GWADW2019

Topics on Commissioning of KAGRA

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and the KAGRA Collaboration

KAGRA

Overview

-- The current status of IFO commissioning of KAGRA

 * X arm experiment

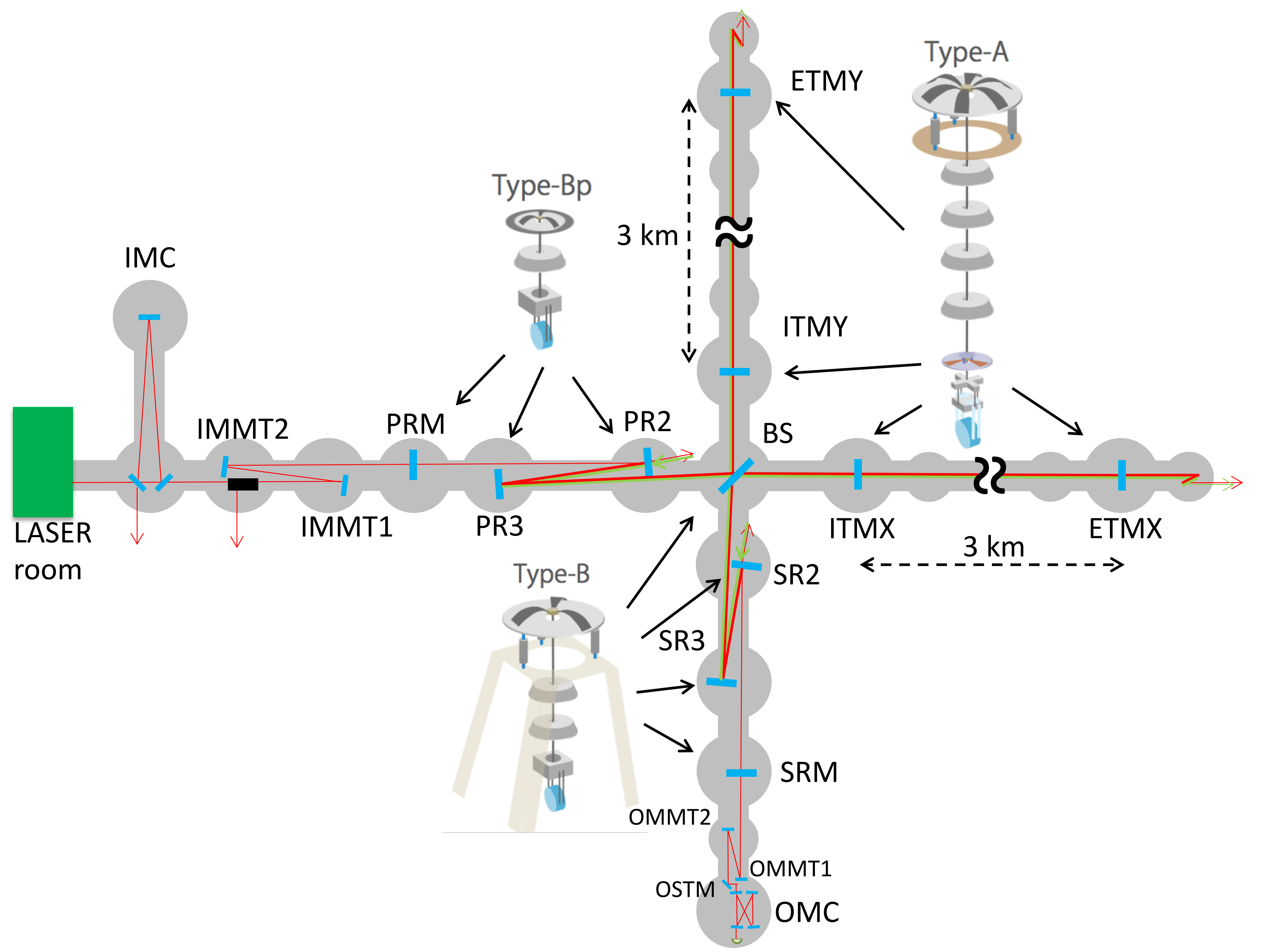
 * Feedback to test mass (commissioning with both arms)

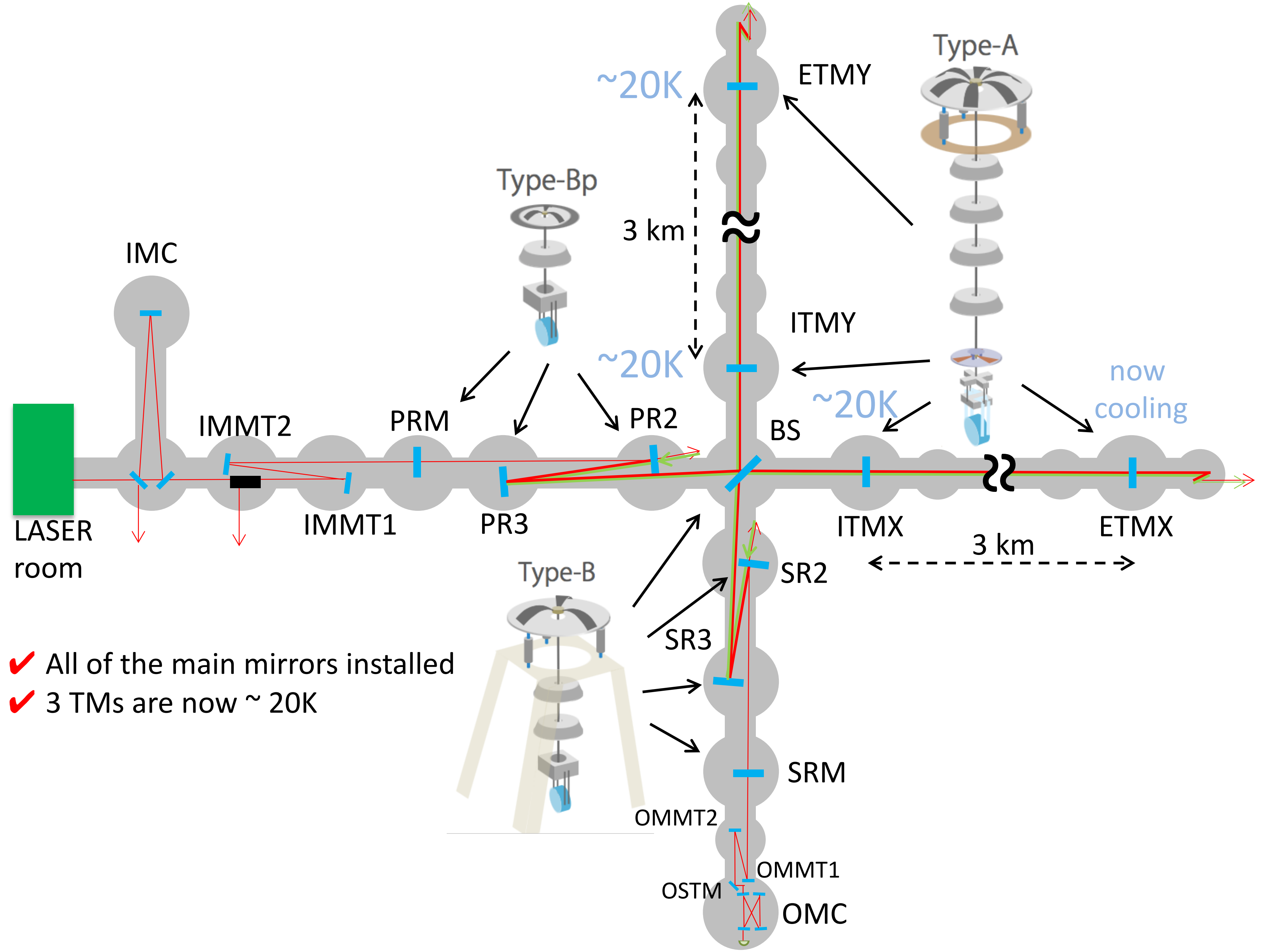
-- Commissioning topics from KAGRA

 * ALS (green lock)

 * Mach-Zehnder modulator

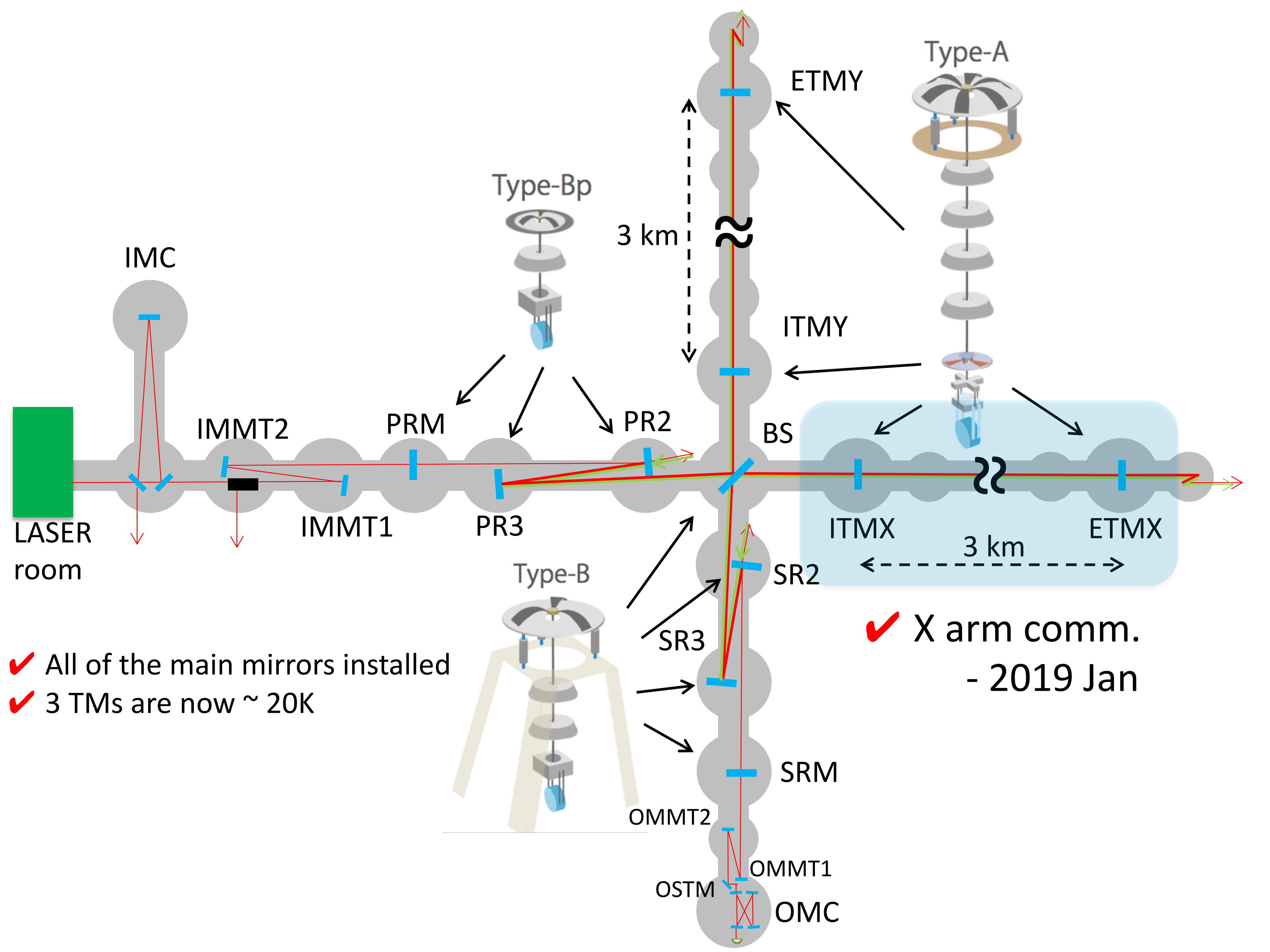
Current Status


Type-A
ETMY
3 km
Type-Bp
IMC
ITMY
IMMT2
PRM
PR2
BS
LASER room
IMMT1
PR3
ITMX
ETMX
3 km
Type-B
SR2
SR3
SRM
OMMT2
OMMT1
OSTM
OMC



✔ All of the main mirrors installed

✔ 3 TMs are now ~ 20K



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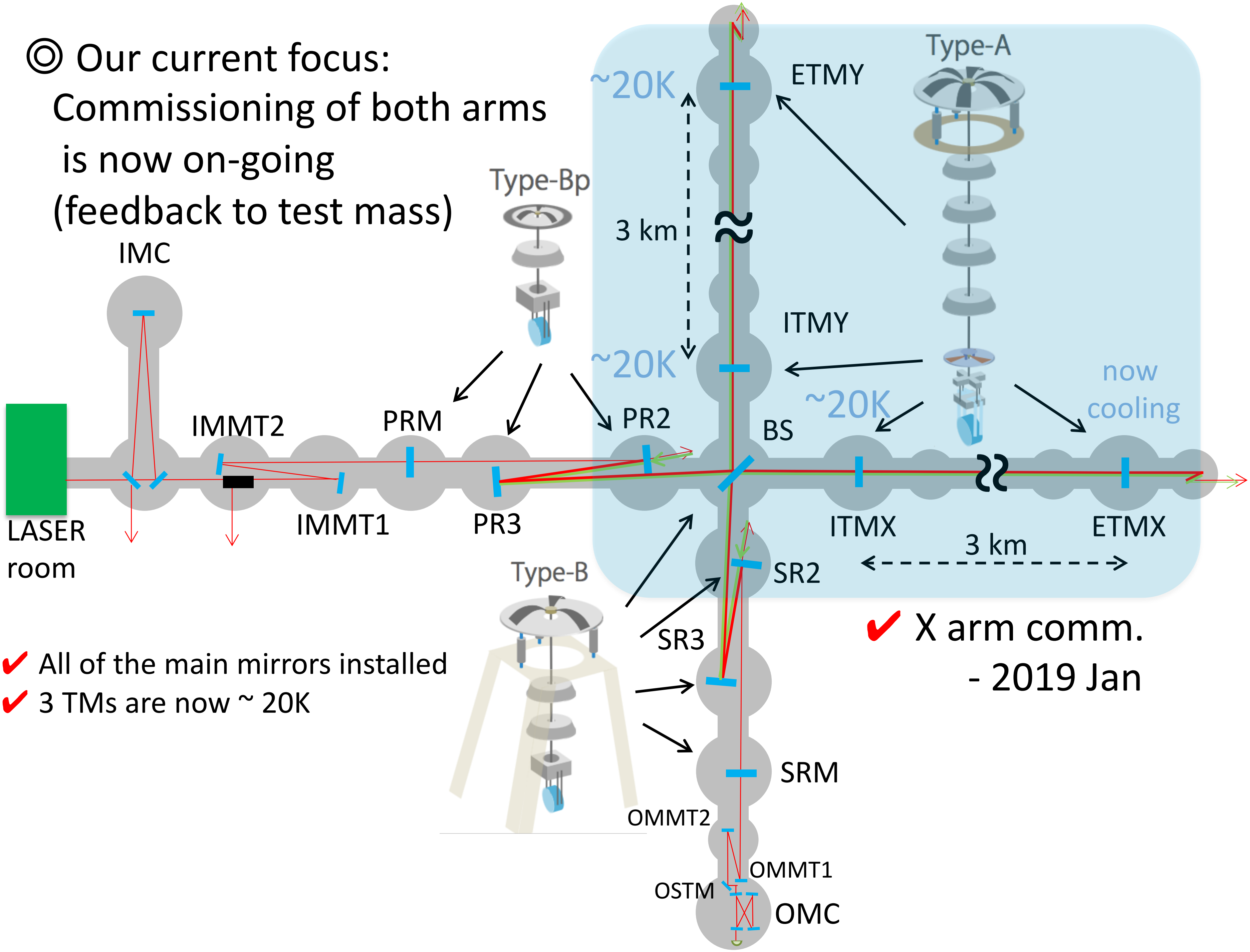
Type-B
SR2
SR3
✔ X arm comm.
- 2019 Jan
✔ All of the main mirrors installed
✔ 3 TMs are now ~ 20K
SRM
OMMT2
OMMT1
OSTM
OMC

◎ Our current focus:
Commissioning of both arms is now on-going (feedback to test mass)



✔ All of the main mirrors installed
✔ 3 TMs are now ~ 20K

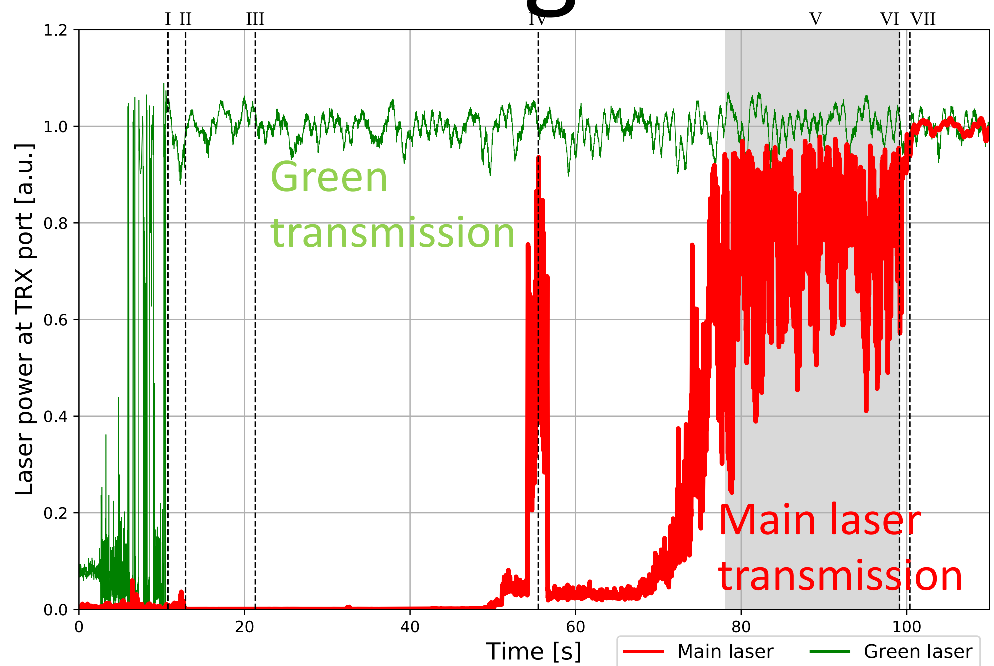
✔ X arm comm.
- 2019 Jan

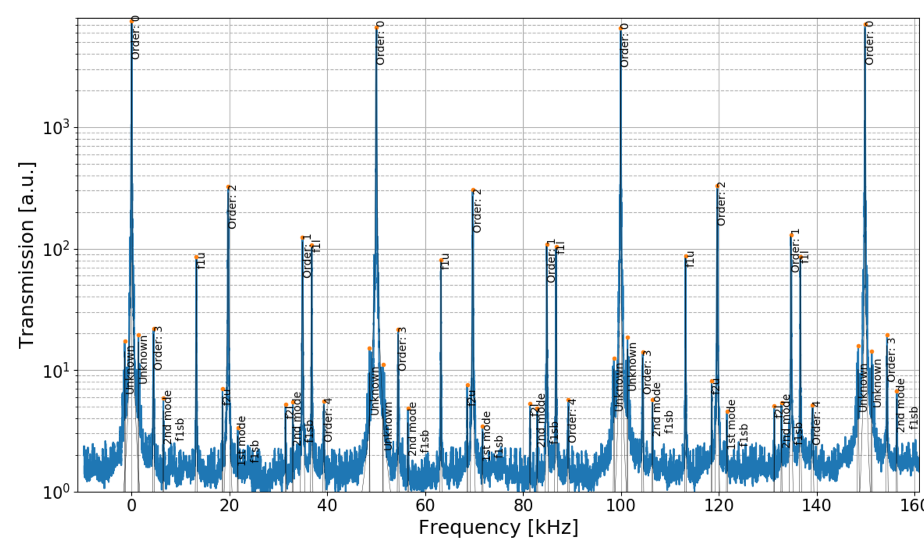
X arm commissioning

-- Succeeded in locking the X arm
  * hand-over from ALS to the main laser signal
  * direct lock of the main laser freq to X arm
  * longest lock: > 1day

-- Characterized the cavity, and test mass suspension
  * cavity scan
  * ringdown
  * loss measurement
  * suspension TF measurement

=> No major issues found



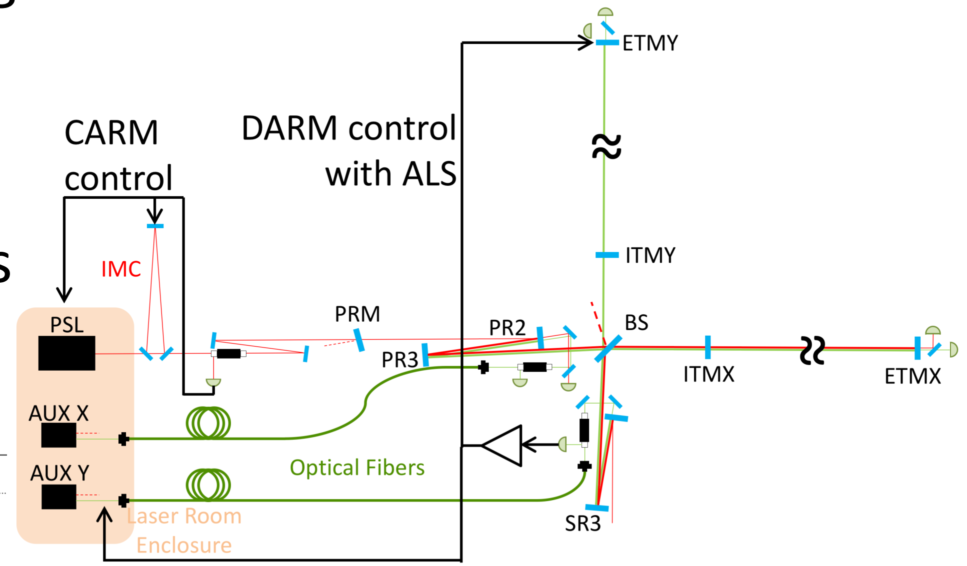


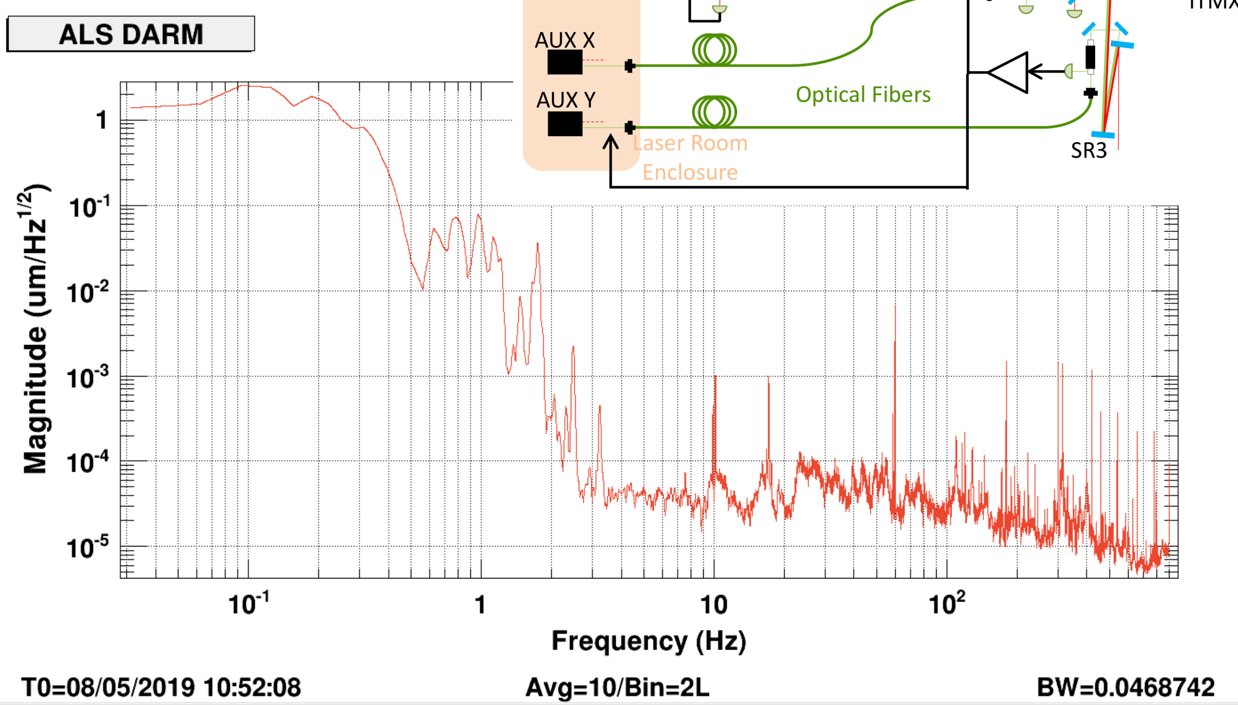
Feedback to test mass

<u>Configuration:</u> use X arm (CARM) to stabilize the main laser frequency, and then feedback the green lock signal of Y arm to ETMY

- Use a cryogenic test mass as actuators of LSC for the first time
- damping of mechanical resonances
- design of the blending filter for each stage
- trial of the lock

→ Ongoing





Topics

ALS (green lock)

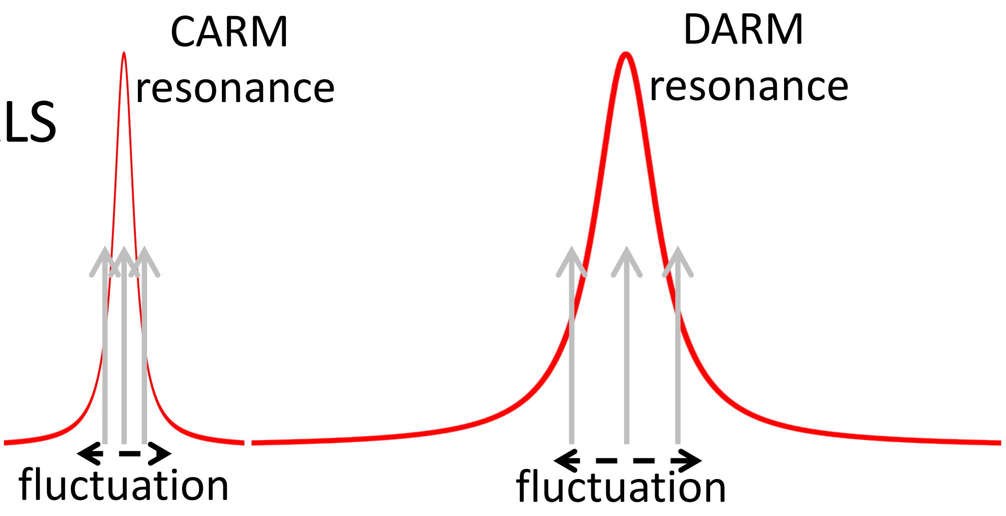
-- LIGO/KAGRA type lock acquisition needs ALS

1. keep the main laser off-resonant by the ALS
2. lock the central interferometer
3. put the main laser frequency at resonances of both arms

-- Requirement of control by ALS

CARM < ~ 1-10 Hz

DARM < ~200 Hz

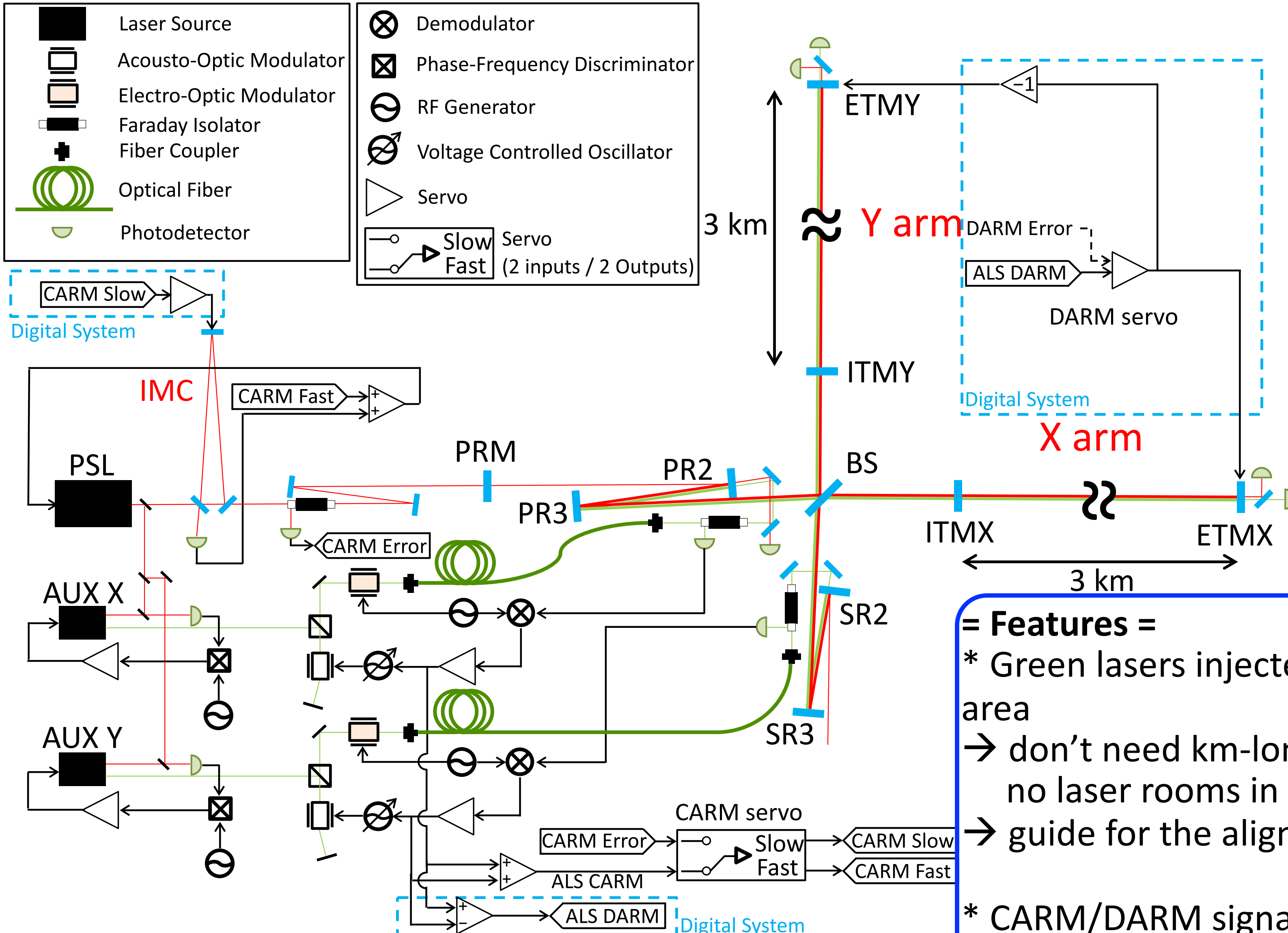


-- Requirement for ALS CARM will be more stringent in 3G

=> $CARM_{3G}$ < ~ 0.1-1 Hz

(CARM linewidth ∝ [roundtrip loss in arm] / L, assuming efficient power recycling)

KAGRA ALS



= Features =

* Green lasers injected from center area

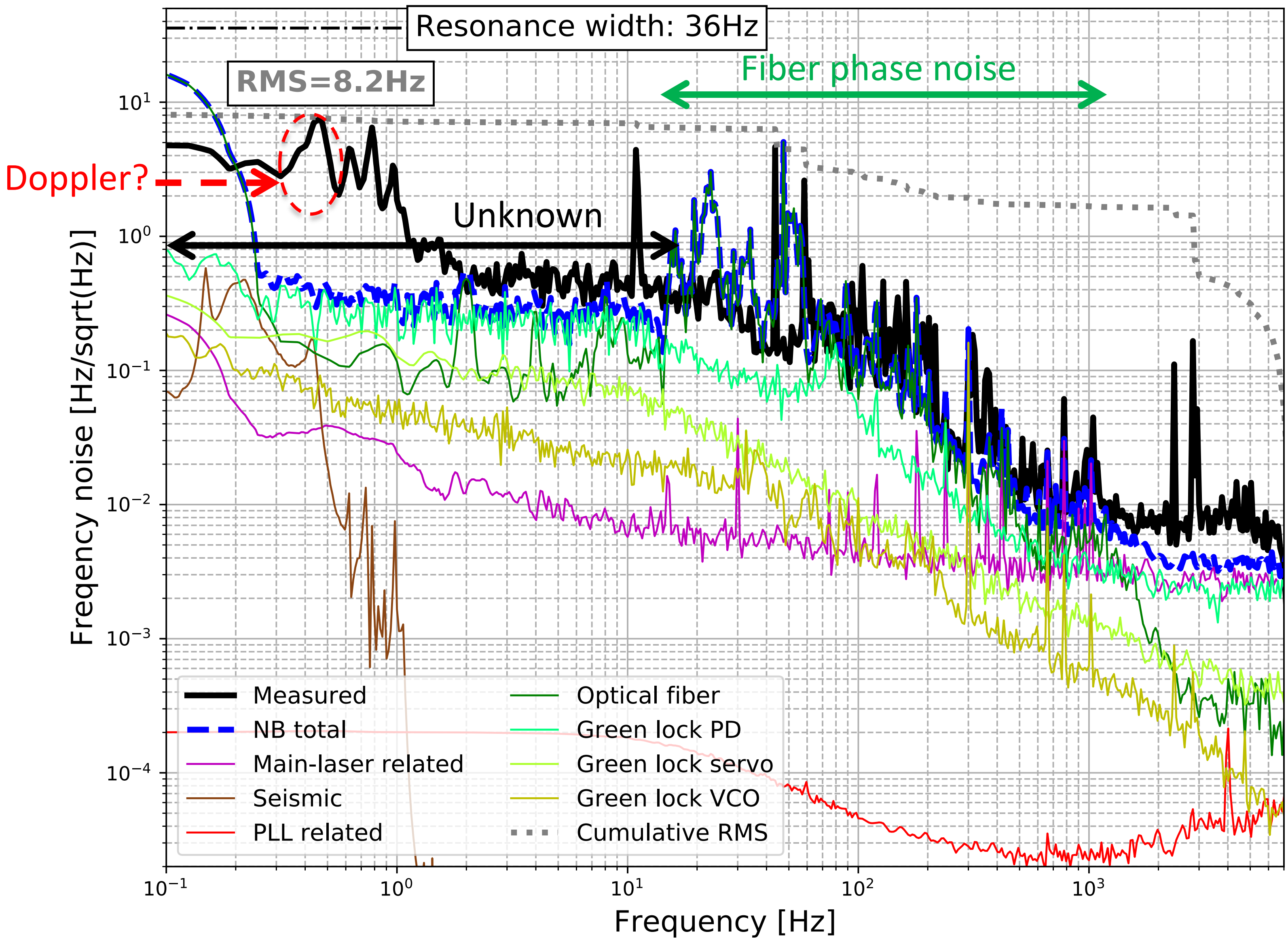
→ don't need km-long optical fibers, no laser rooms in end stations

→ guide for the alignment

* CARM/DARM signals are obtained by the sum/diff of voltage signals

→ optical beat notes in aLIGO

KAGRA ALS: Noise characterization



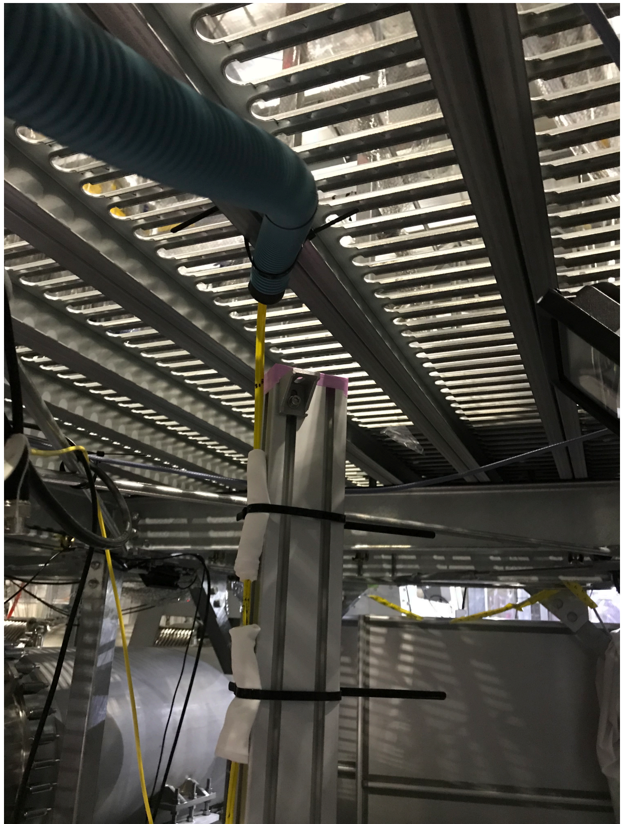
Found issues: Fiber noise

-- To meet the requirement, we had to carefully reduce the fiber noise.
→ fix the fibers to stable pillars
→ remove the vibration source for the fibers;
we stopped clean filter units

-- Still the fiber noise is limiting the ALS noise.

TO DO:

=> Implementation of fiber noise cancellation technique

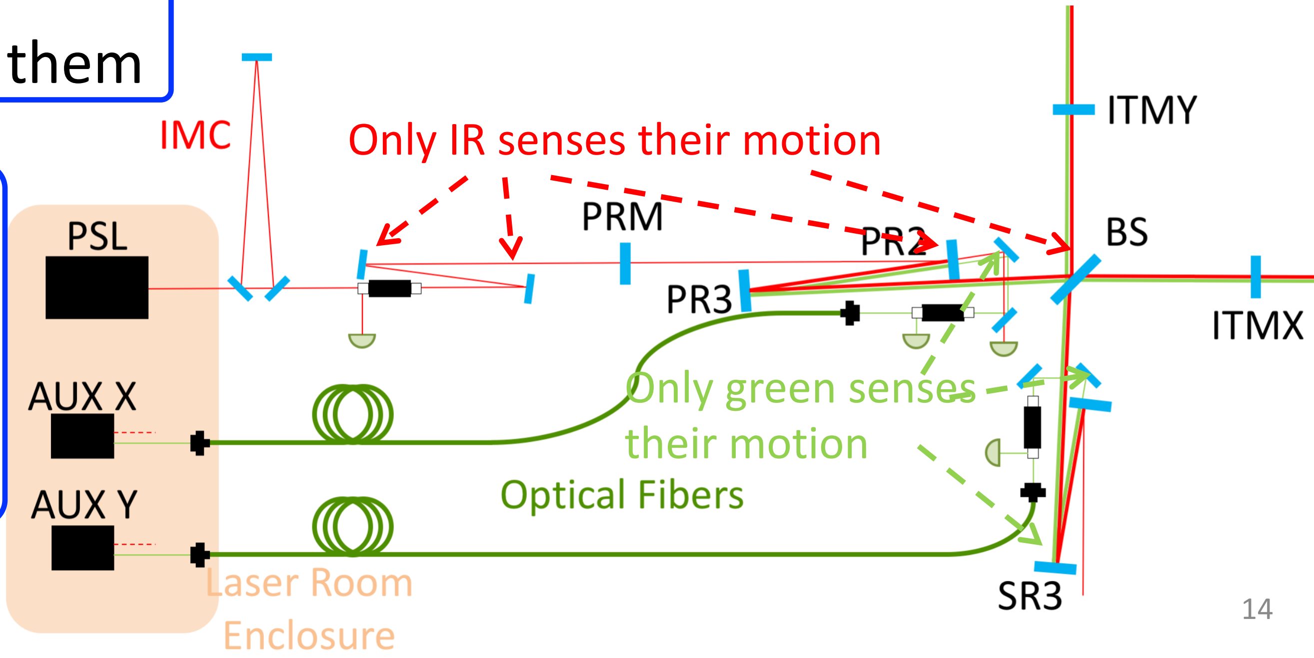


Found issues: Doppler noise

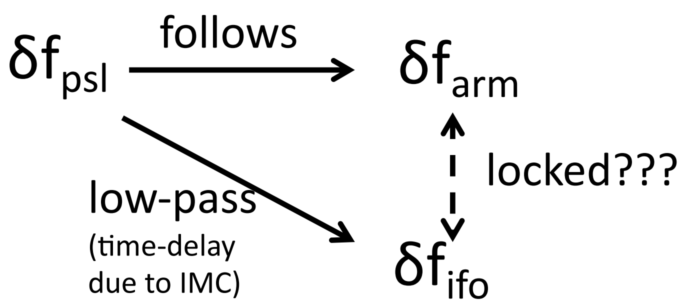
-- The main laser and the green lasers take **<u>different paths</u>** before their injection to arms.
-- The motion of each suspended mirror that reflects only IR or green causes the phase noise → Doppler noise
-- Coherence found between PR2 motion and the ALS noise, in fact.

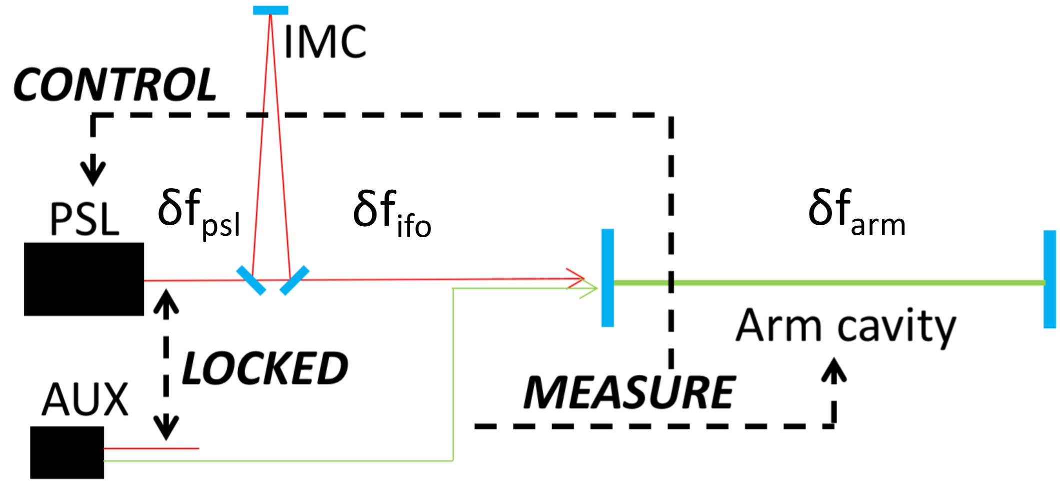
TO DO:
=> Careful damping of them

For 3G ALS design…
=> Pick off the main beam more down-stream
or inject green from more up-stream



Found issues: IMC cavity pole





$$\delta f_{\rm psl} = \delta f_{\rm arm}$$

$$\delta f_{\rm ifo} = \frac{\delta f_{\rm psl}}{1 + if/f_{\rm imc}}$$

=> $\delta f_{\rm arm} - \delta f_{\rm ifo} = \frac{if/f_{\rm imc}}{1+if/f_{\rm imc}} \delta f_{\rm arm}$ Limit to the maximum suppression of arm length

* Let us consider the arm length fluctuation at 0.2 Hz.

* Let us assume $\delta f_{\rm arm}$ ➔ 1 um/sqrt(Hz) at 0.2 Hz

Case1: $f_{\rm imc}$ = 5 kHz (2G case) => $\delta f_{\rm arm} - \delta f_{\rm ifo} > 0.1\,{\rm nm}/\sqrt{\rm Hz}$ OK

Case2: $f_{\rm imc}$ = 500 Hz => $\delta f_{\rm arm} - \delta f_{\rm ifo} > 1\,{\rm nm}/\sqrt{\rm Hz}$ Problematic

=>
- * Pick off the main beam after IMC for the lock of AUX laser

  or

- * Avoid using high finesse/very long IMC

in 3G detectors

Toward 3G: silicon is black

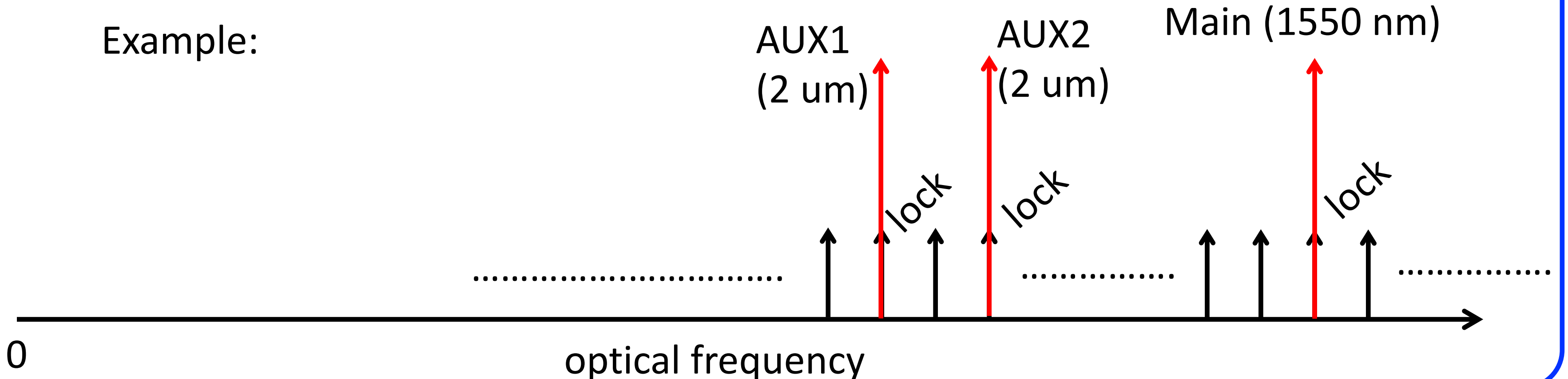
https://en.wikipedia.org/wiki/Silicon

2G detectors: 1064 nm, fused silica or sapphire
=> test mass is transparent for green (532nm)

In 3G detectors, we might use 1550nm/2um and silicon
=> silicon is black for 775nm or 1um
=> we can't use "green lock"

We have to develop green-lock like technique
with, for example, Optical Frequency Comb, instead of SHG

Example:



Mach-Zehnder modulator

-- Design of KAGRA or ET includes detuning of SRC

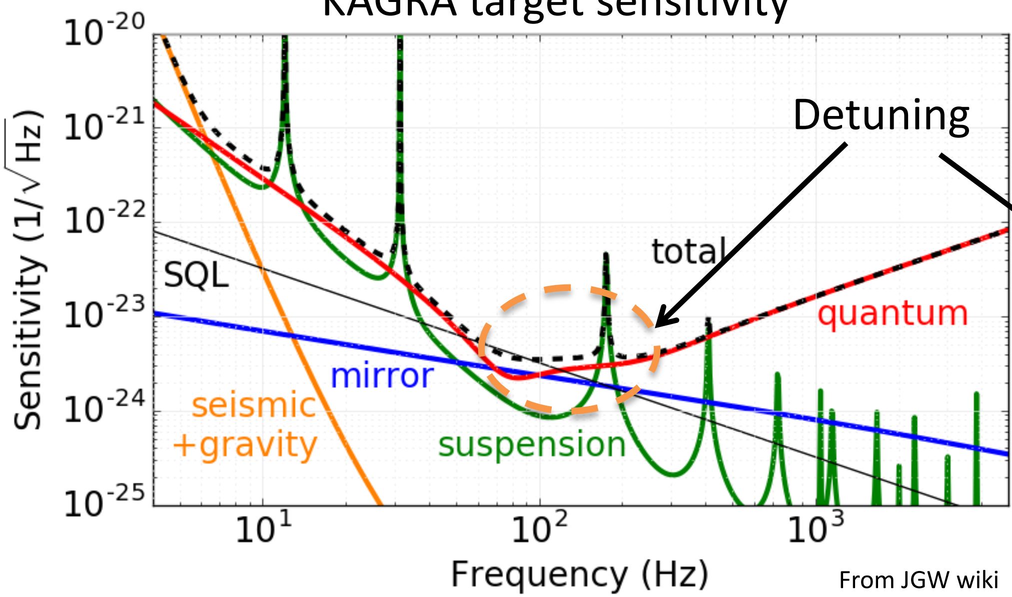
-- Detuning can re-shape the quantum noise spectra, but increase some noise couplings.

<u>Major coupling</u>: phase noise of the oscillator for the modulation

* RF AM can reduce such couplings

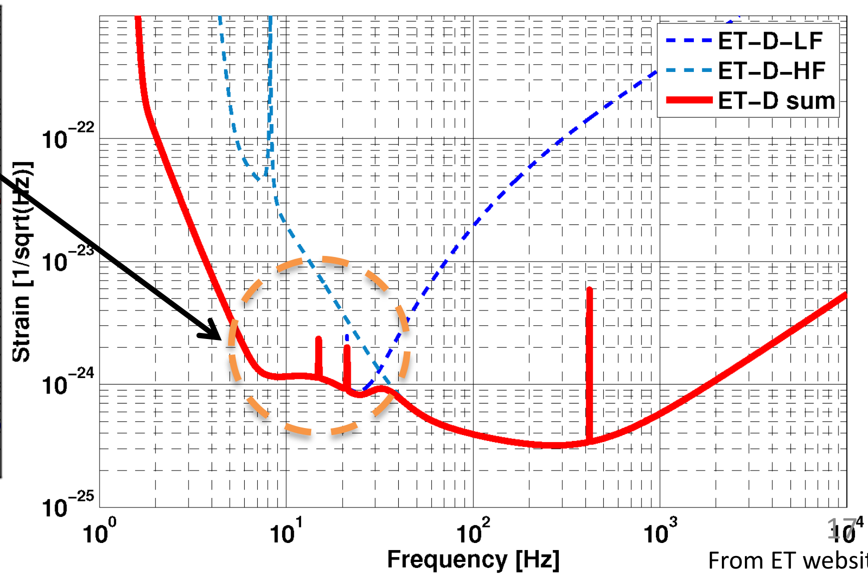
→ RF AM generation using *Mach-Zehnder modulator* is proposed and tested.

KAGRA target sensitivity



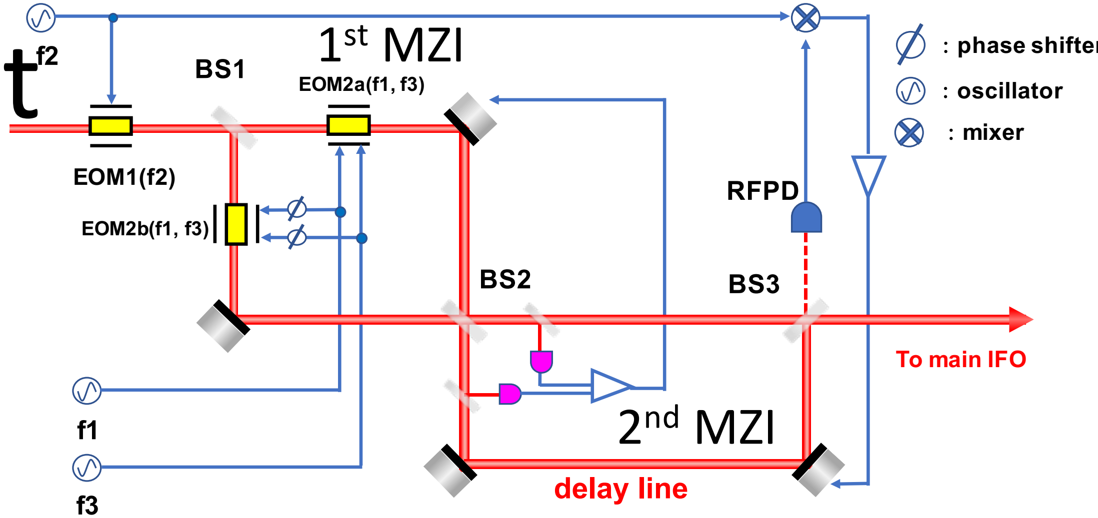
From JGW wiki

ET-D target sensitivity



From ET website

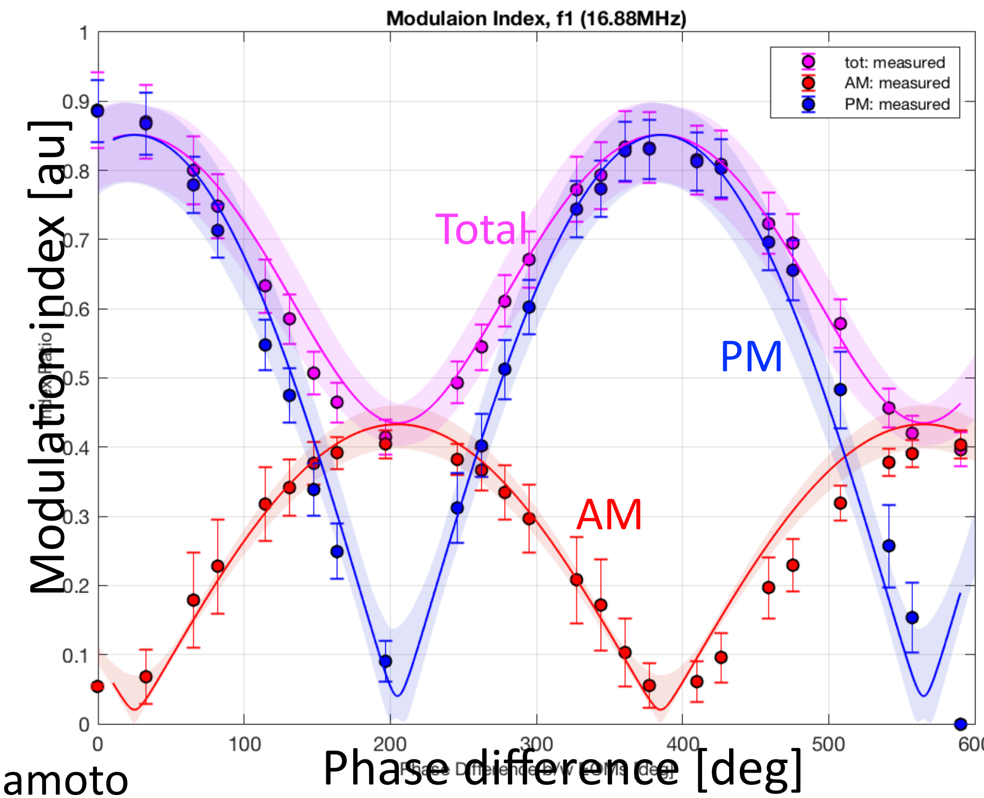
On-site test



-- MZM can create arbitrary combination of AM and PM, by changing the phase difference btw signals applied to two EOMs

-- Basic function has been demonstrated:

* modulation index vs phase diff.
* long-term stability

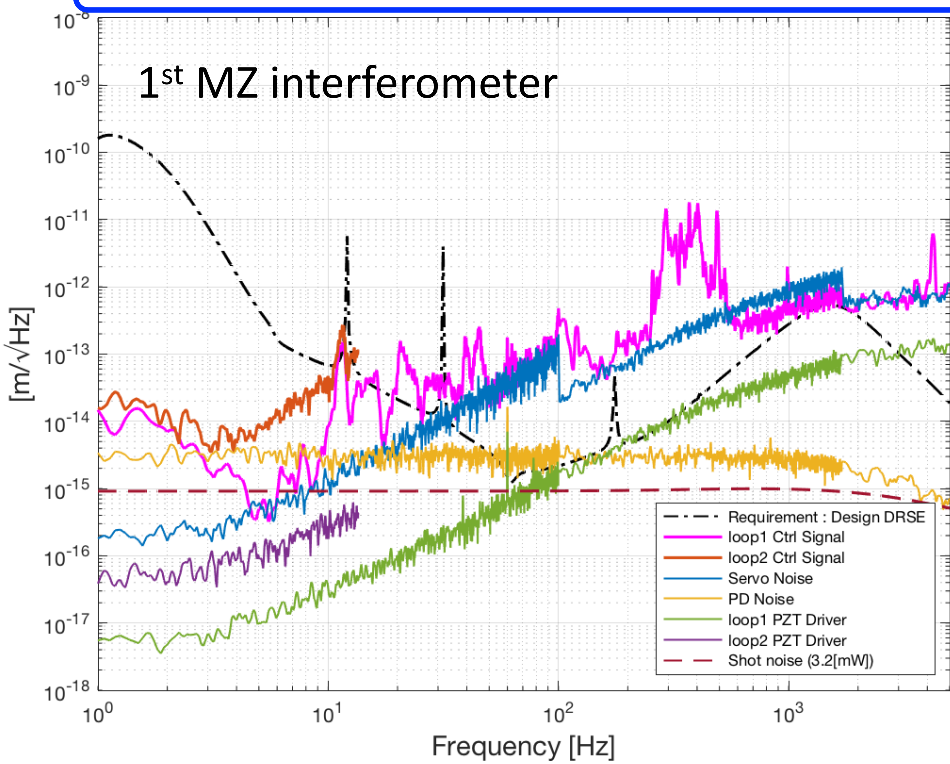


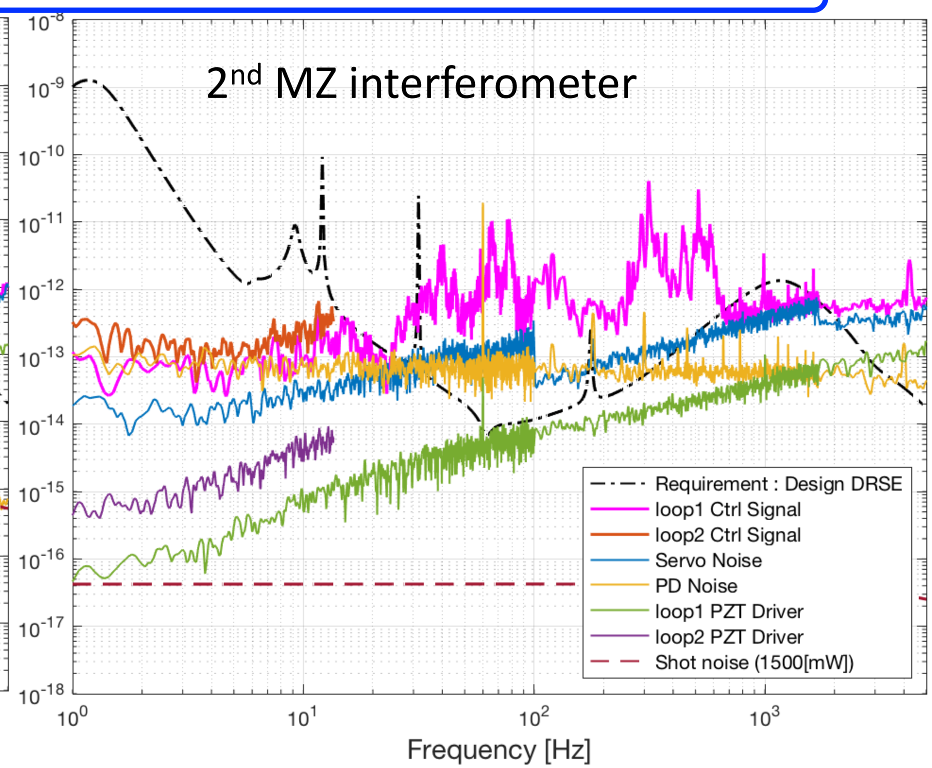
From a paper in preparation by Kohei Yamamoto

On-site test: Noise issue

-- Our system could not yet meet the requirement for the residual displacement noise of each MZI

TO DO: * larger bandwidth for improved suppression
* make MZM system less sensitive to external vibrations





From a paper in preparation by Kohei Yamamoto

Summary

-- All the mirrors installed, X arm commissioned.
-- Our current focus: To lock both arms → feedback to test mass

-- presented two topics:

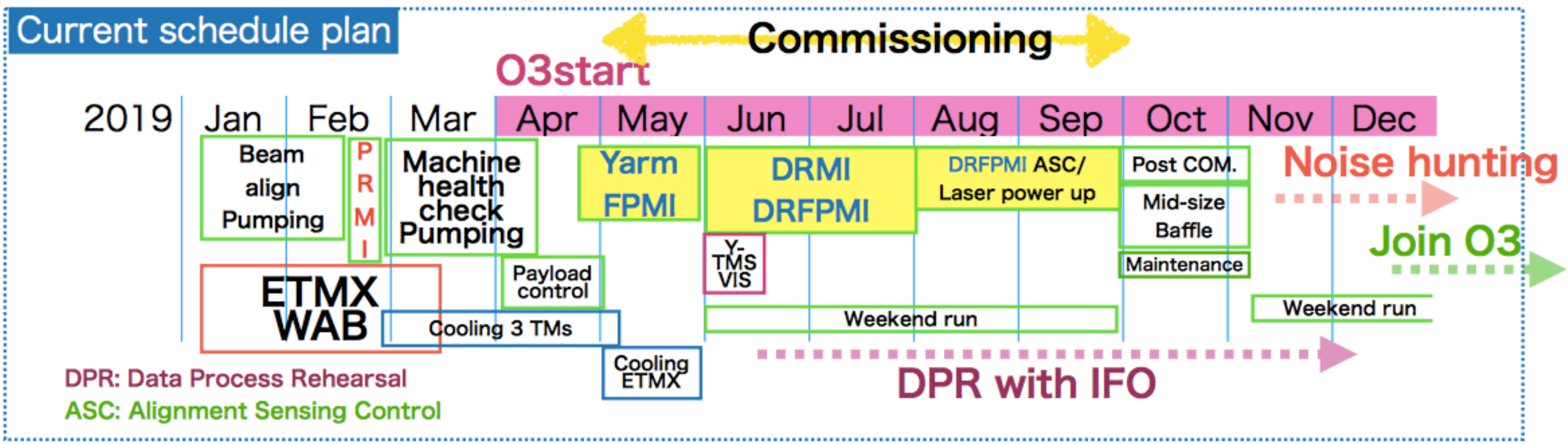
KAGRA ALS

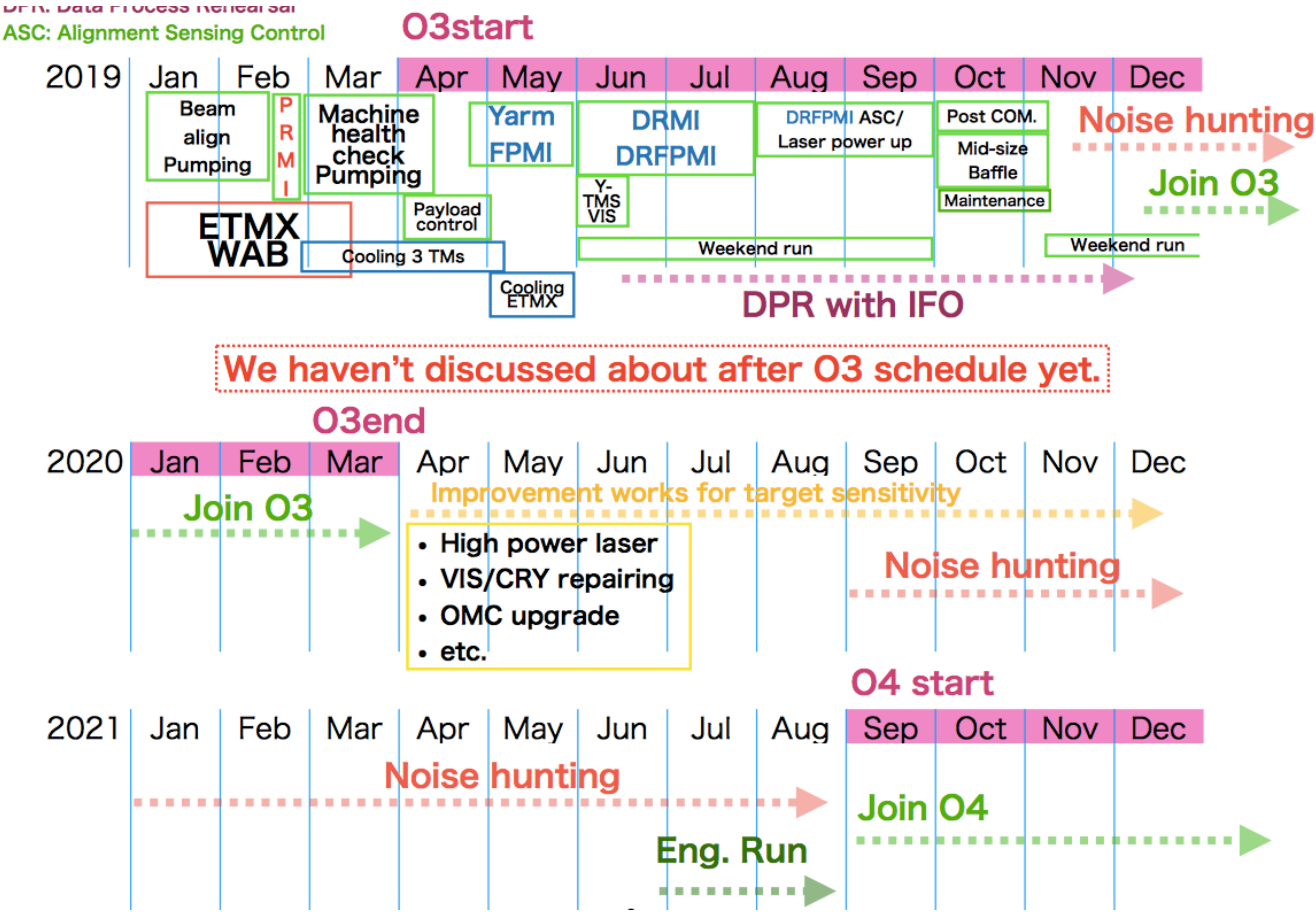
* basically working well
* scalable to 3G (don't need ~10km-long fibers)
* issues to be addressed toward 3G
  - fiber noise, doppler noise, effect of IMC cavity pole

Mach-Zehnder modulator

* detuning may require an advanced technique on modulation
* on-site test was done, and the basic functions were confirmed
* displacement noise needs to be reduced

END


Current schedule plan
Commissioning
O3start
2019
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Beam align Pumping
PRMI
Machine health check Pumping
Yarm FPMI
DRMI DRFPMI
DRFPMI ASC/ Laser power up
Post COM.
Mid-size Baffle
Maintenance
Noise hunting
Join O3
ETMX WAB
Payload control
Cooling 3 TMs
Y-TMS VIS
Weekend run
Weekend run
Cooling ETMX
DPR with IFO
DPR: Data Process Rehearsal
ASC: Alignment Sensing Control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DRMI DRFPMI
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Maintenance
Noise hunting
Join O3
ETMX WAB
Payload control
Y-TMS VIS
Cooling 3 TMs
Weekend run
Weekend run
Cooling ETMX
DPR with IFO
We haven't discussed about after O3 schedule yet.
O3end
2020
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Join O3
Improvement works for target sensitivity
• High power laser
• VIS/CRY repairing
• OMC upgrade
• etc.
Noise hunting
O4 start
2021
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Noise hunting
Join O4
Eng. Run

ROOM TEMP

Measured parameters

= primary parameters =

Good: within requirement

* Roundtrip loss of X arm cavity 86(3) ppm (klog 7307)
* Cavity finesse (IR) 1411(02)(30) (klog 7307)
* Cavity finesse (Green) 41.0(3) (klog 6697)

Good: consistent with measured T

* Mode matching to the cavity (IR) 91(1) % (klog 7307)
* Mode matching to the cavity (Green) ~ 70 % (klog 7335)
* Gouy phase separation of two QPDs (IR & Green) (klog 7575, 7502)
* loss map on test mass surface → ✖
* CMRR for the cavity displacement → Miyo-kun is analyzing the data
* Transverse mode spacing 34.79(5) kHz (klog 7332) <--> 34.70(2) kHz from measured RoCs

does not match with the estimation from measured RoCs, but still within requirement

= others =

* Cavity length 2999.990(2) m (klog 7332,7301)
* Various transfer functions of the test mass suspensions

→ measured by Fujii-kun and under analysis by him

* Beam profile of the IR on TMSX table (klog 7502)

Current status

-- Hardware readiness:

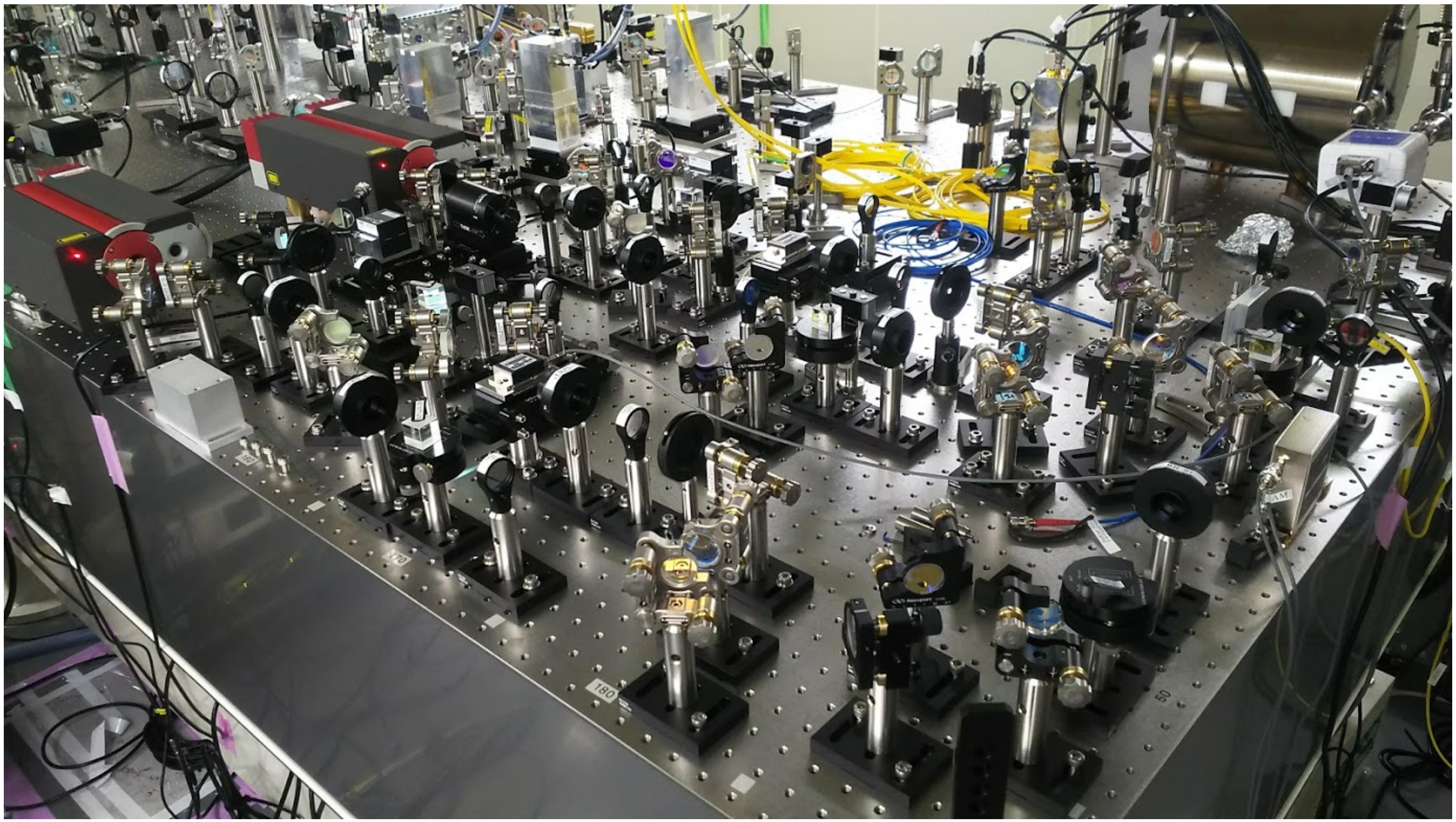
* All of the mirrors installed
* 3 out of 4 test masses are now at ~20K.
  The rest will reach ~20K in one month.

-- Interferometer commissioning Status:

* Single arm (X arm) commissioning was done (~Jan 2019)
  → ALS (green lock) was tested.
* Our current focus: lock both arms at the same time
  → feedback to test mass actuators (hierarchical control)

Green-lock related optics

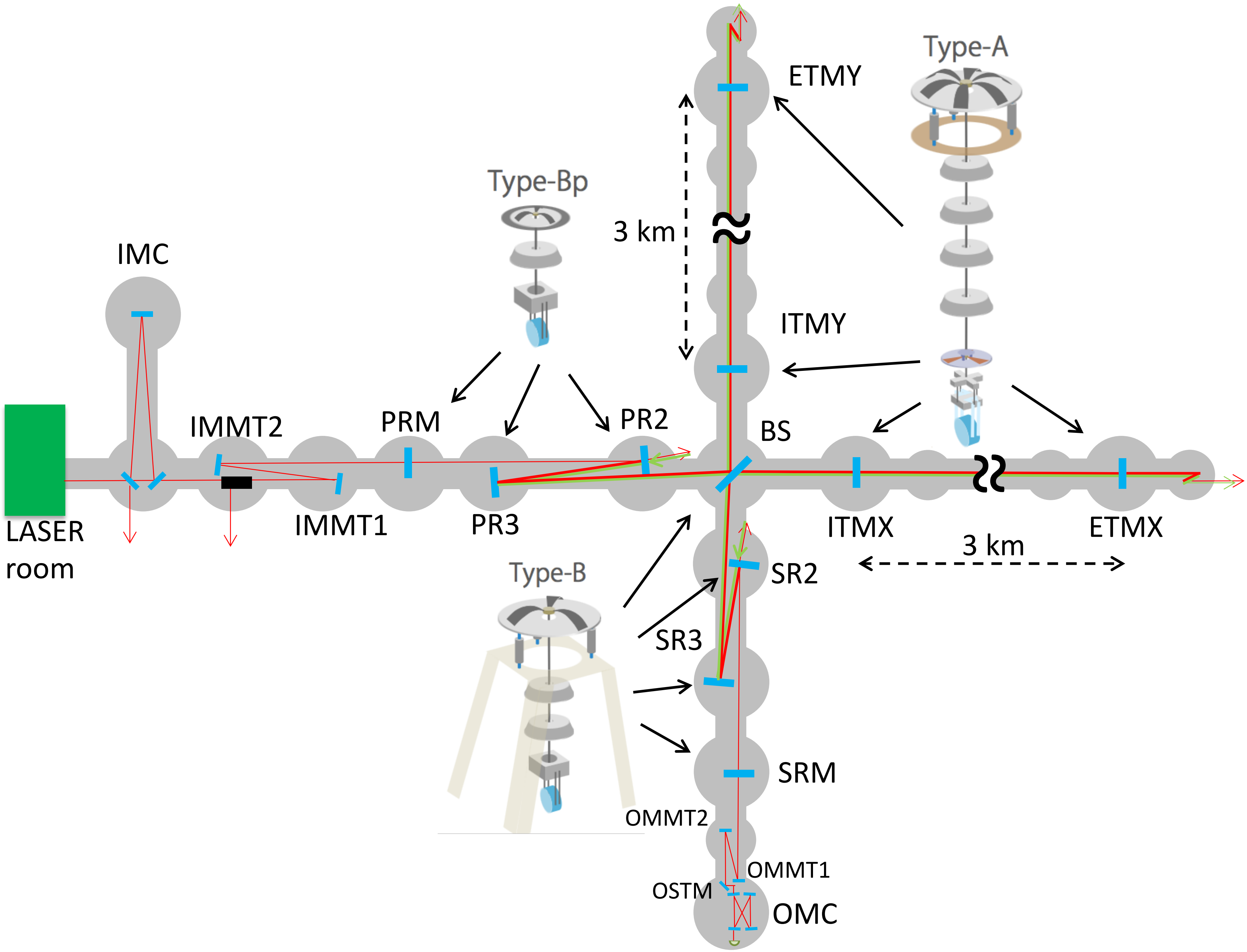
PSL table



We will align green beam to X arm as well as IR beam in September.

-- On PSL table, optics for both X and Y are ready. For POP table, optics for X are ready early in September.

-- ~ 50 m long green fibers have been laid.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