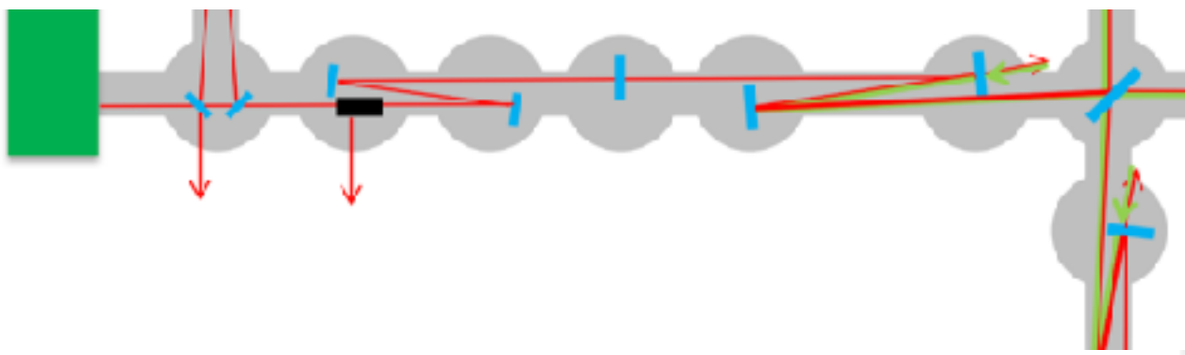
Detector Characterization KAGRA

Workshop on the development of innovative tools for new collaborations within gravitational wave detection experiments , April 15, 2022 online workshop

Takaaki Yokozawa (ICRR) on the behalf of the KAGRA collaboration

KAGRA DetChar



- KAGRA organization chart

KAGRA

KAGRA Observatory
- Safety Control Office
- Safety Committee

KAGRA Council

PI
Vice PI

Program Advisory Board (PAB)

International Board of Representative

Executive Office (EO)

System Engineering Office (SEO)

Installation Scheduler

- Analog Electronics
- Auxiliary Optics
- Cryogenics
- Digital Systems
- Facility
- Geophysics Interferometer
- Input/Output Optics
- Laser
- Main Interferometer
- Mirror
- Physical Environmental Monitors
- Vacuum
- Vibration Isolation

Operations Division (T. Sawada)

- Calibration WG (D. Chen, T. Sawada)
- Computing & Software WG (N. Kanda)
- **Detector Characterization WG (T. Yamamoto, H. Yuzurihara)**
- Low Latency WG (S. Morisaki, H. Tagoshi)
- Open Data WG (L. Lin, J. G. Park)
- Run Planning Committee (S. Miyoki)

KAGRA Scientific Congress (KSC)

KSC board

Data Analysis Committee (DAC)
- Burst
- CBC
- CW
- Stochastic
- Identity & Access Management

Future Strategy Committee (FSC)
- Advanced R&D
- Project R&D
- White Paper Writing Team

- Author-List Committee
- Collaborator-List Manager
- Committee of Publication Control
- Diversity Committee
- Education & Public Outreach
- International Cooperation WG
- Joint Detection Committee
- Joint Editorial Board
- Joint Meeting Committee
- KSC Newsletter Editorial Team
- LVK Climate Change WG
- Overleaf Maintenance
- Theory Group

- Now, managed by operations division
  - T.Yamamoto, H.Yuzurihara

JGW-G2214000-v1
LIGO-G2200417-v2

KAGRA DetChar

- Current ongoing tasks

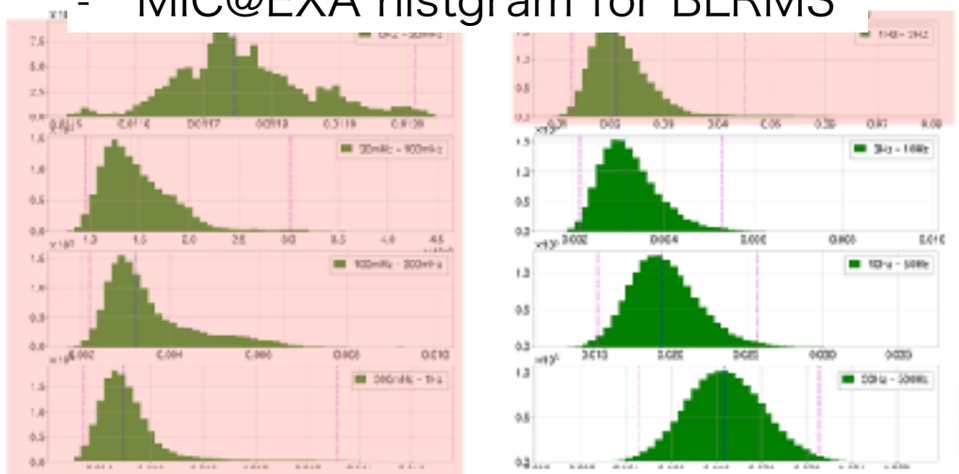
- Slide from OpsDiv call Mar, 2022

- **Unify conda environment**
  - Unification for the version of DET tools as igwn-py39 is ongoing.
  - Some tools doesn't work because of no info. about NDS2 and DATAFIND servers for 'K1' data.

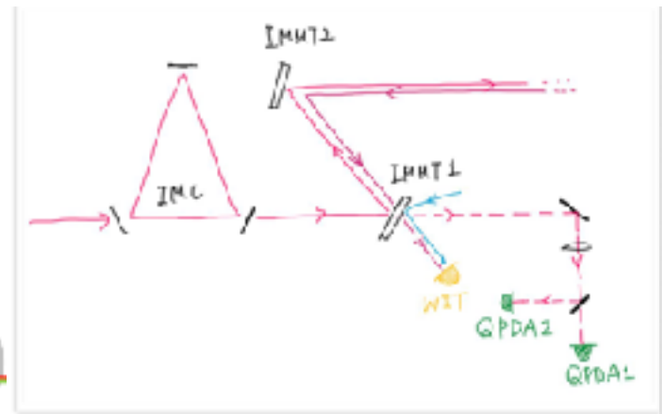
- **DQR update**
  - Operation tests of the tools (TaskManager, igwn-alert) are on-going on the dedicated computer at KAGRA site.

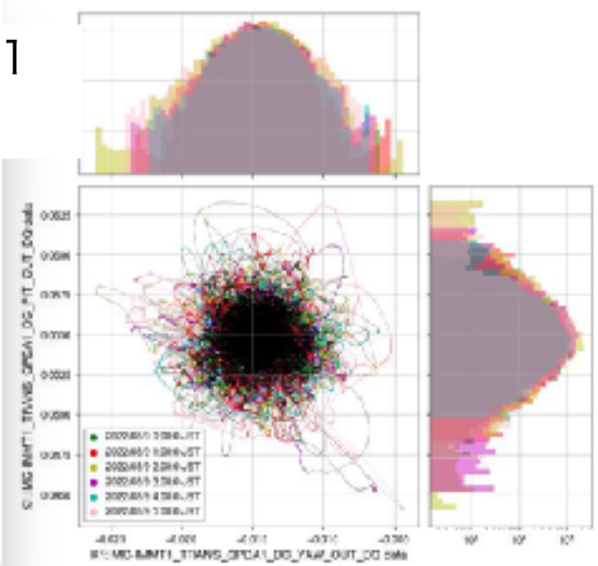
- **Noise investigation**
  - Unknown glitches on IMMT1 oplev was occuring during commissioning.
  - Young students stayed KAGRA site and helped the investigation of the cause. The cause is still unknown. They will continue to work on this as a remote task.

- MIC@EXA histgram for BLRMS



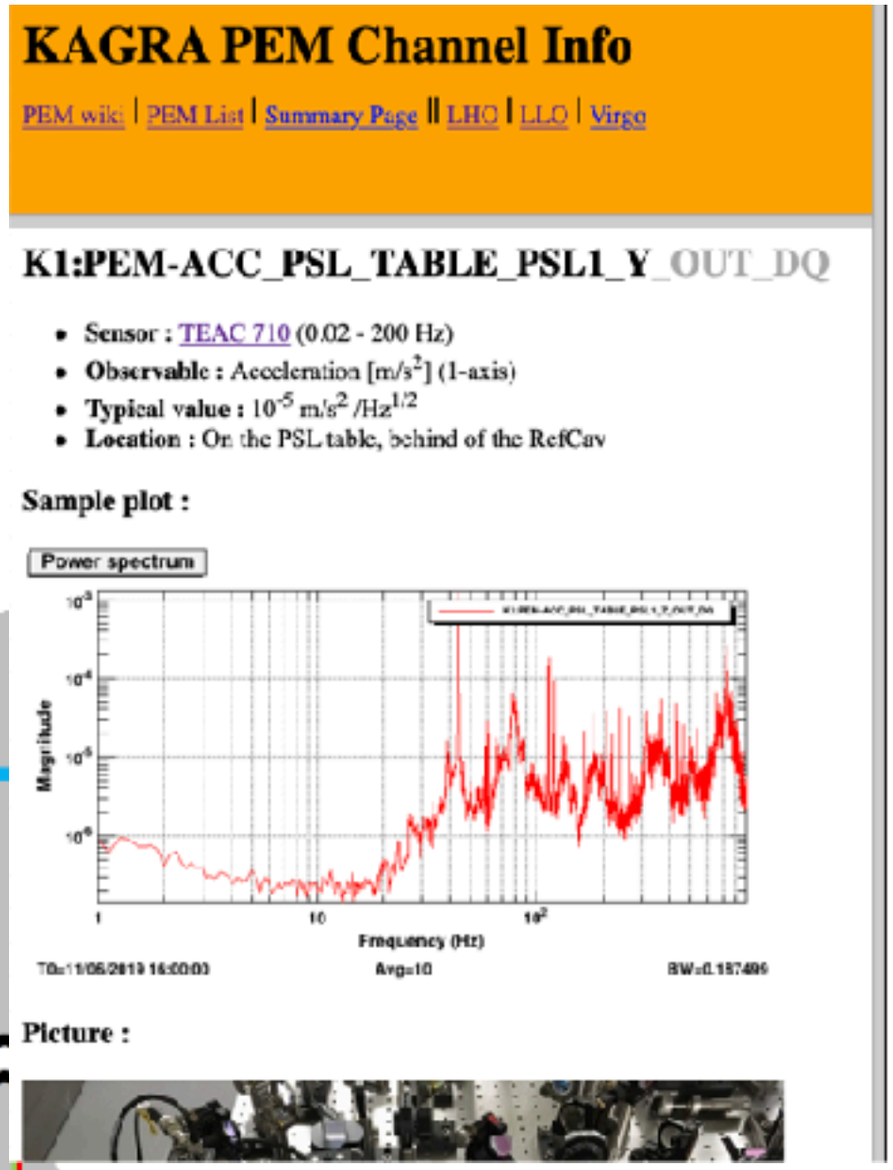
- Glitch investigation for IMMT1 witness channel

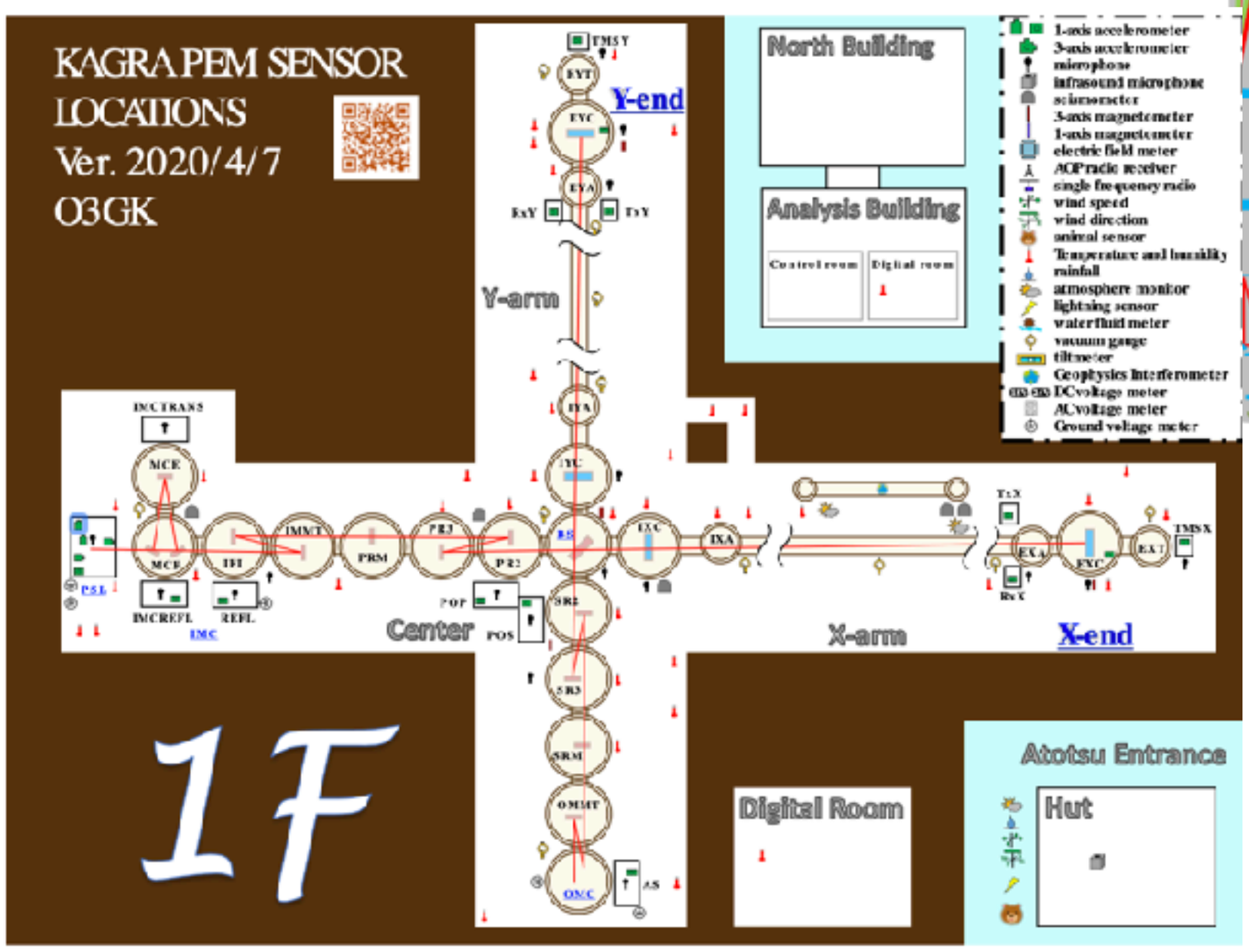




KAGRA PEM

- KAGRA O3GK PEM map(https://www.icrr.u-tokyo.ac.jp/~washimi/KAGRA/PEM/PEMmap/archives/O3GK/)

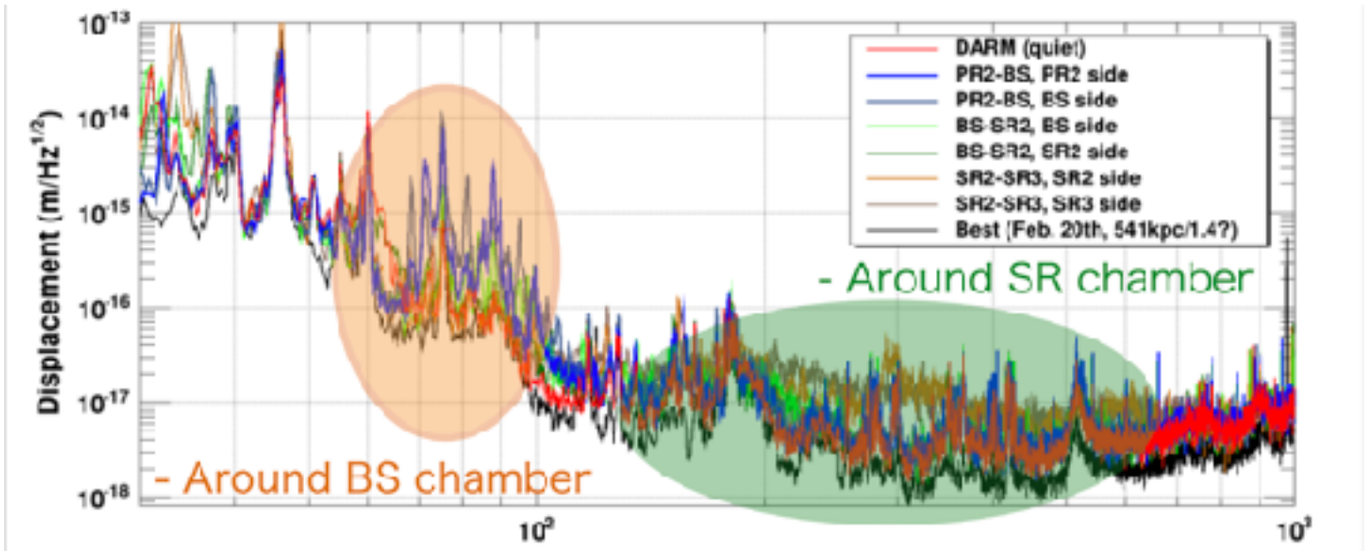


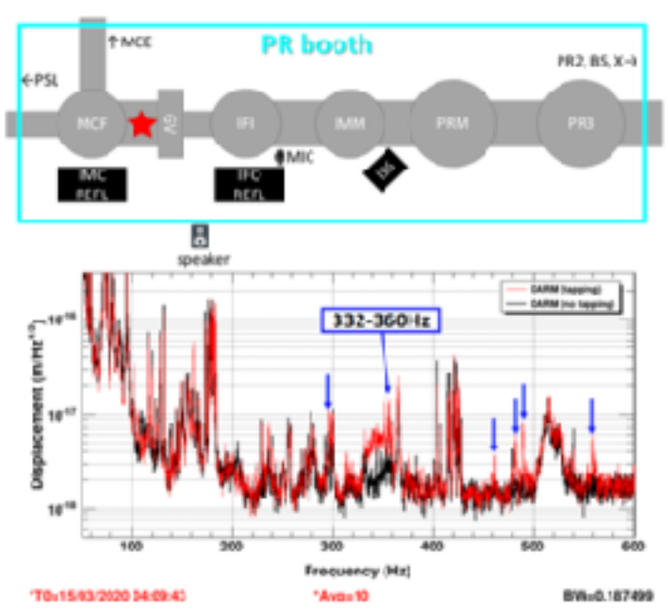


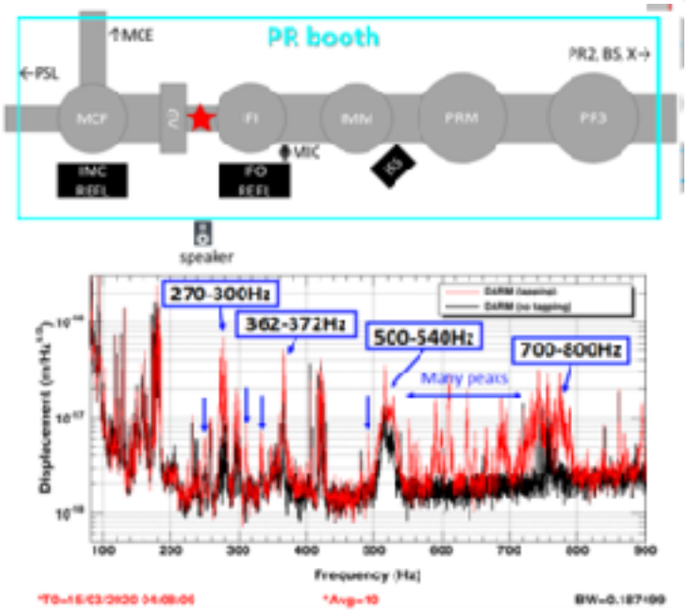
- KAGRA PEM (Physical Environmental monitors)
  - Installed and managed various monitors (mic, magnetometer, …)
  - Support the commissioning, detector characterization, …
    - Report some activities in this slide

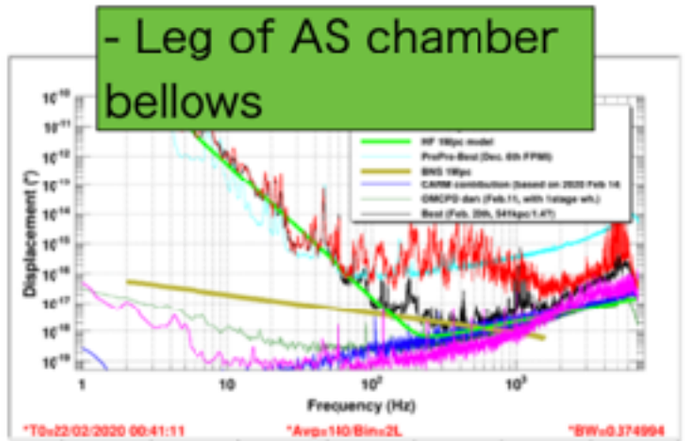
https://academic.oup.com/ptep/article/2021/5/05A102/6146420?login=true

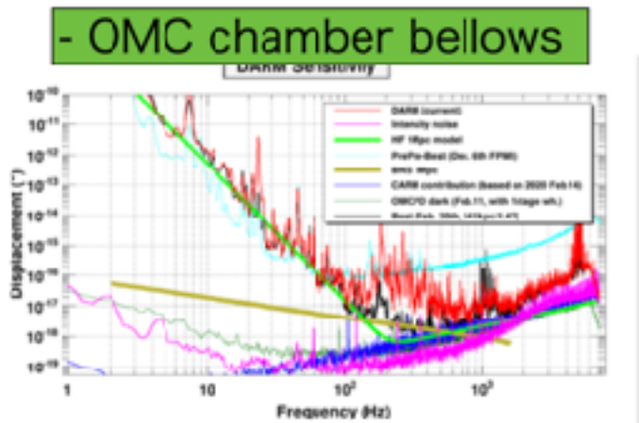
O3GK:Noise hunting

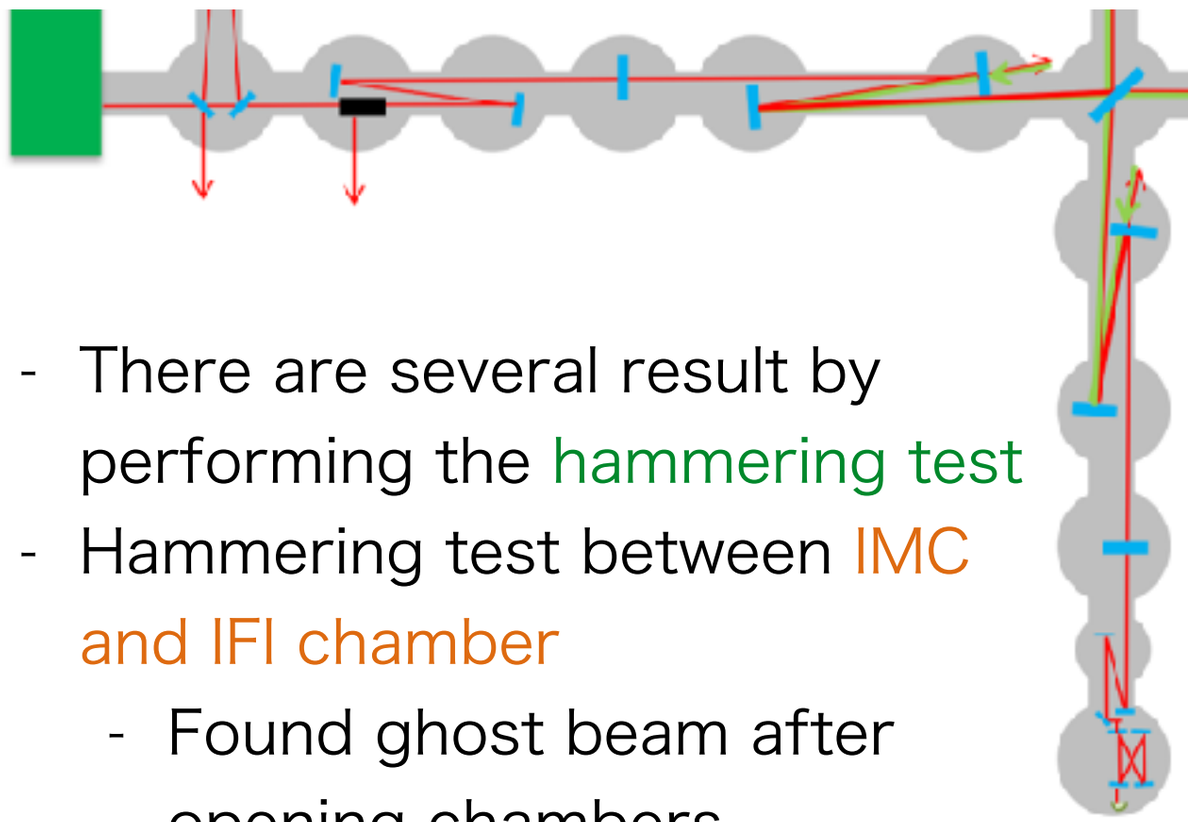






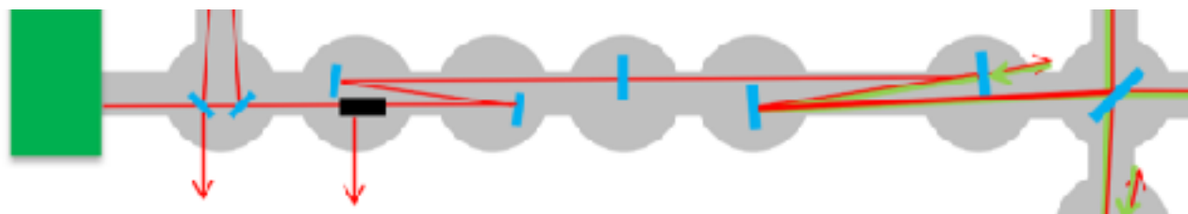


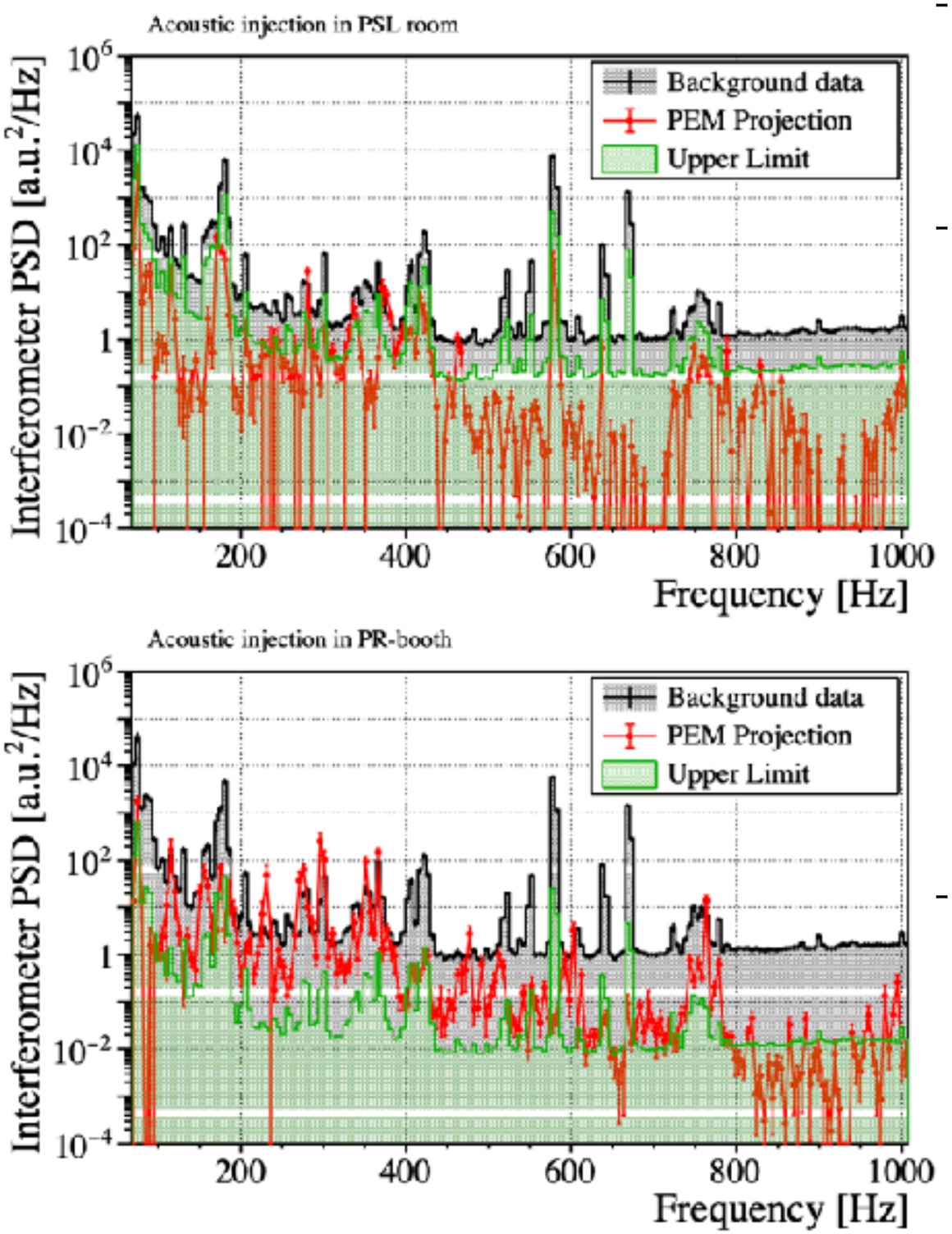




- There are several result by performing the hammering test
- Hammering test between IMC and IFI chamber
  - Found ghost beam after opening chambers
- BS and SR area
  - Different frequency, scattered light from SRM?
- AS table and OMC chamber
  - Some sensitivity limit by air compressor for gate valve
  - Performed additional hammering test -> seismic motion gave vibration to OMC

O3GK:Acoustic noise





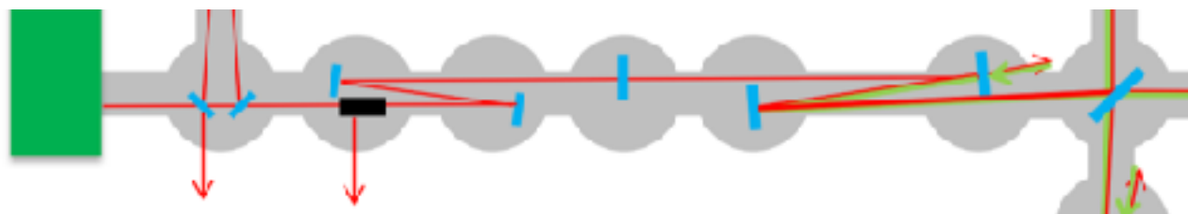
- PEM injection played the important role to evaluate the O3GK noise budget
  - Acoustic injection
- Injection method, analysis are established in the post O3GK measurement.
  - Response function including the linear and non-linear response

$$S_{\mathrm{PEM}}(f) = \int \left[R(f, f') \cdot P_{\mathrm{bkg}}(f') \cdot \varepsilon \right] \mathrm{d}f',$$

  - CQG 38 125005 (2021)

- There are several acoustic related noise in the PSL room and PR booth
  - PSL room : Microphone signal near the PMC has coherent with DARM
  - Offline noise subtraction

O3GK:Offline noise subtraction



- We investigated the offline noise subtraction, which detected the coherence between GW channel and auxiliary channels
  - One study is Independent Component Analysis with O3GK

Introduction: **I**ndependent **C**omponent **A**nalysis : ICA

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 1 & H_{01} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} s \\ n \end{pmatrix}$$

$x_1(t)$: strain channel
$x_2(t)$: environmental channel
observed

$s(t)$ GW signal
$\mathbf{n}(t)$ Env noise
source

※Assume gravitational wave and environmental noise are independent
⇨Assume cross spectrum of gravitational wave and environmental noise = 0

$$\overline{H_{01}(f)} := \frac{\langle \tilde{x}_1(f), \tilde{x}_2(f) \rangle}{\langle \tilde{x}_2(f), \tilde{x}_2(f) \rangle}$$

※$\langle a(f), b(f) \rangle$:cross spectrum of $a(f)$ and $\mathrm{b}(f)$
※$\overline{H_{01}}$ estimated Transfer function
※using average cross spectrum ∵statistical error

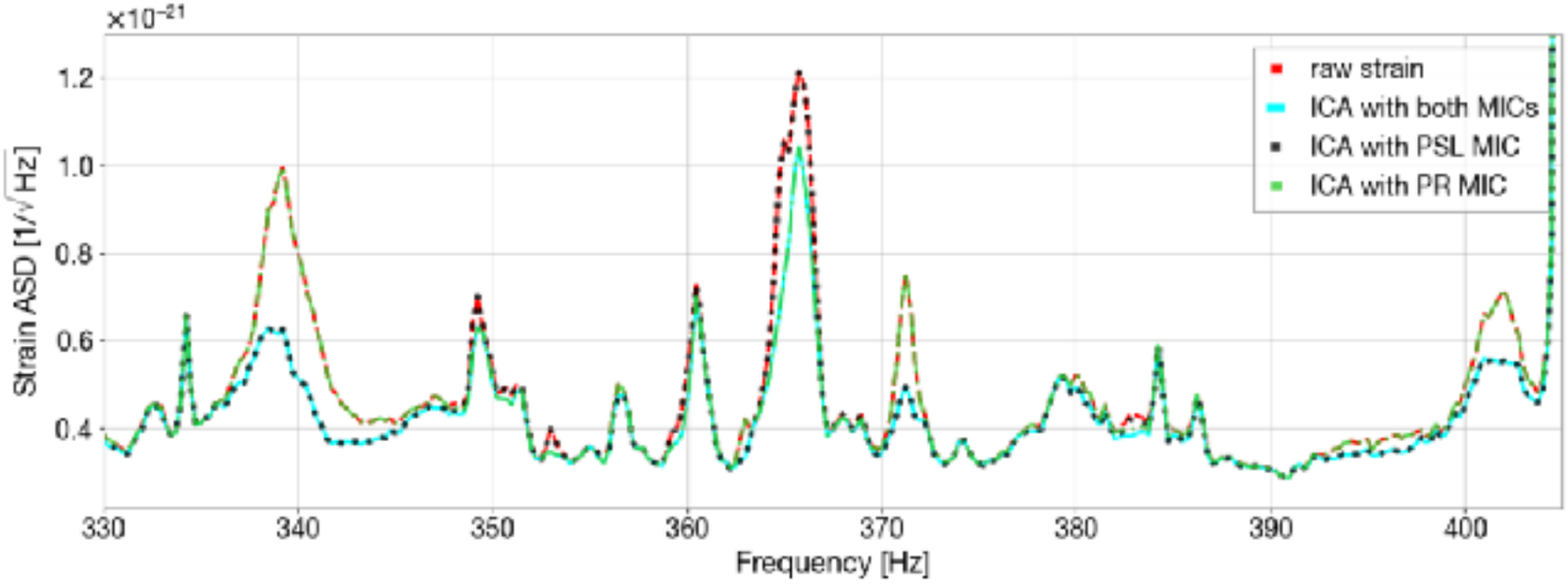
Signal subtracted noise:

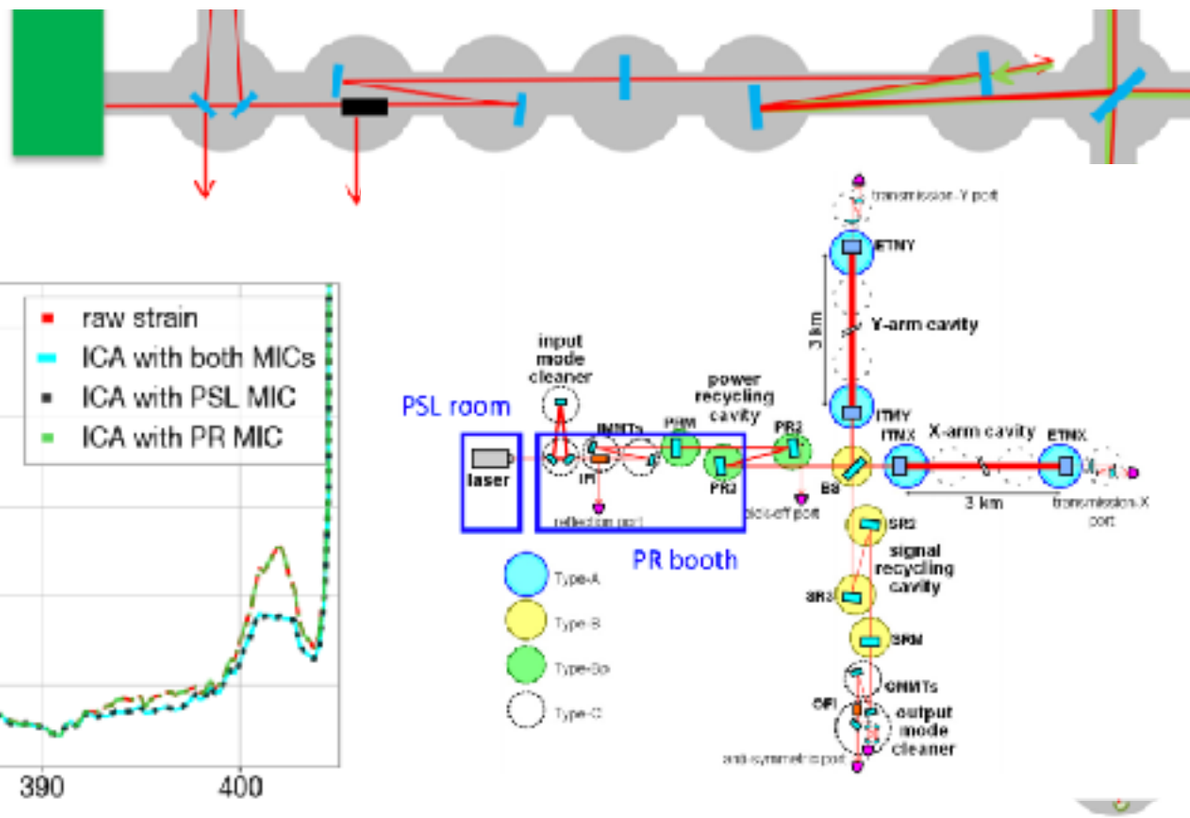
$$\bar{s} = x_1 - \overline{H_{01}} x_2$$

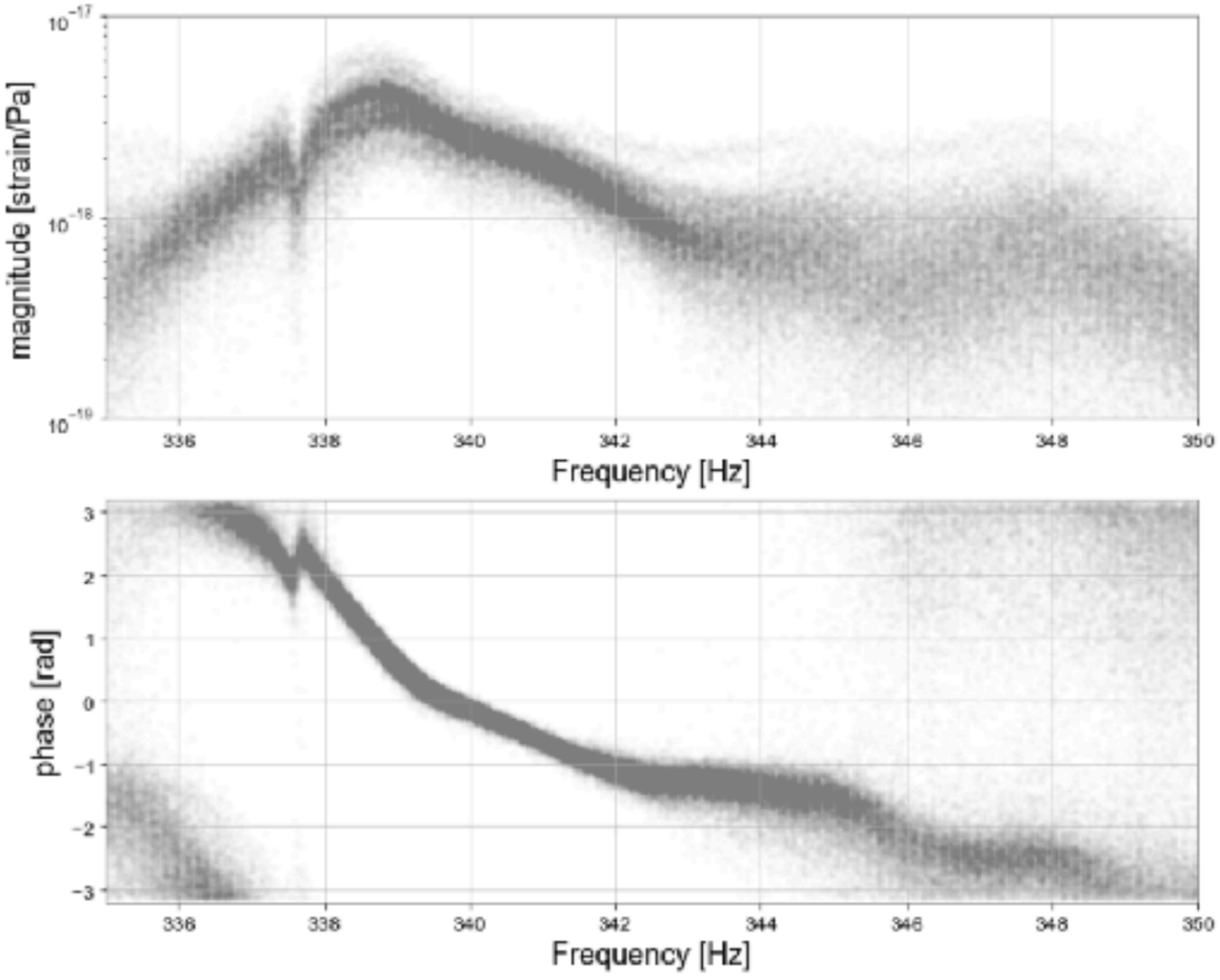
→Time dependence of Transfer Function

→ Evaluate the SNR by software injection, etc

O3GK:Offline noise subtraction

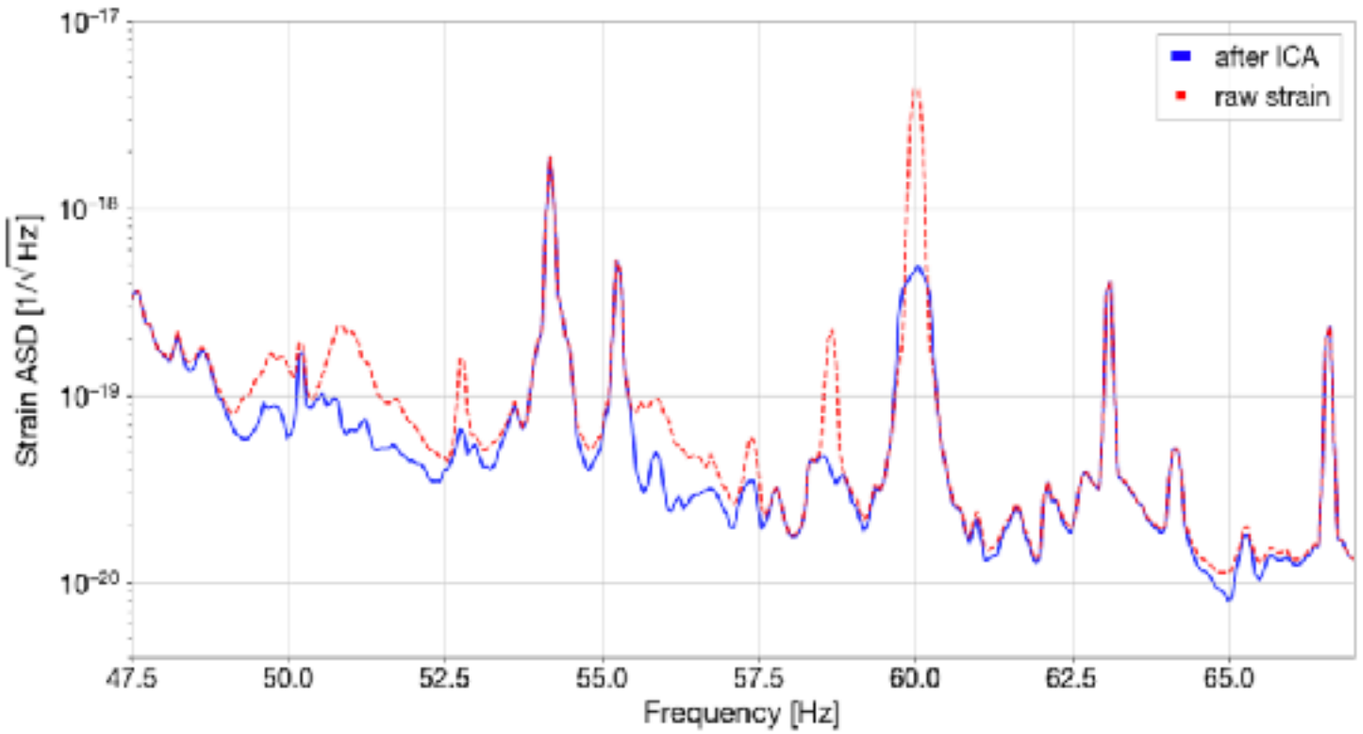


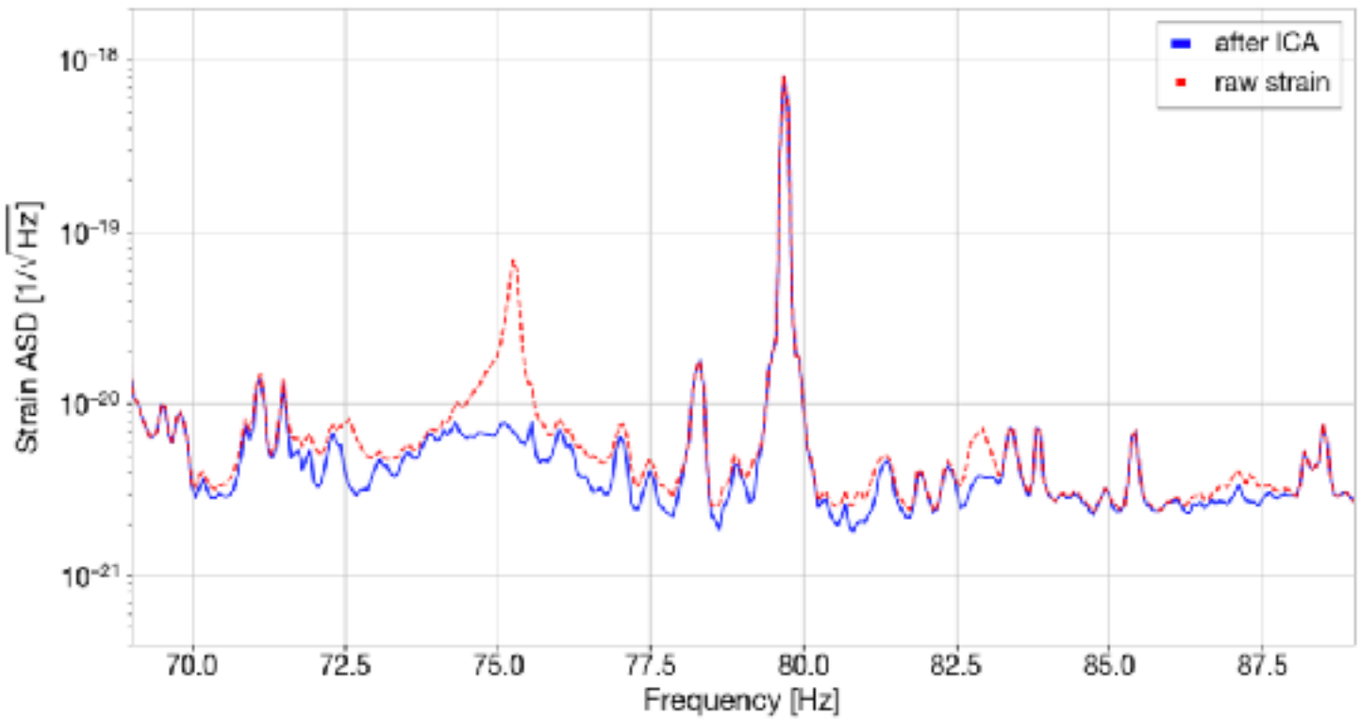


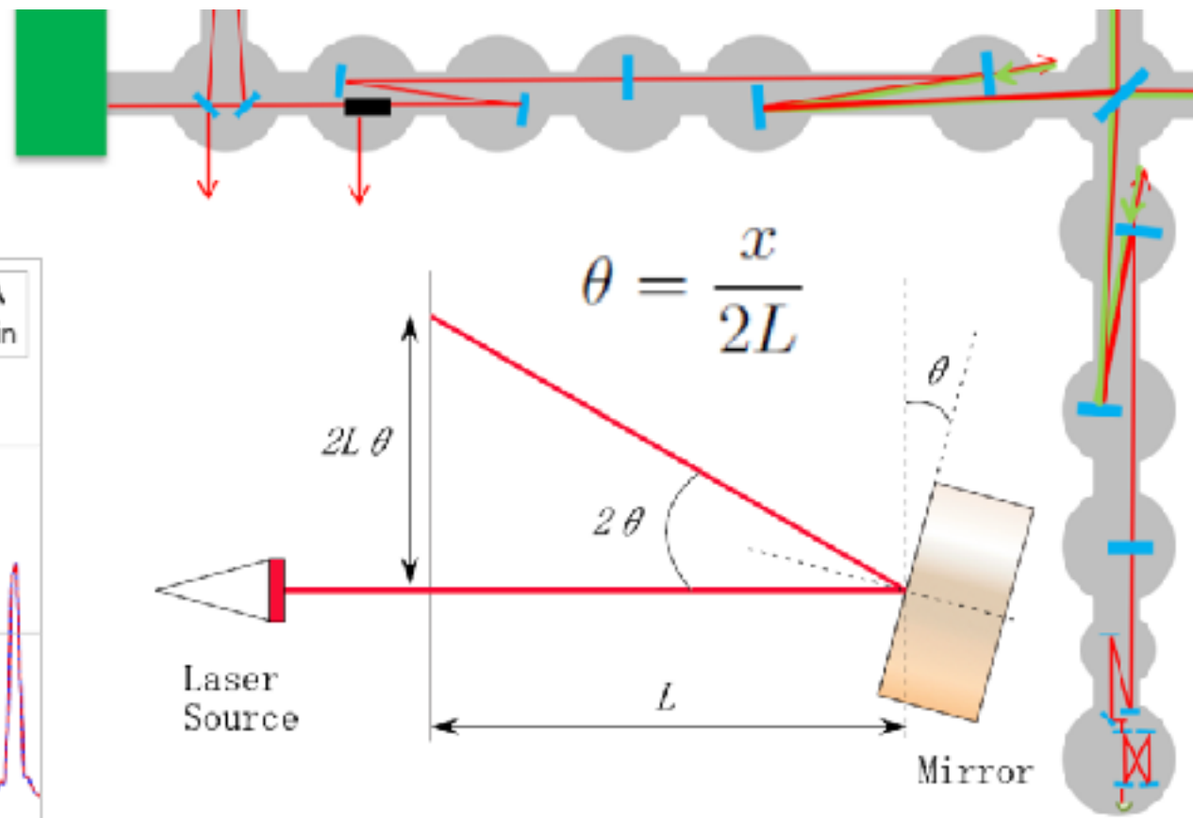


- Result1 : Noise subtraction using microphone at PSL and PR area
  - Performance check by acoustic injection data
  - Noise was subtracted at the middle frequency
  - Checked the stability of transfer function during O3GK

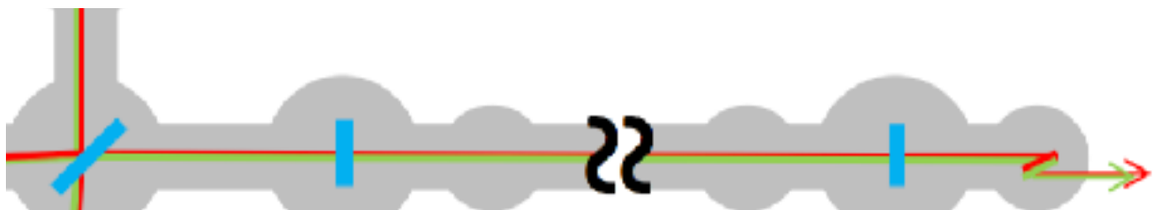
O3GK:Offline noise subtraction



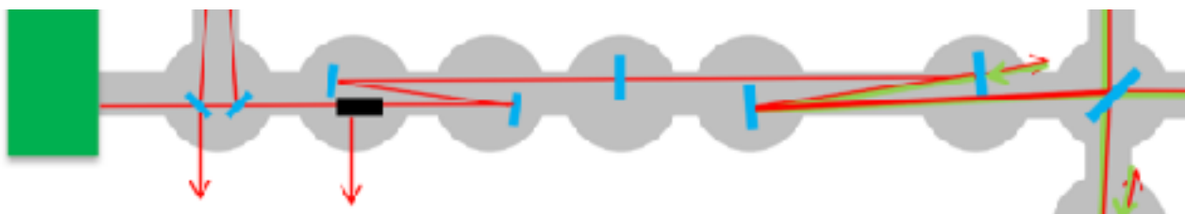




- Result2 : Noise subtraction using optical lever for PRs
  - Noise subtraction was demonstration, need to evaluate the noise path
- We are preparing toward the journal paper
- We also performed the non-linear noise subtraction



O3GK:Lock loss study

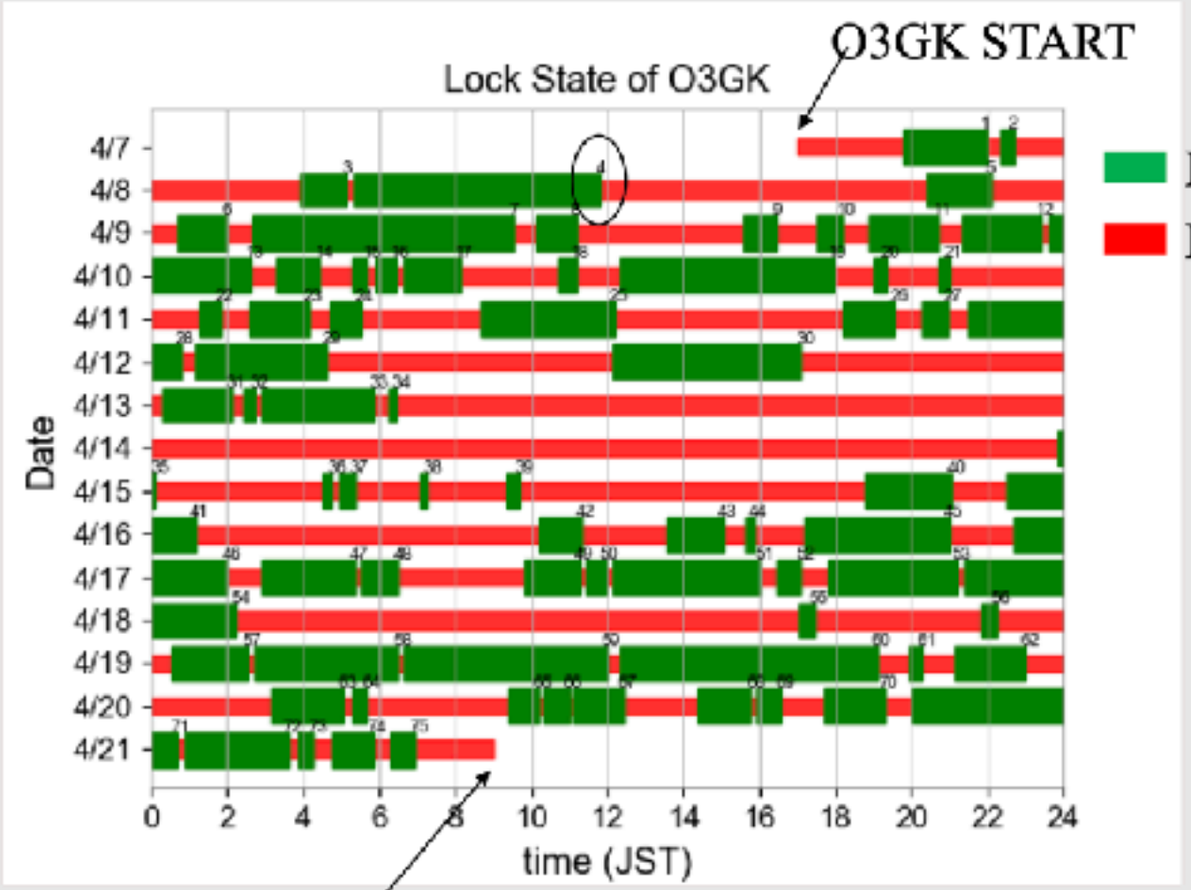


- Lock loss study (Search the reason why lose the Fabry Perot cavity)
  - Total 75 lock loss during O3GK (for >10 min lock)

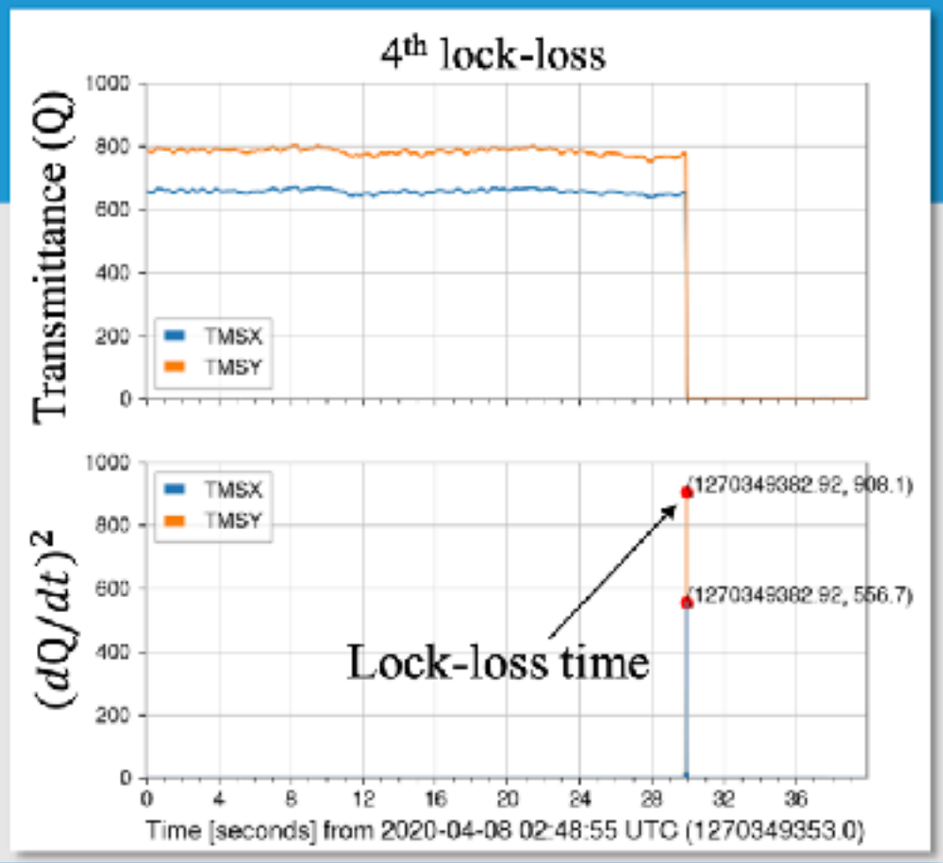
Lock-loss in O3GK

1

Number is identified lock-loss in O3GK is 75

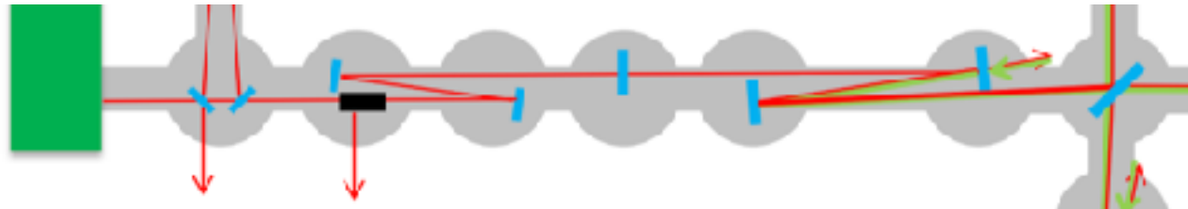


Lock rate:42.5 %



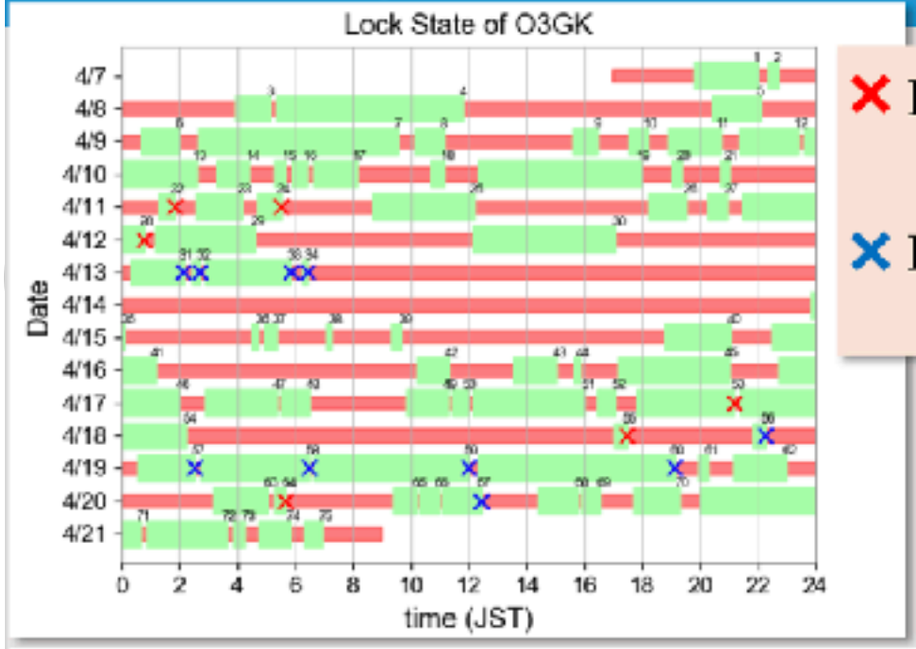
*want to avoid lock-loss during observation
*however, lock-loss process has not been systematically studied
*want to investigate lock-loss reason
*Lock-loss study is meaningful

O3GK:Lock loss study



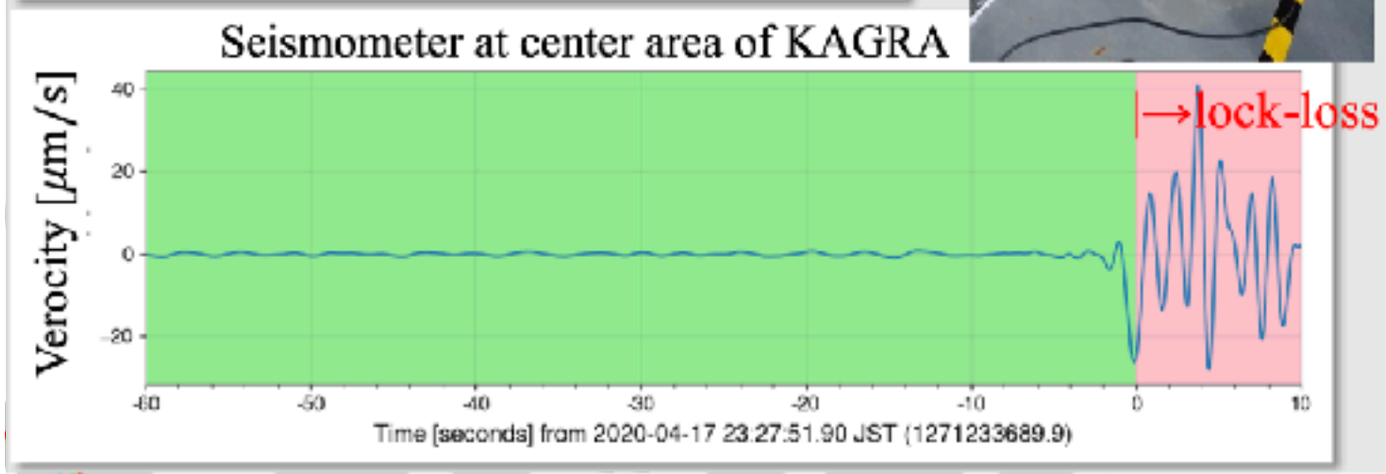
- Lock loss study (Search the reason why lose the Fabry Perot cavity)
  - Total 75 lock loss during O3GK (for >10 min lock)
  - One study for seismic motion (micro-seismic, earthquake and dam)

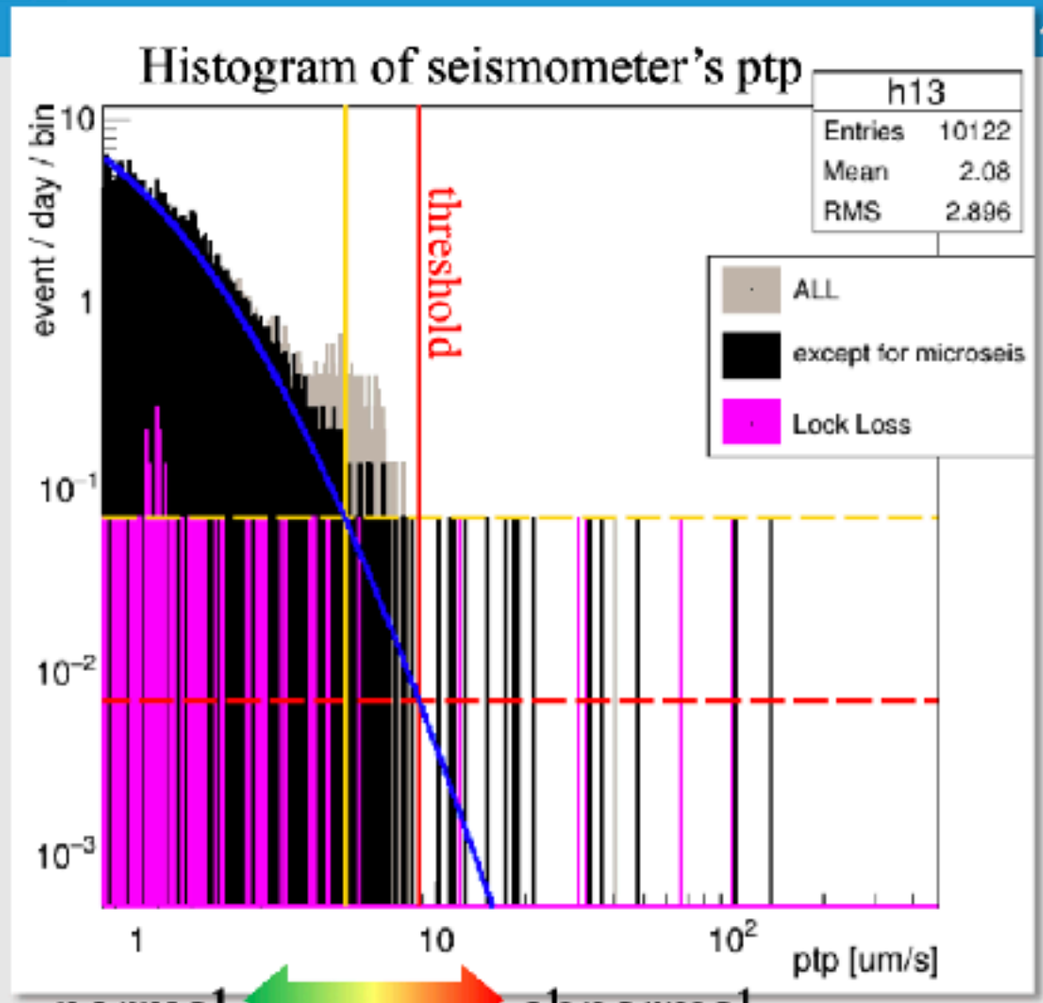
Analysis from causation



✕ Lock-loss by ground vibration

✕ Lock-loss by large microseismic

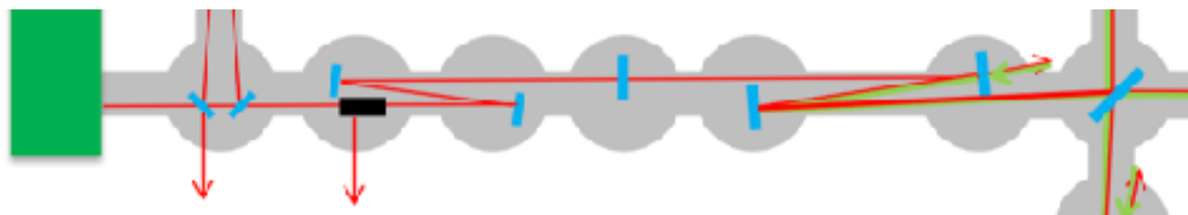




normal ⟷ abnormal

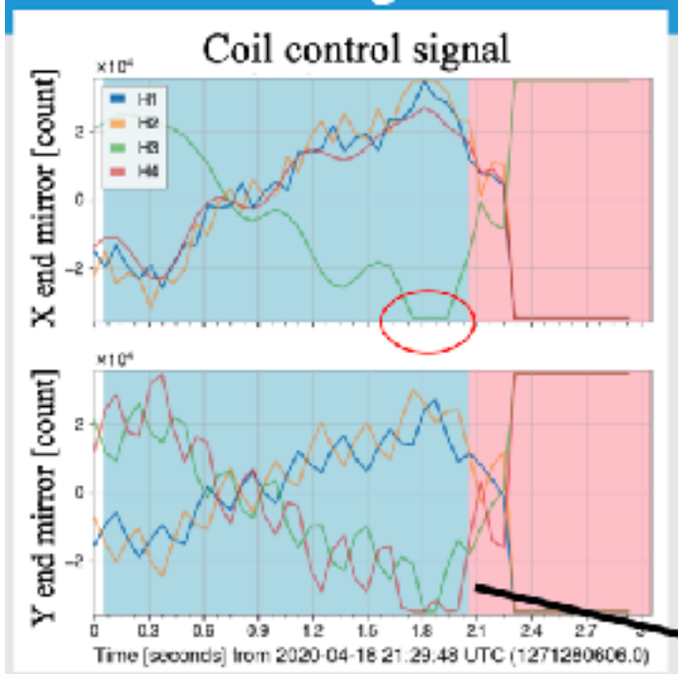
Yellow zone（1 time /15days）

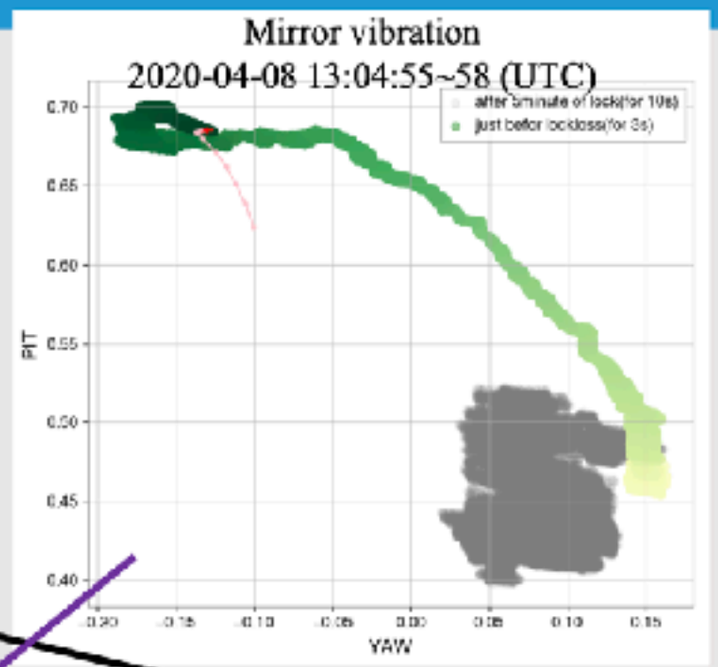
O3GK:Lock loss study

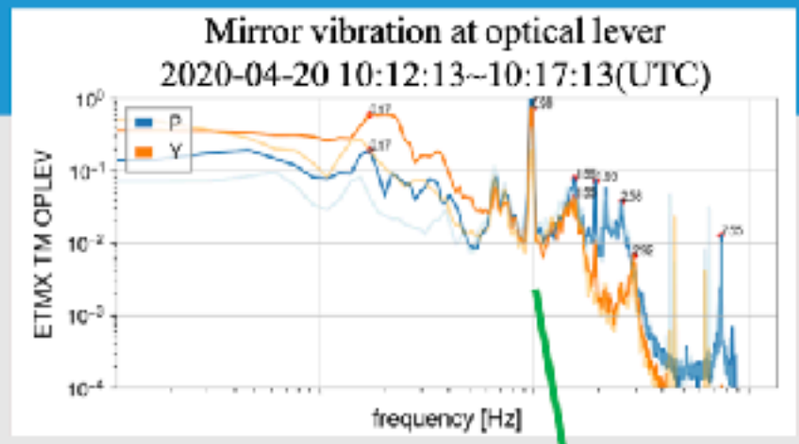


- Lock loss study (Search the reason why lose the Fabry Perot cavity)
  - Total 75 lock loss during O3GK (for >10 min lock)
  - Coil saturation, cavity angular motion(alignment check) and control

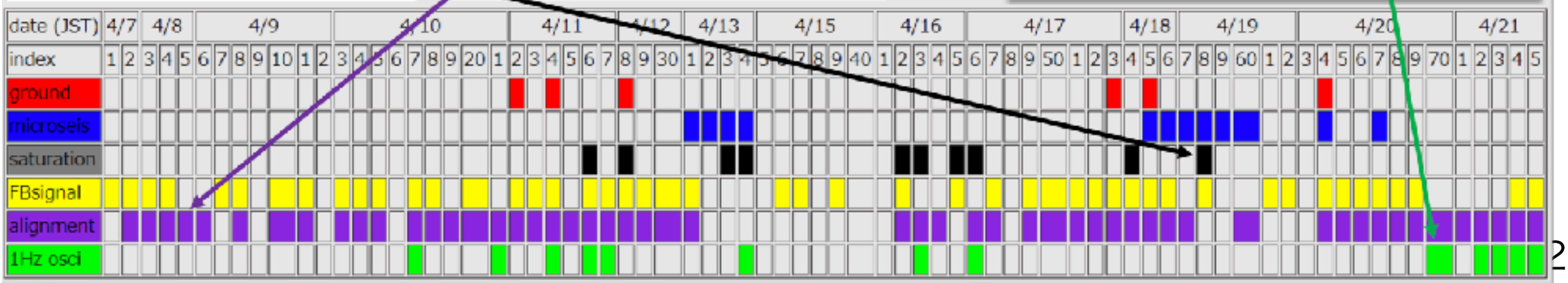
Analysis from result side



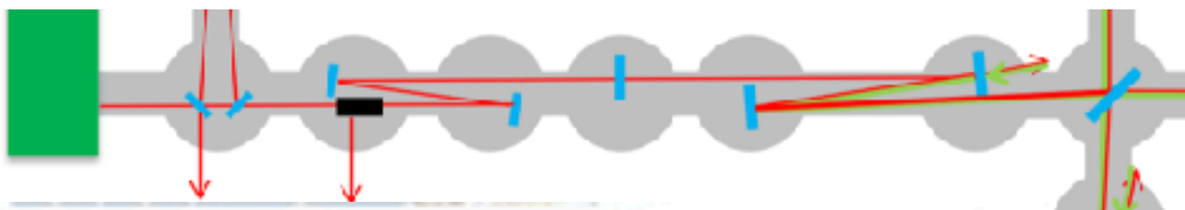




- Saturation (10 times)
- Abnormal feedback signal (48times)
- Bad alignment (53 times)
- 1 Hz oscillation (13 times)



Telephoto camera



KAGRA telephoto camera system(TCam) :

Purpose of TCam system

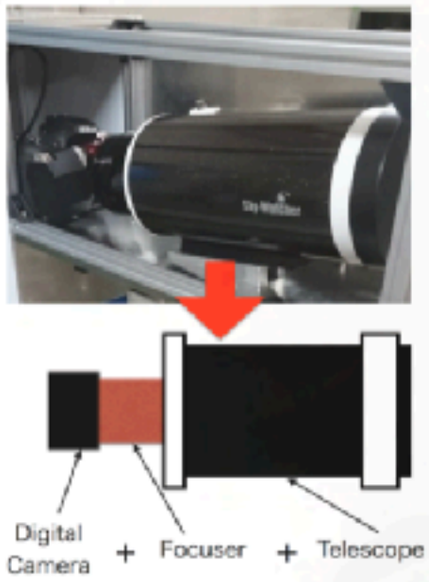
- Monitoring the surface of sapphire mirror(dusts, ···)
- Monitoring the mirror position (Change due to cryogenic)
- Monitoring the main, green and pcal laser position
- Trouble shooting for emergency

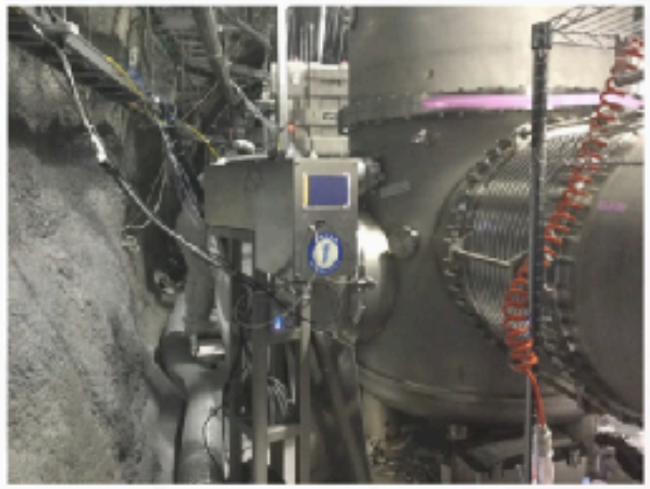
Y-end

Y-front

X-end

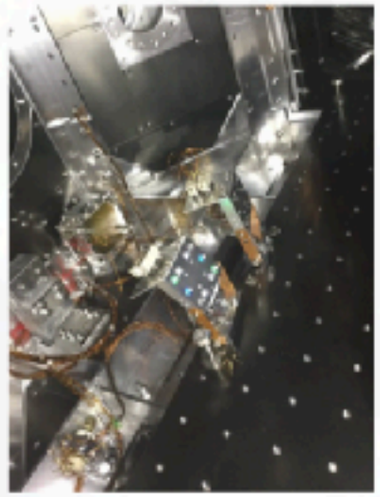
X-front



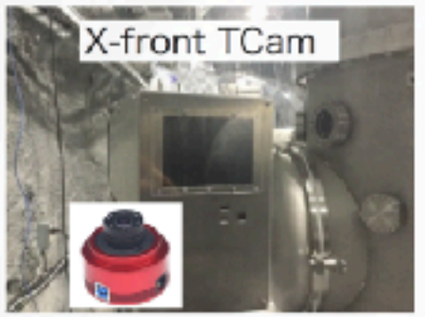


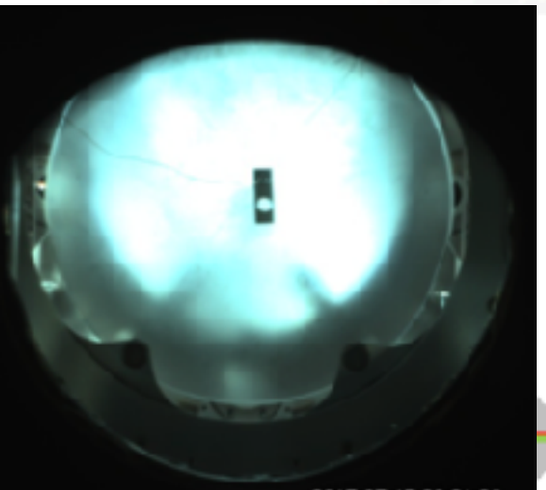
Y-end TCam

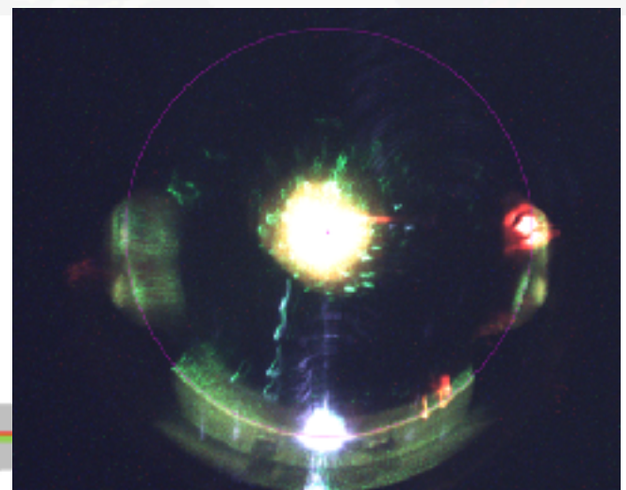
Inside the A chamber

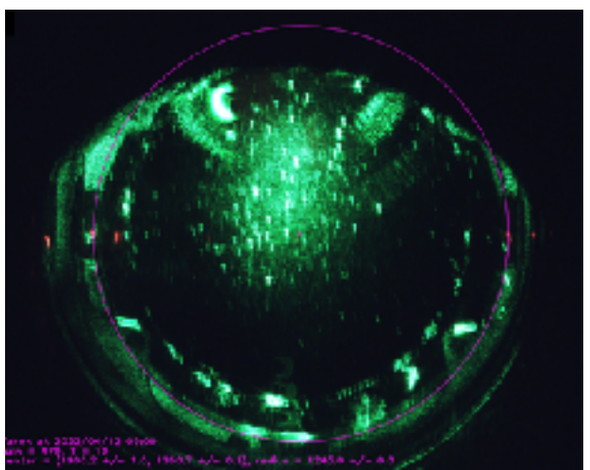


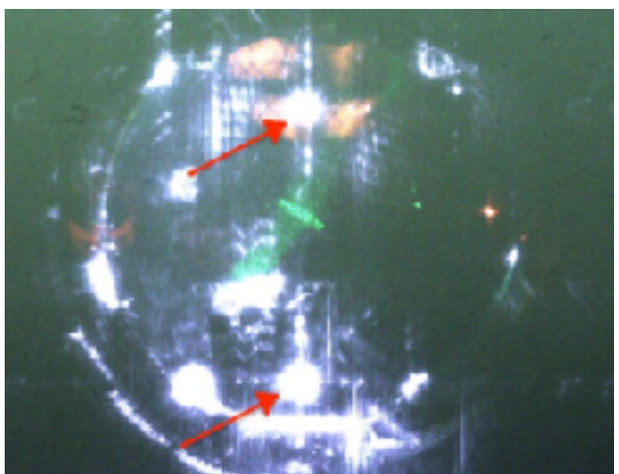
Illuminator



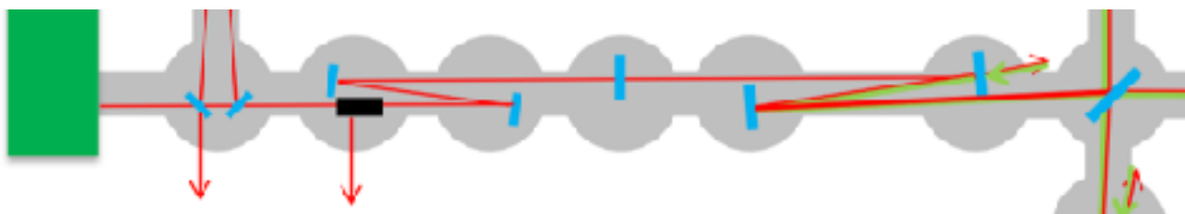




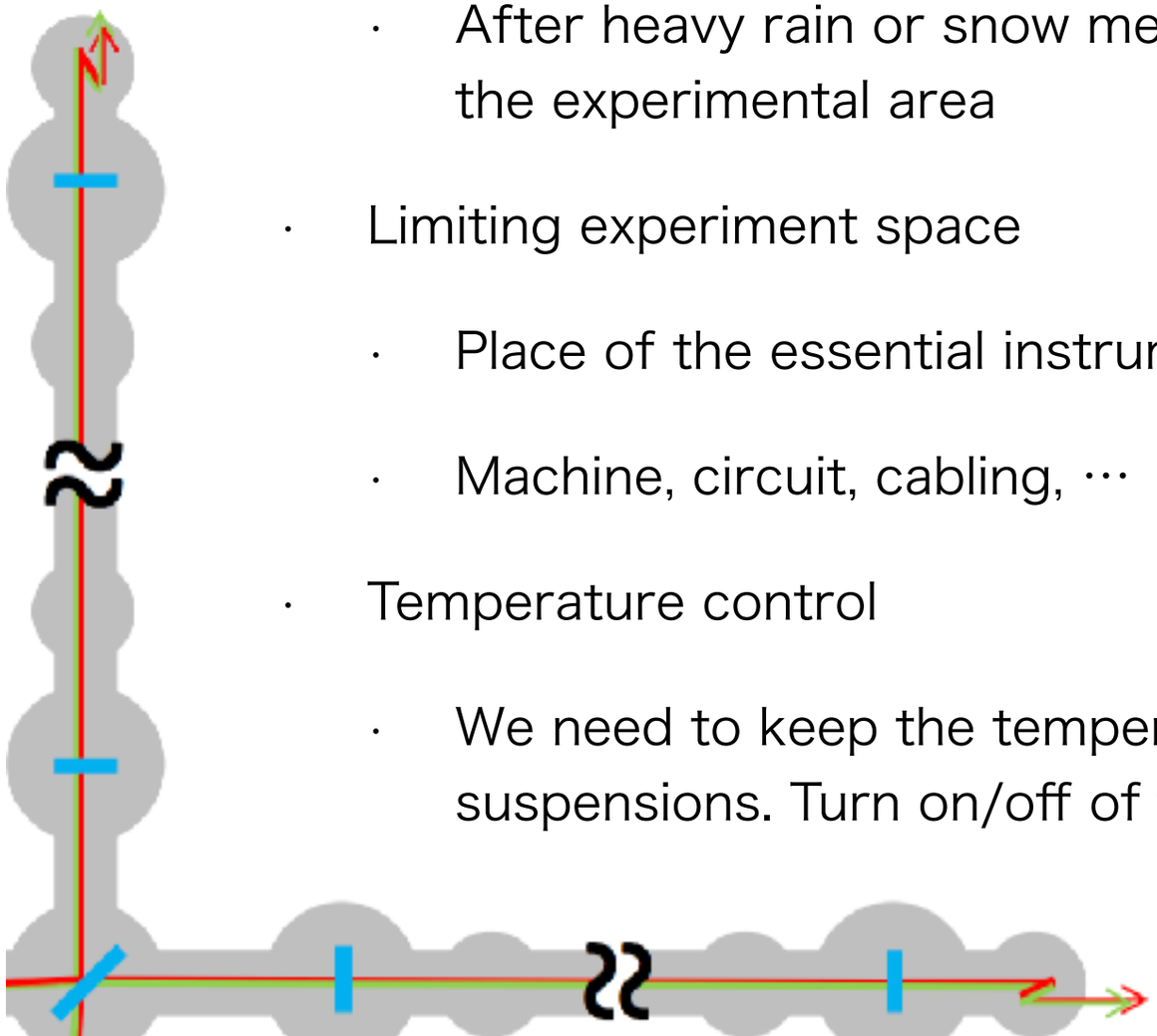




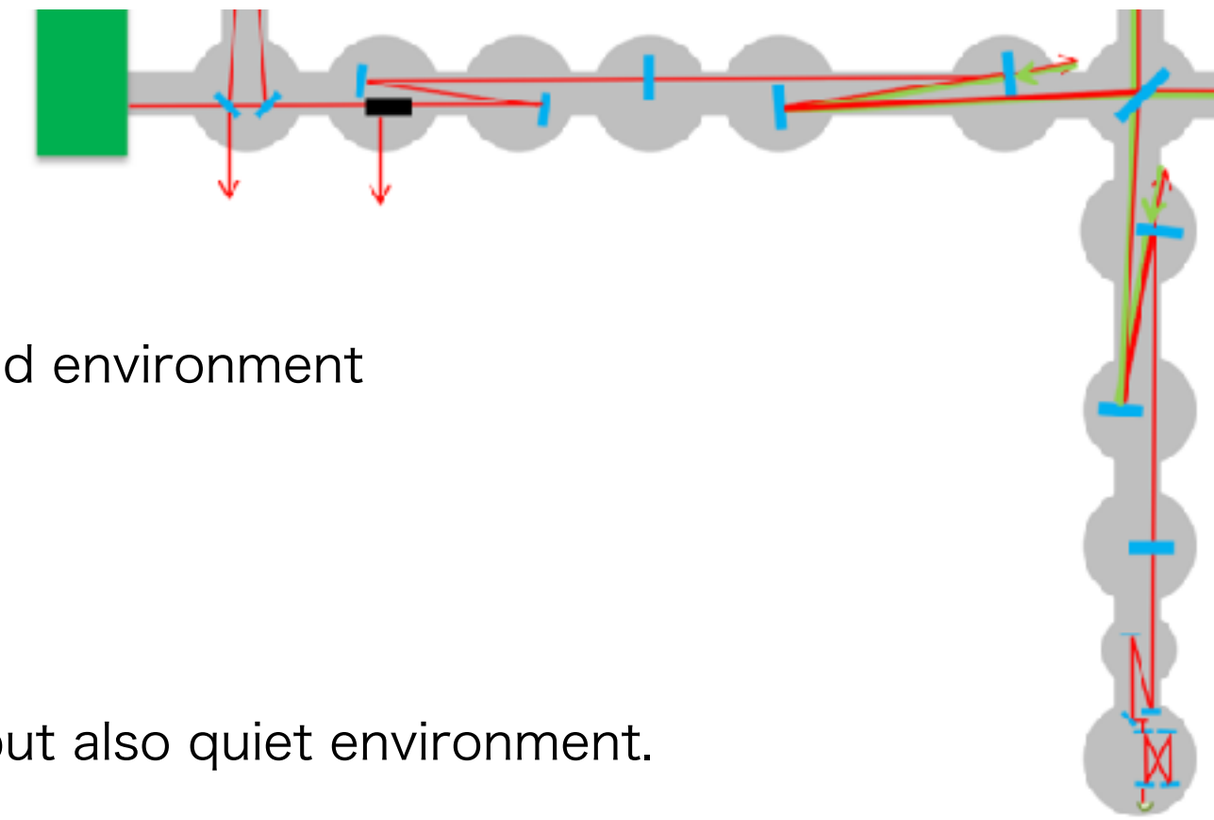
Underground interferometer



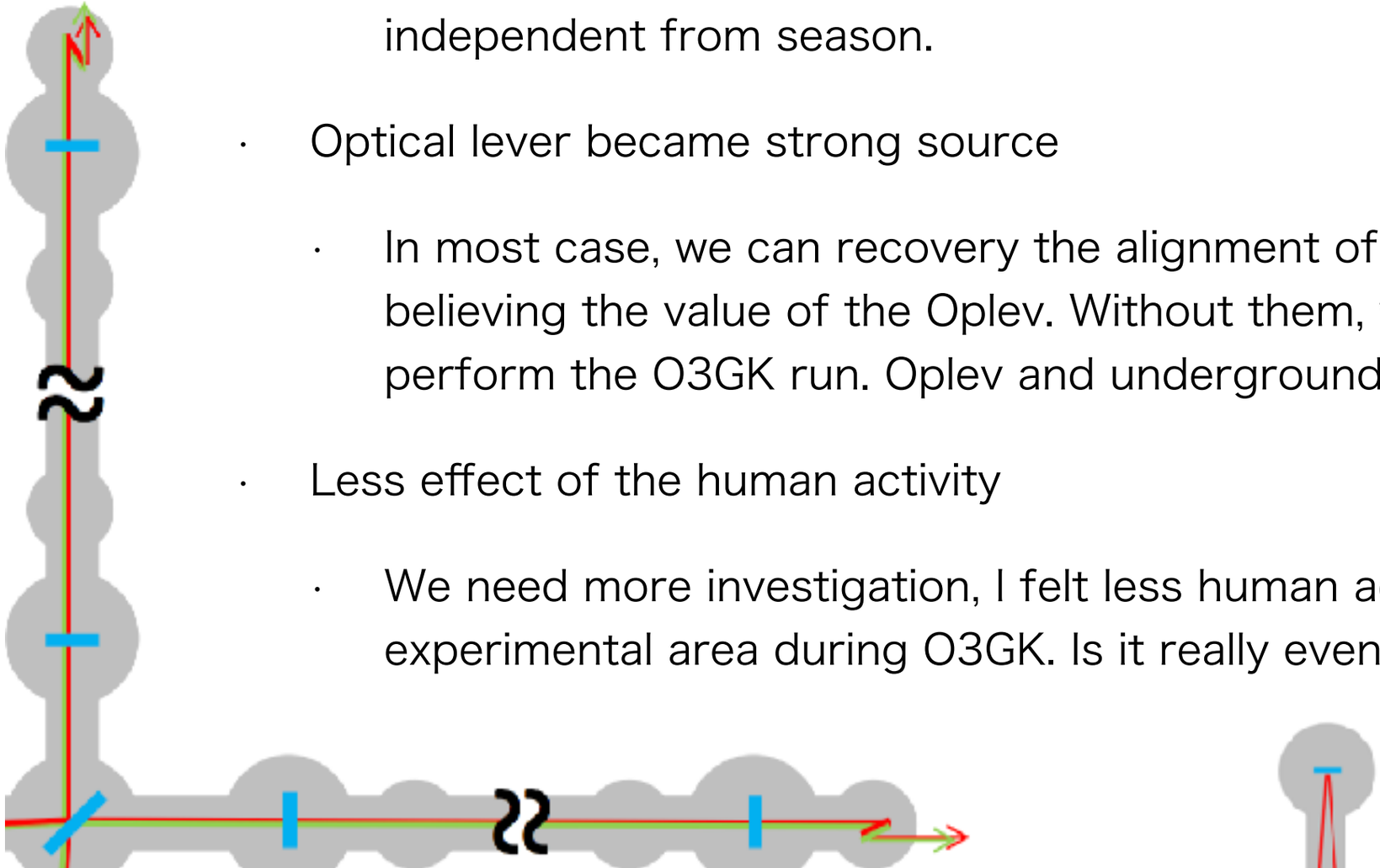
- (My personal) Comment about underground environment
- Difficult (Hard) point
  - Access to experimental area
    - Some trouble (or need to turn on/off instruments) detected in control room -> 10 min to center area -> +15 min to end area
    - After heavy rain or snow melting water season, there are many waters in the experimental area
  - Limiting experiment space
    - Place of the essential instrument (Air compressor, pumps, coolers, …)
    - Machine, circuit, cabling, …
  - Temperature control
    - We need to keep the temperature within 0.5 deg, especially for suspensions. Turn on/off of the one instrument varied the temperature.



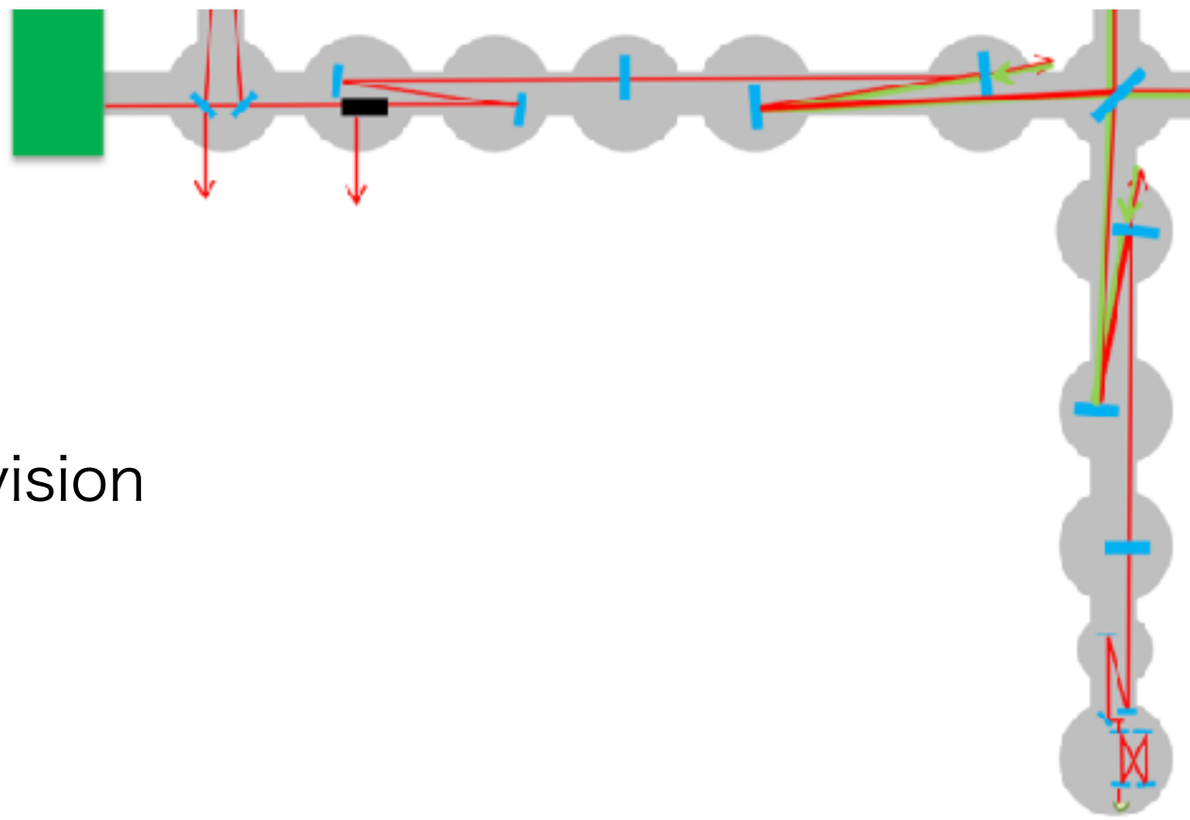
Underground interferometer



- (My personal) Comment about underground environment
- Good (Happy) point
  - Quiet environmental
    - Not only the quiet seismic motion, but also quiet environment.
    - Except of effect of water fluid, underground environment is mostly independent from season.
  - Optical lever became strong source
    - In most case, we can recovery the alignment of interferometer with believing the value of the Oplev. Without them, we might be impossible to perform the O3GK run. Oplev and underground is good compatibility
  - Less effect of the human activity
    - We need more investigation, I felt less human activity outside the experimental area during O3GK. Is it really even became higher sensitivity?



Summary



- KAGRA detector characterization
  - Managed under the Operations Division
- Various results are reported
  - Current DetChar activities
  - Noise hunting / acoustic injection toward the O3GK
  - Offline noise subtraction using ICA
  - Lock loss study
  - Telephoto camera
- Some personal opinions for the underground experiment
  - Good point and difficult point
- Welcome the question about DetChar for underground interferometer!