625 MHz.

(c) Mode Cleaner [2/6]

Parameters

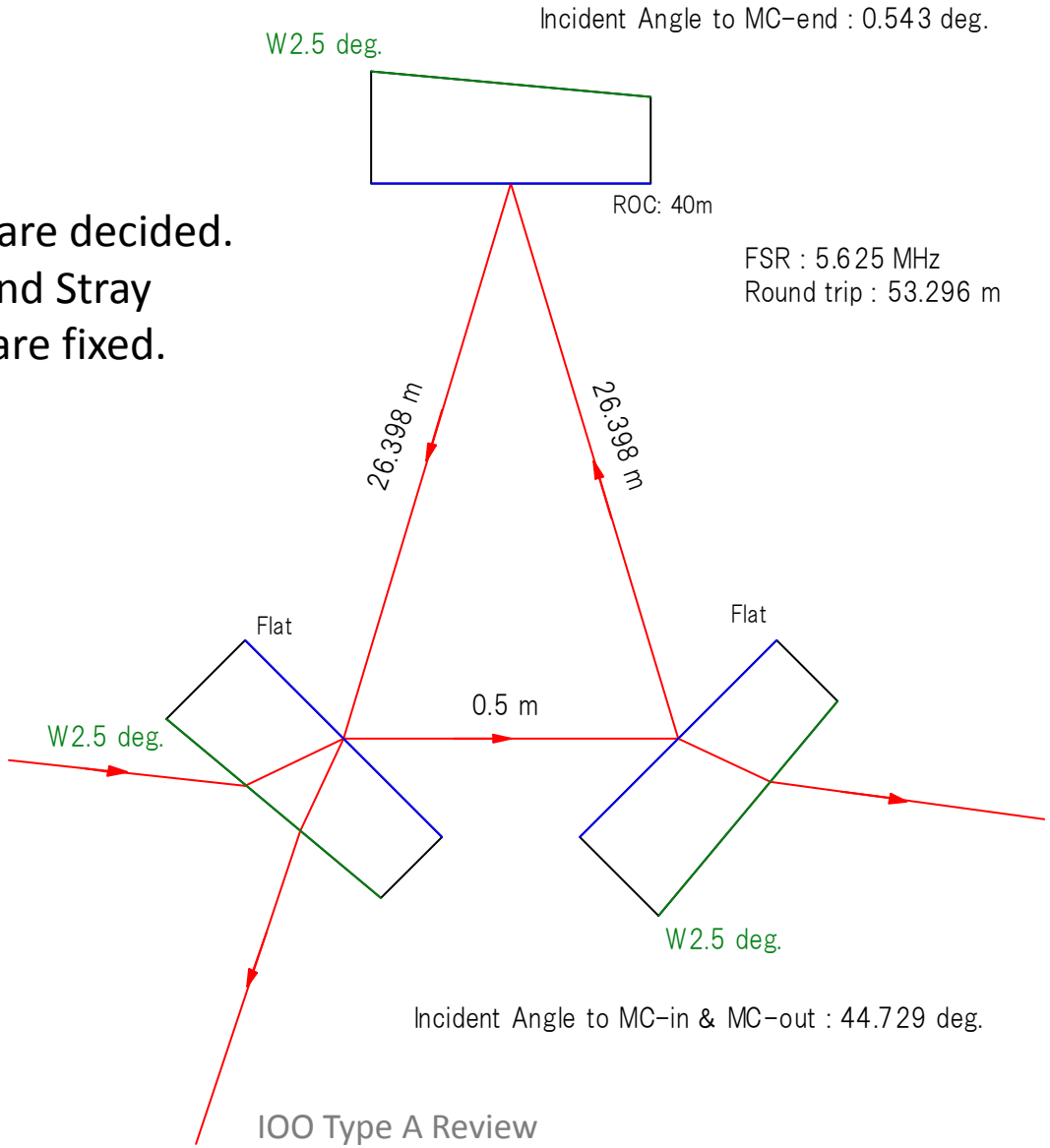
Round-trip length	53.296m
R (In and Out) R (End)	*99.37* % 99.99 %
ROC (In and Out) ROC (End)	**flat** **40m**
dimension (All)	**ϕ100mm, t30mm**
Wedge (All)	**2.5 deg.**

FSR	5.625 MHz
Finesse	about 500
Cutoff frequency	5.625 kHz
Beam radius on mirrors (In and Out) Beam radius on mirrors (End)	2.527 mm 4.377 mm

(c) Mode Cleaner [3/6]

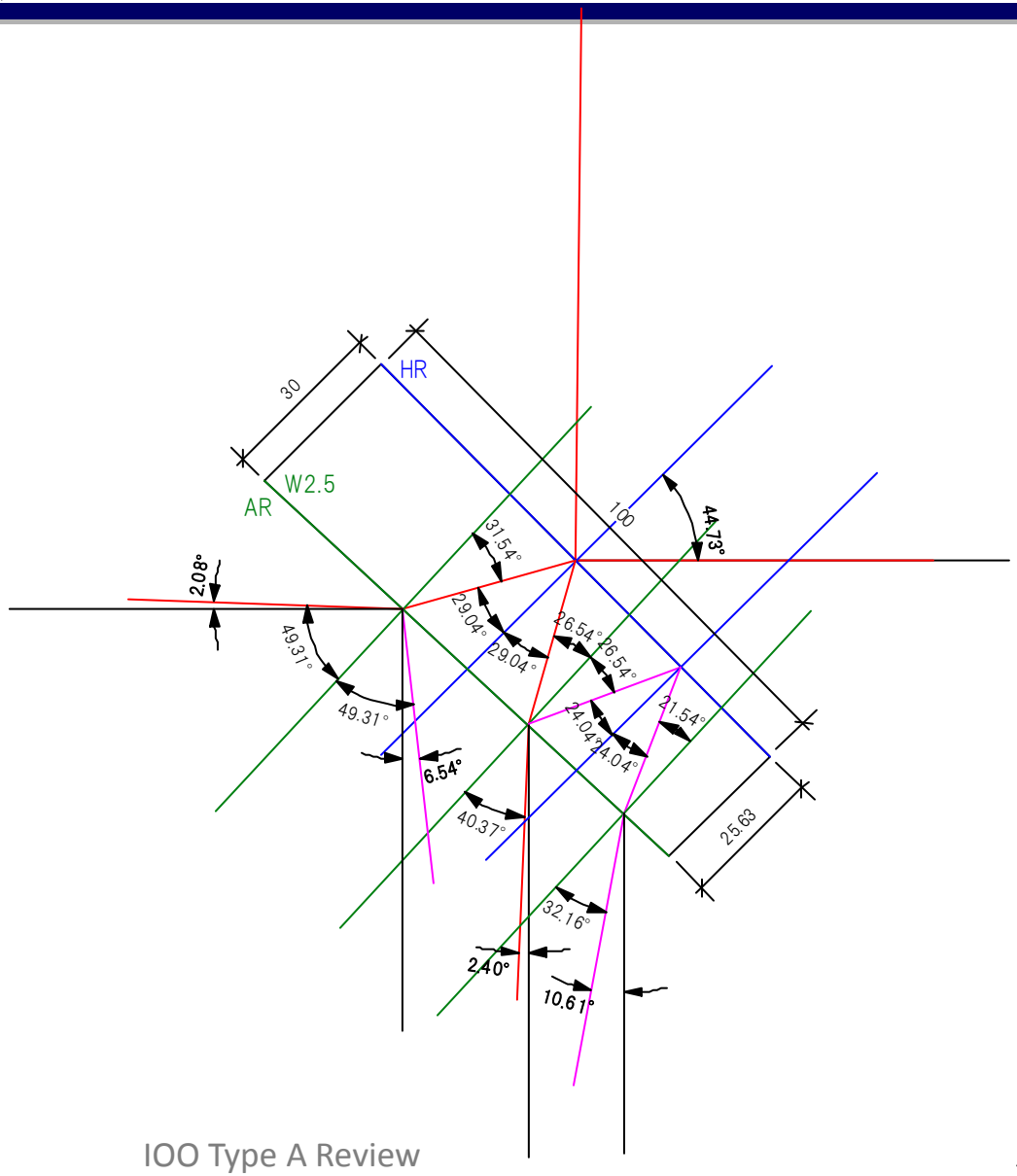
Overview

- Wedge directions are decided.
  -> Input, Output and Stray beams directions are fixed.



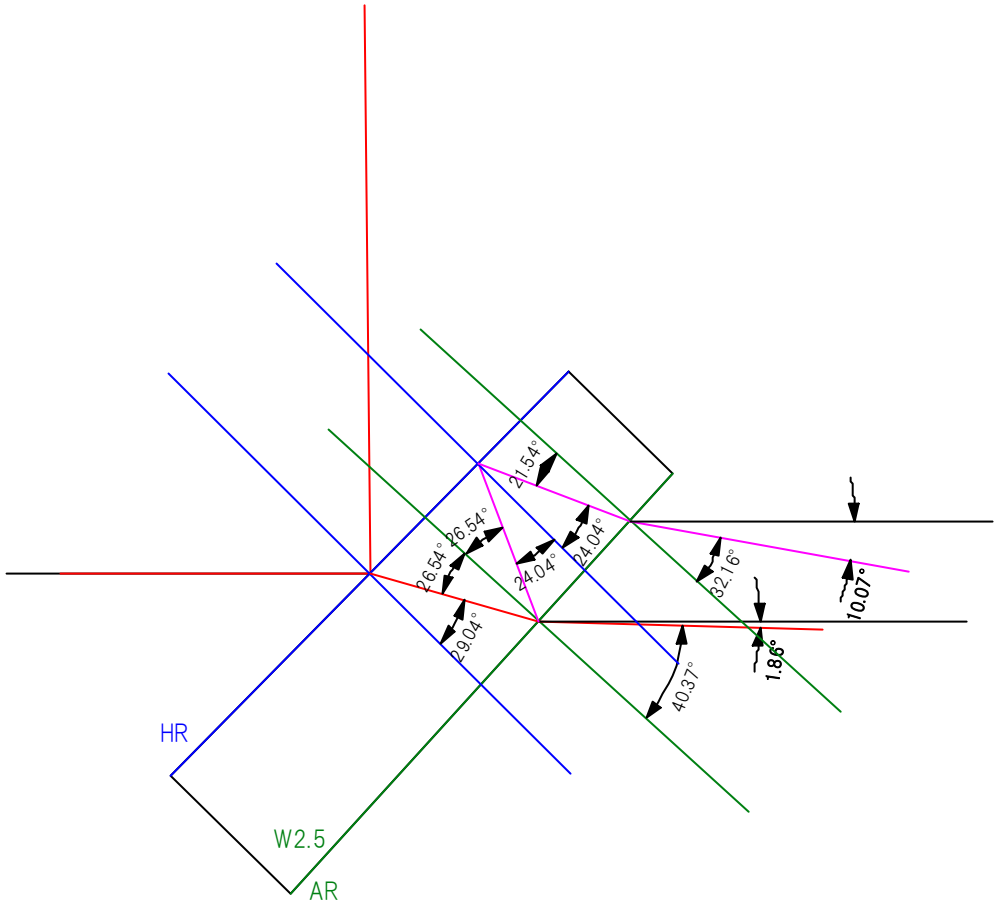
(c) Mode Cleaner [4/6]

MC input mirror



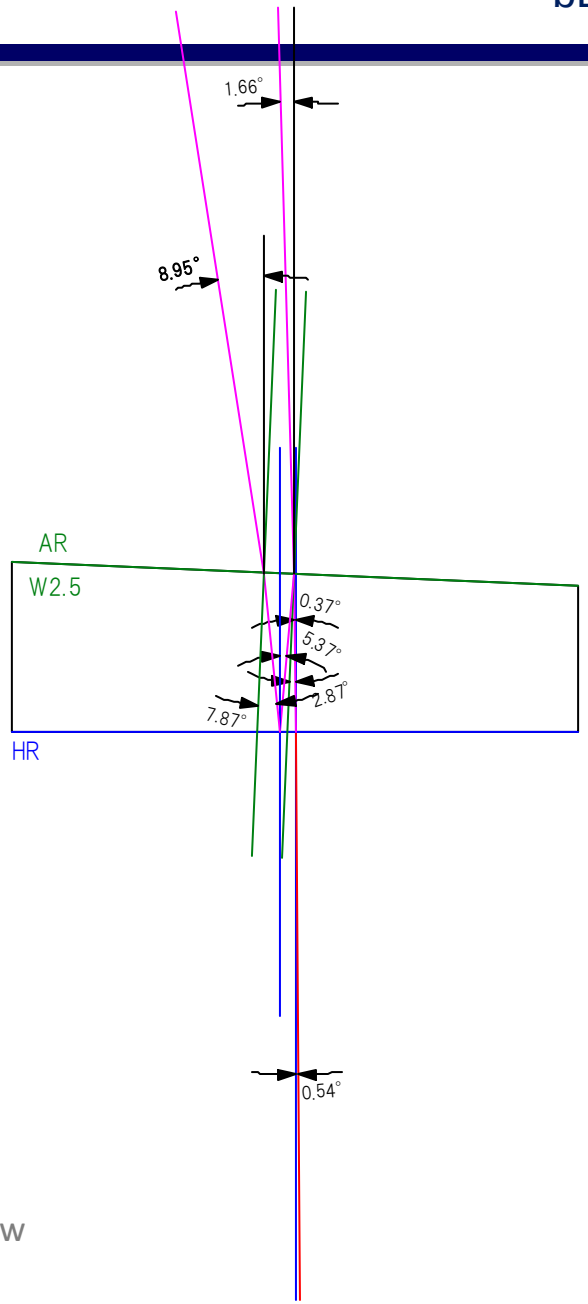
(c) Mode Cleaner [5/6]

MC output mirror



(c) Mode Cleaner [6/6]

MC end mirror



(d) Mode Matching Telescope [1/1]

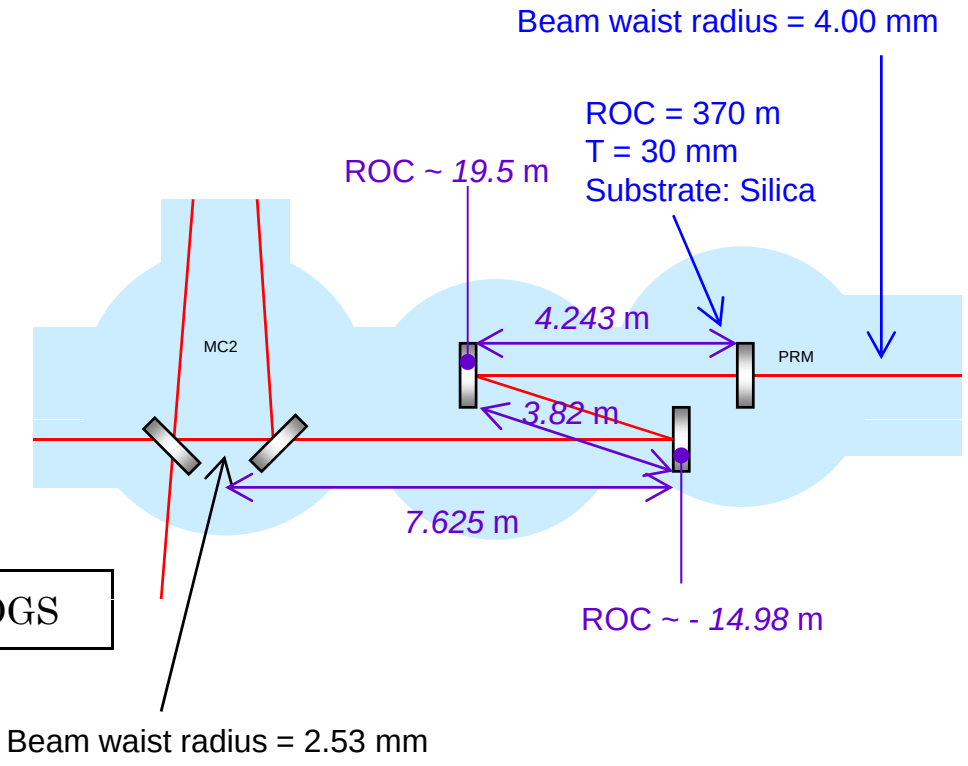
iLCGT ◎
bLCGT ○

Two suspended spherical mirror consist of the mode matching telescope between MC and PRM.
MMT1 is put into PRM vacuum tank.
MMT2 is put into another vacuum tank with optical isolator.

Parameters

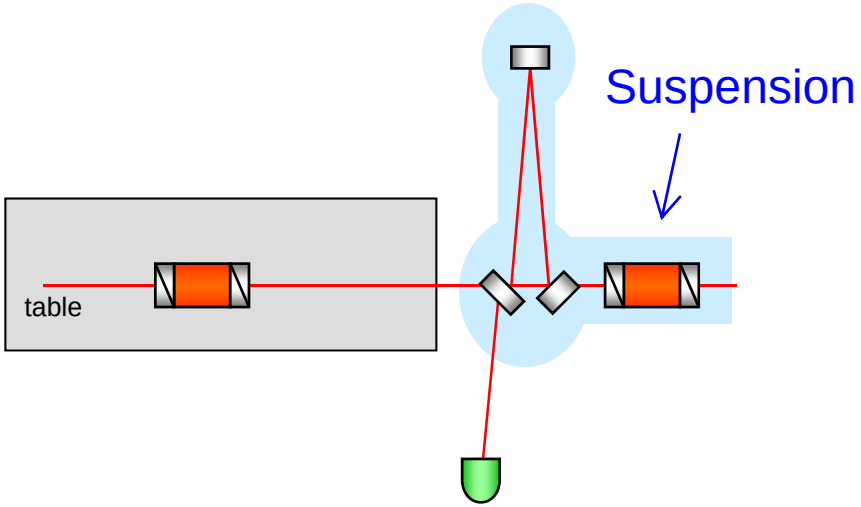
Substrate	Silica
Dimensions	ϕ100mm, t30mm ϕ100mm, t30mm
ROC	~ -14.98 m* ~ 19.5 m*

Interface	->	MIR, VIS, AEL, and DGS



(e) Isolator [1/1]

Faraday isolator is placed after the MC for pickoff backward light from the main interferometer.
The Faraday isolator is suspended for vibration isolation and placed in vacuum.



Interface	->	VIS

(f) Output Optics [1/1]

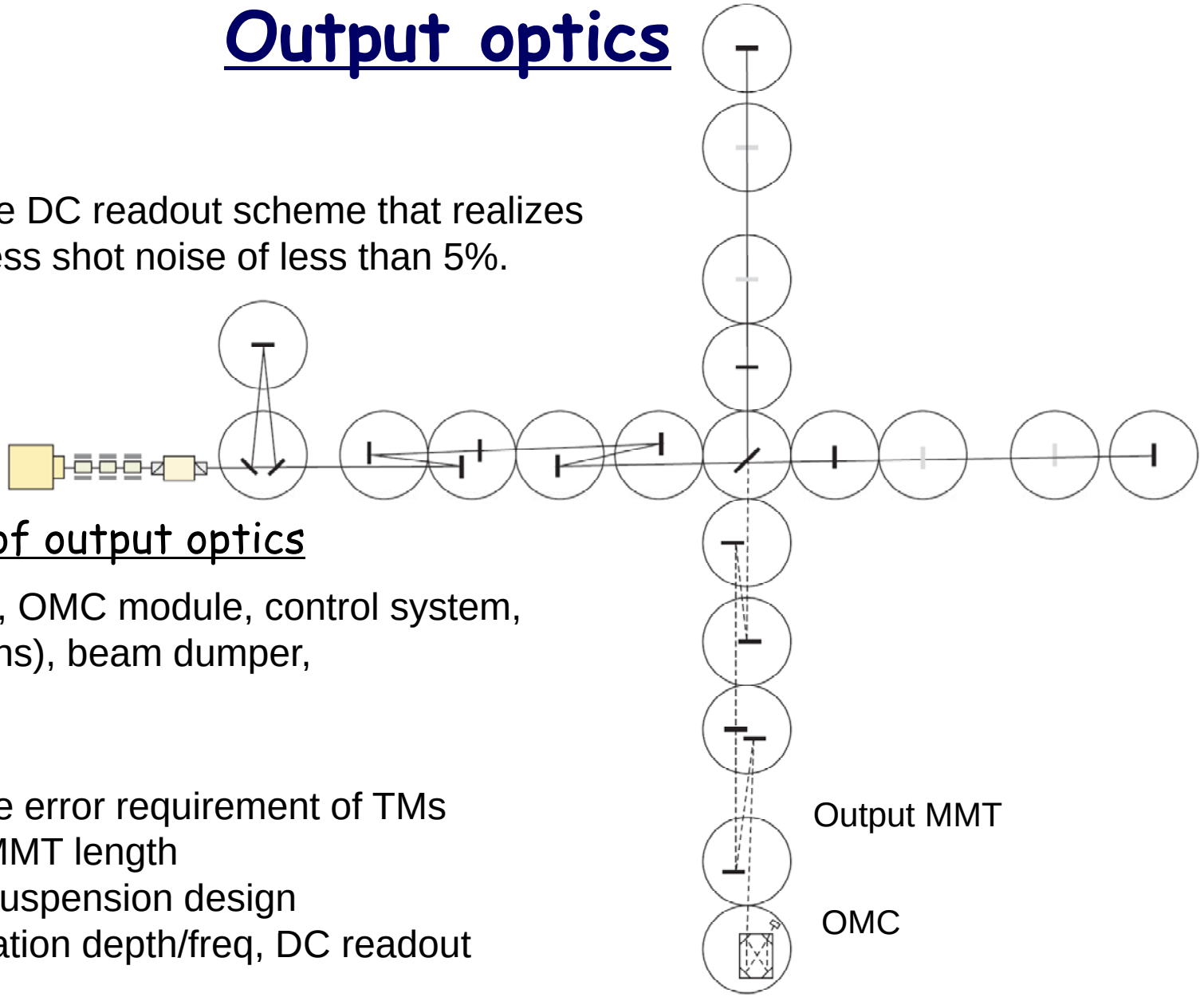
We will prepare all of output optics include Beam Reducing Telescope and , mirrors, lenses, BSs, PBSs, isolators, mirror mounts, …. , optical tables, and so on.

Interface	<-> FCL, VAC, VIS, DFT and MIF

Output optics

Scope

Establish the DC readout scheme that realizes BAE w/excess shot noise of less than 5%.



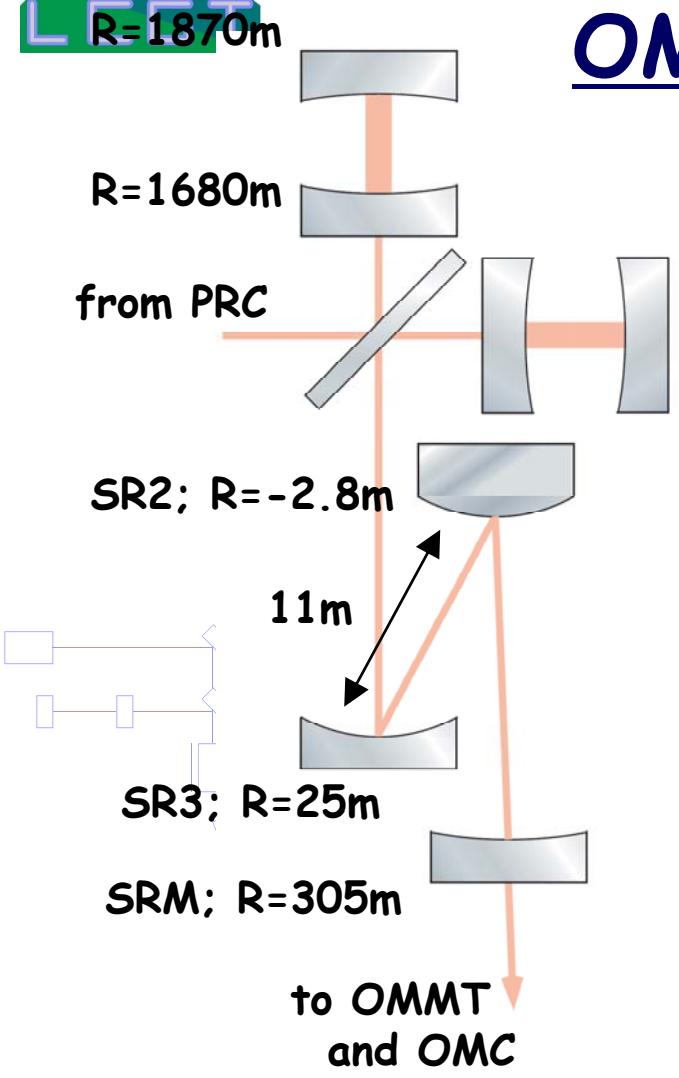
Components of output optics

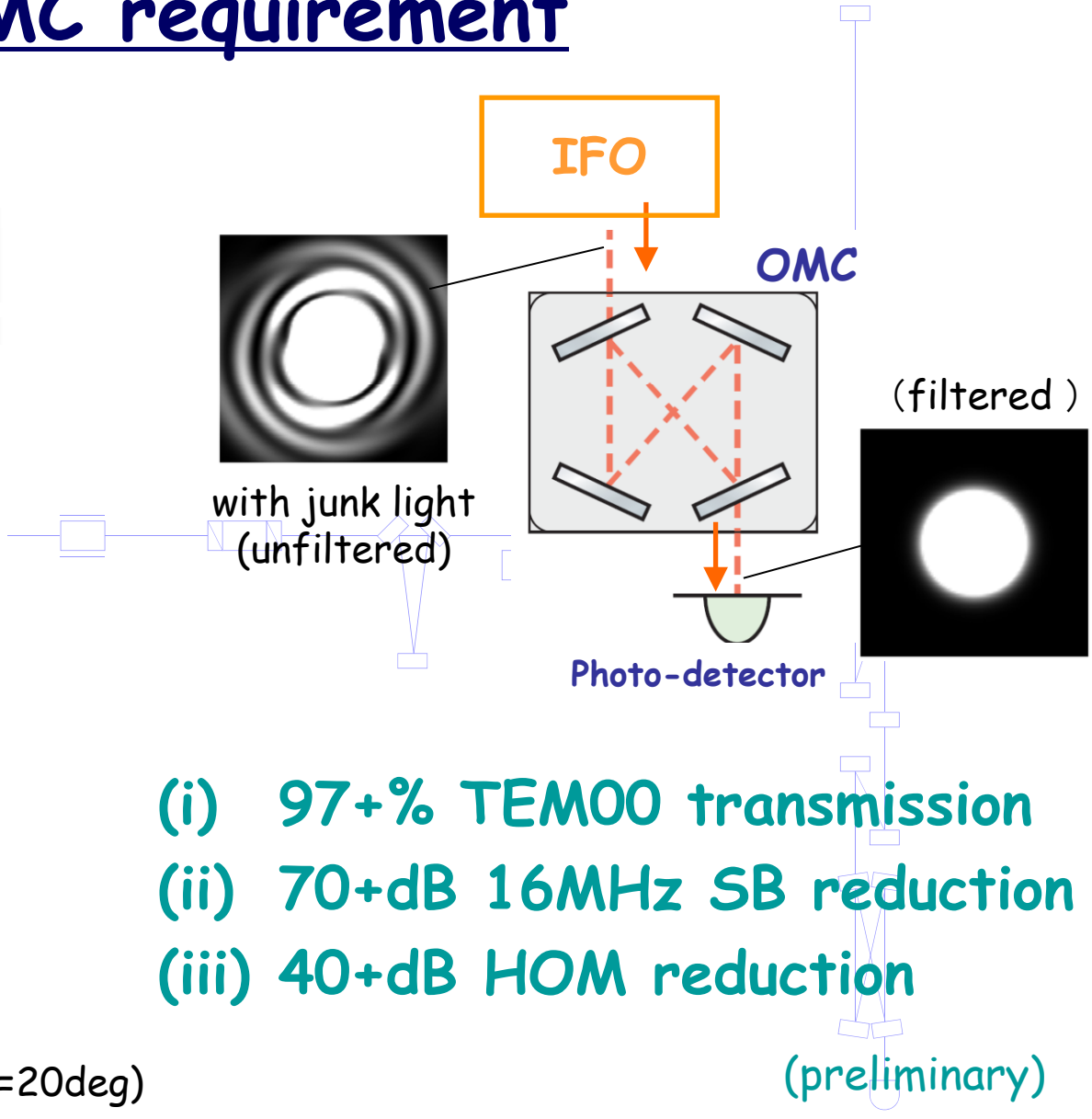
output MMT, OMC module, control system,
PD (refl, trans), beam dumper,

Interface

MIR: surface error requirement of TMs
VAC/FCL: MMT length
VIS: OMC suspension design
MIF: modulation depth/freq, DC readout

OMC requirement





(i) 97+% TEM00 transmission

(ii) 70+dB 16MHz SB reduction

(iii) 40+dB HOM reduction

(preliminary)

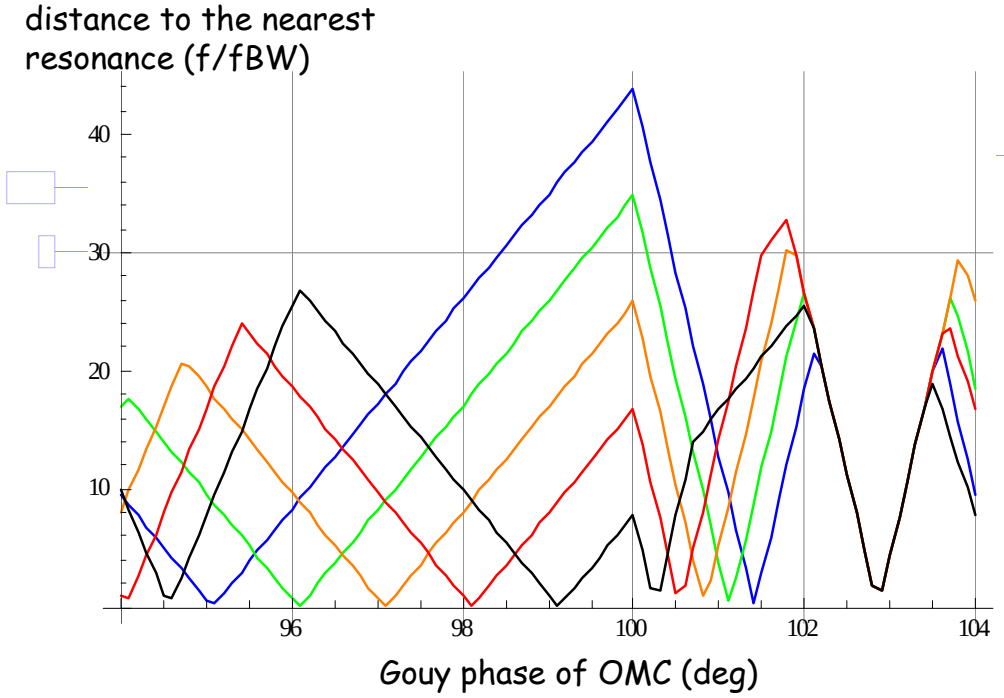
(w_{SRM}=4.0mm, w_{SR2}=4.0mcm,
w_{SR3}=36mm, w_{ITM}=35mm, η_{SRC}=20deg)

OMC design

* TM loss: 41ppm/49ppm

RF						DC					
TEM00	TEM20	TEM02	TEM40	TEM04	TEM22	TEM00	TEM20	TEM02	TEM40	TEM04	TEM22
72mW	0.7mW	0.7mW	0.5mW	0.5mW	0.3mW	2.2mW	0.15W	0.15W	13mW	13mW	8.7mW

(preliminary)



(L=0.5m,0.6m,0.7m,0.8m,0.9m)

- simulation work under progress
- prototype exp to be started in Feb
- risk management:
  ~ alternatives to the conv. OMC
  ~ relying on variable RSE
- work milestone:
  ~ ommt/omc roc fixed by 2012/3
  ~ prototype exp. done by 2014/3

(h) Photo Detector [1/1]

Parameters

Details are not fixed.
We will develop photo detectors with Analog electronics group.

Interface	<- MIF <-> AEL

(i) Beam Shutter [1/2]

iLCGT ◎
bLCGT ○

Beam shutters will be put due to protection of photo detector and safety.

The details are not fixed.

- Fast (quick?) shutter: ~ 1 ms

  Mechanical shutter or suspension taught by Rana.

- Slow shutter: ~ 1s

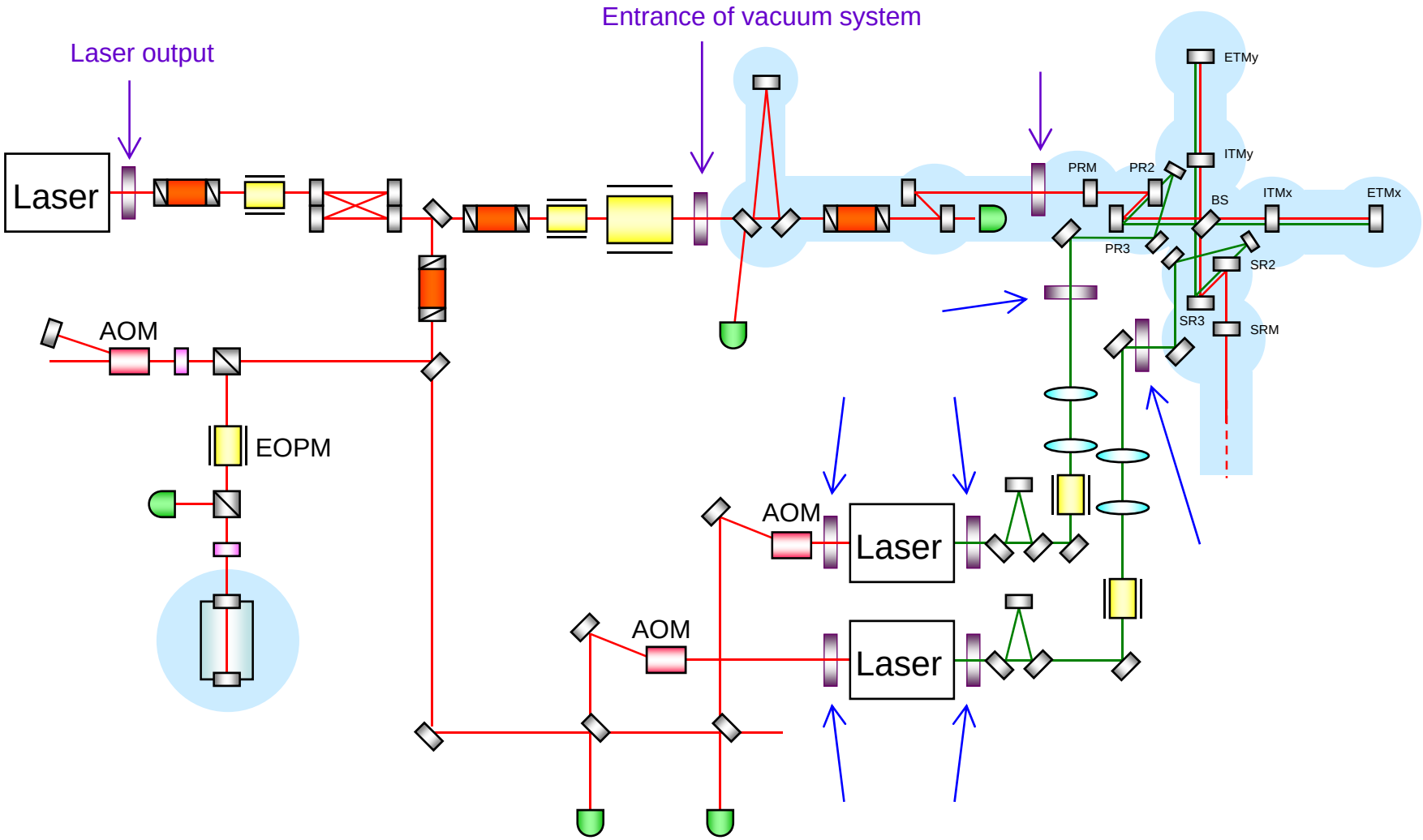
  Variable attenuator

We will develop beam shutters with Analog electronics group.

Interface	<-> AEL and DGS

(i) Beam Shutter [2/2]

iLCGT ◎
bLCGT ○

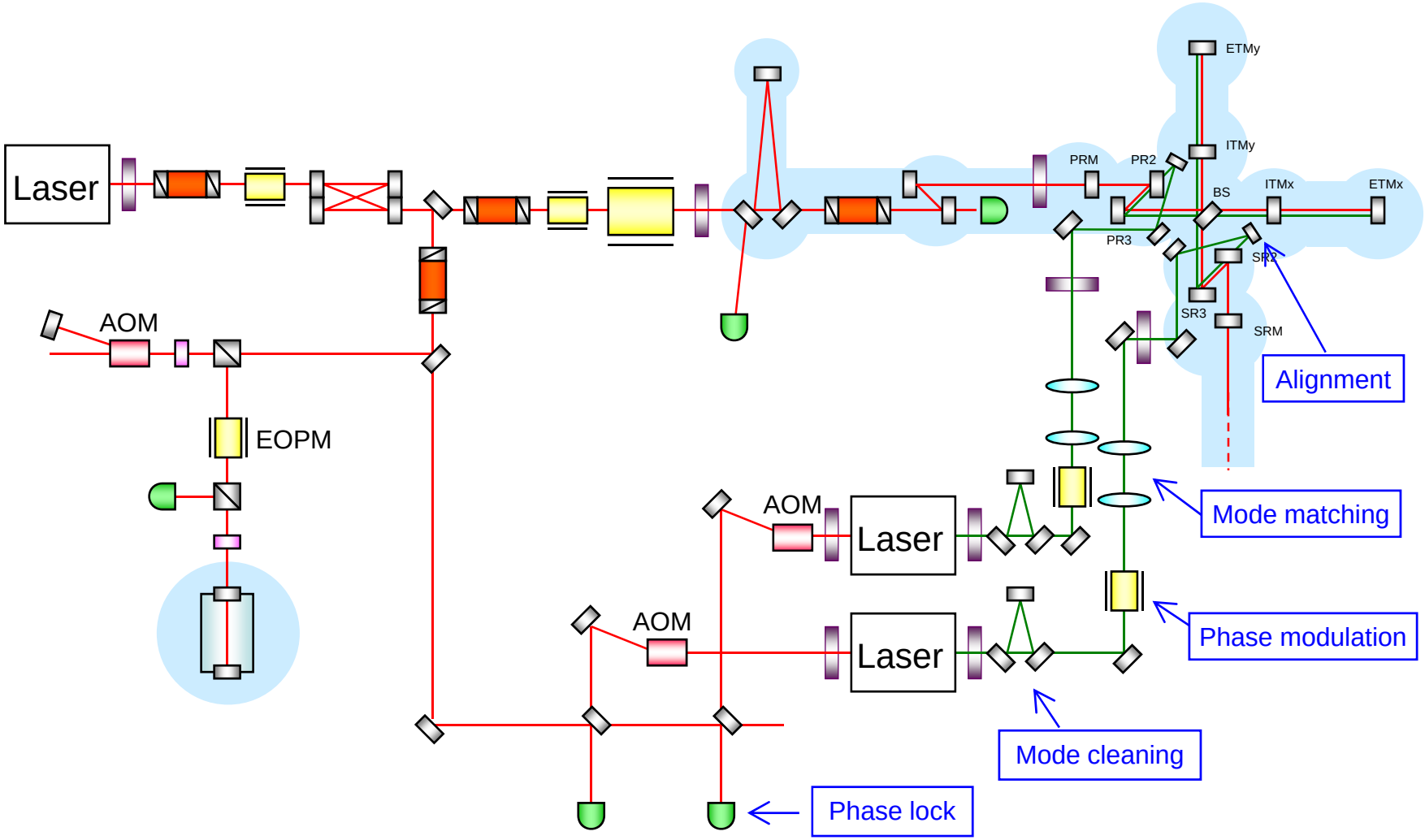


(j) Green Laser [1/2]

- The green laser systems for pre-lock of arm length are installed.
- The green lasers are stabilized as the reference of the main laser frequency with offset lock scheme.
- The green lasers are inputted from the center room or from the end room. It is not fixed.

Interface	<-> LAS, MIR, AEL, DGS, DET and MIF

(j) Green Laser [2/2]

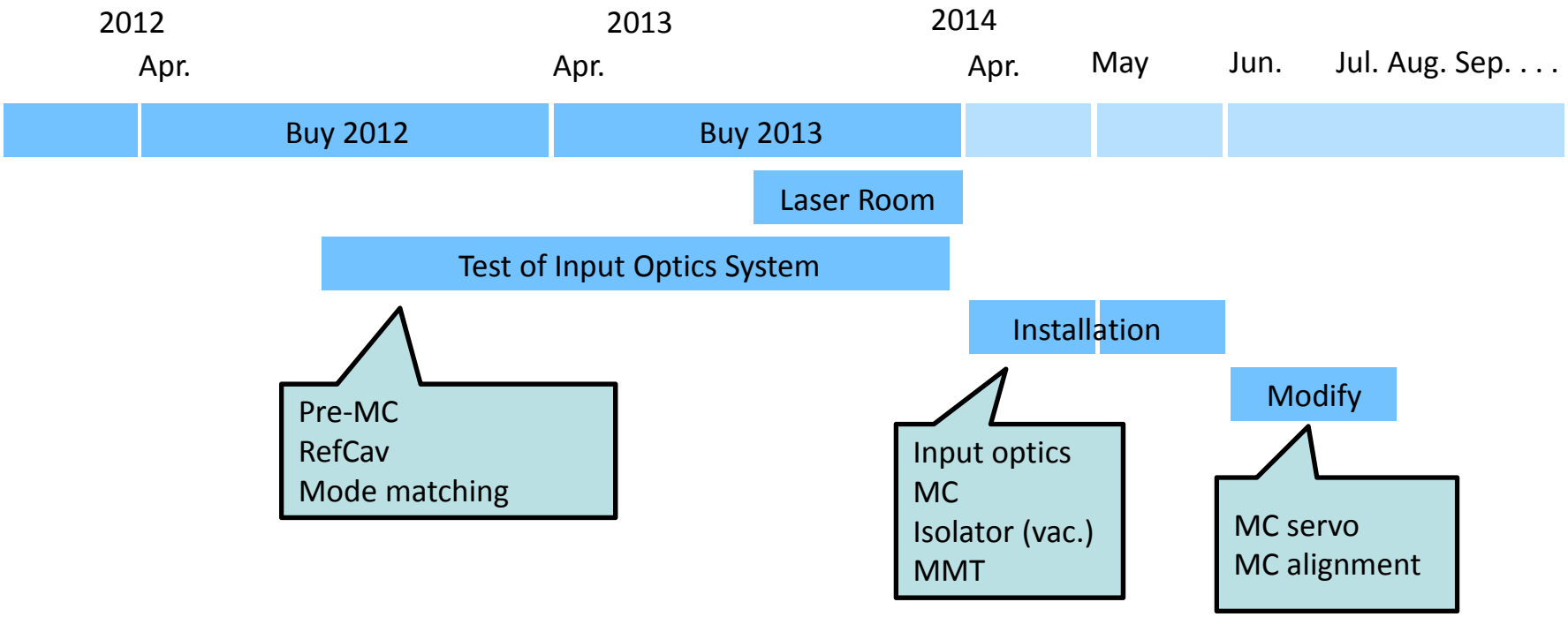


Schedule

bLCGT

It will be same time as change from iLCGT to bLCGT.

iLCGT



Summary

We have a lot of items !!!
Almost items can be performed and developed.
We should fix final designs.
We will prepare those.

Thanks

Appendix

Subgroup symbols

DAS	Data Analysis
TUN	Tunnel
FCL	Facility
VAC	Vacuum
VIS	Vibration Isolation
CRY	Cryogenics
MIR	Mirror
DET	Detector Configuration
MIF	Main Interferometer
DGS	Digital System
AEL	Analog Electronics
IOO	Input/Output Optics
LAS	Laser
GIF	Geophysics Interferometer
AOS	Auxiliary Optics System