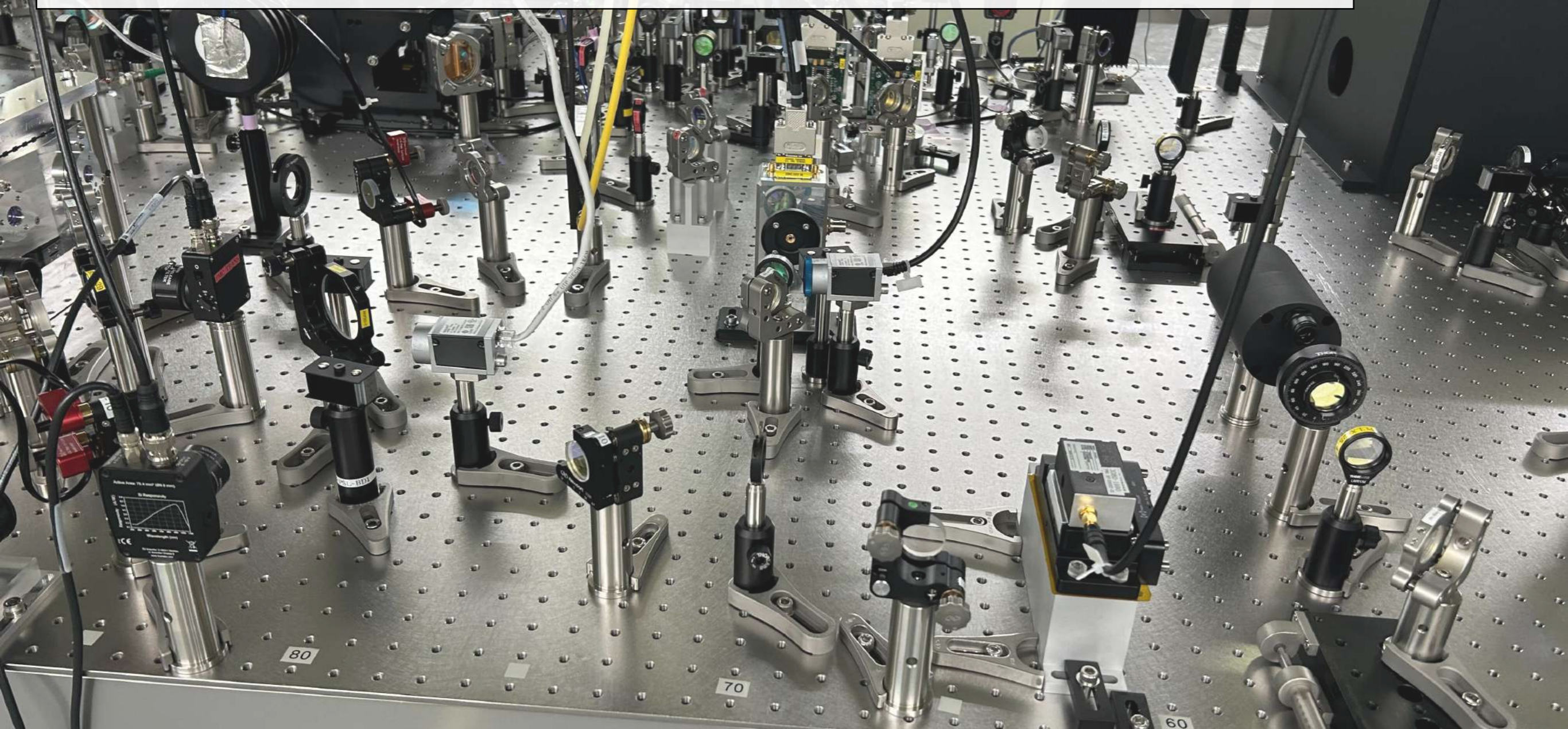


Evaluation of the vibration noise for KAGRA detector

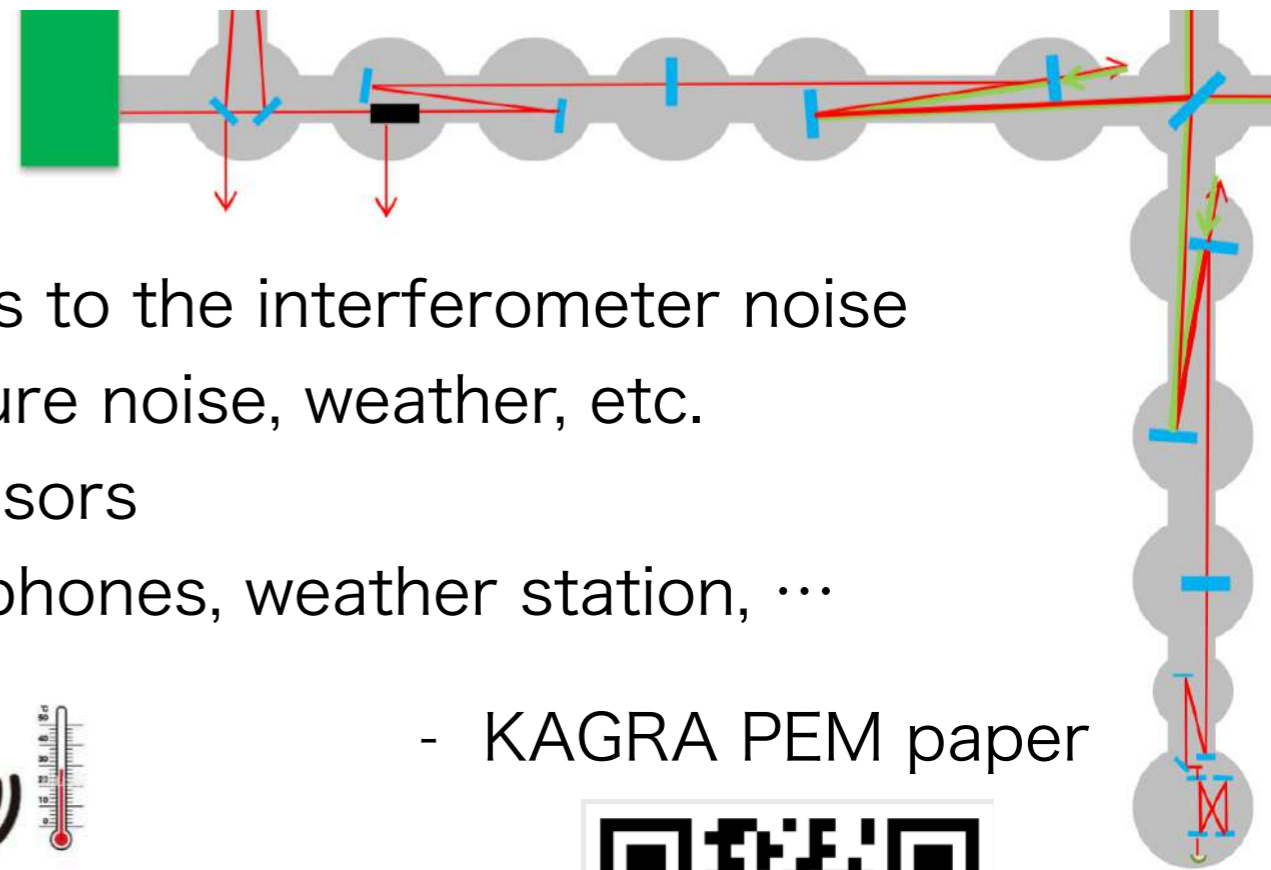


The 14th KAGRA International Workshop
15th May, 2026 Raffaello room at the Sina Brufani Hotel, in Perugia
Takaaki Yokozawa (ICRR) on behalf of KAGRA collaboration



Background

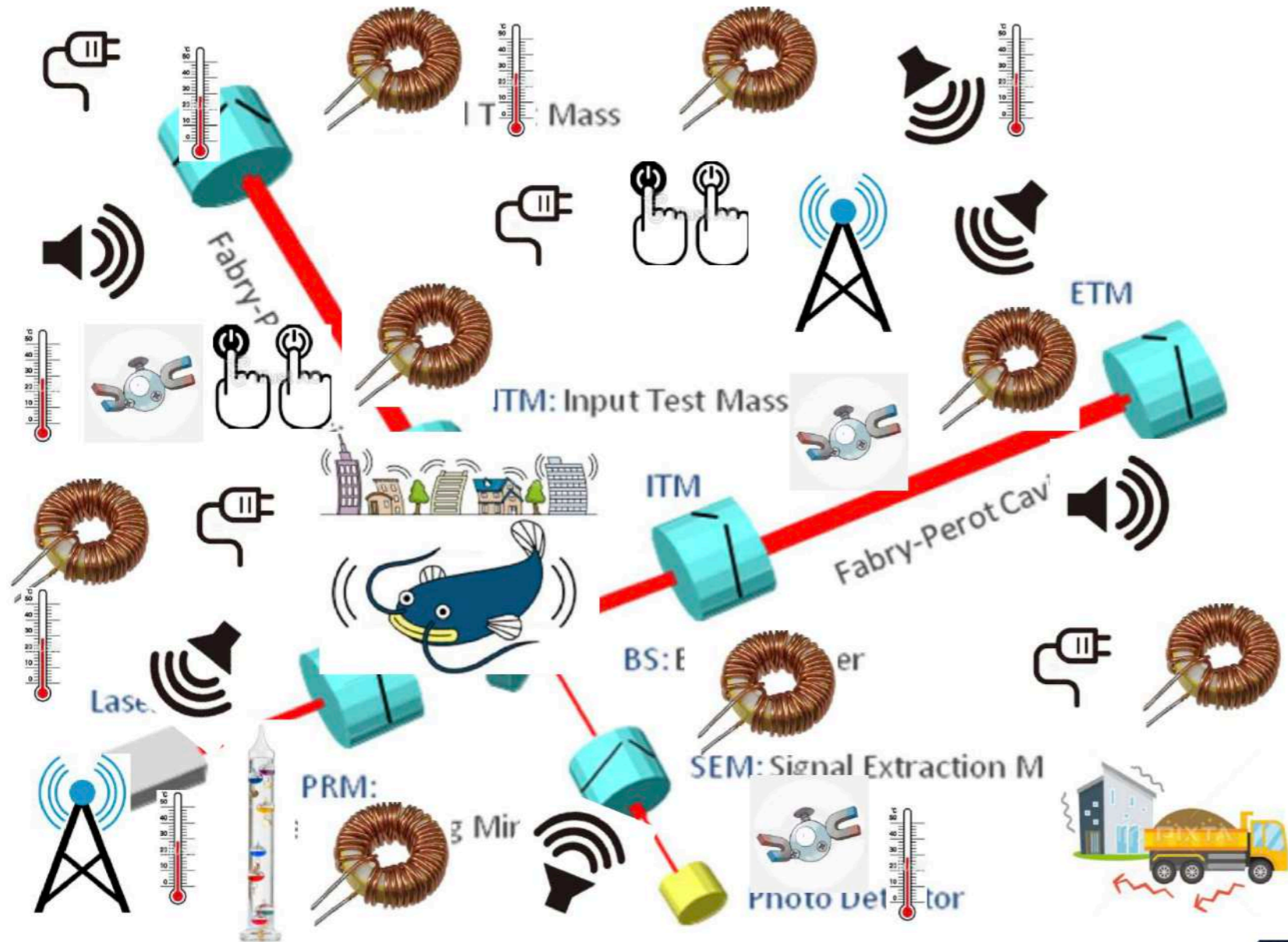
- Various environmental phenomena affects to the interferometer noise
 - Ground motion, lightening, infrastructure noise, weather, etc.
- To monitor them, we installed various sensors
 - Seismometers, accelerometers, microphones, weather station, ...



- KAGRA PEM paper

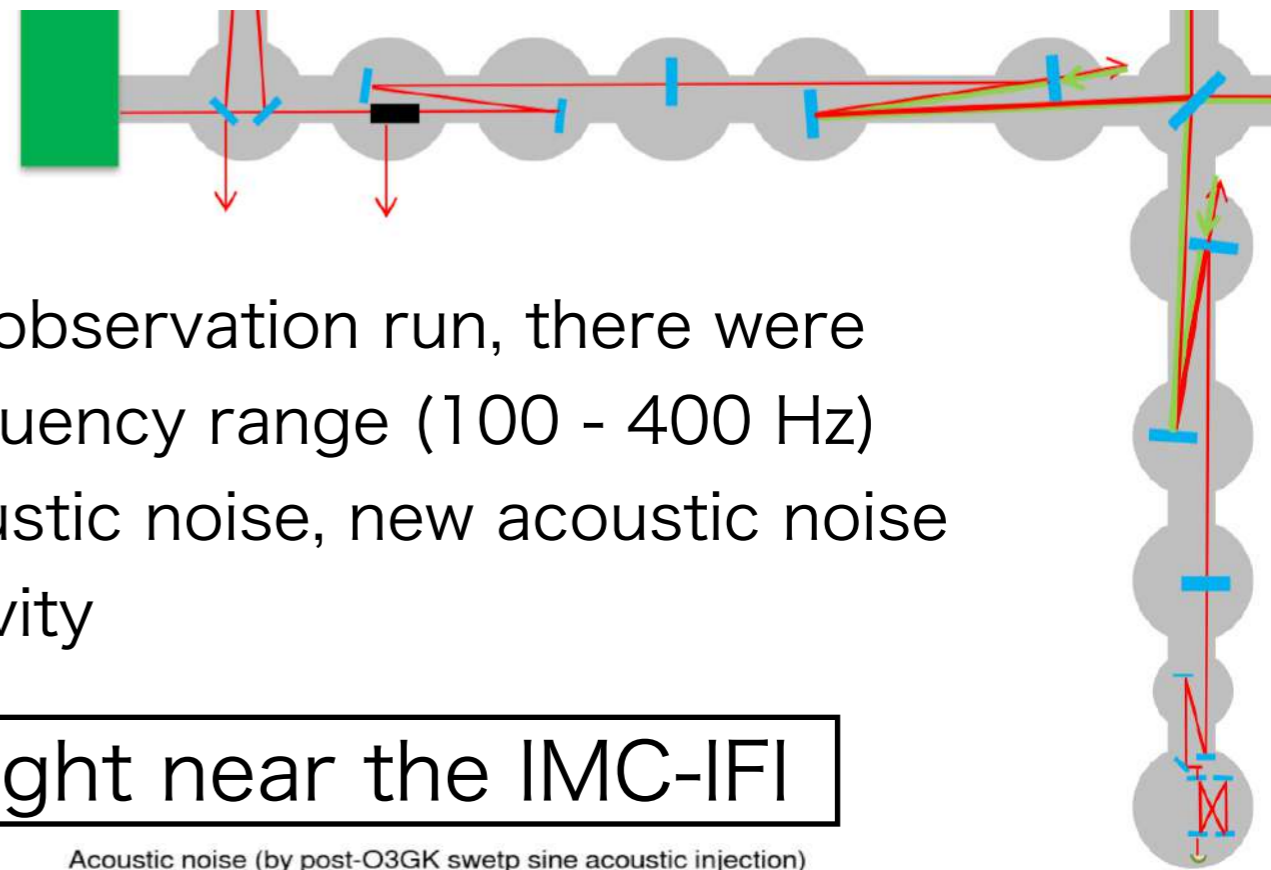


- KAGRA PEM MAP





Environmental noise hunting



- In the noise budget study for the past observation run, there were various “acoustic noise” in the GW frequency range (100 - 400 Hz)
 - We hunted noise path for each acoustic noise, new acoustic noise appeared with improving the sensitivity

- O3GK (Apr. 2020), scattered light near the IMC-IFI

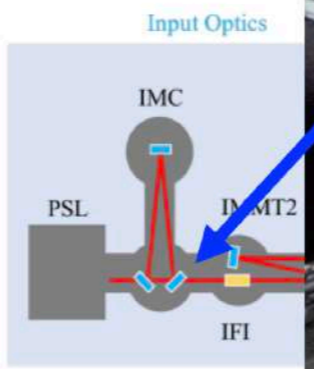
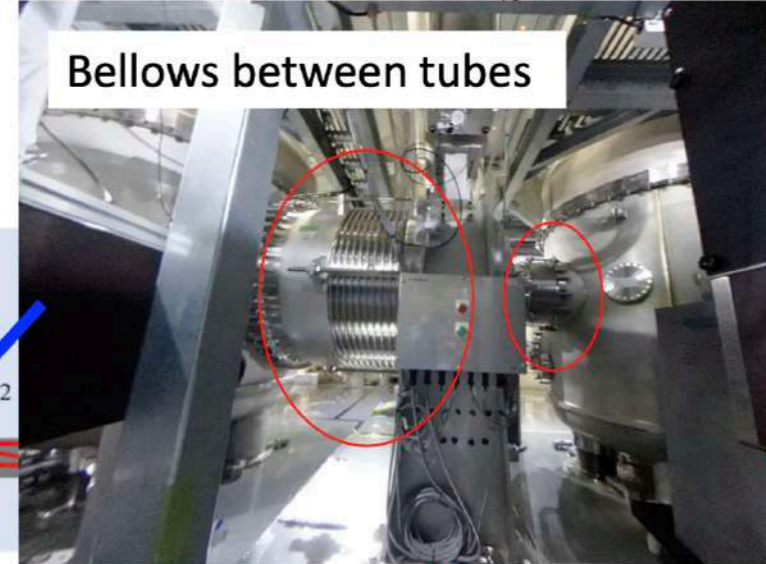
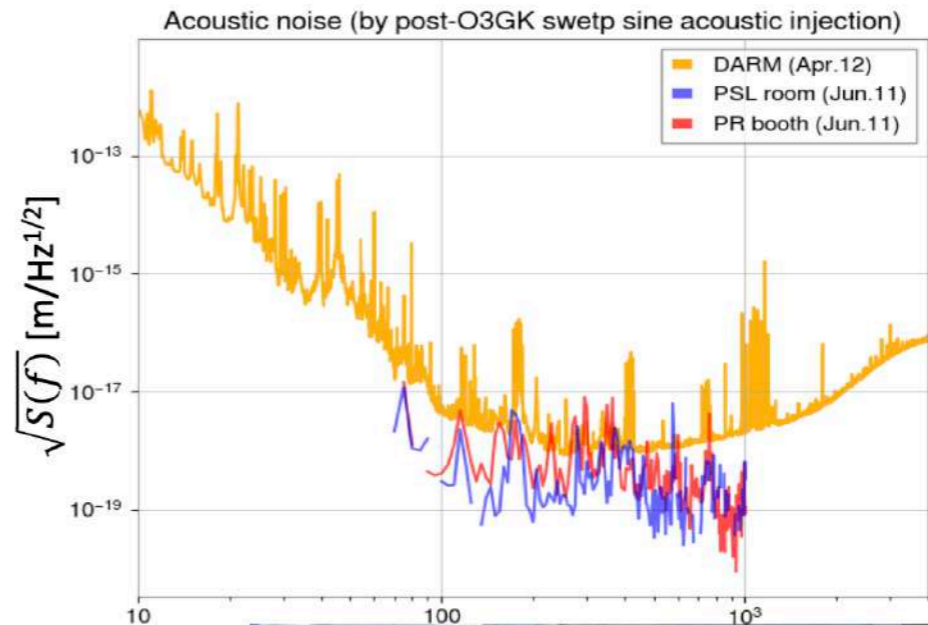
Acoustic Noise

- Evaluated by the PEM injection test.

$$S_{PEM}(f) = \int [R(f, f') \times P(f')] df'$$

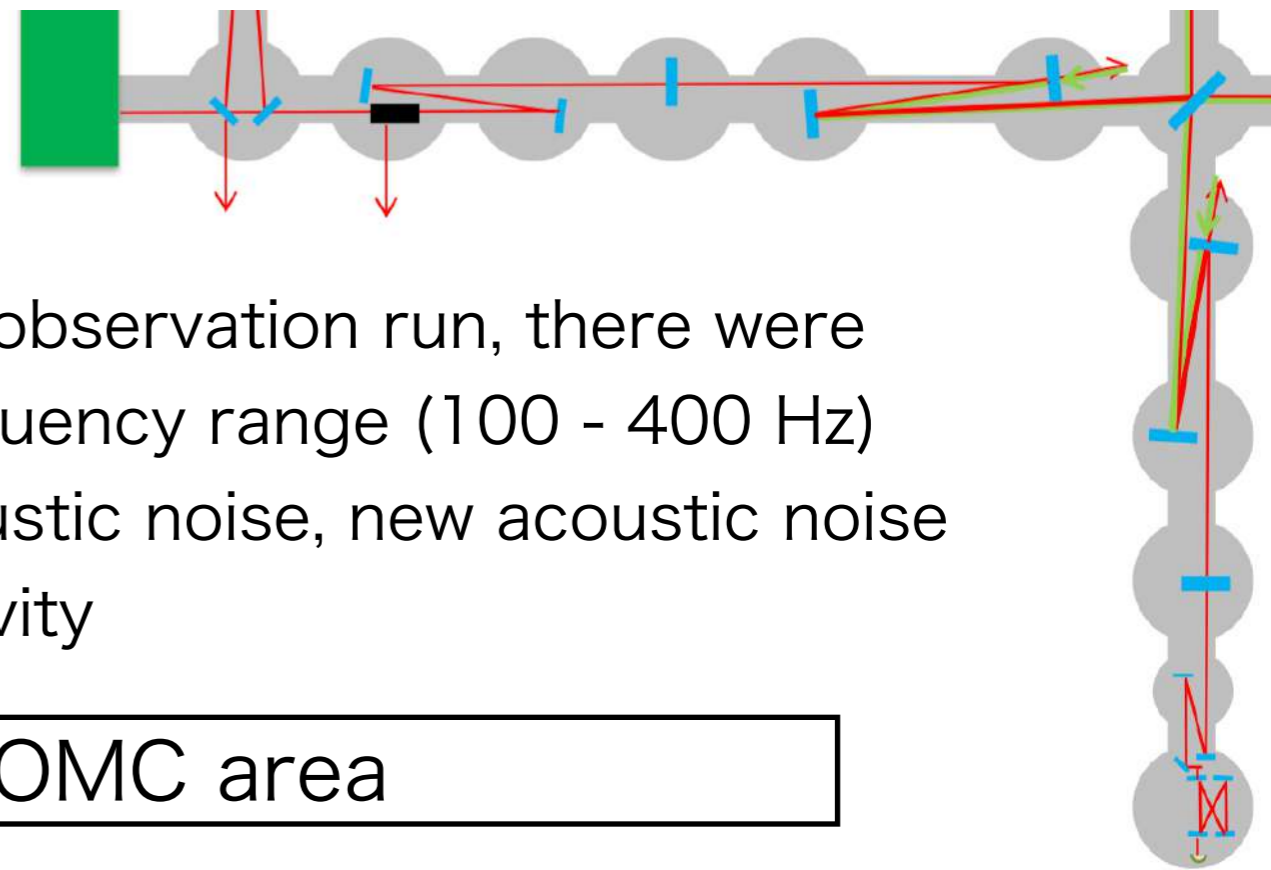
$S_{PEM}(f)$: Acoustic noise in DARM PSD
 $P(f')$: Acoustic field PSD
 $R(f, f')$: Response function

- The most effective point was the beam-tube between the IMC chamber and IFI chamber.
 - See T. Yokozawa [ID34] and T. Washimi [ID41] in Experimental status session and arXiv:[2012.09294](https://arxiv.org/abs/2012.09294)



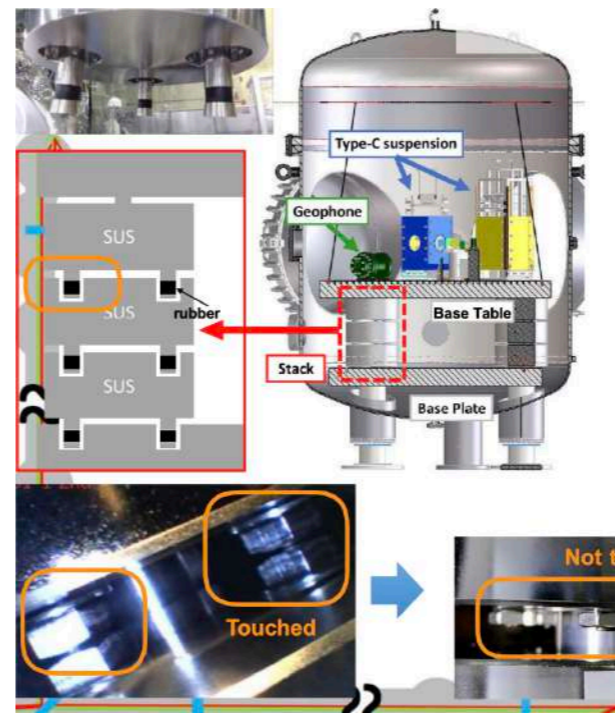
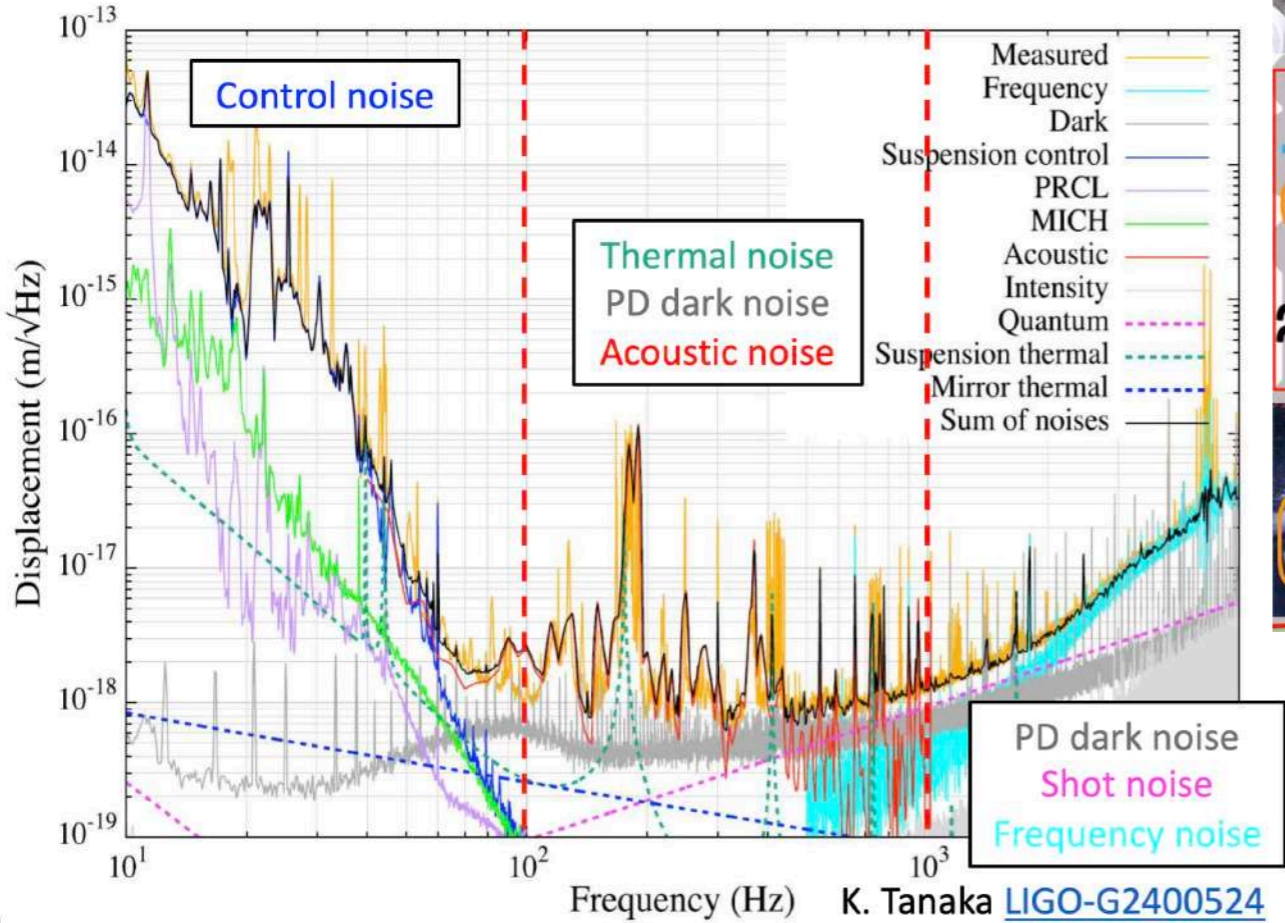


Environmental noise hunting

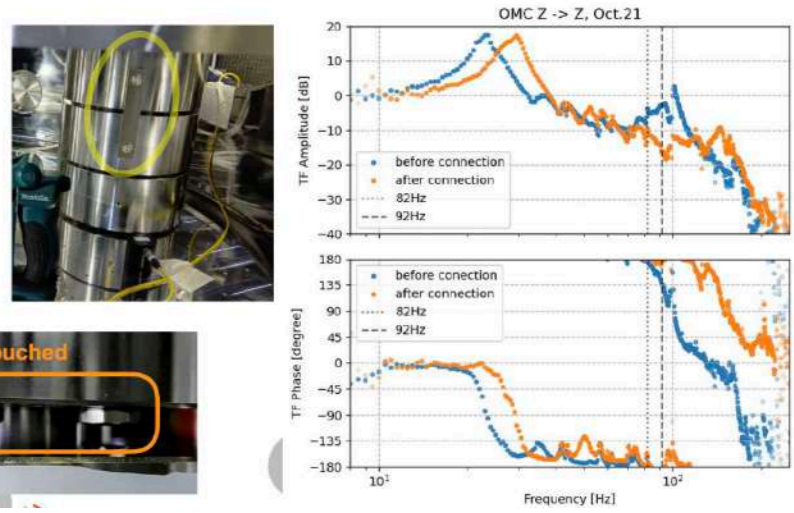


- In the noise budget study for the past observation run, there were various “acoustic noise” in the GW frequency range (100 - 400 Hz)
 - We hunted noise path for each acoustic noise, new acoustic noise appeared with improving the sensitivity

- O4a (May. 2023), vibration at OMC area

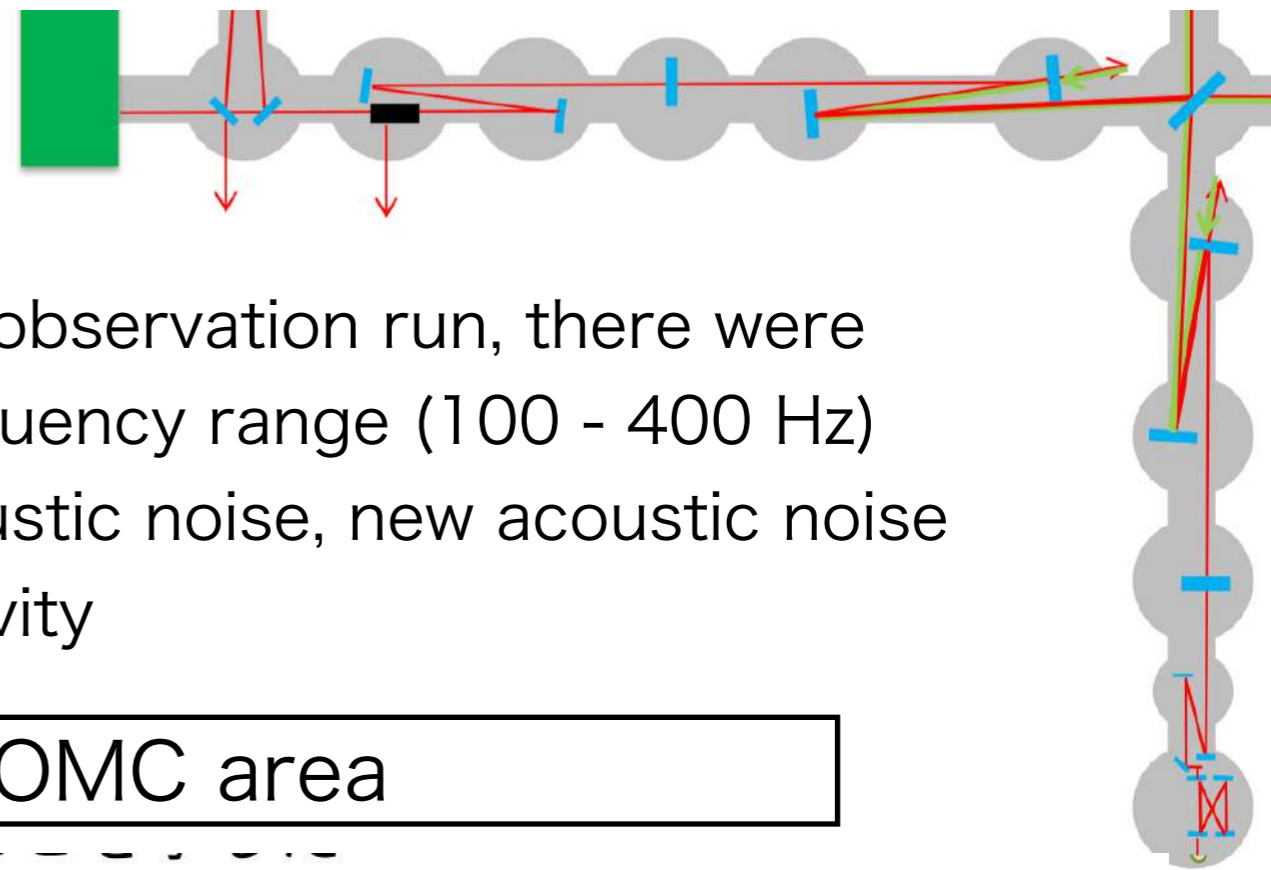


- Performance by the stack damping was significant better by this work!



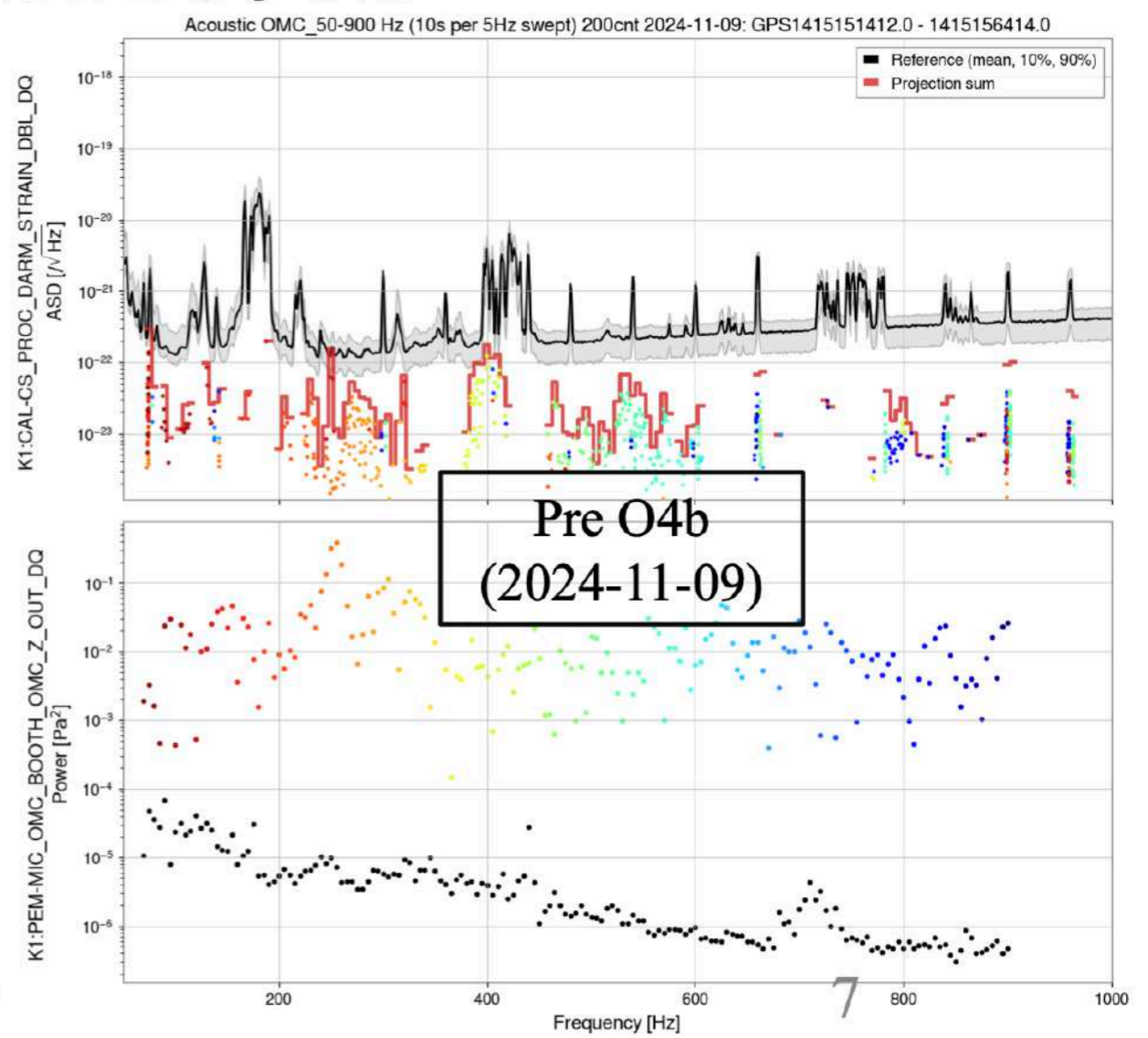
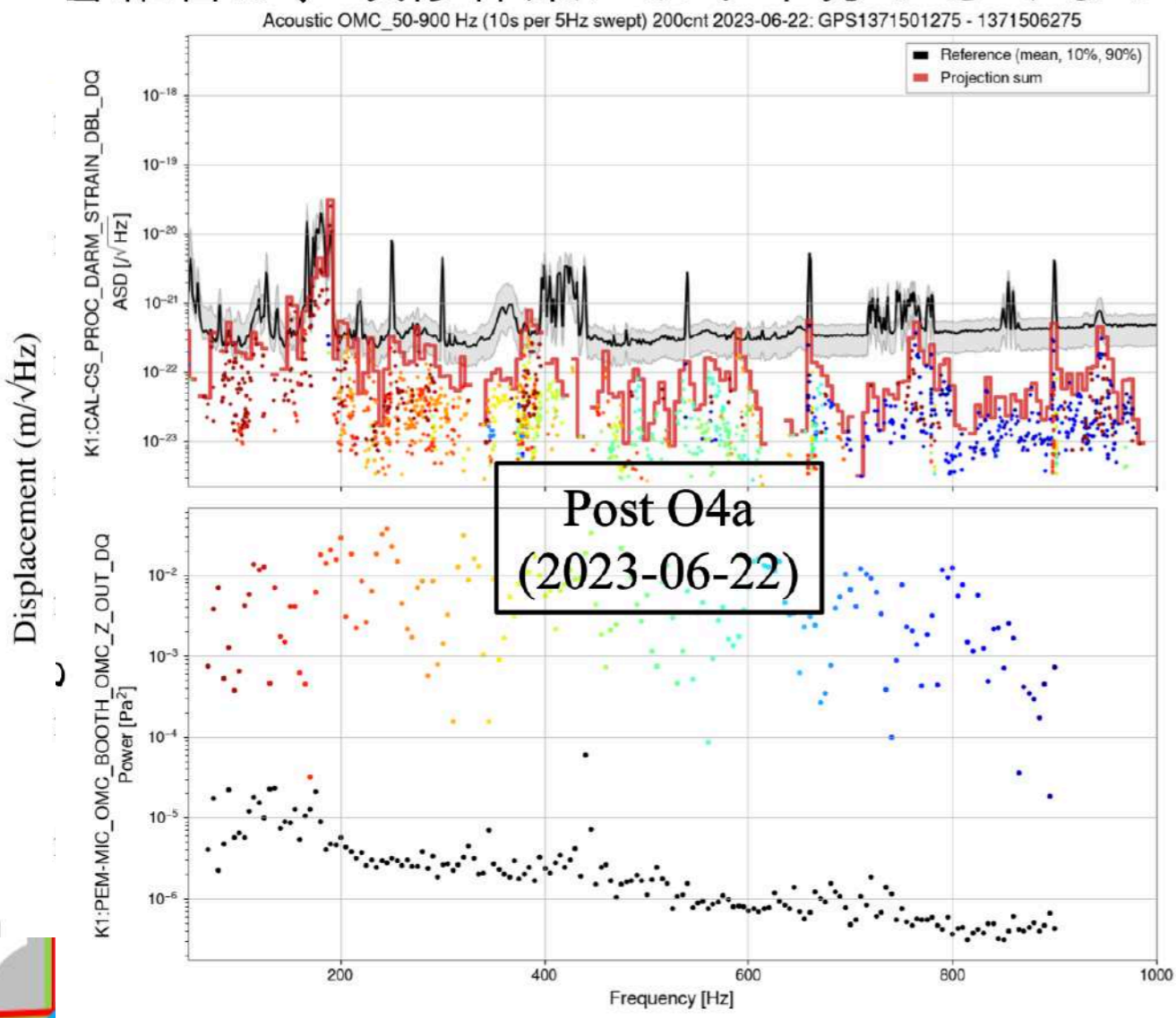


Environmental noise hunting



- In the noise budget study for the past observation run, there were various “acoustic noise” in the GW frequency range (100 - 400 Hz)
 - We hunted noise path for each acoustic noise, new acoustic noise appeared with improving the sensitivity

- O4a (May. 2023), vibration at OMC area

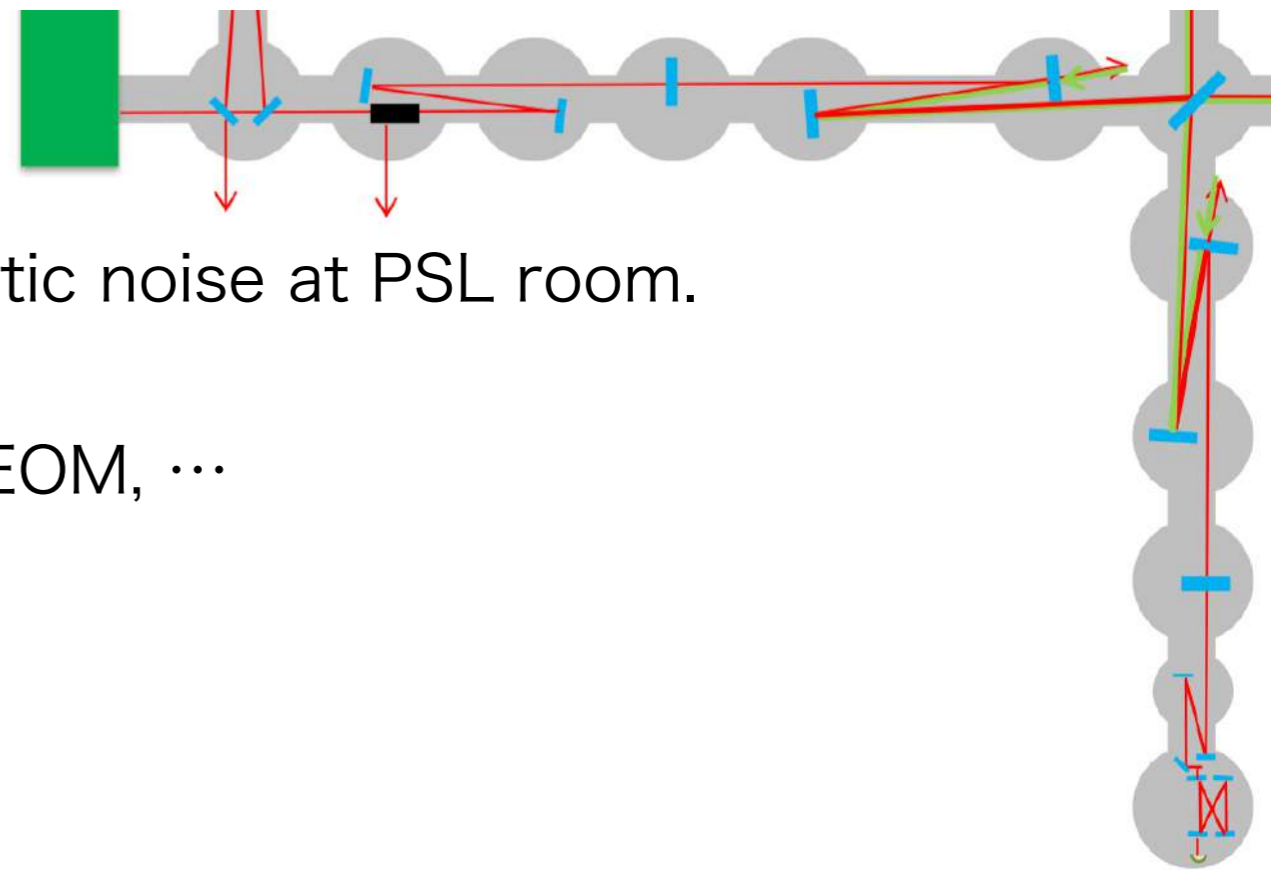


ping
ork!

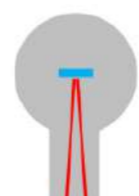
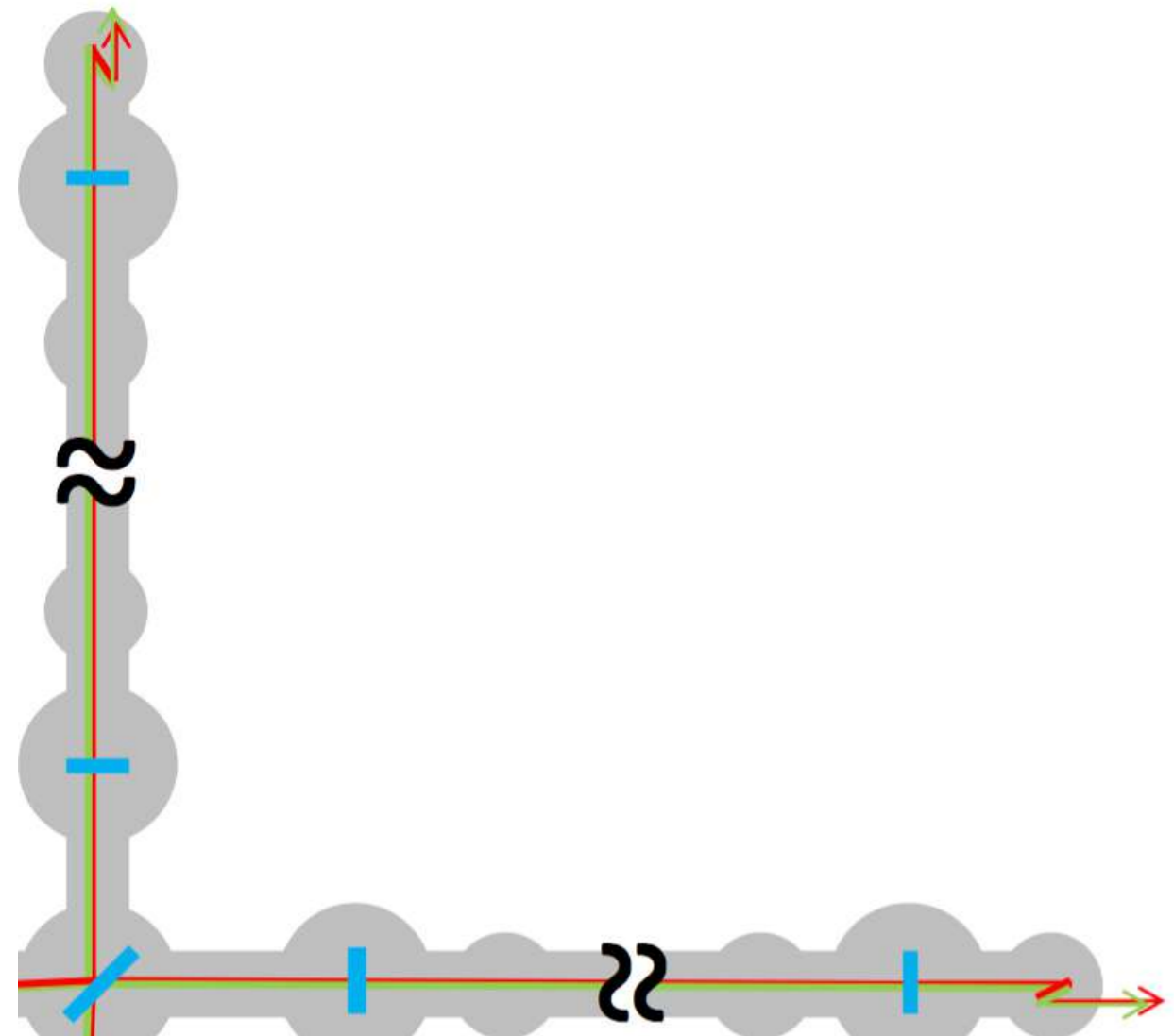




PSL room noise hunting

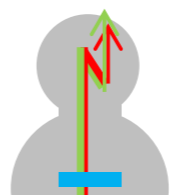


- Next target : Investigation of the acoustic noise at PSL room.
 - PSL : Pre-Stabilized Laser room
 - Master laser, Pre Mode Cleaner, EOM, ...

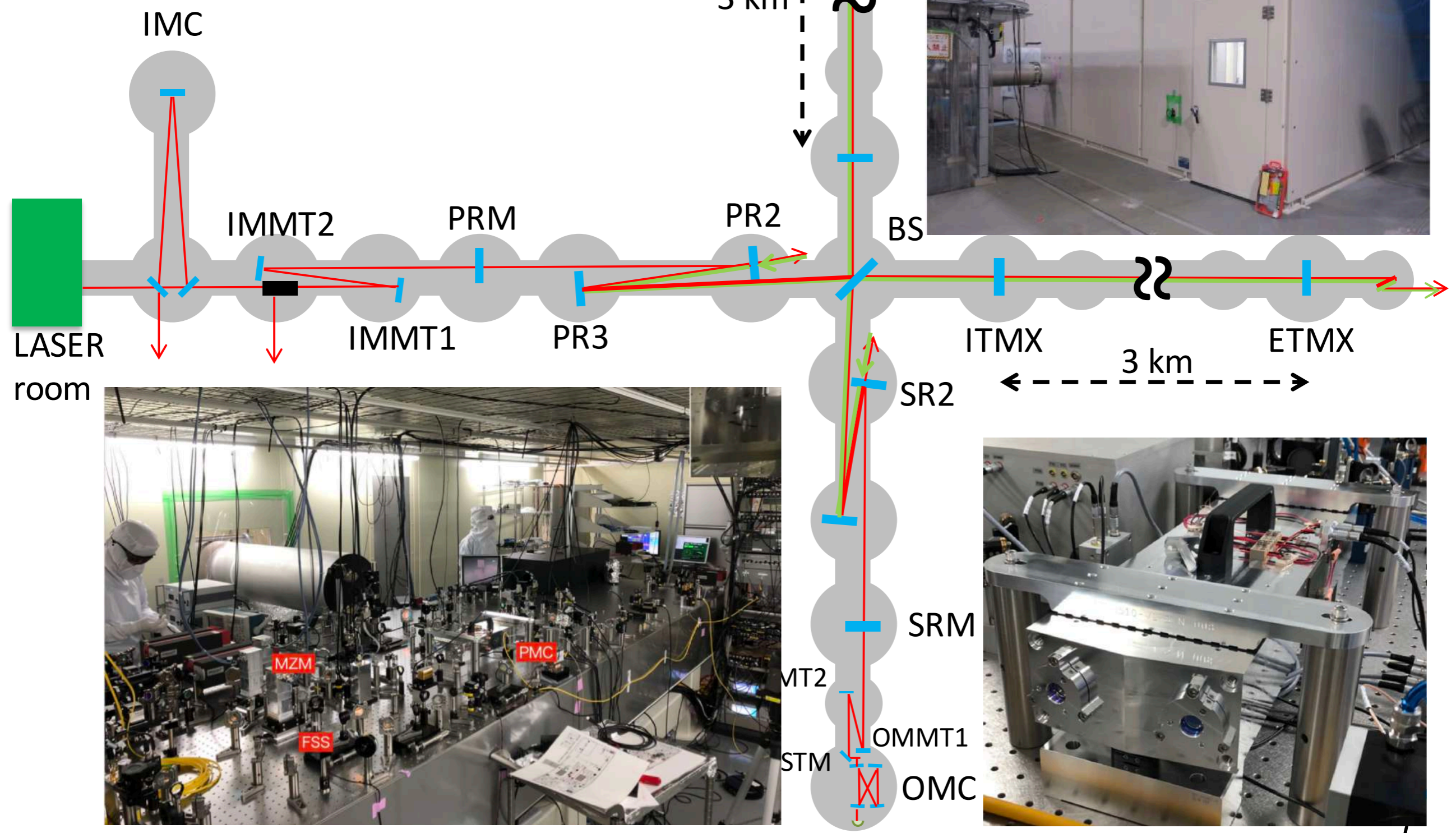




PSL room noise hunting

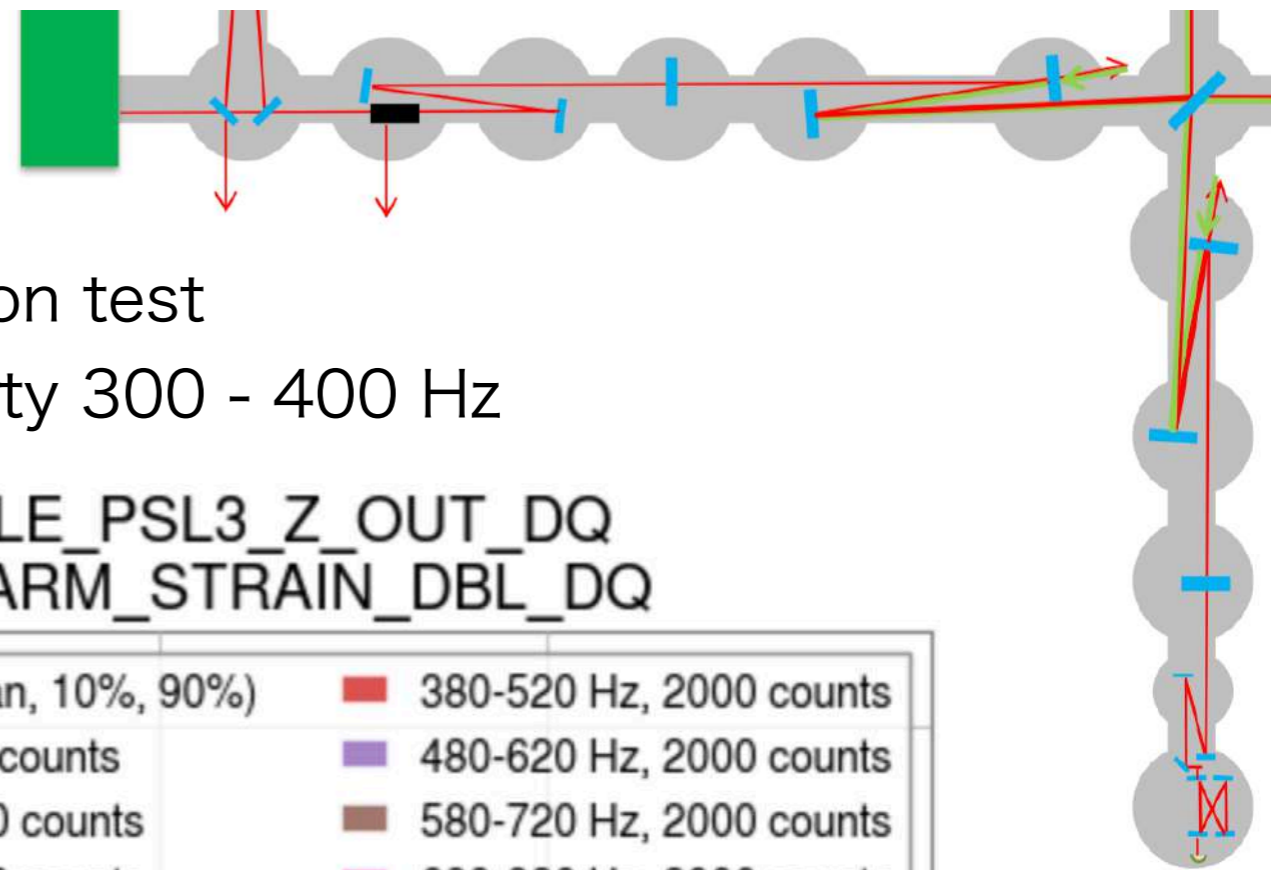


- Next target : Investigation of the acoustic noise at PSL room.
- PSL : Pre-Stabilized Laser room
 - Master laser, Pre Mode Cleaner, EOM, ...



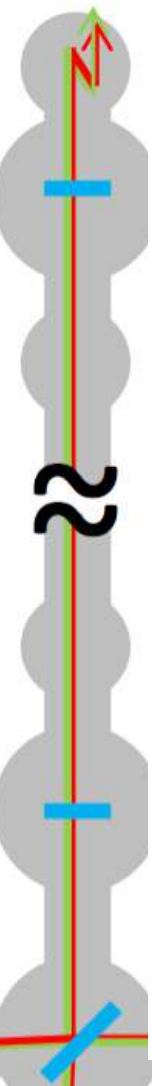
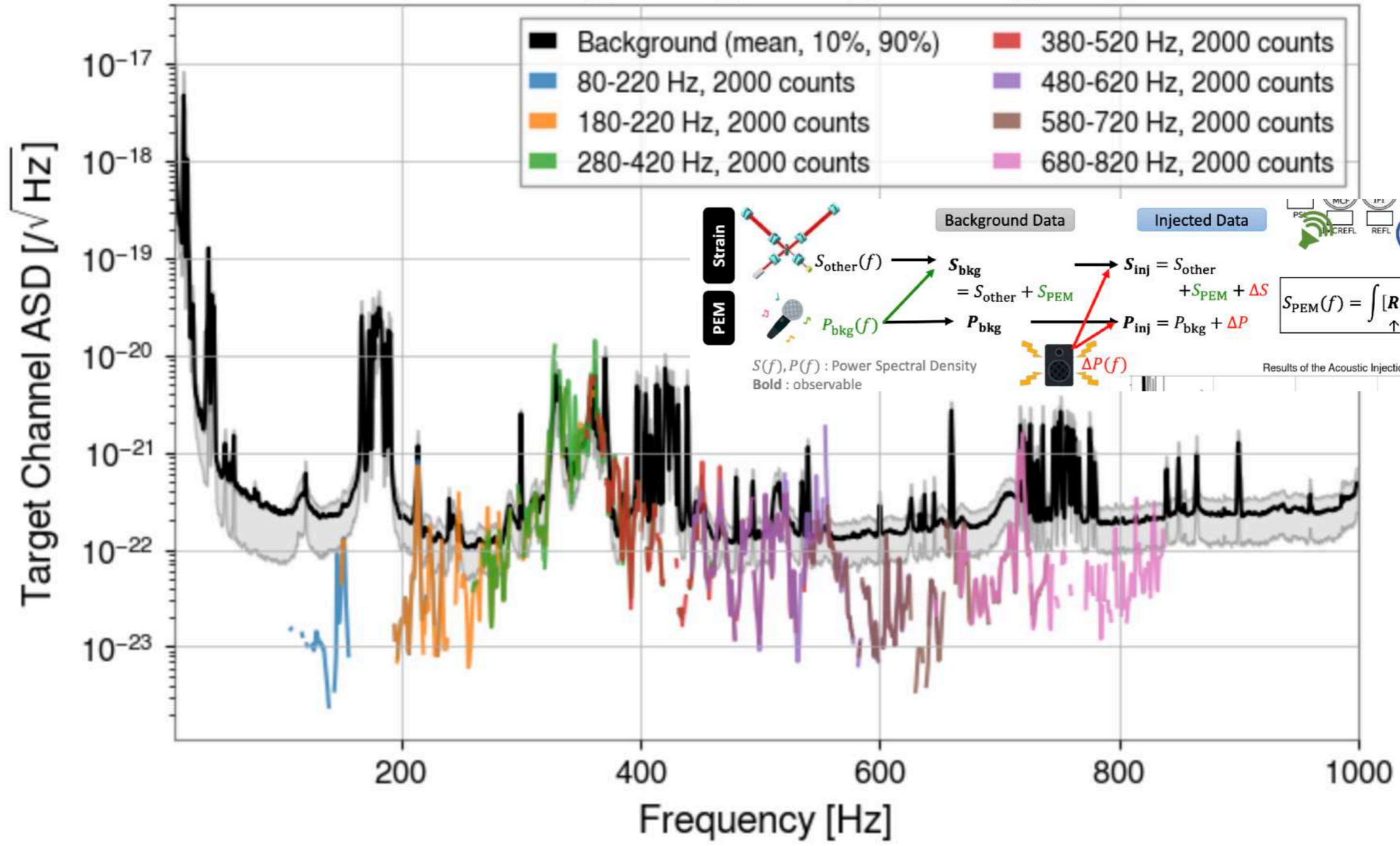


Acoustic noise PSL room



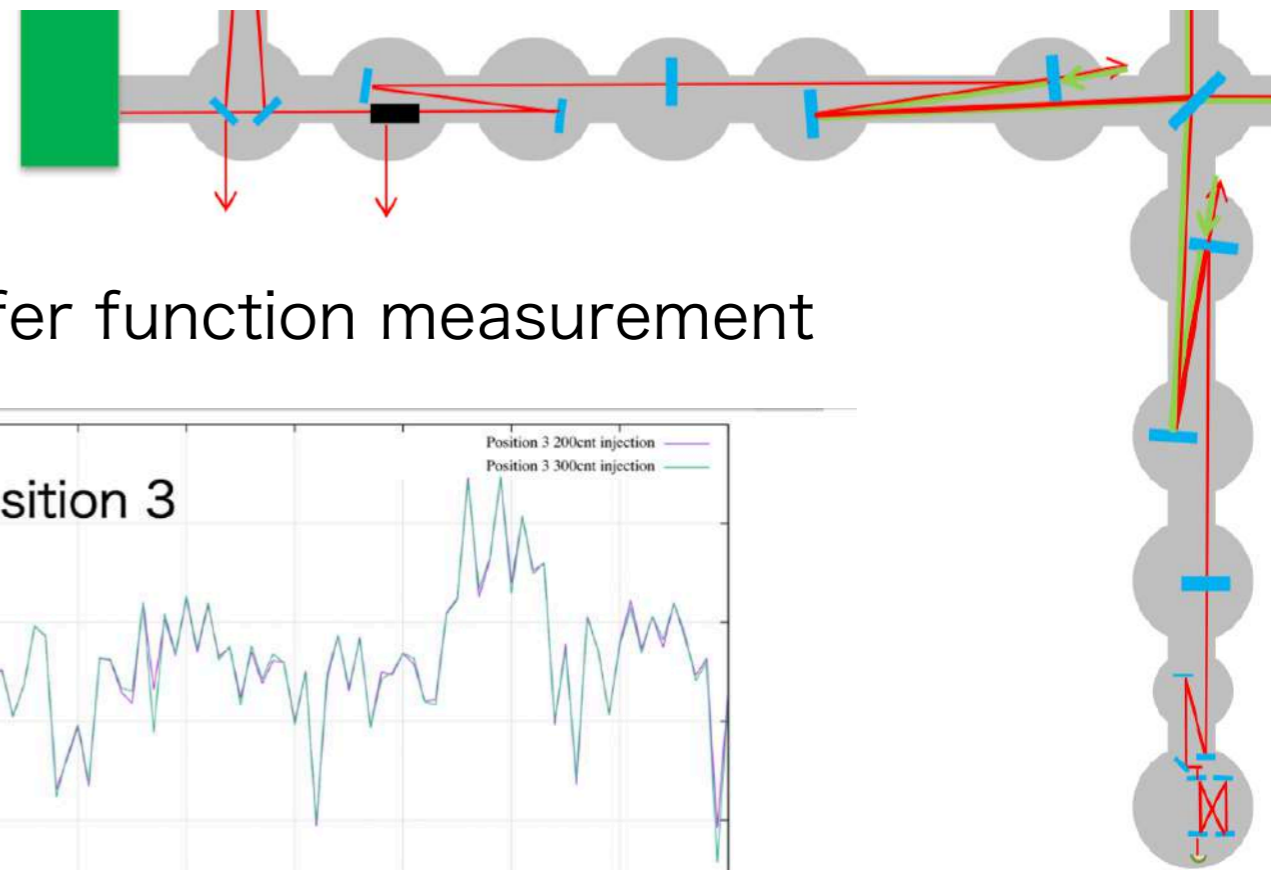
- Noise projection by the acoustic injection test
 - 30th Jan., 2026, limiting the sensitivity 300 - 400 Hz

K1:PEM-MIC_PSL_TABLE_PSL3_Z_OUT_DQ
 -> K1:CAL-CS_PROC_DARM_STRAIN_DBL_DQ

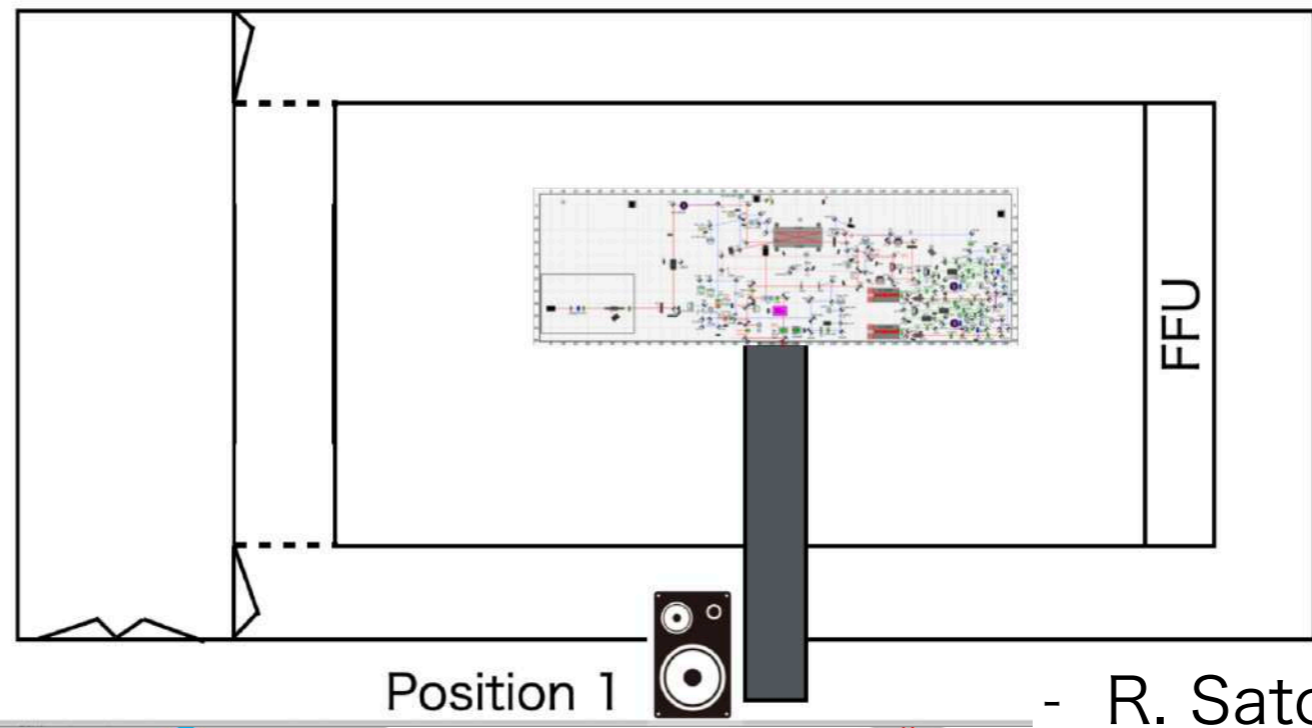
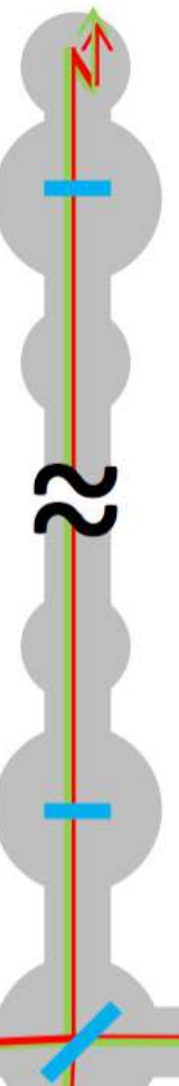
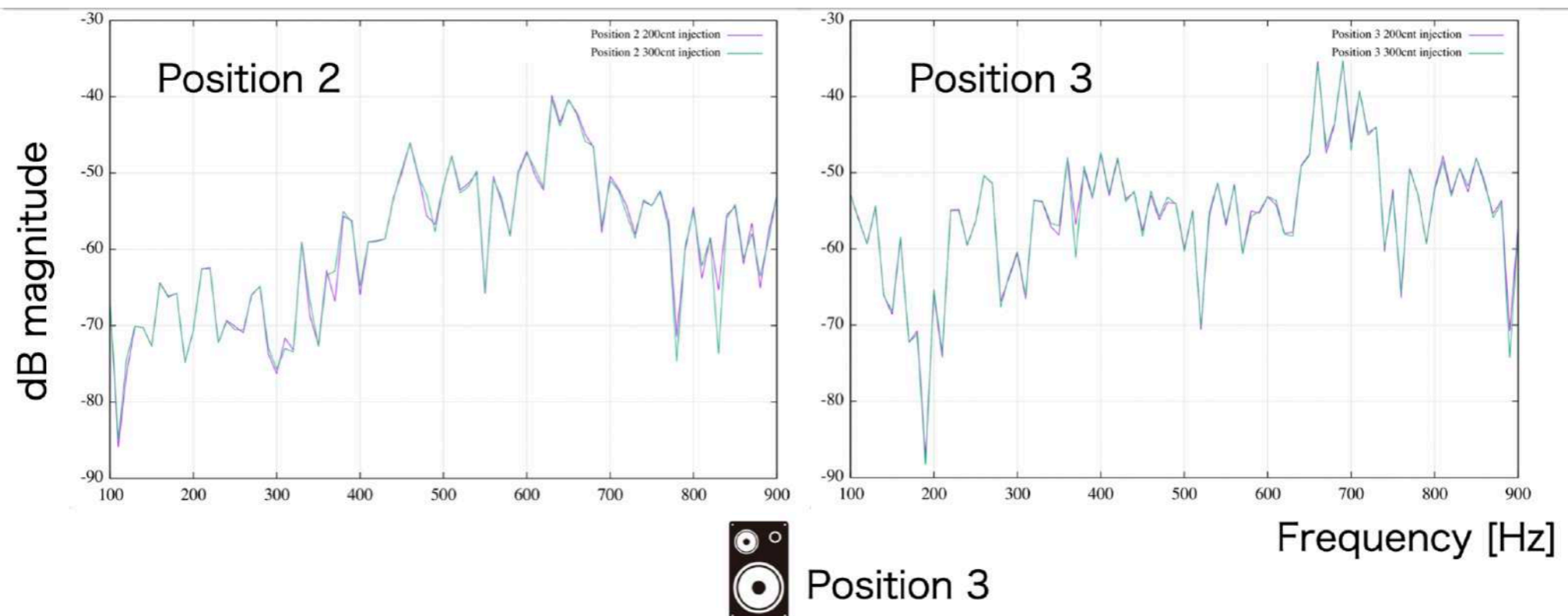




Past studies for PSL room



- Sound protection from outside : Transfer function measurement

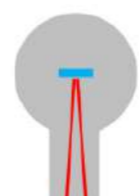
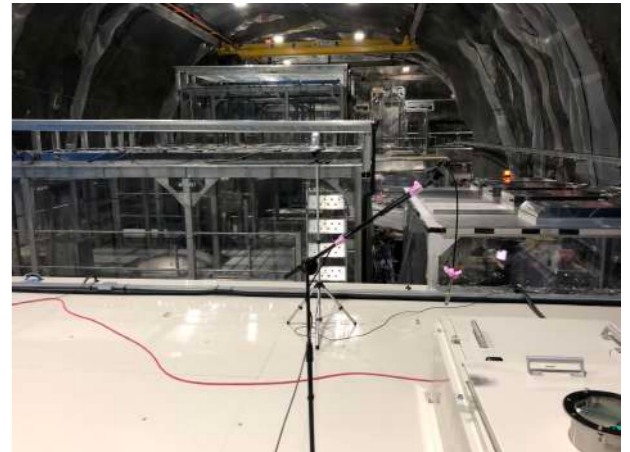
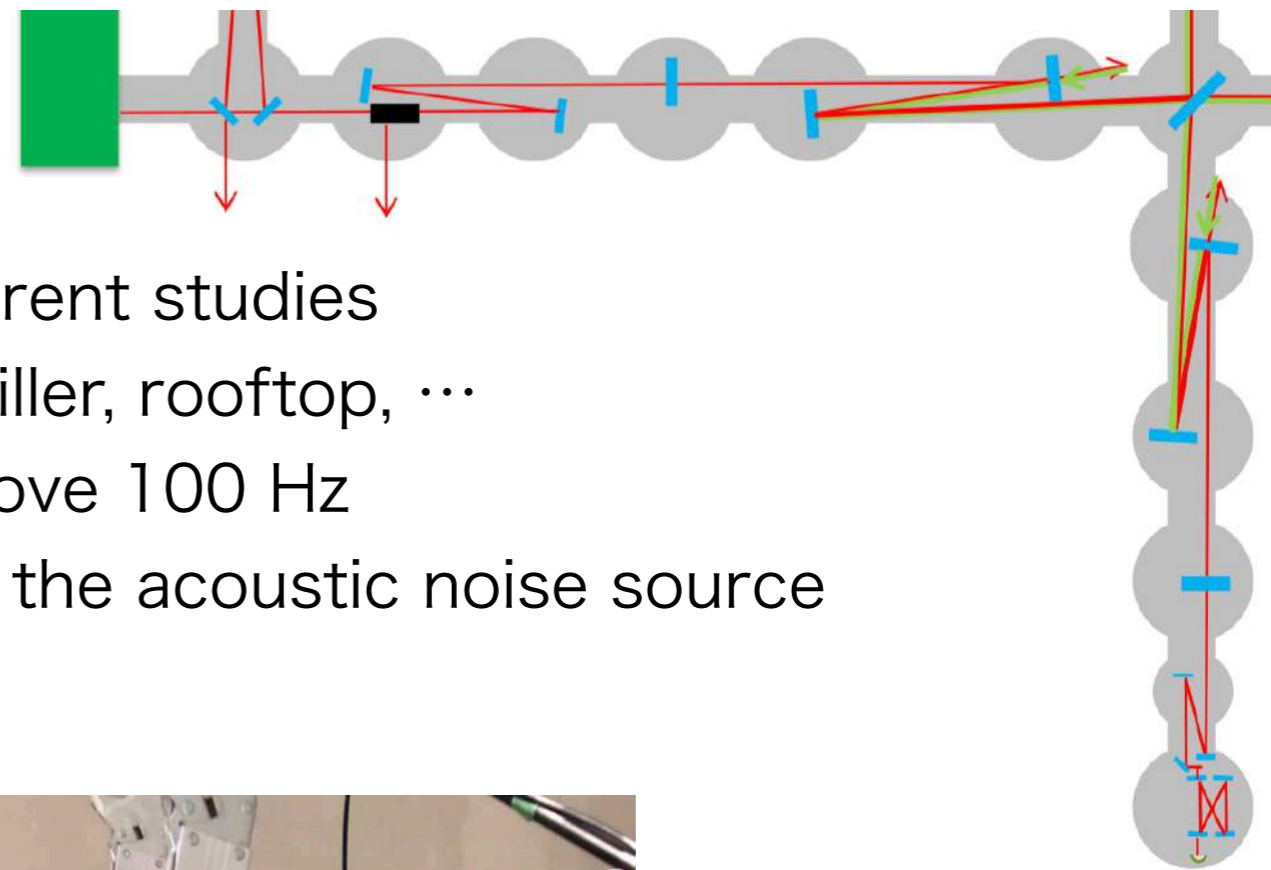


- R. Sato (Niigata U)



Past studies for PSL room

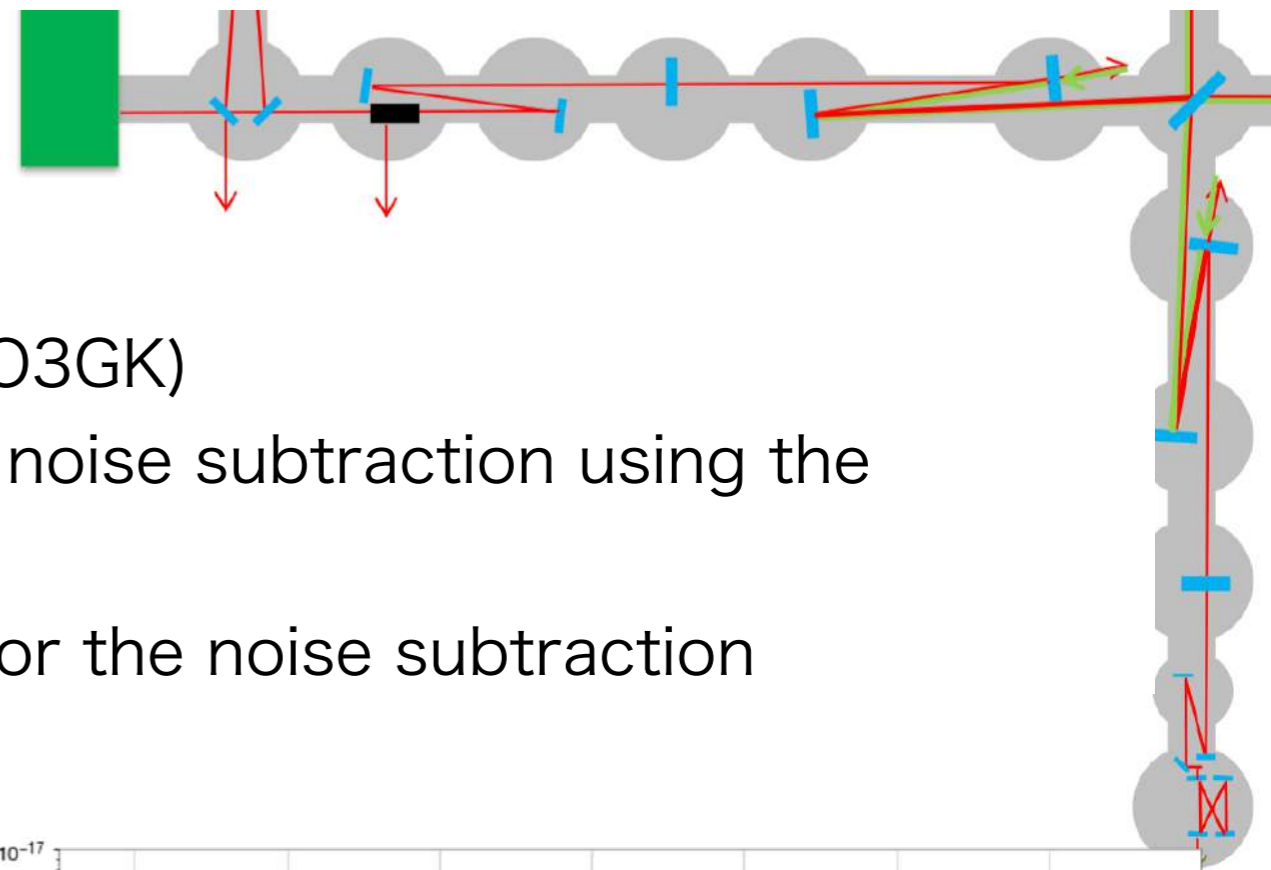
- Sound protection from outside : Coherent studies
 - Near the precision cooler, water chiller, rooftop, ...
- No significant coherence detected above 100 Hz
- So, it would be difficult to explain that the acoustic noise source come from outside of the PSL room



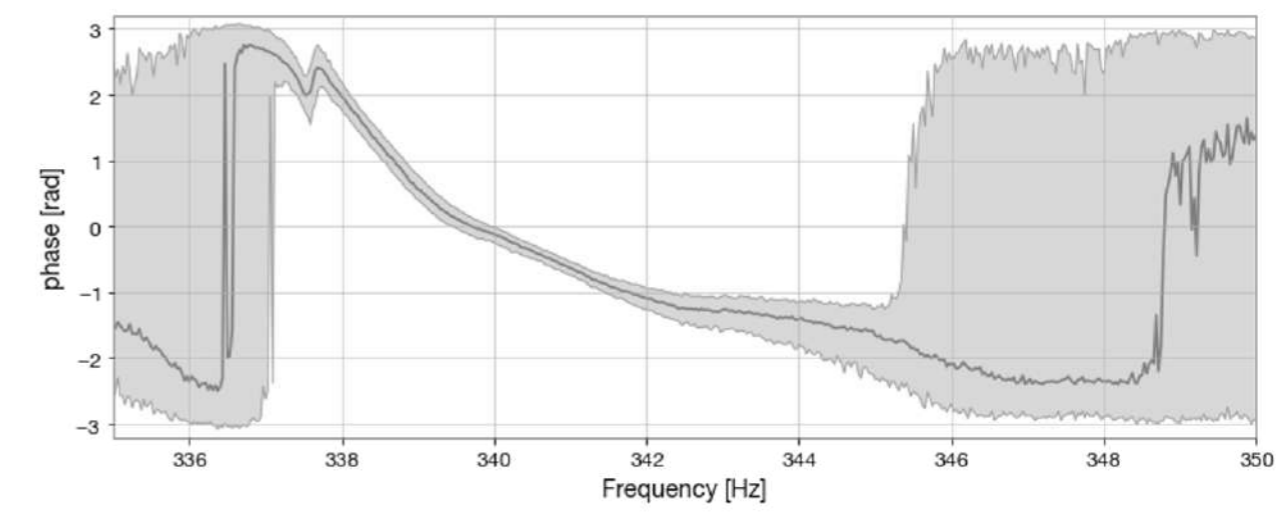
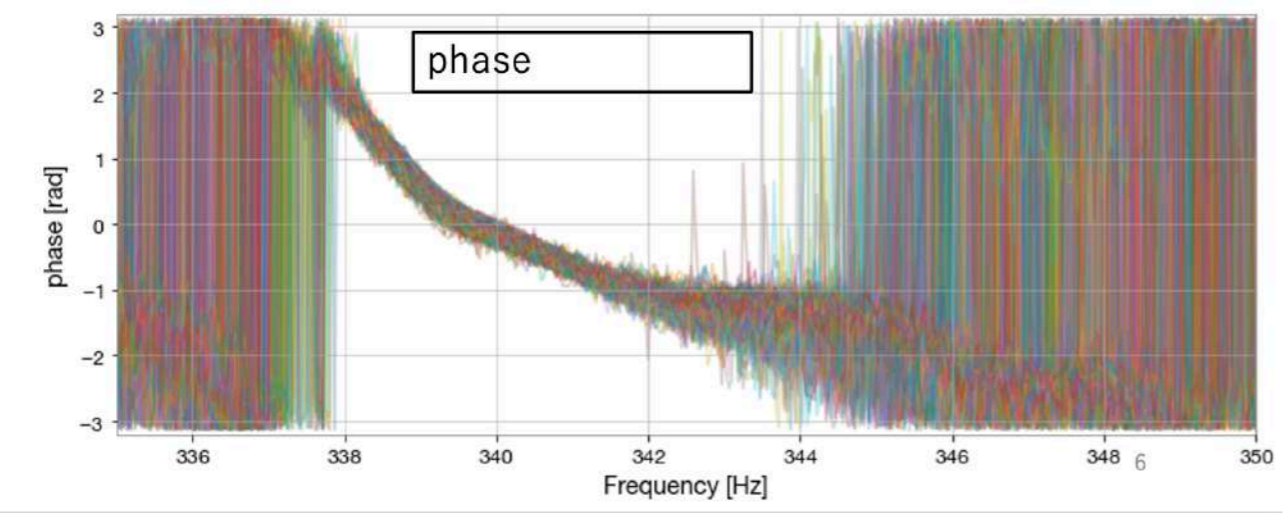
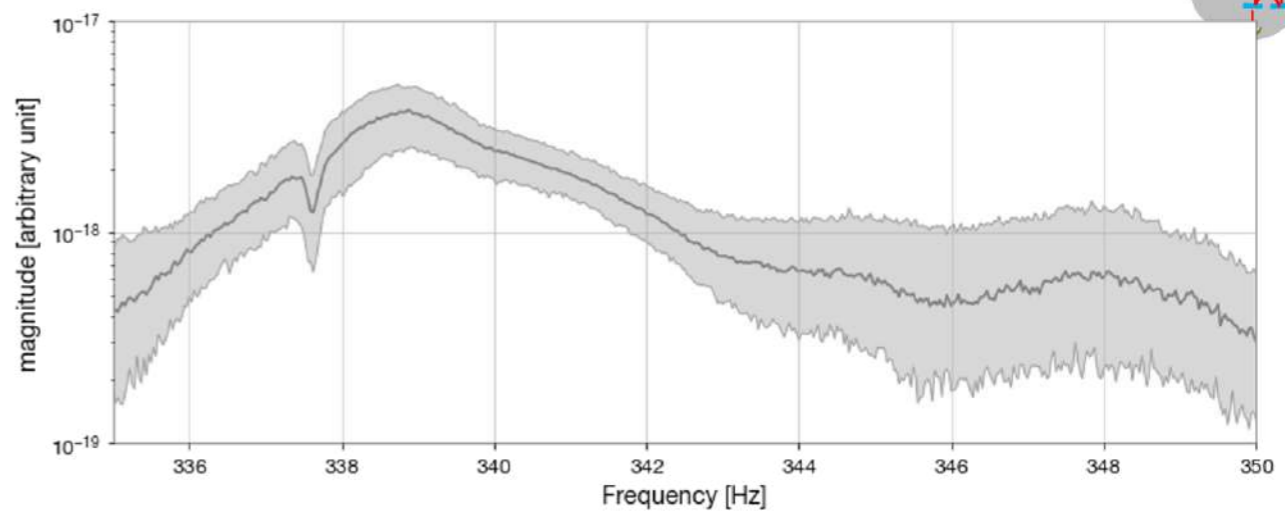
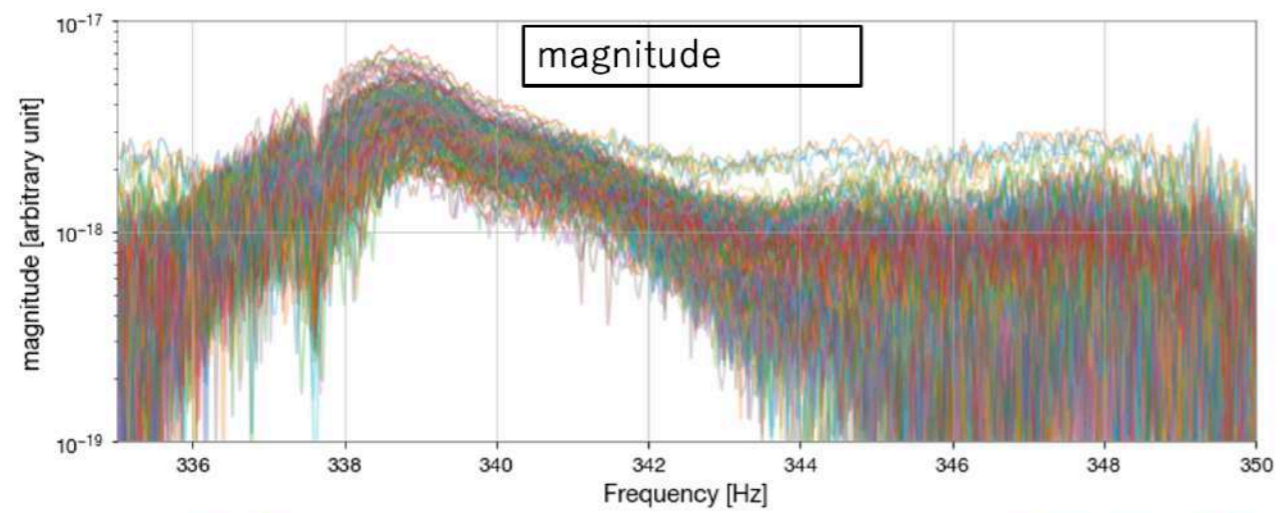
- H. Yuzurihara



Past studies for PSL room

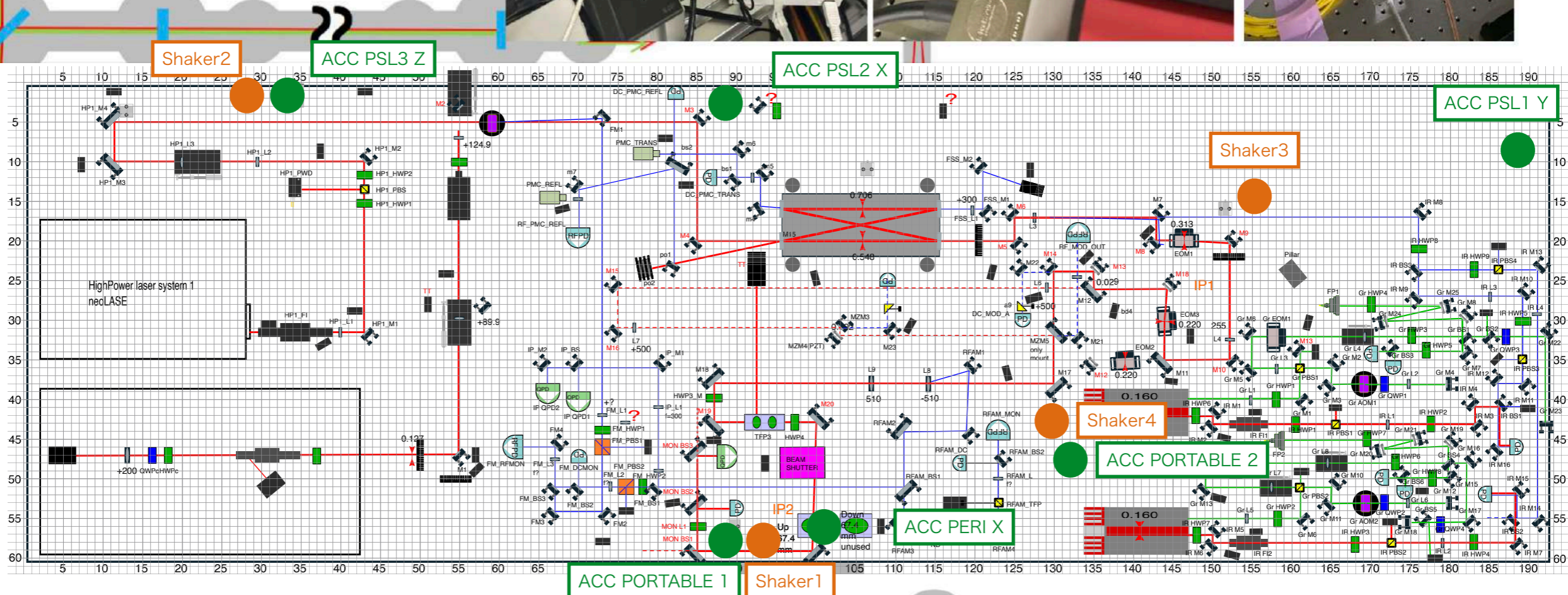
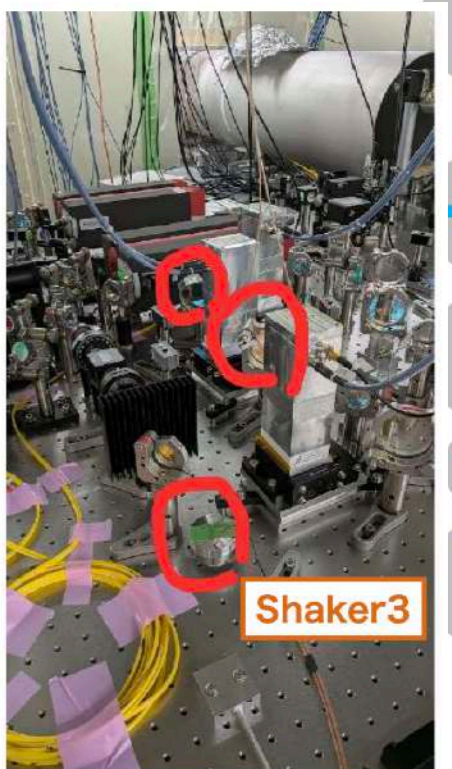
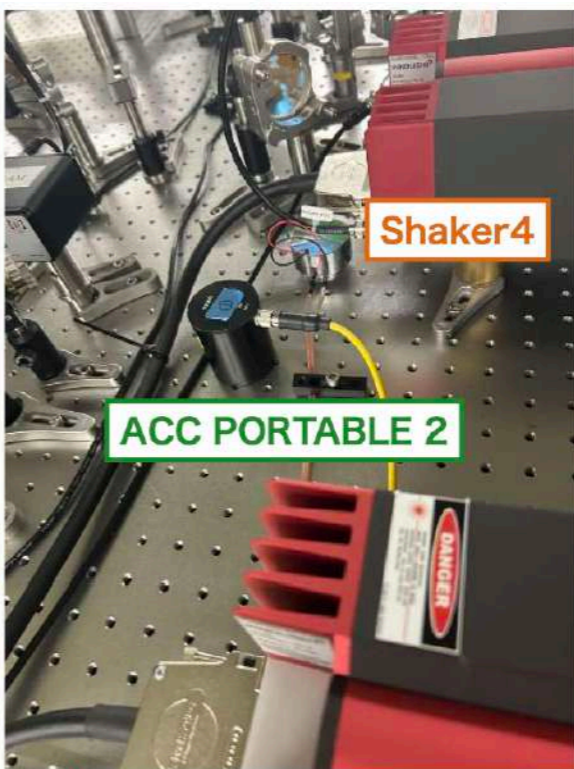
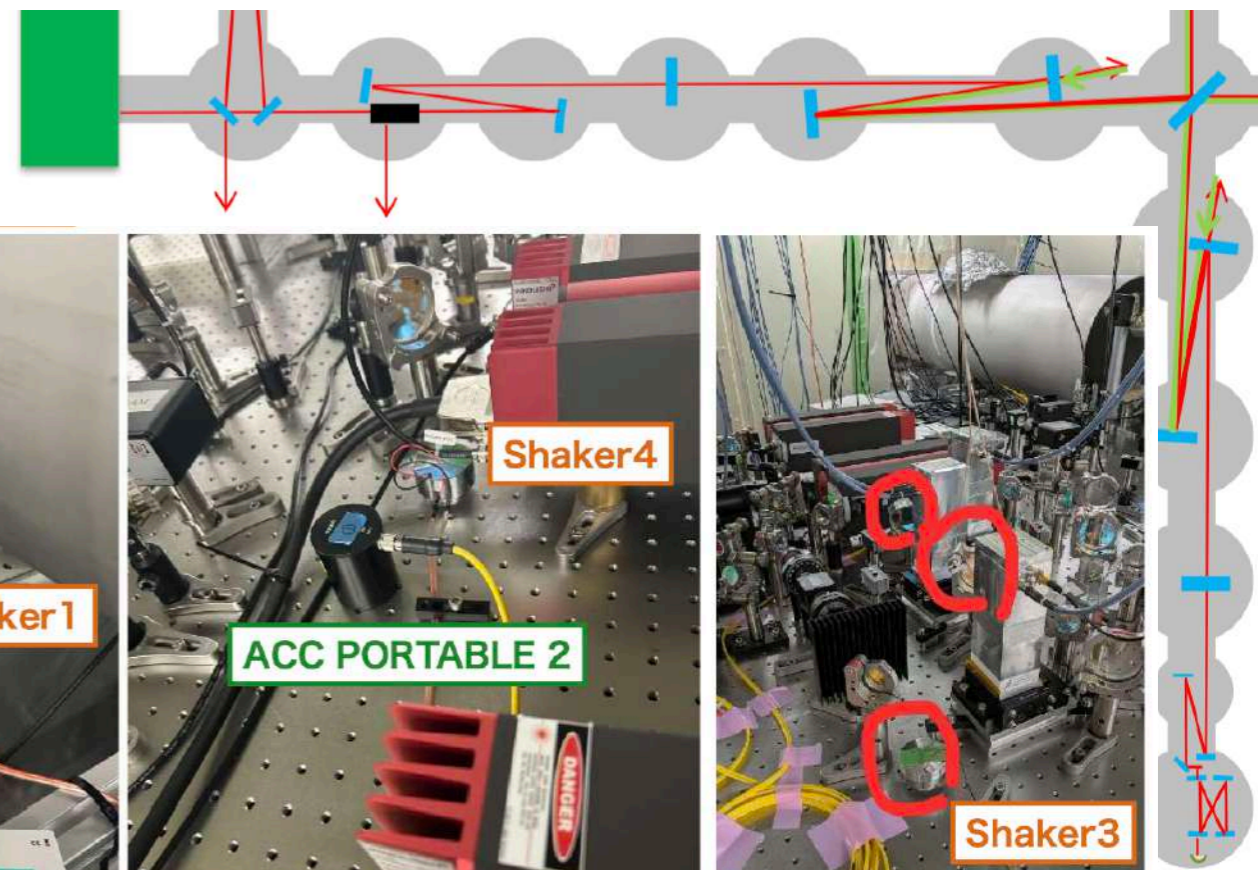


- Transfer function variation to DARM (O3GK)
 - To investigate the possibility of the noise subtraction using the auxiliary channel (microphone)
 - Independent Component Analysis for the noise subtraction



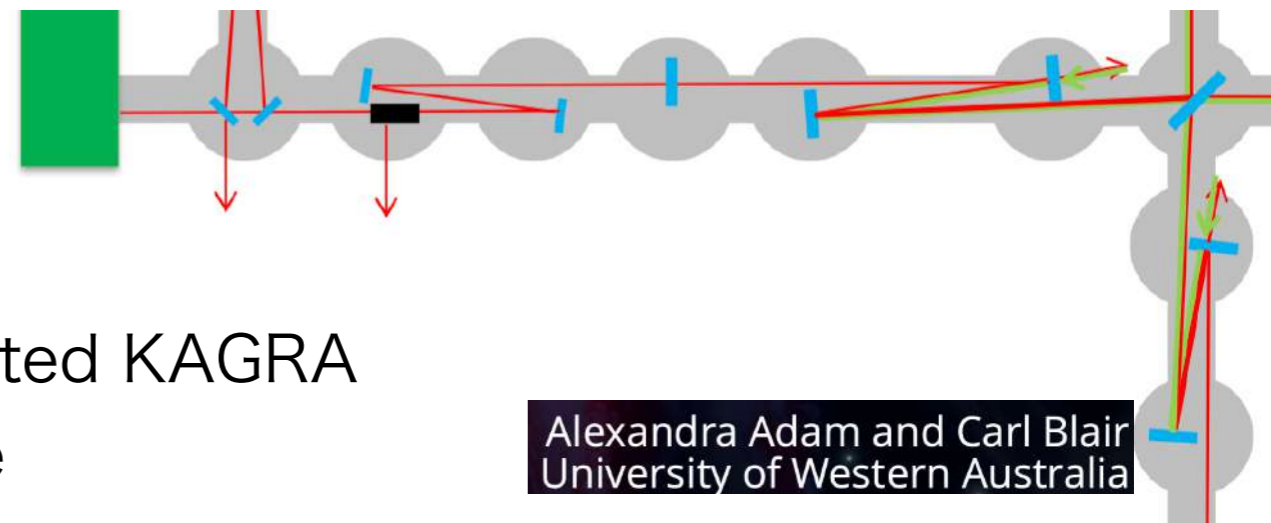


Shaker injection test PSL room



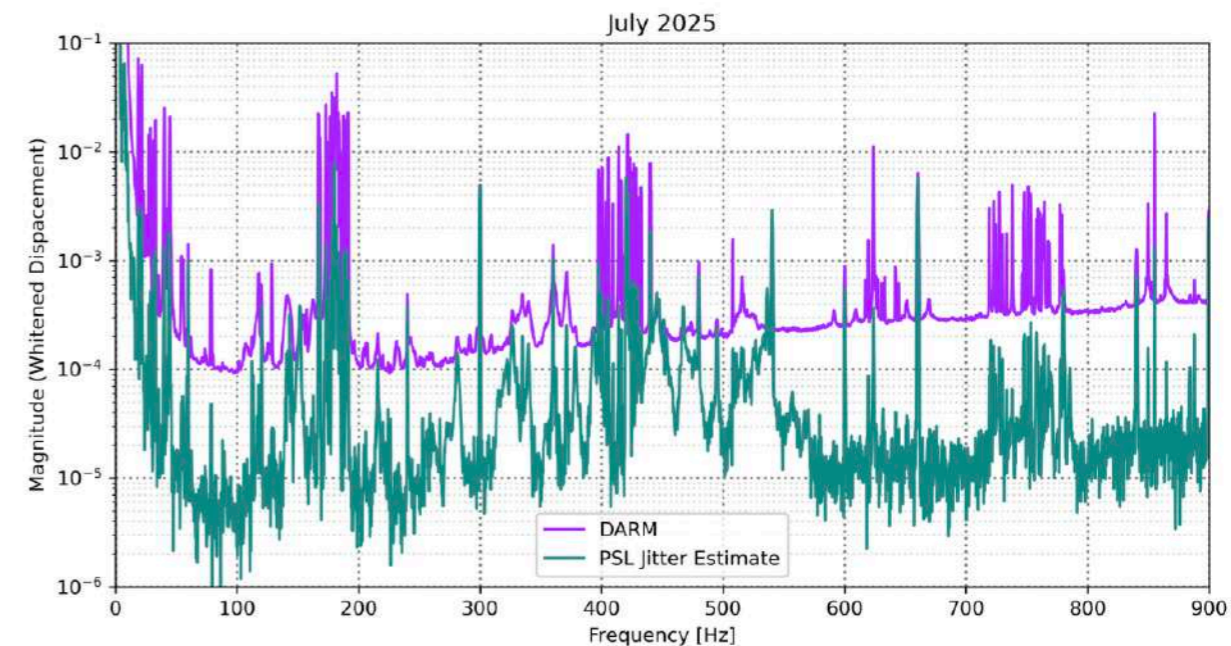
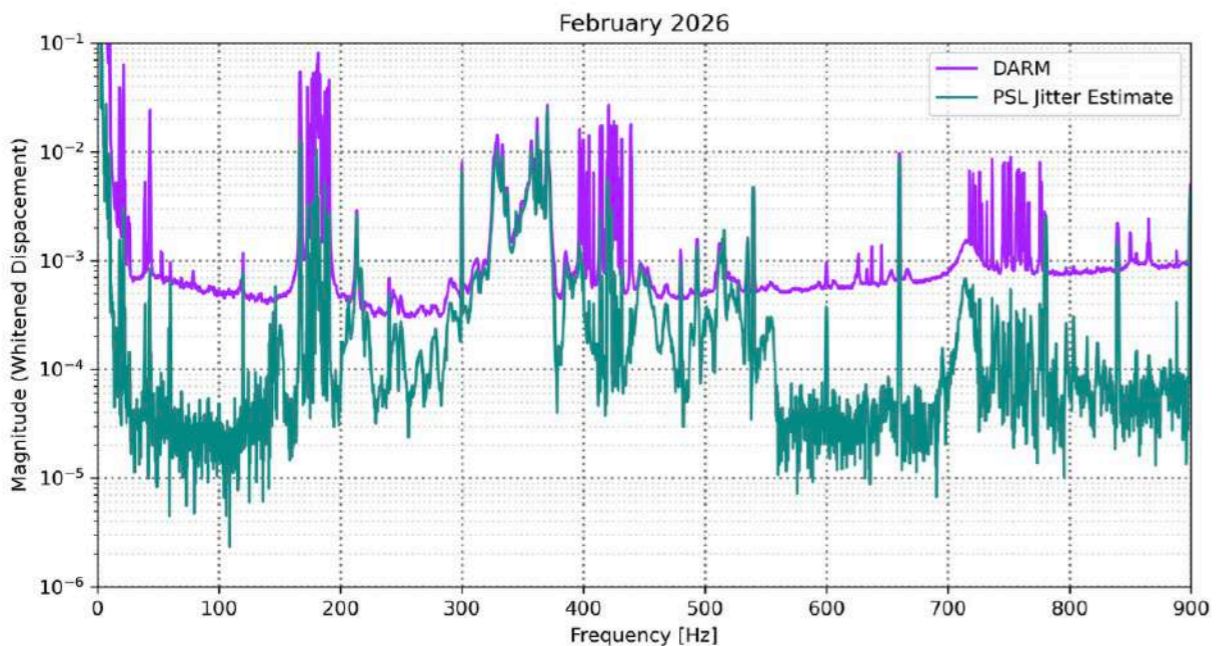
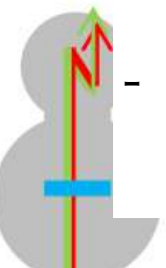


Beam jitter noise investigation



- Feb. - Mar., 2026, OzGrav members visited KAGRA site and evaluated the beam jitter noise investigation by the auxiliary channels
- They also described the beam jitter noise increased from July 2025 to February. 2026
 - Jul. 2025 : 10 W, Cryo, fiber laser
 - Feb. 2026 : 5 W, room temp., Neolase laser
- We also performed the shaker injection test and tapping test inside the PSL room.

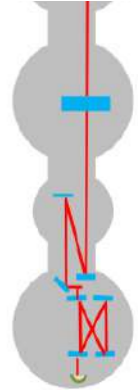
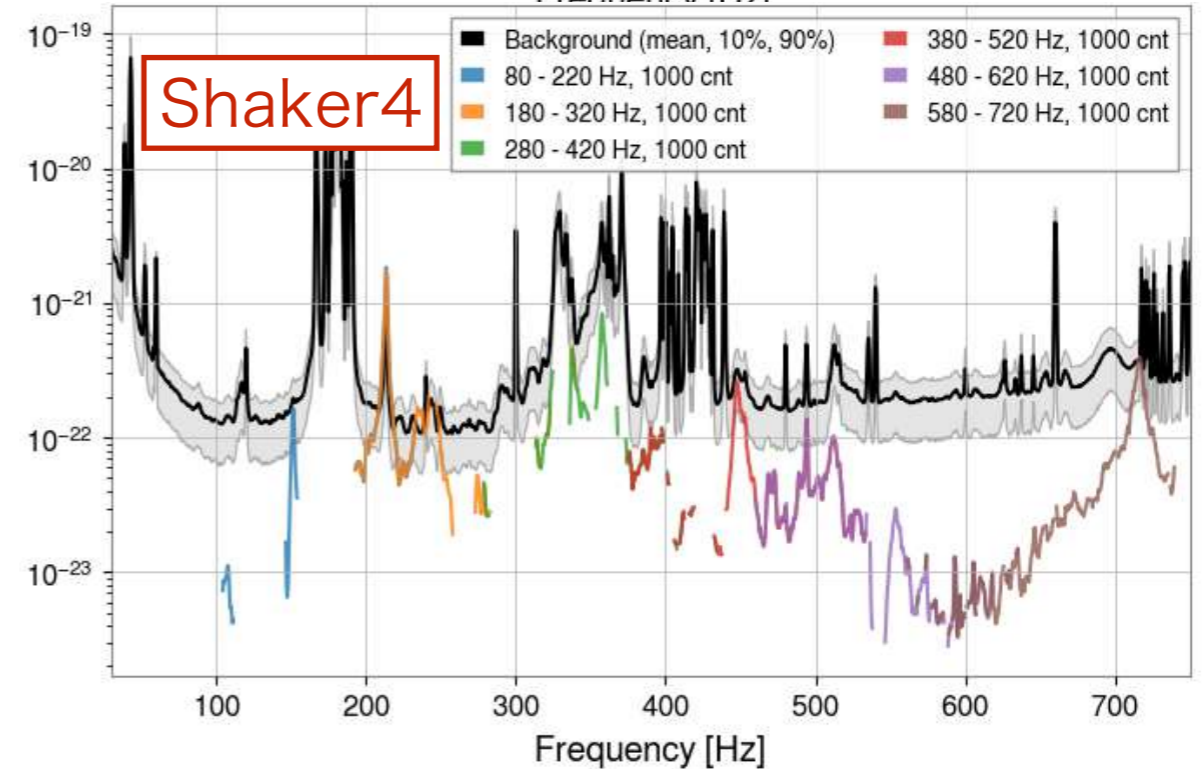
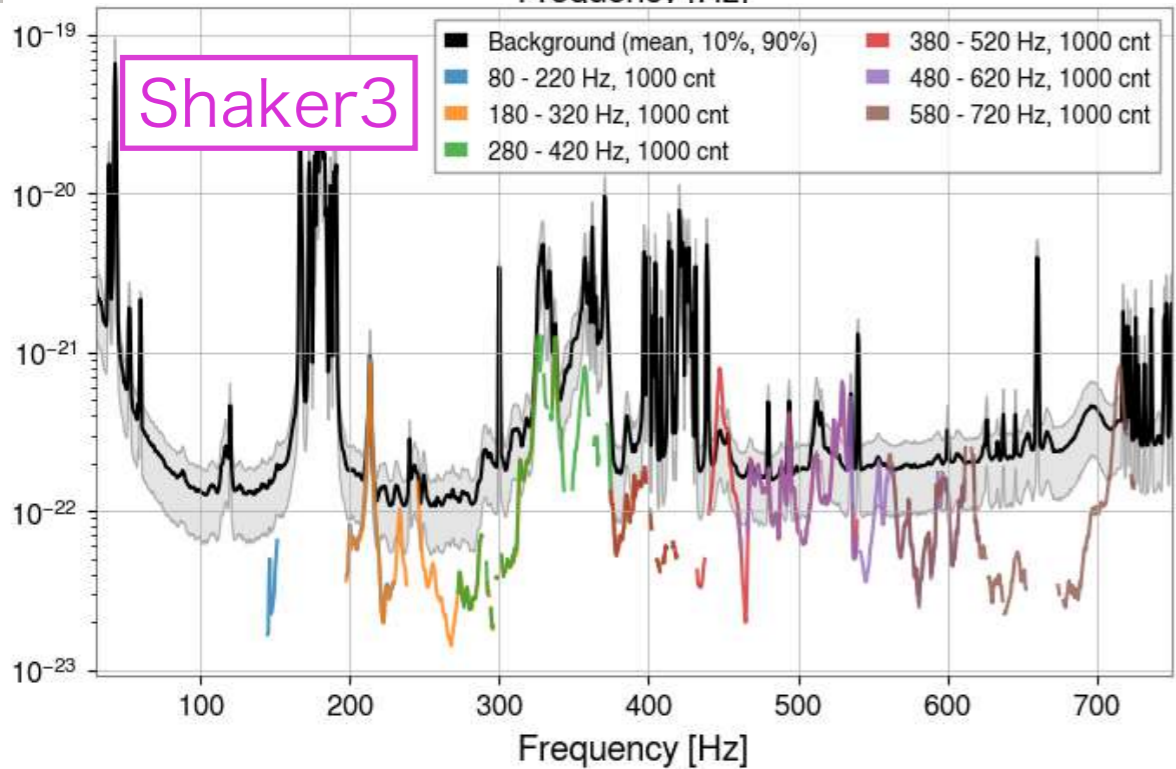
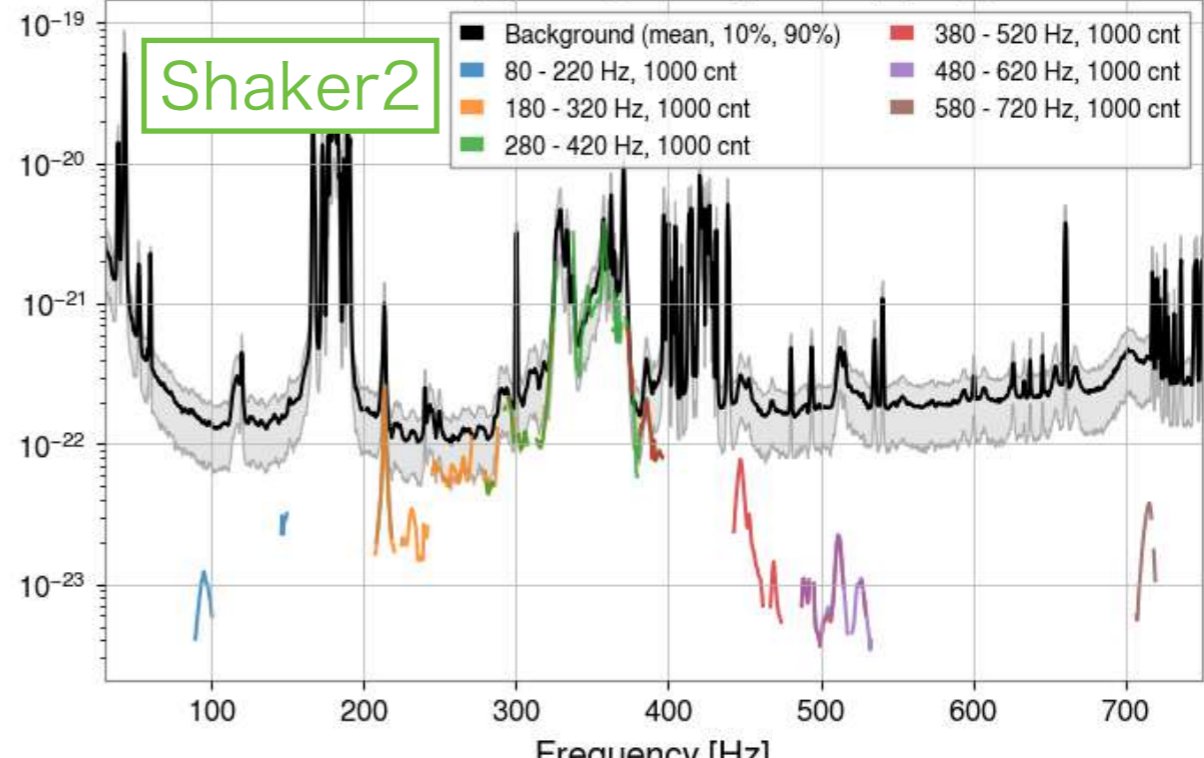
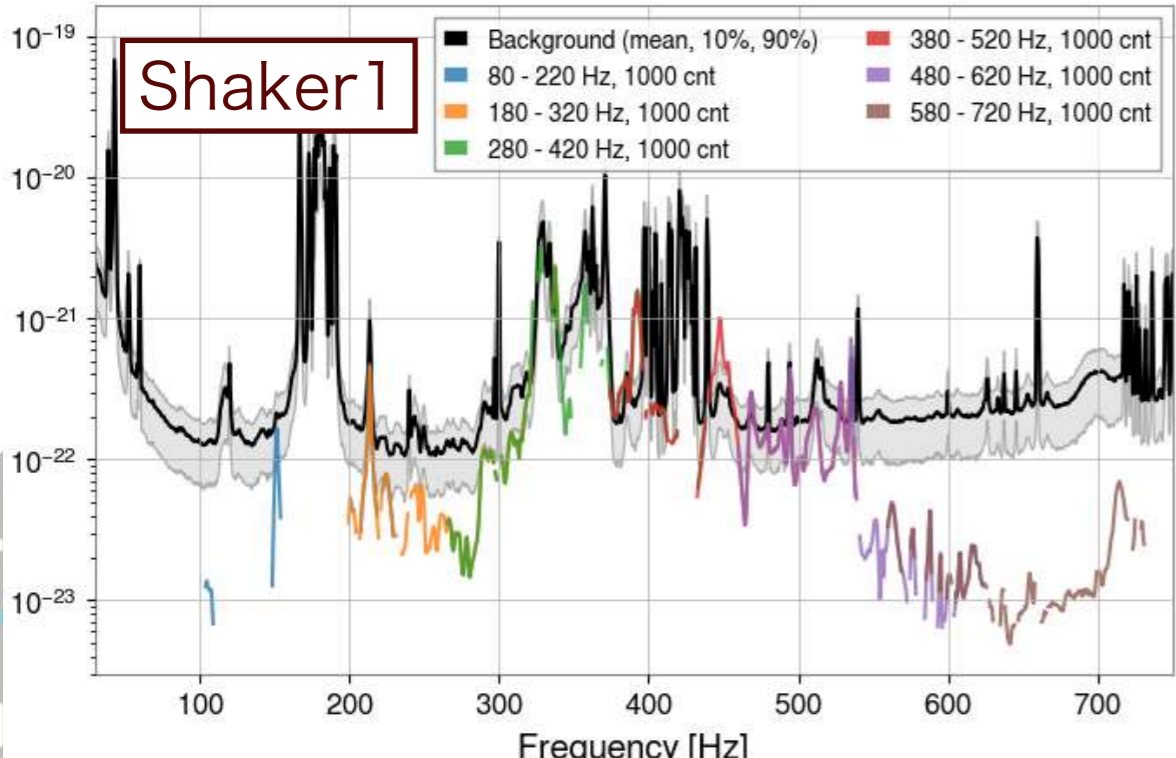
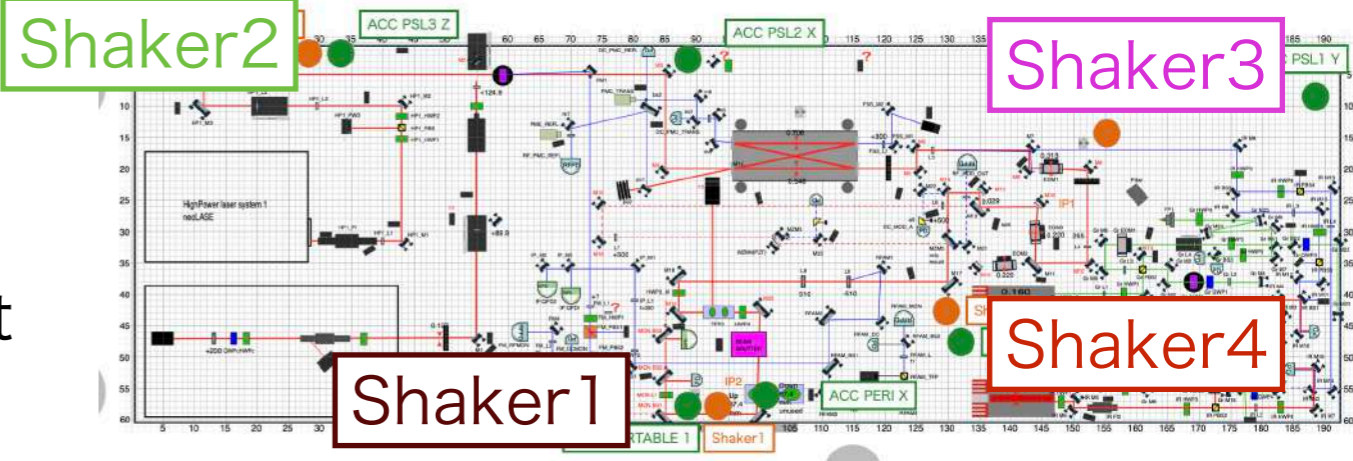
Alexandra Adam and Carl Blair
University of Western Australia





Shaker/tapping PSL room

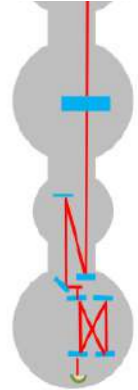
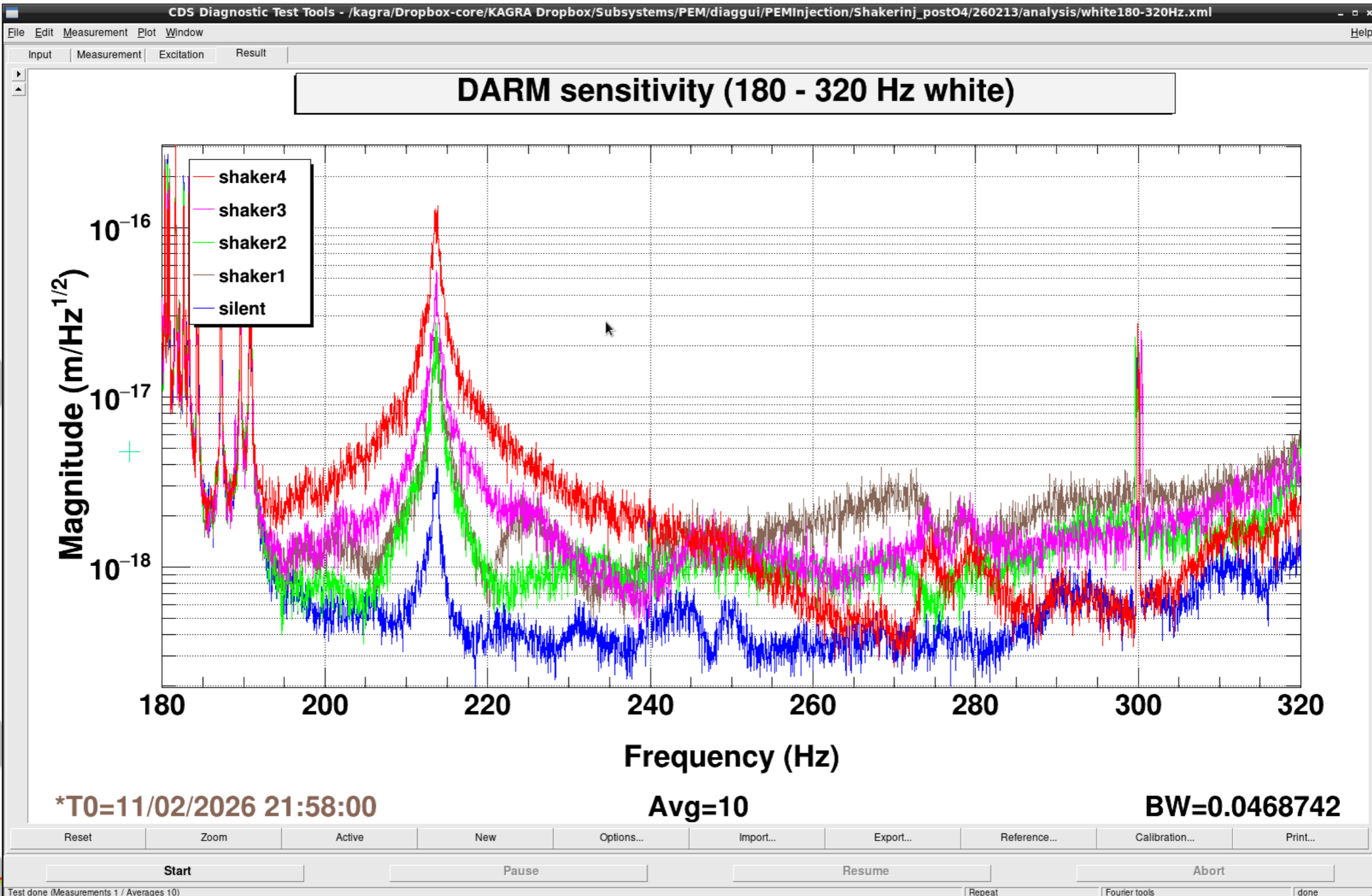
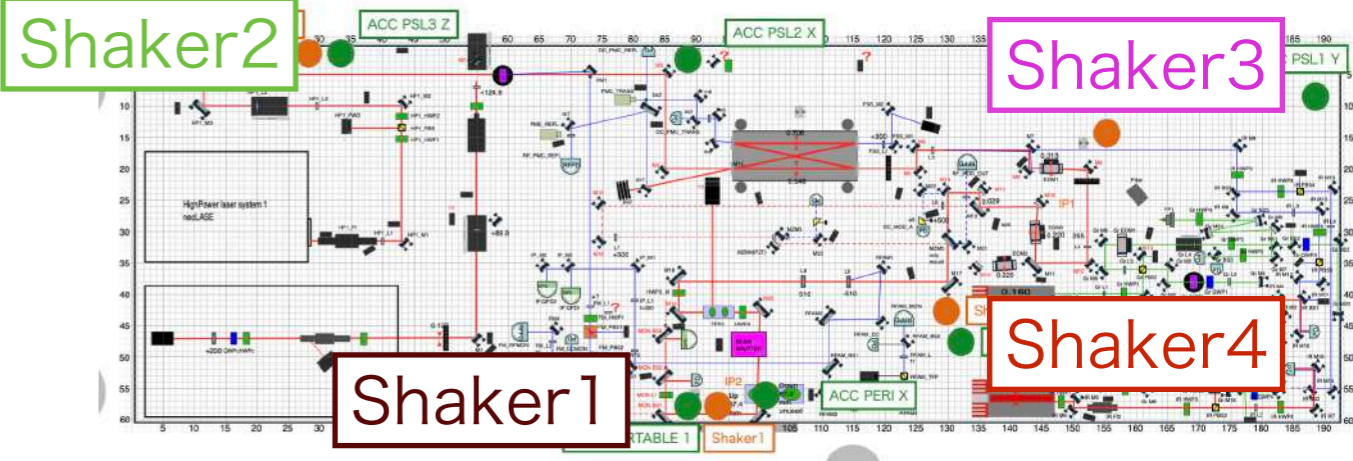
- Noise projection by each shaker test





Shaker/tapping PSL room

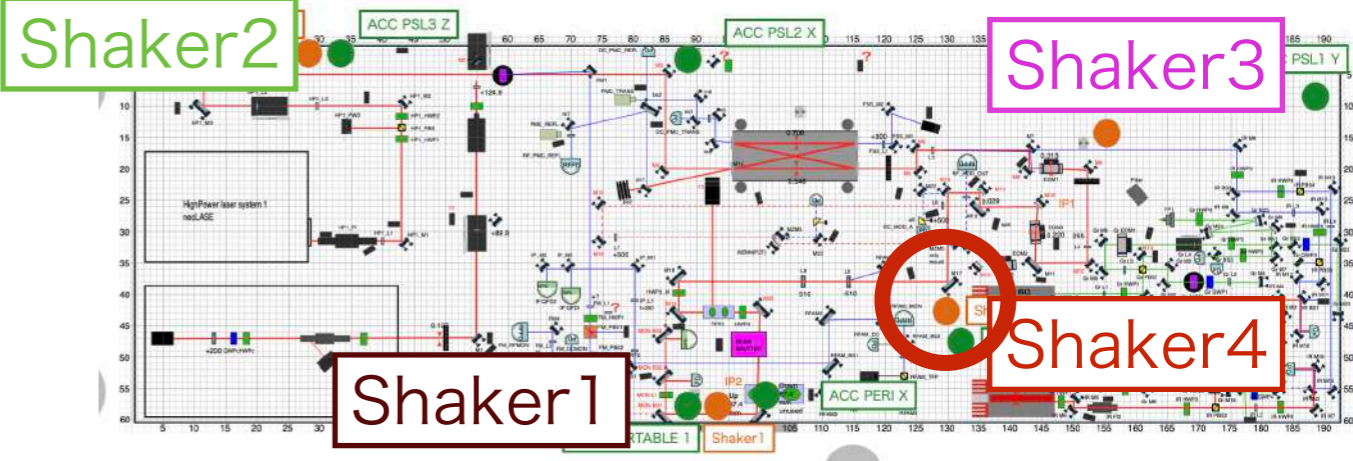
- For the 214 Hz peak, the amplitude
- 4 > 3 > 1 = 2 > silent



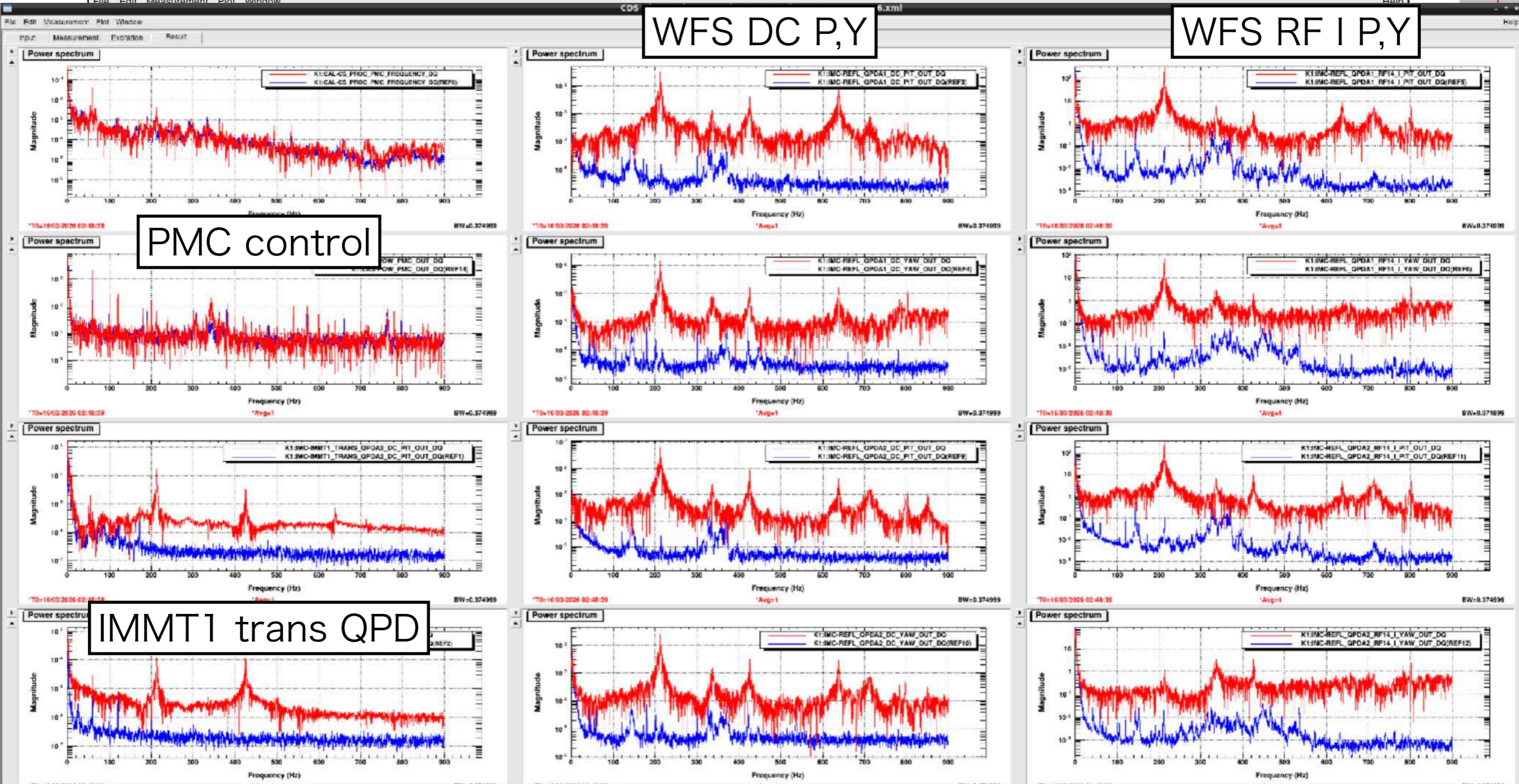


Shaker/tapping PSL room

- From the tapping test, M17 (2inch) mirror suspected.



CDS Diagnostic Test Tools - /kagra/Dropbox-core/KAGRA Dropbox/Subsystems/PEM/diaggi/PEMinjection/Shakerinj_post04/260213/analysis/white180-320Hz.xml



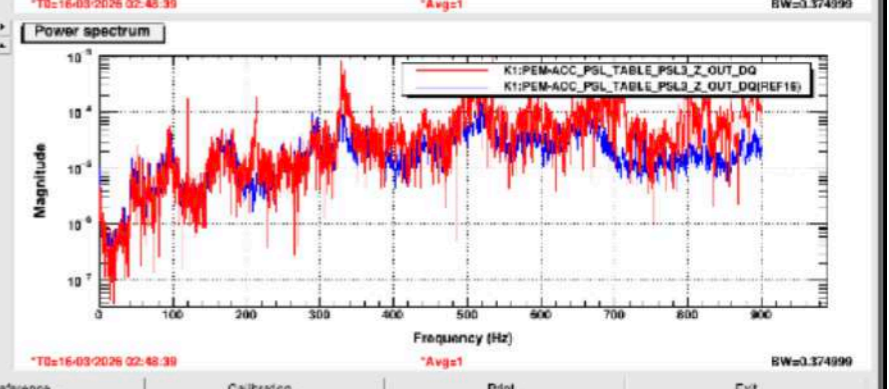
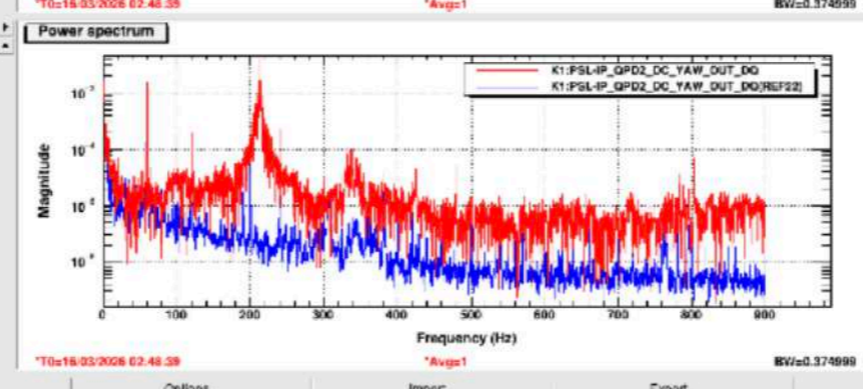
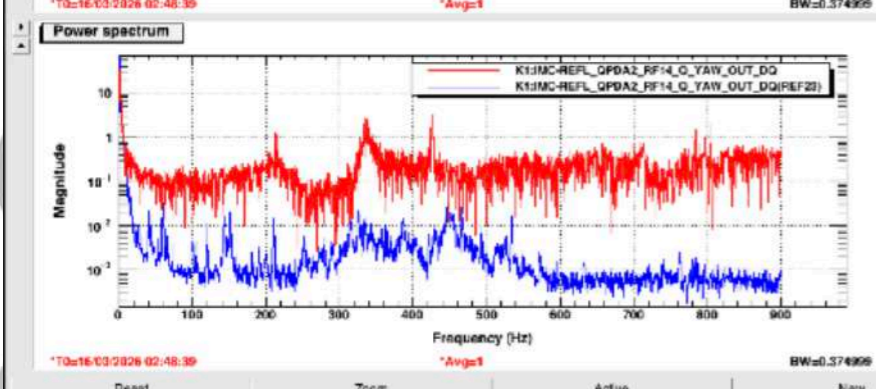
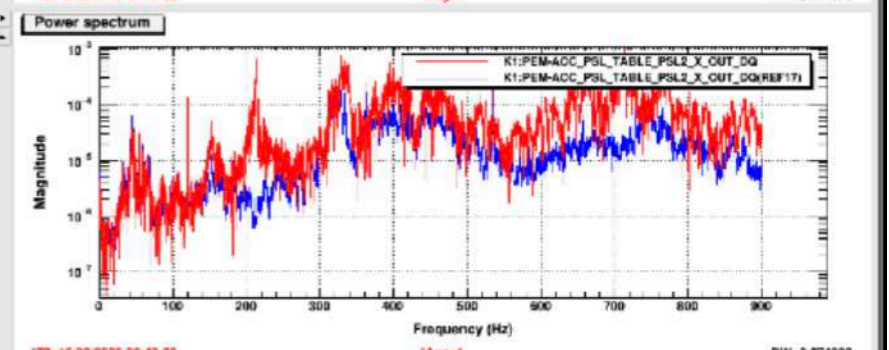
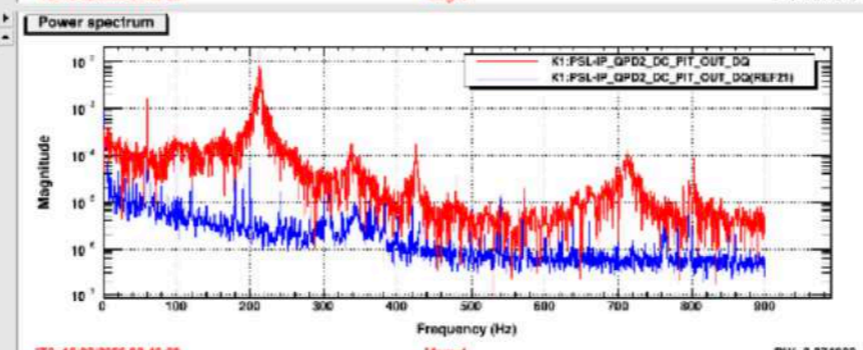
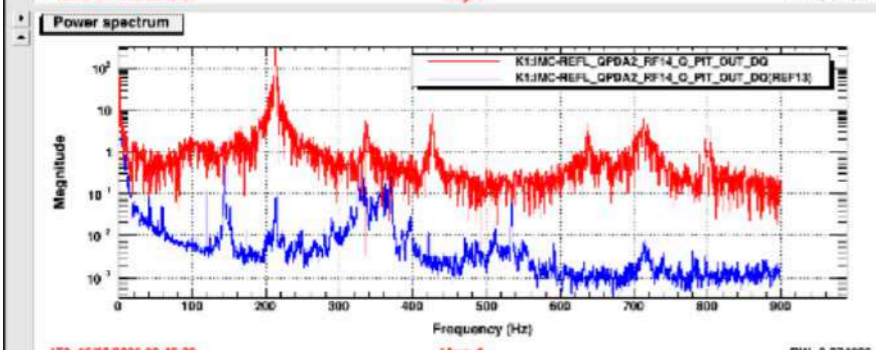
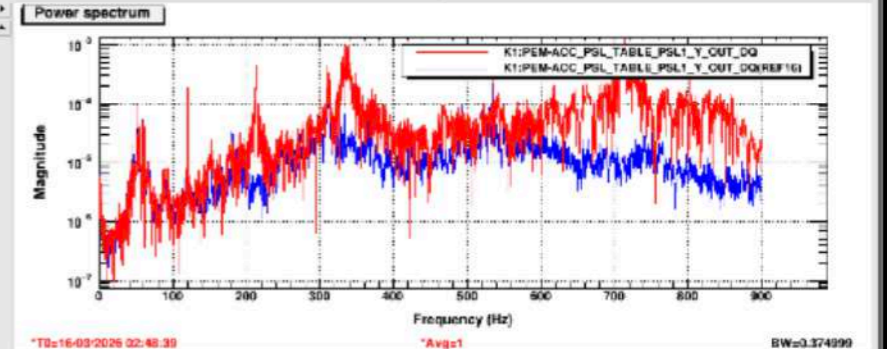
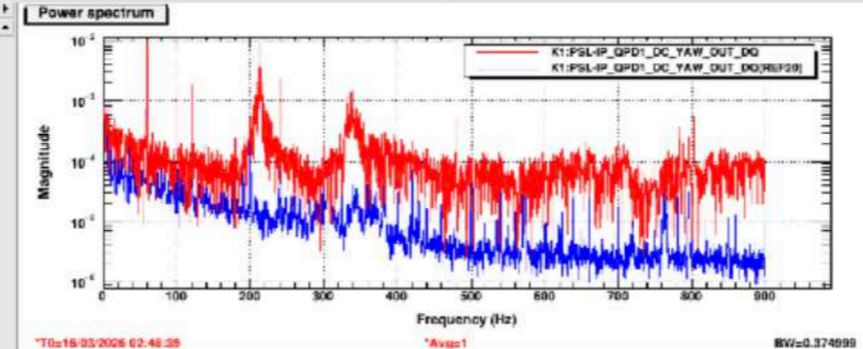
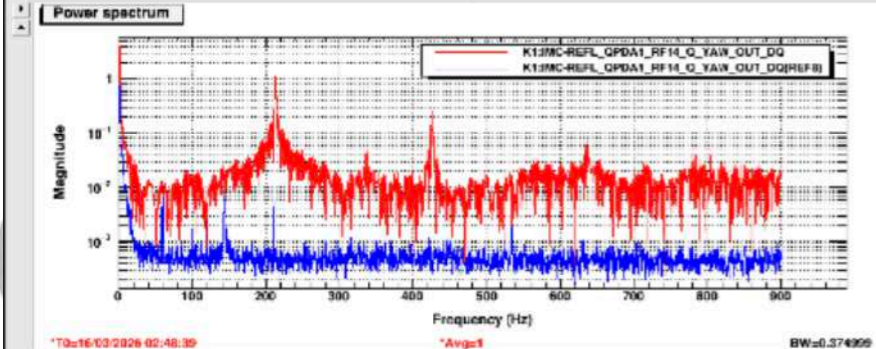
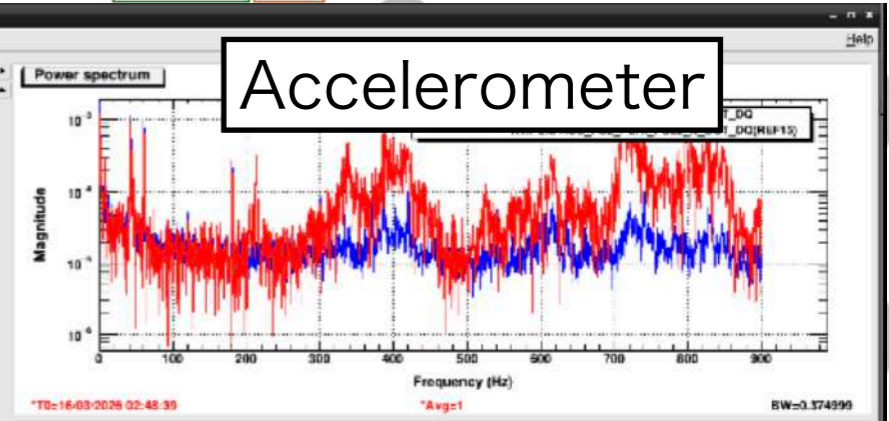
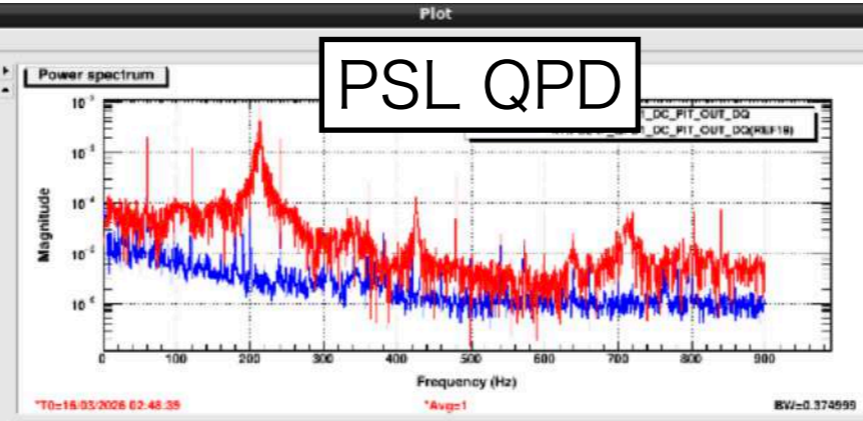
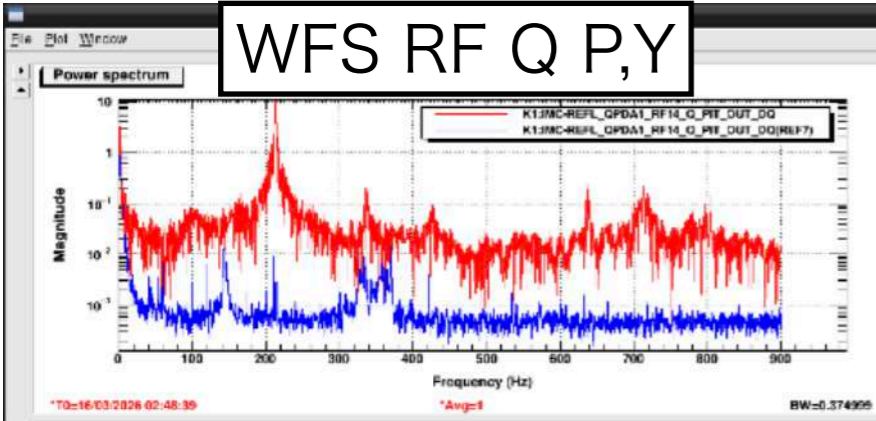
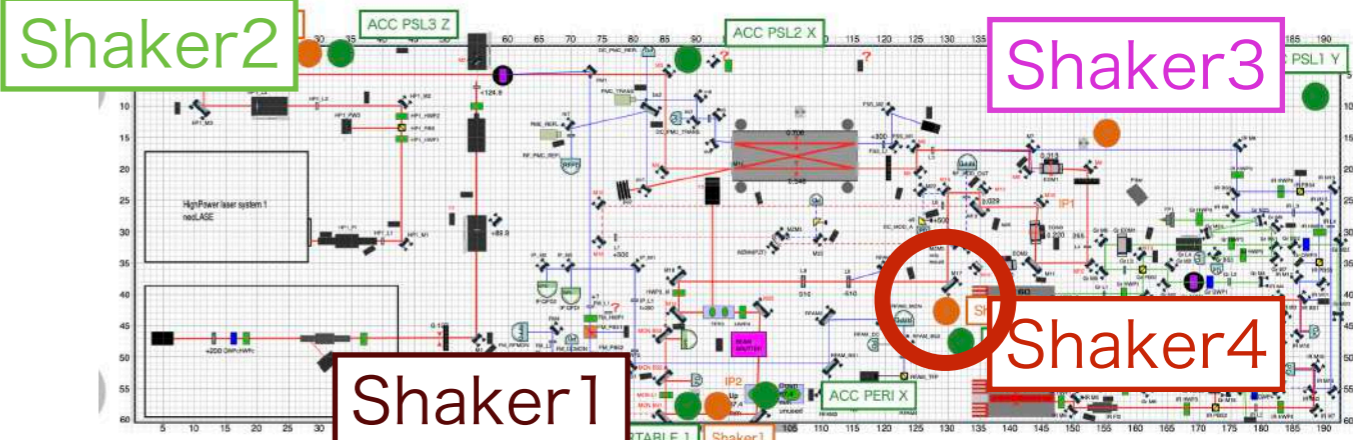
Start Pause Resume Abort

Test done (Measurements 1 / Averages 10) Repeat Fourier tools done



Shaker/tapping PSL room

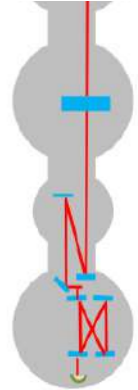
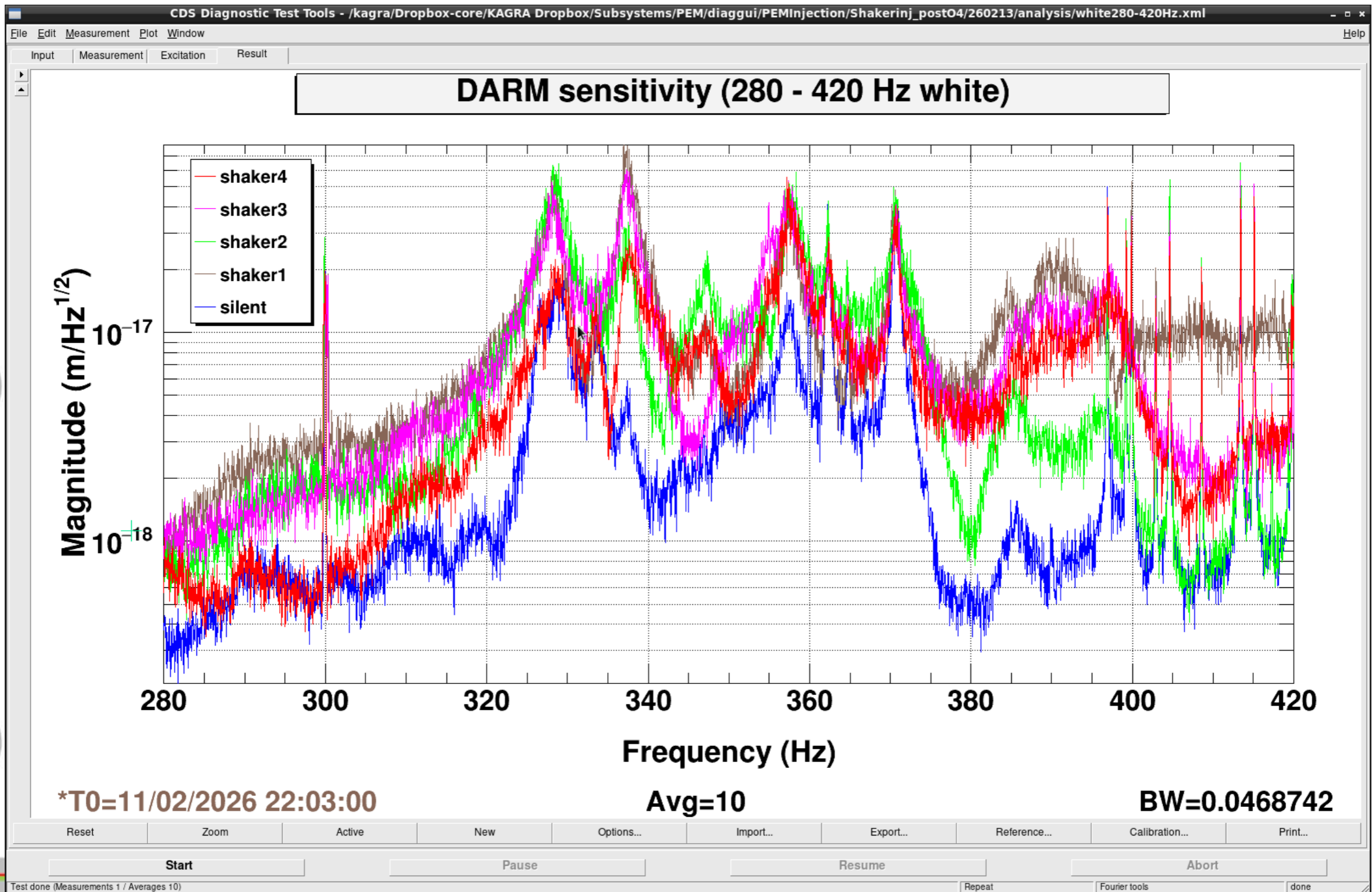
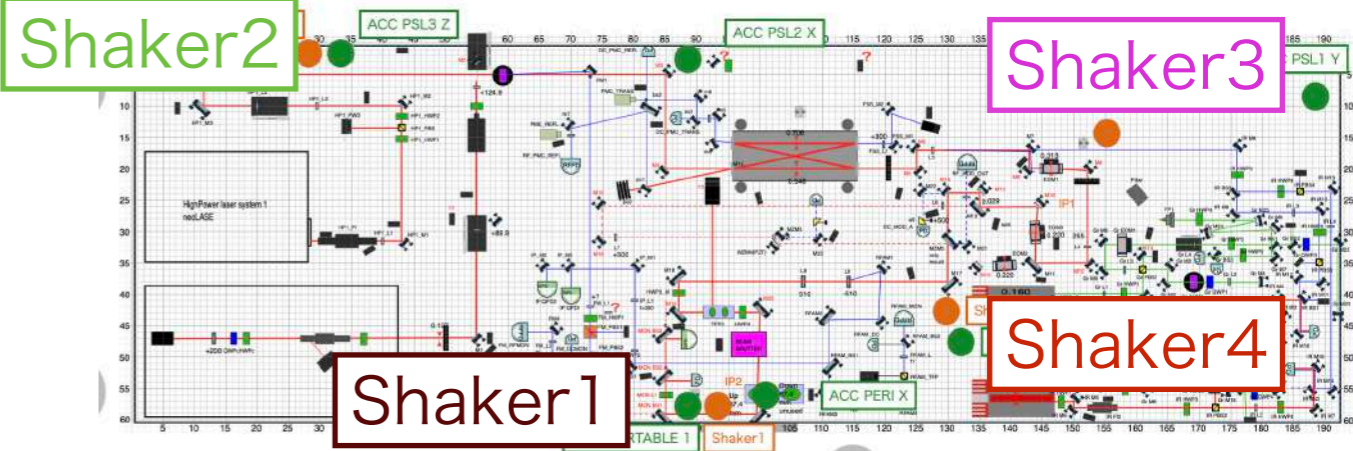
- From the tapping test, M17 (2inch) mirror suspected.





Shaker/tapping PSL room

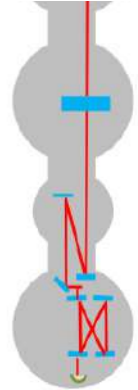
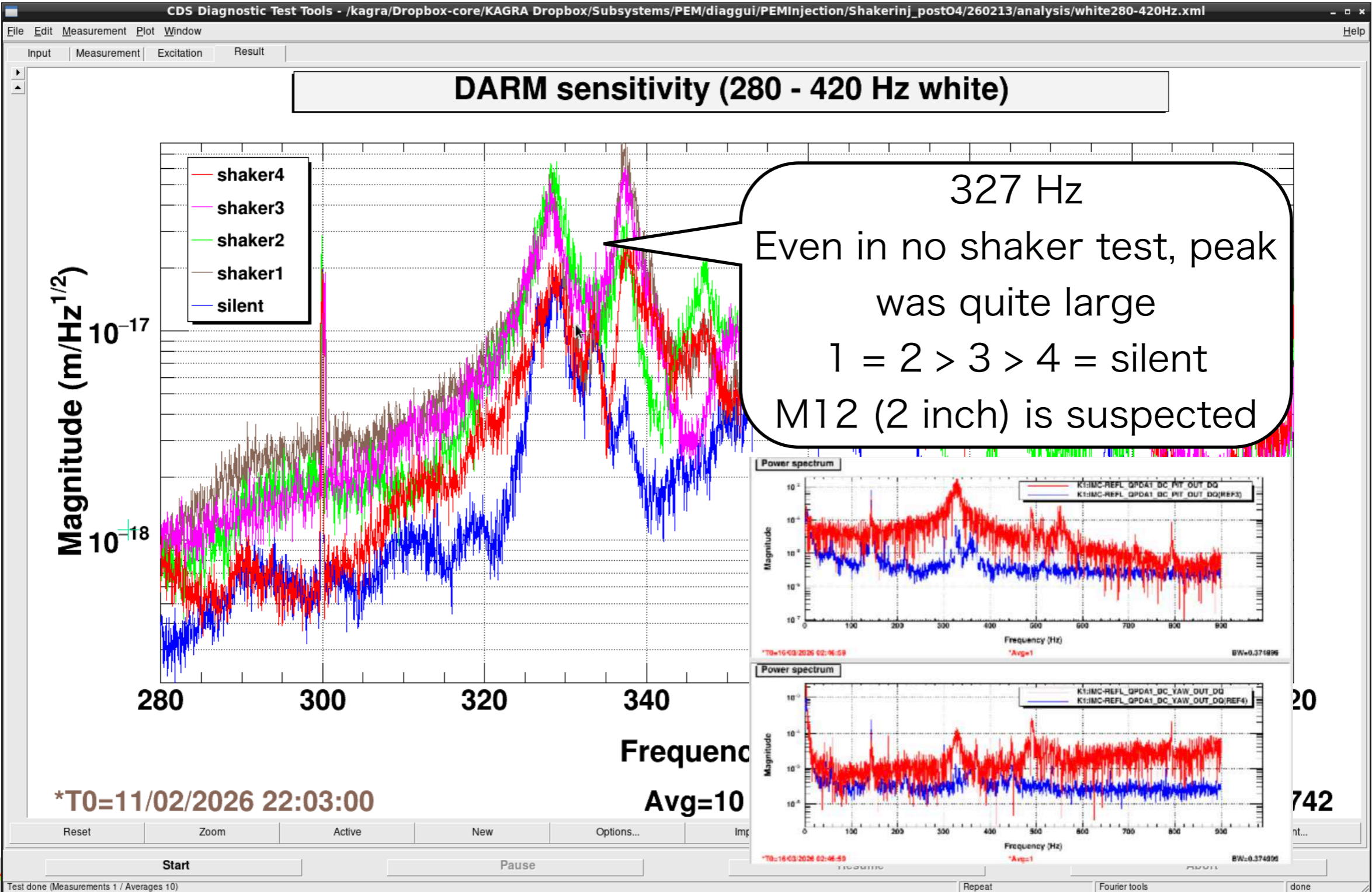
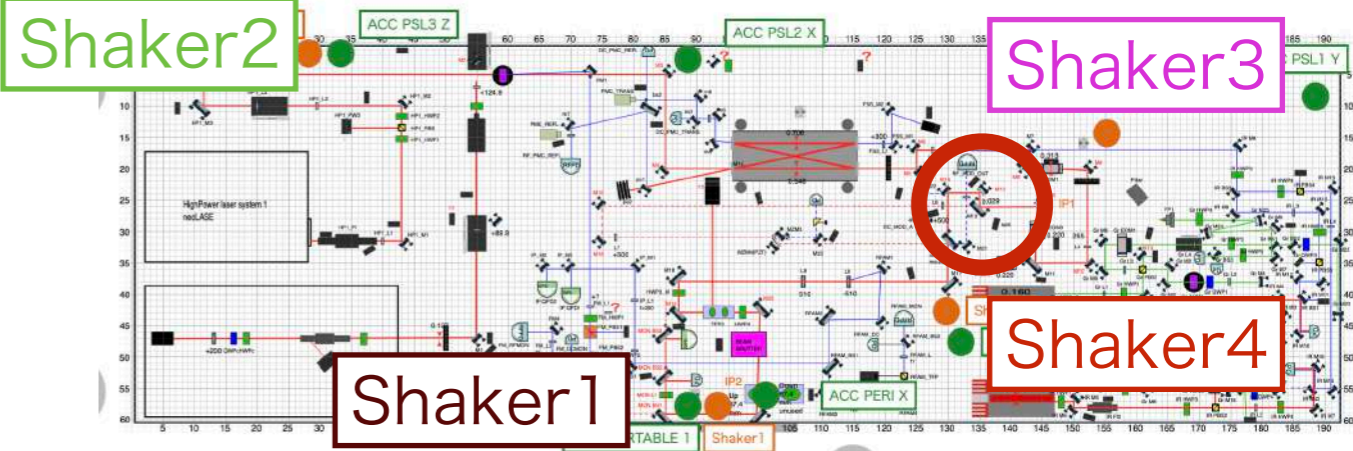
- Most interesting frequency
- 300 - 400 Hz





Shaker/tapping PSL room

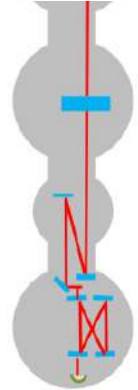
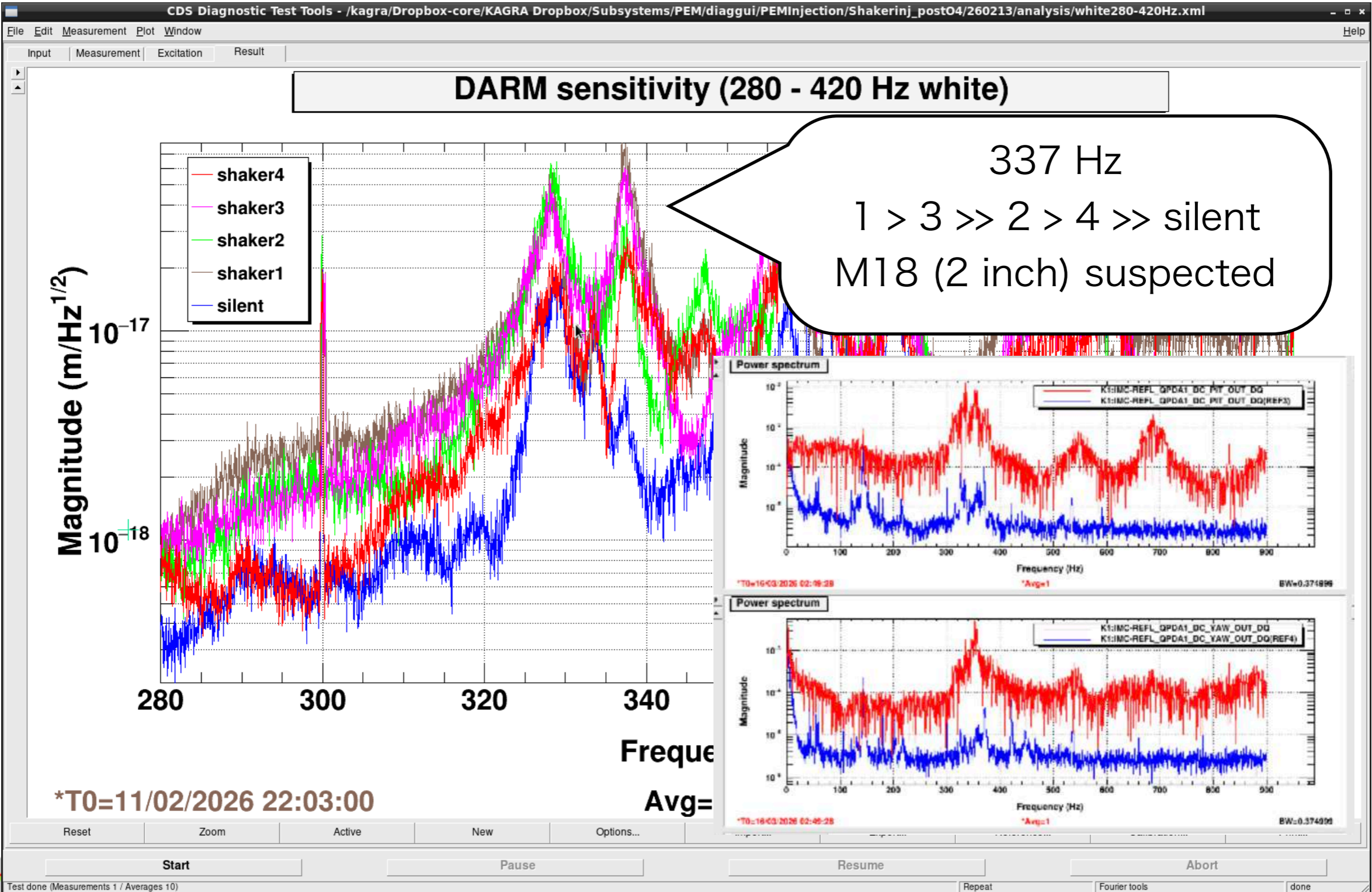
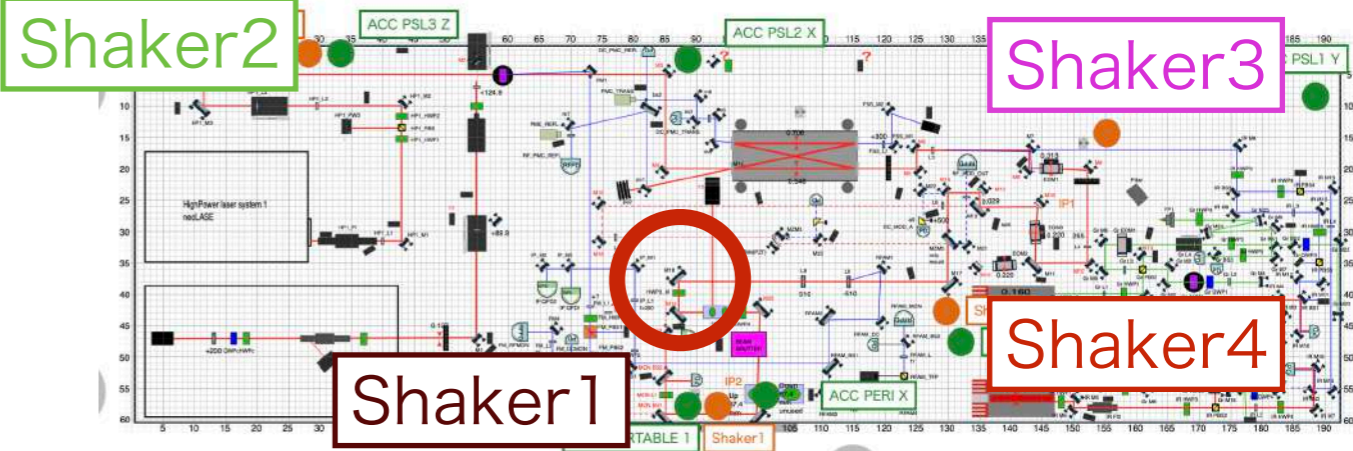
- Most interesting frequency
 - 300 - 400 Hz





Shaker/tapping PSL room

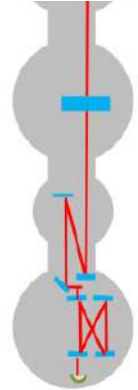
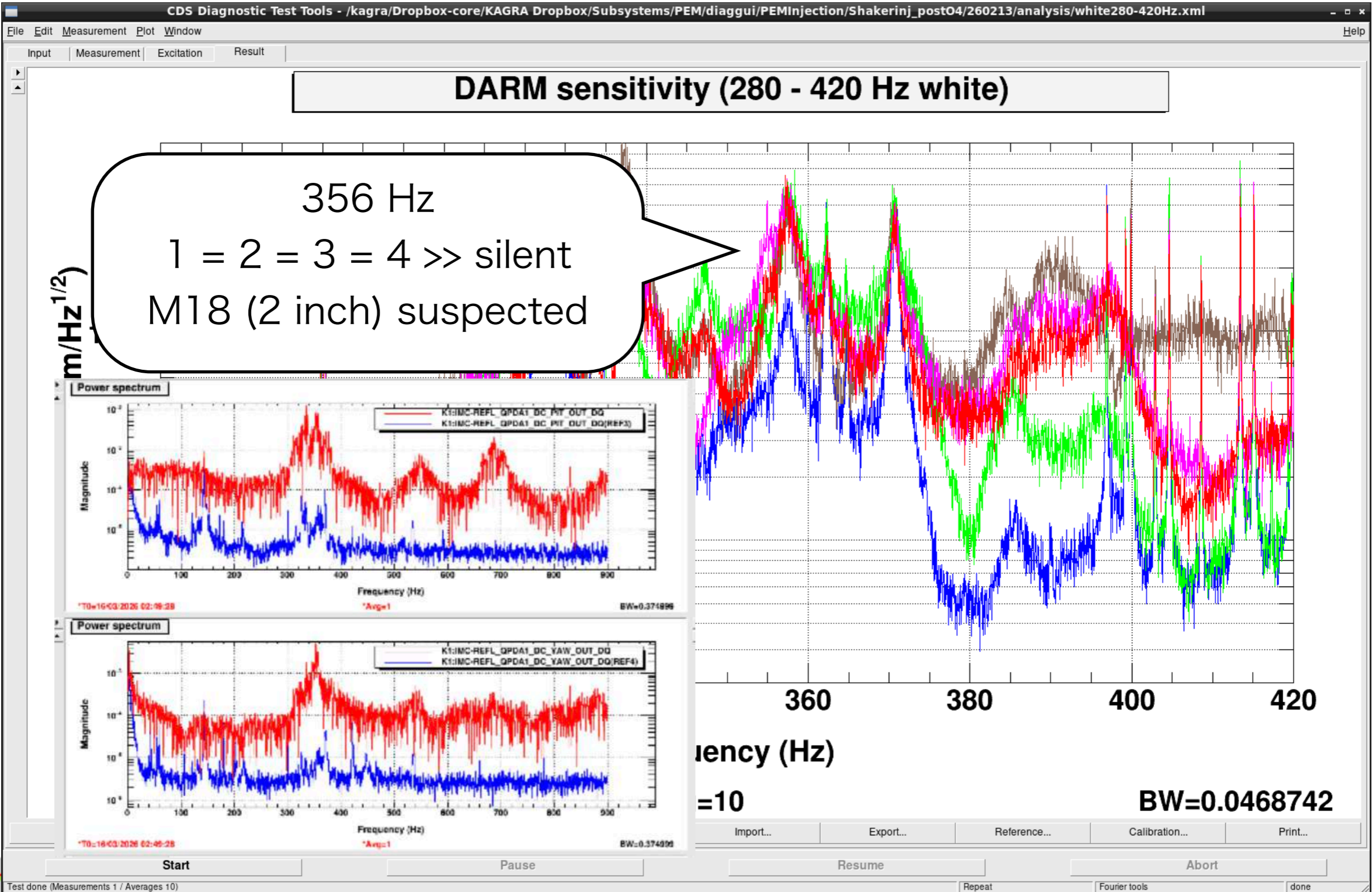
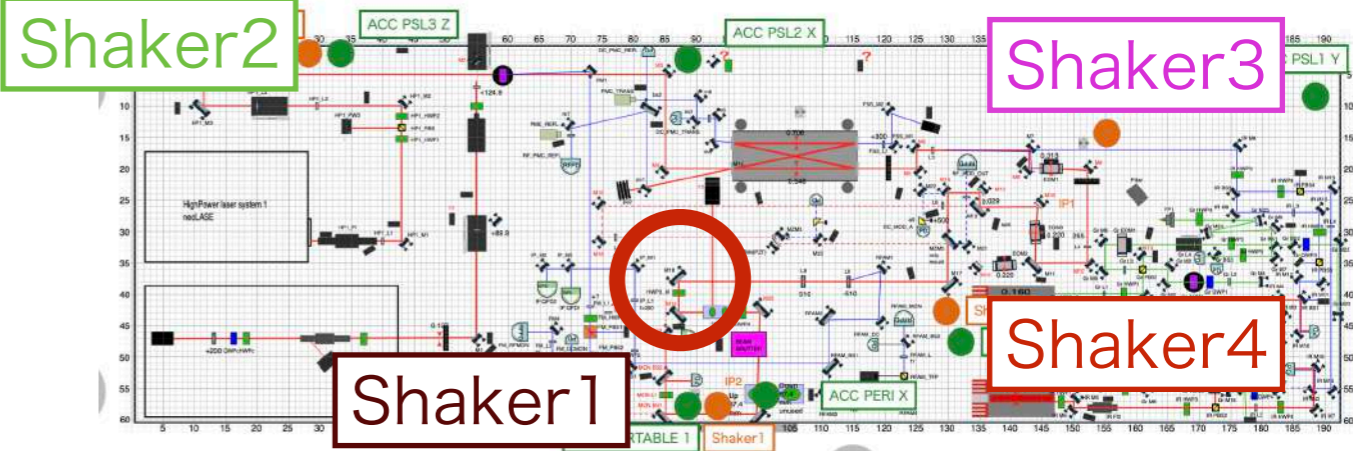
- Most interesting frequency
- 300 - 400 Hz





Shaker/tapping PSL room

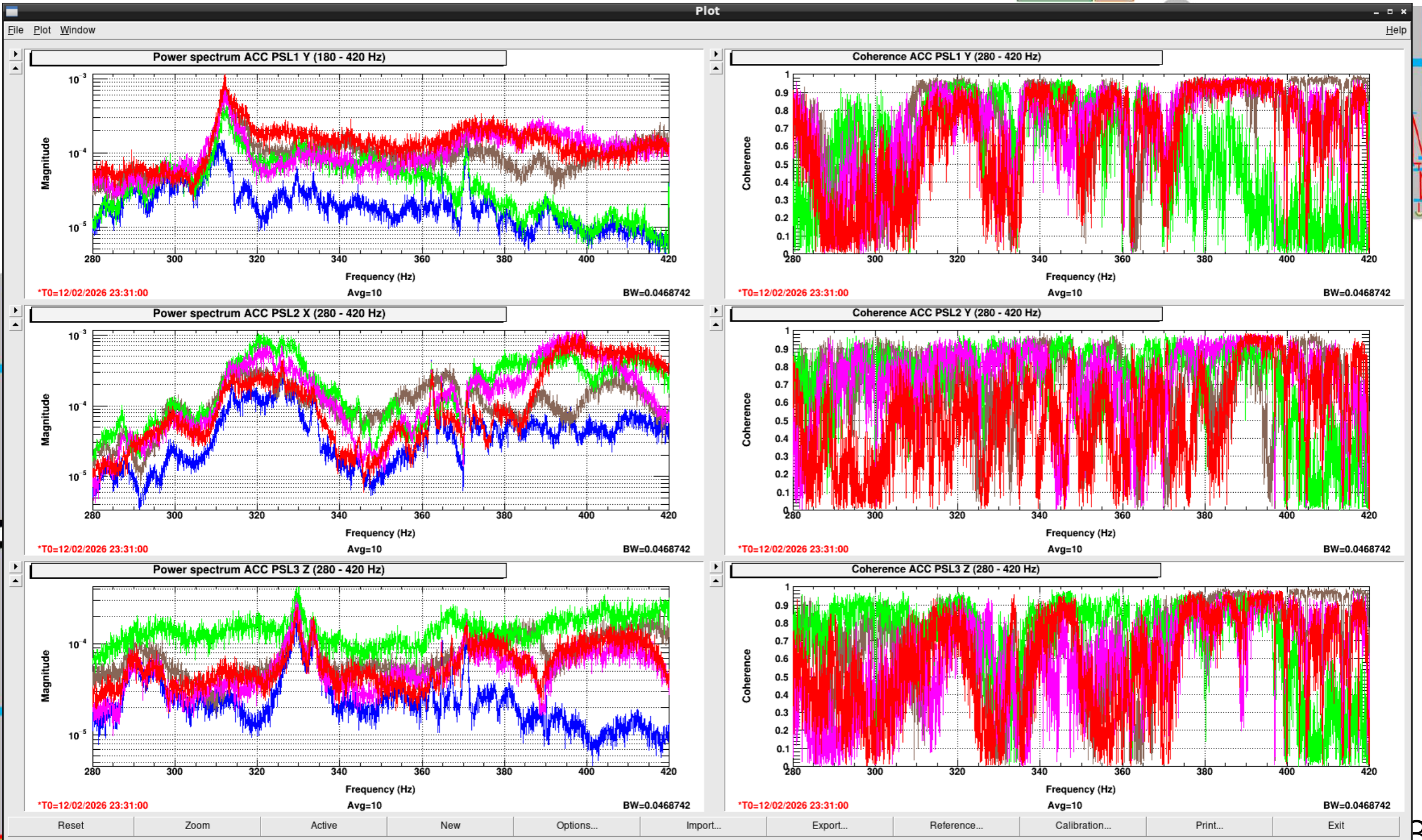
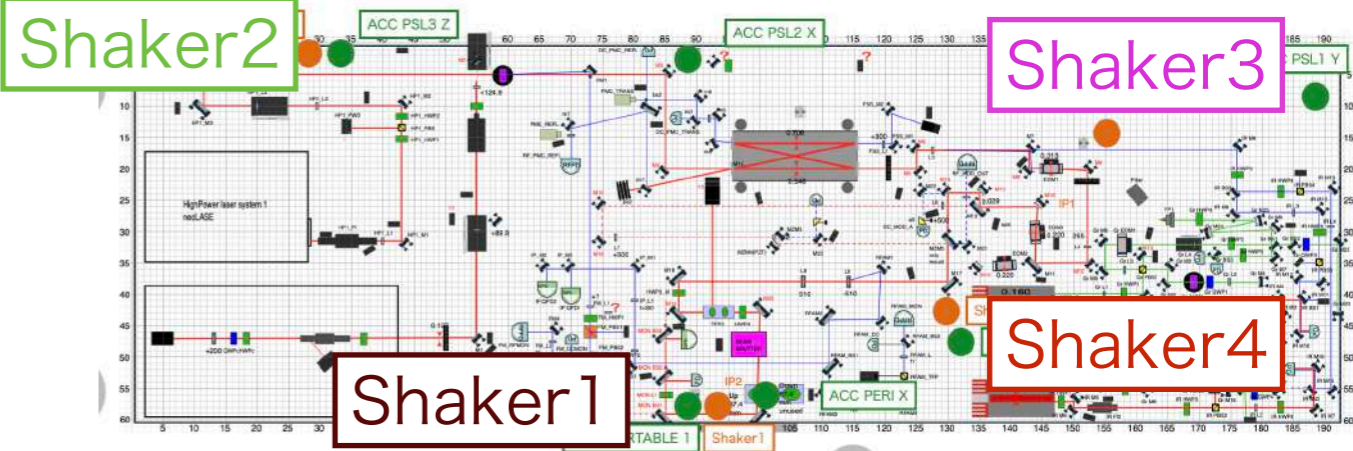
- Most interesting frequency
- 300 - 400 Hz





Shaker/tapping PSL room

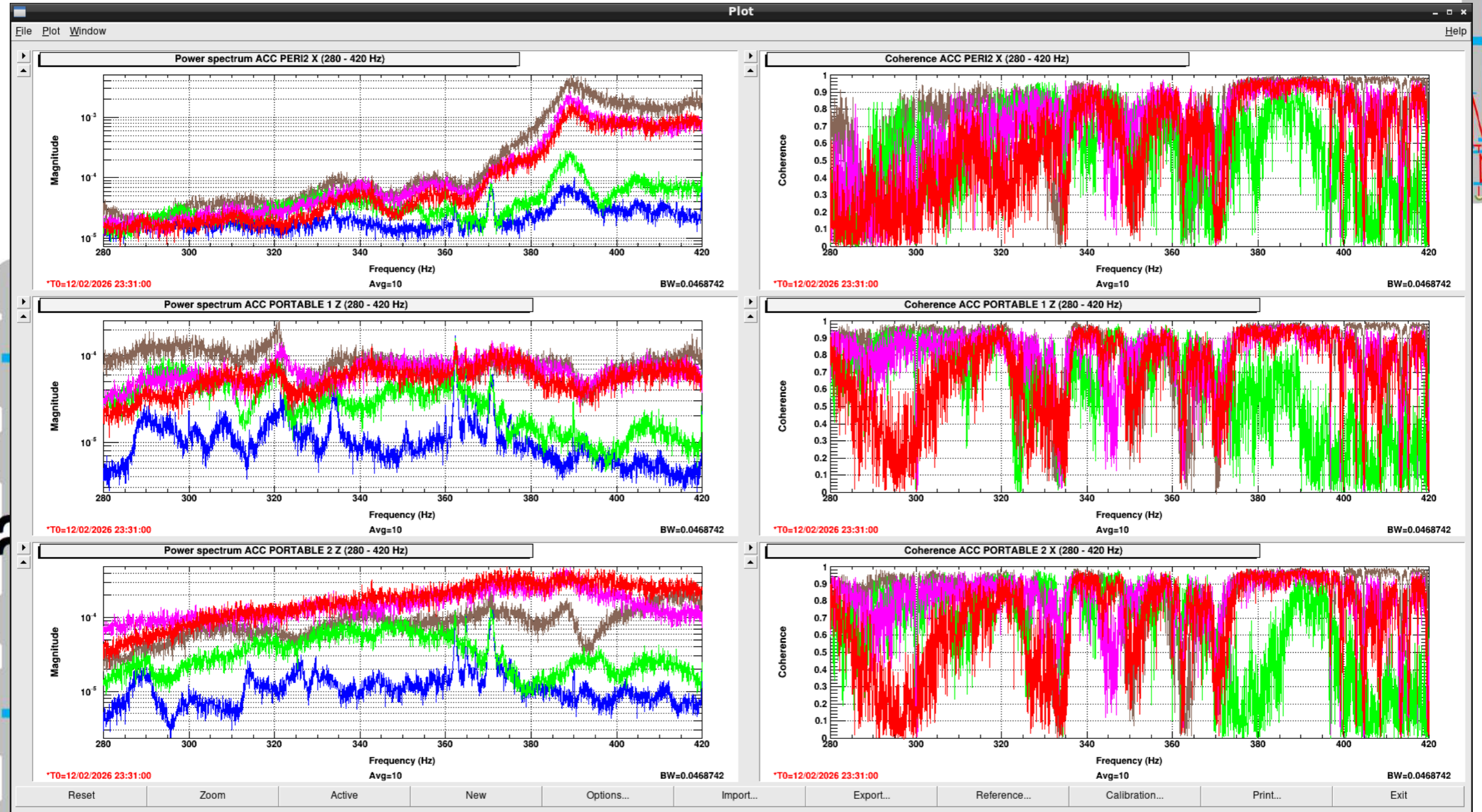
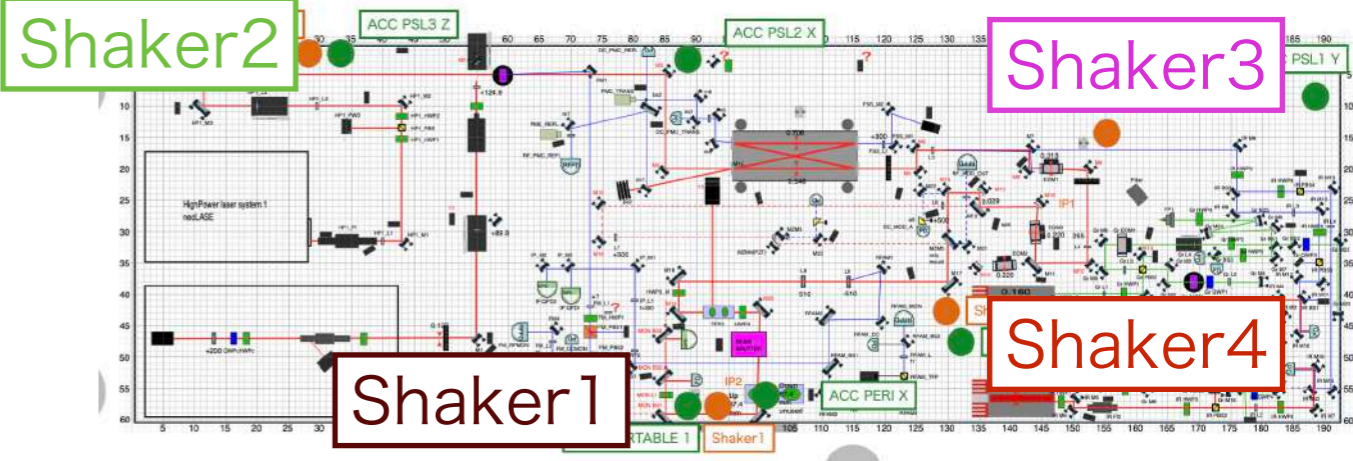
- Most interesting frequency
- 300 - 400 Hz





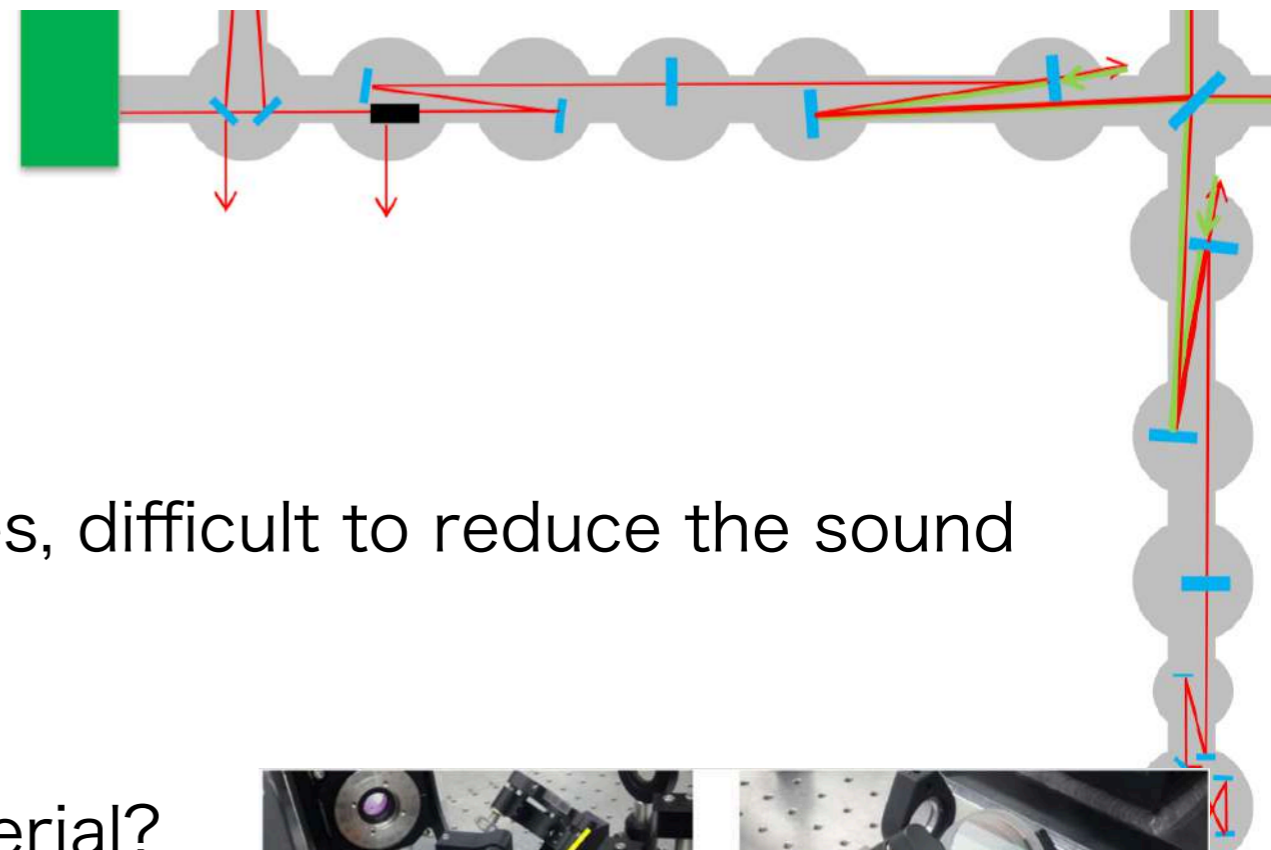
Shaker/tapping PSL room

- Most interesting frequency
- 300 - 400 Hz

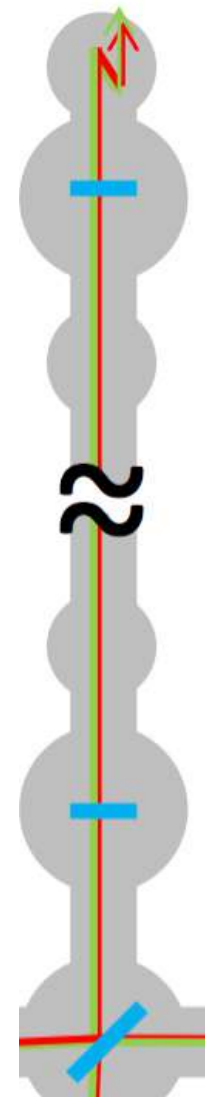
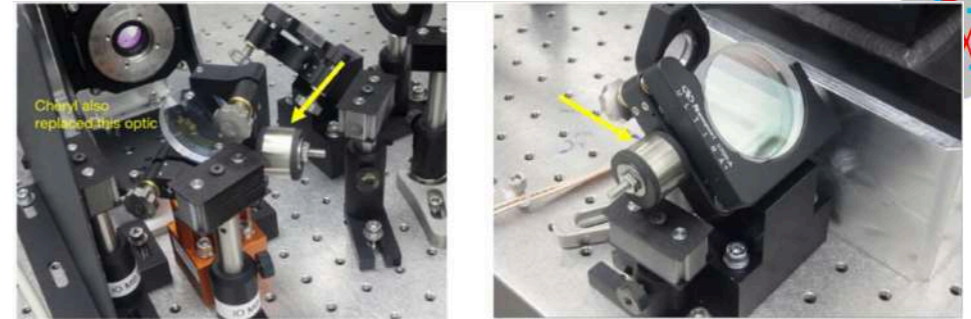




How to reduce the noise?

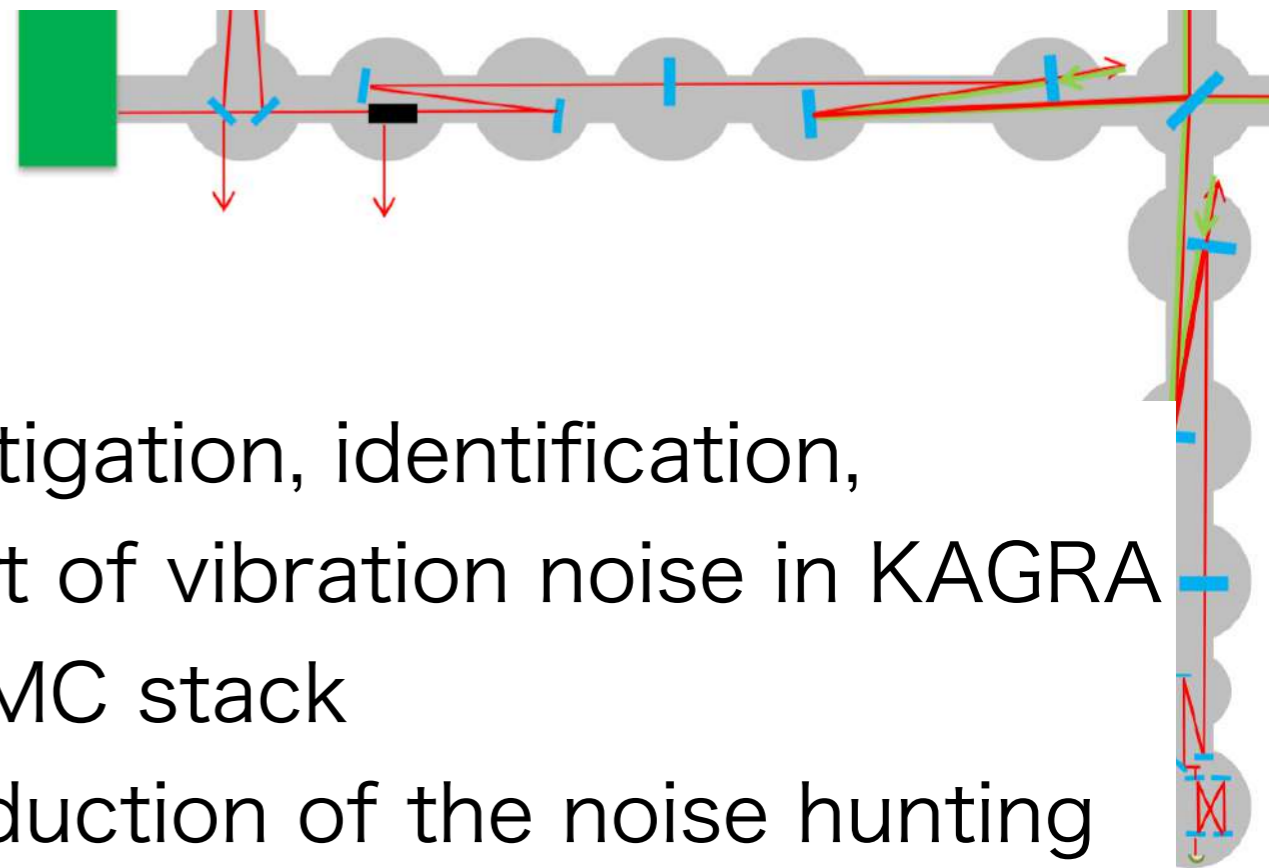


- Silent environment
 - Already minimum infrastructures, difficult to reduce the sound and vibration
- Check the optics frame
 - Loose connection? Update material?
- Install the damper
 - Experience of LIGO
- Reduce the effect of the ground motion
 - Grouting the PSL table
- Applying the noise subtraction
 - Which witness channel was effective?
 - Several WFS, QPD, PD exist up to the IMC
- Others
 - If you have suggestion and/or advice, please contact to me!





Summary and future plan



- There are many stories, investigation, identification, evaluation, reducing the effect of vibration noise in KAGRA
 - Strong scattered light -> OMC stack
- In this presentation, the introduction of the noise hunting for the PSL room was performed
- Investigation of sound outside of PSL room
- Acoustic injection test -> Shaker injection test -> Tapping test -> Identification of the suspected optics
- Next, reducing the effect of vibration and obtain better sensitivity.
- Any suggestion, comments, advices were welcome

