Status of Cryogenic Mirror Suspensions for KAGRA Gravitational Wave Detector

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ICRR, KAGRA Collaboration

The 5th KAGRA International workshop

Perugia, Italy, February 14 - 15, 2019

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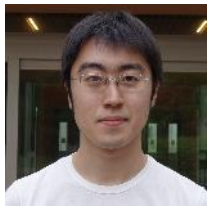

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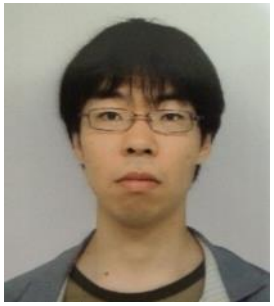

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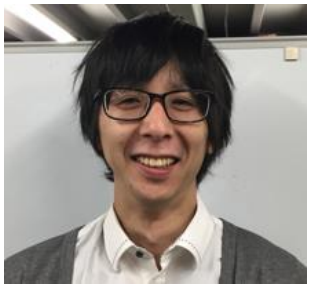

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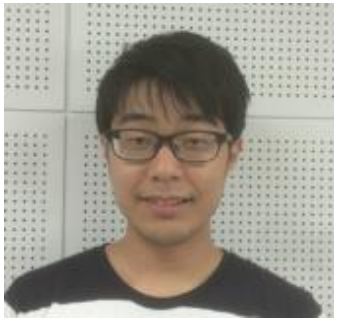

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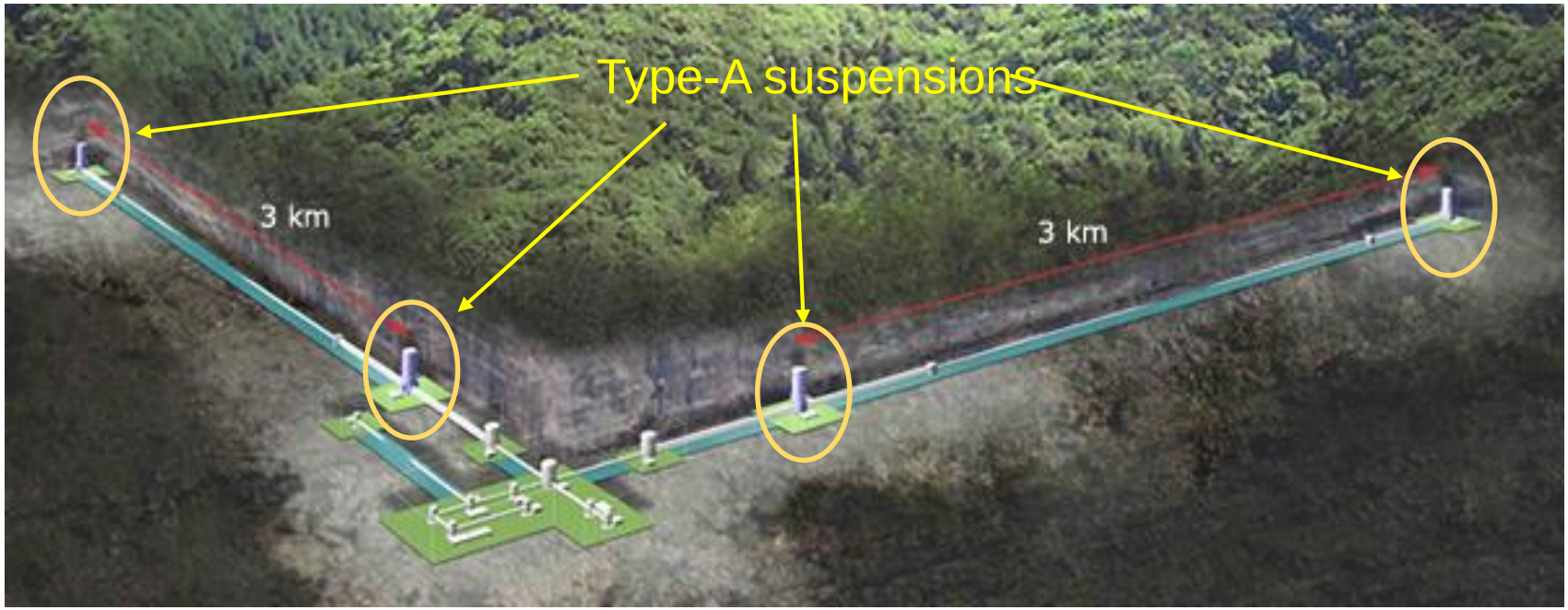
Contents

- Introduction of KAGRA cryogenic system
- Installation status
- Performance evaluation
- Summary

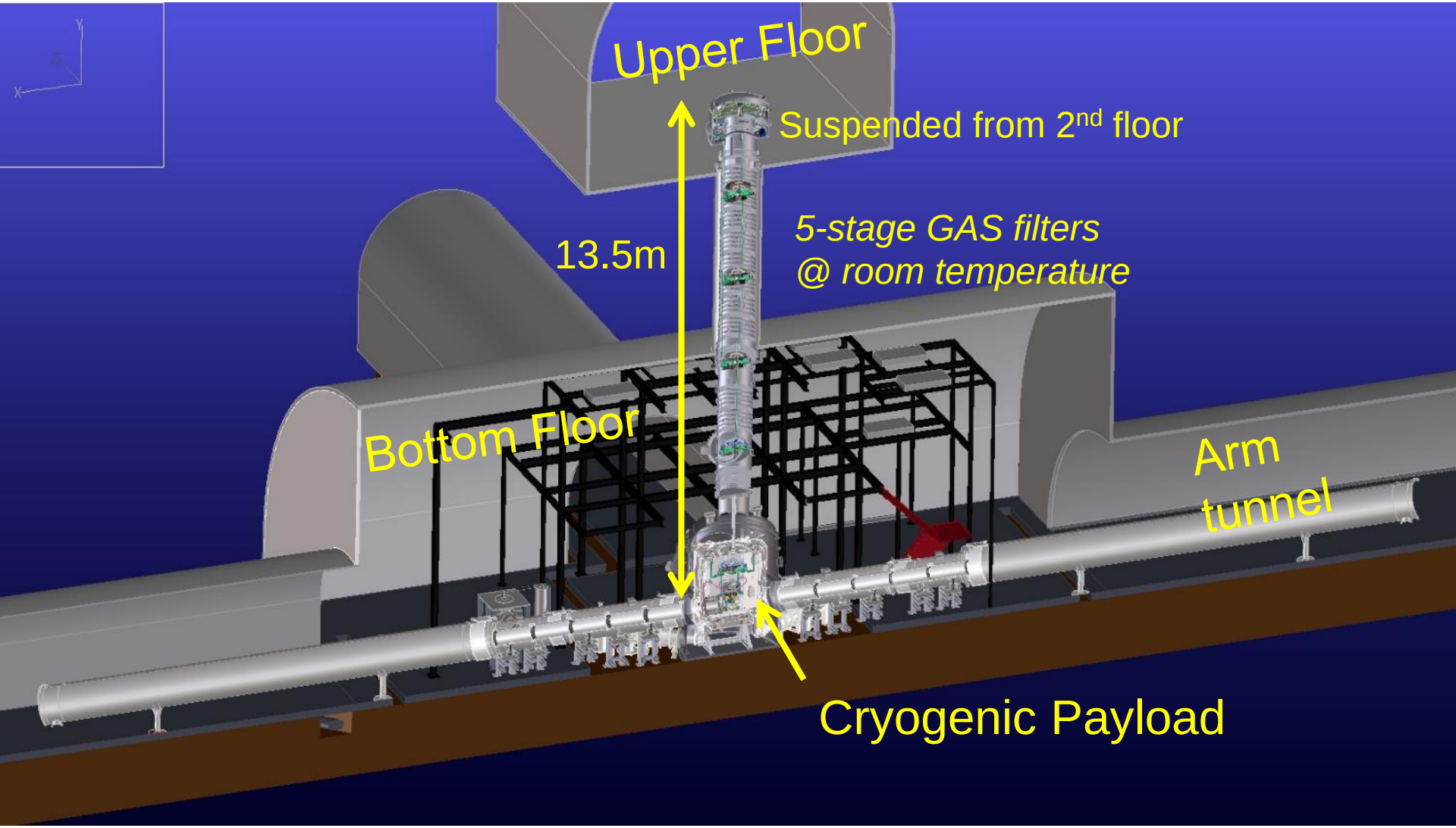
KAGRA gravitational wave detector

- 3-km arm interferometric gravitational detector.
- Located at Kamioka in Japan near Super Kamiokande.
- Key features:
  - Using underground site
  - Using a cryogenic mirrors



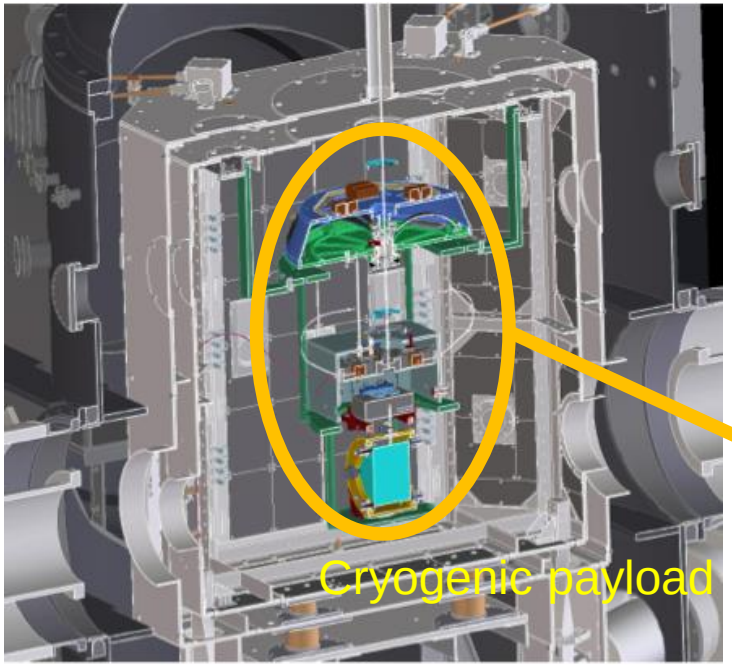
Type-A suspension for KAGRA TMs

9-stage 13.5-m suspension for vibration isolation with a cryogenic mirror

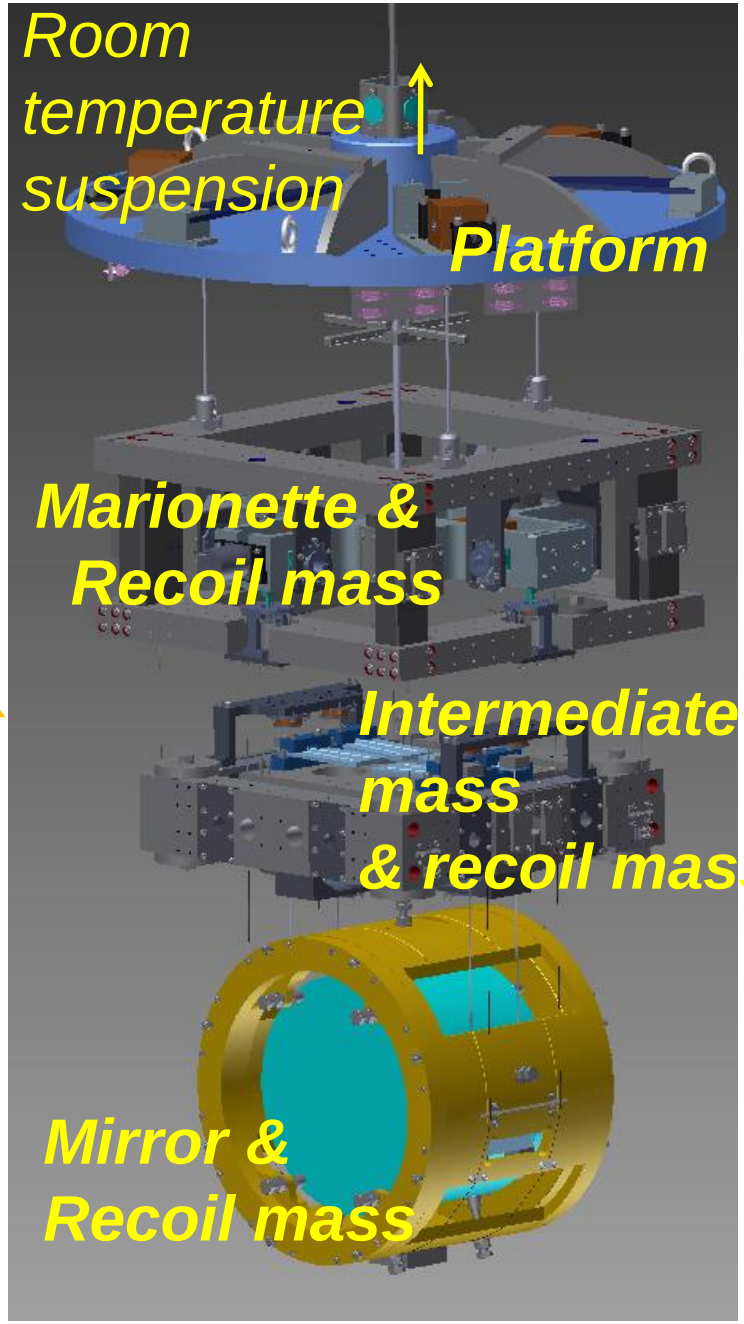


Cryogenic payload

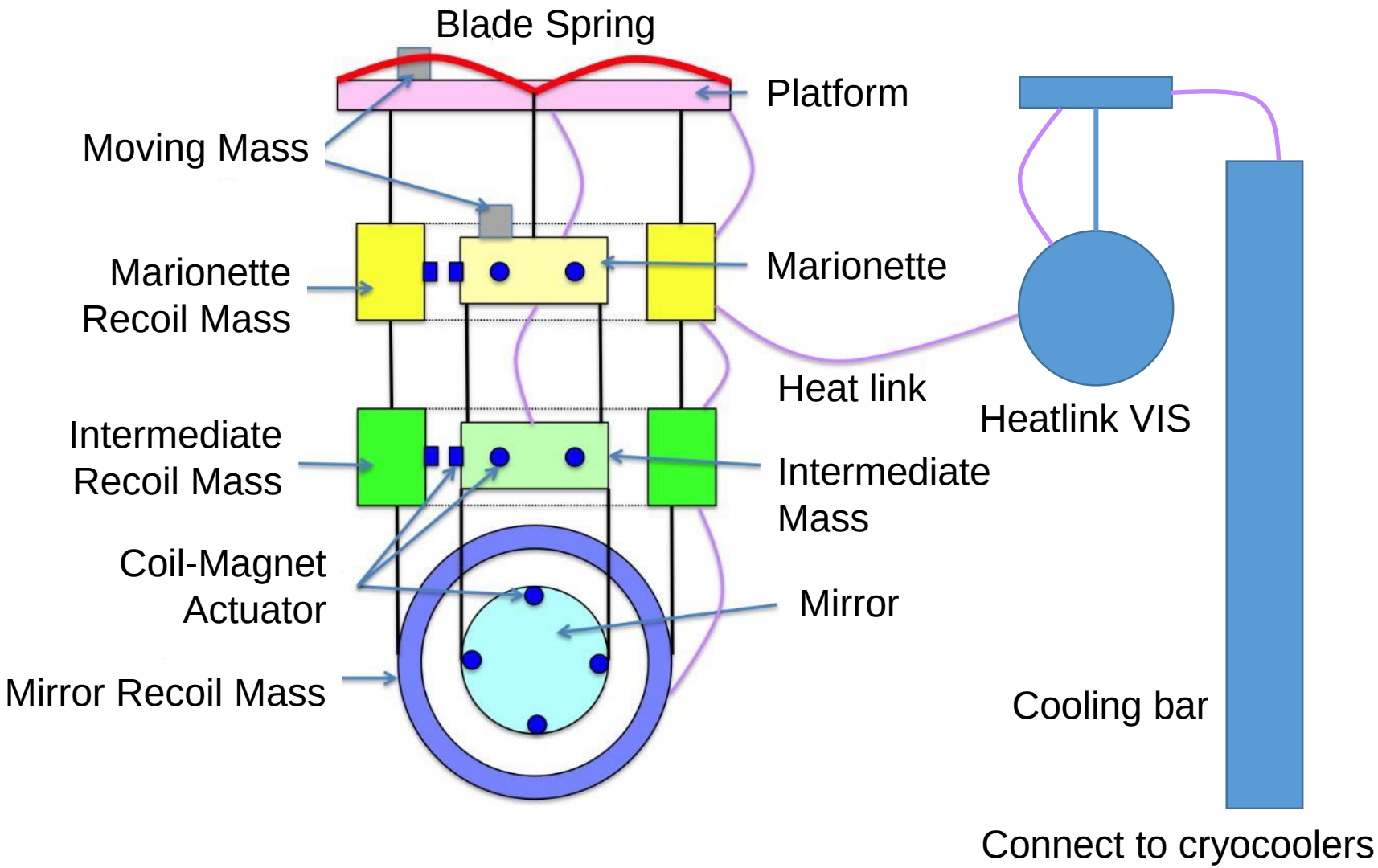
Inside cryostat



- Suspended by single wire from room temperature suspension.
- Test mass chain and recoil mass chain is individually suspended from platform stage.



Cryogenic payload design



Schematic view

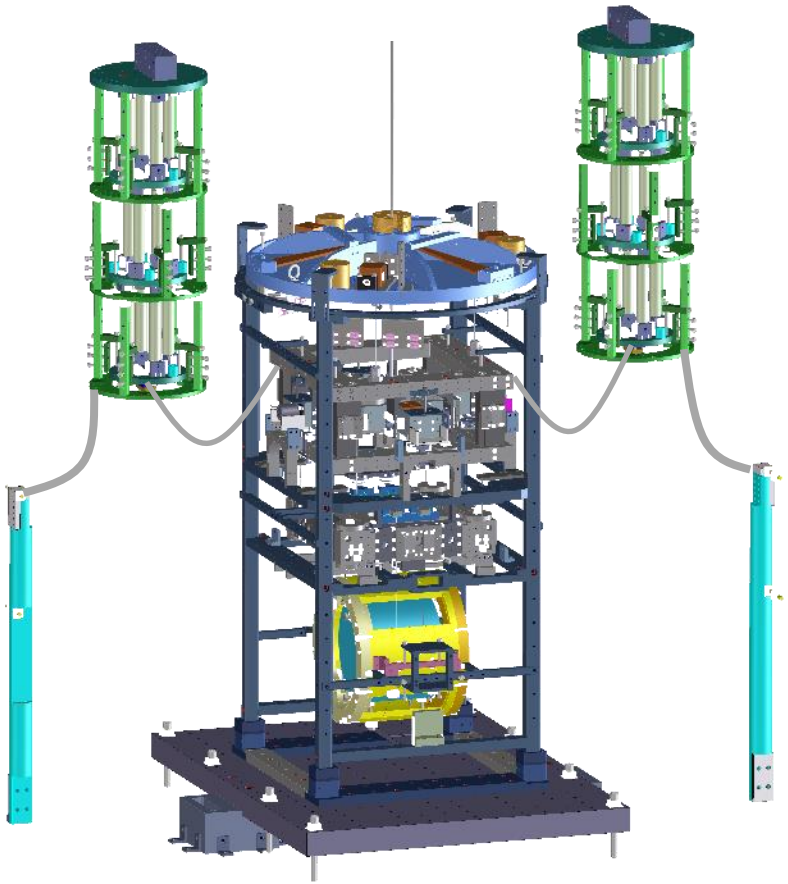
Unique design of our payload

There are some difficulties to achieve the cryogenic mirror suspension.

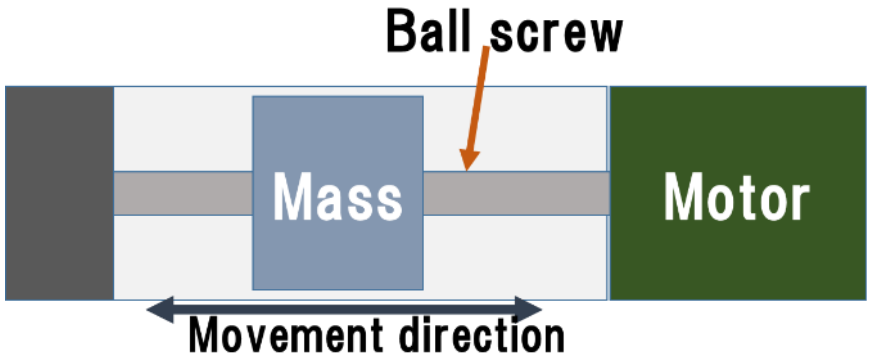
- Inclination adjustor at cryogenic temperature
- Heat extraction mechanism from mirrors
- Isolation system for vibration via heatlinks (Tomohiro's talk)
- Cryogenic displacement sensors (Masashi's talk)

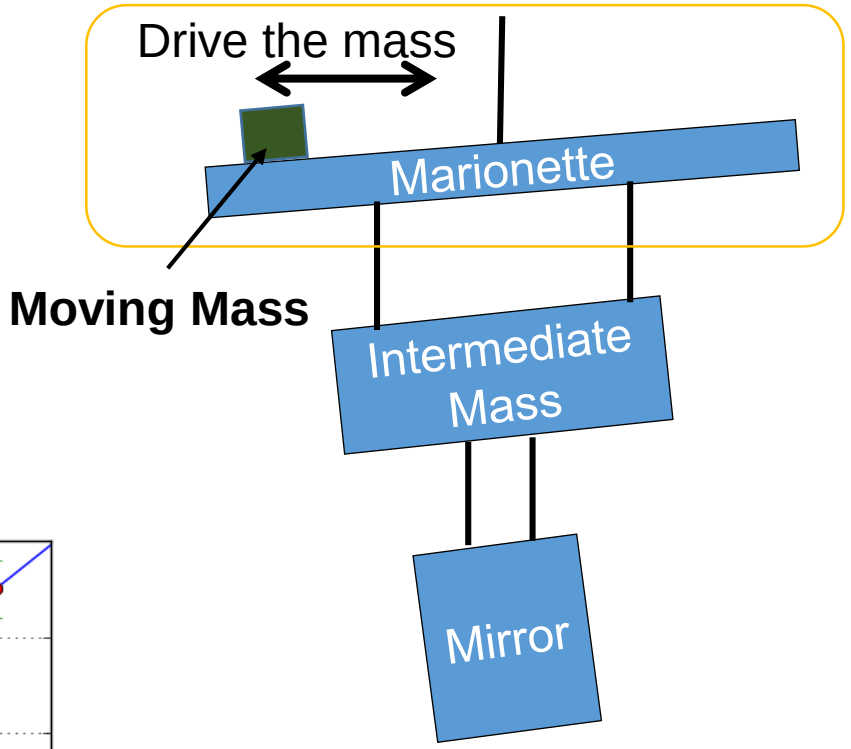
To solve them, there are several unique design in our suspension

- Moving mass system
- Sapphire suspension system
- Heatlink vibration isolation system
- Reflective-type photosensors



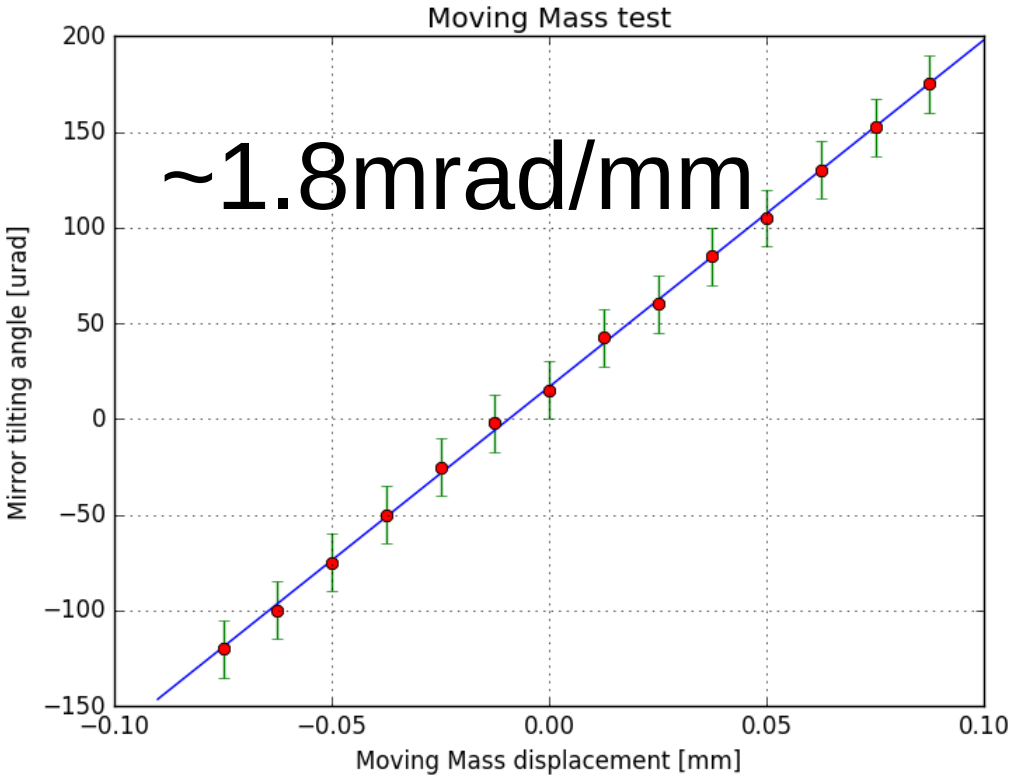
Moving mass system





Schematic view

Performance test result at 15 K



Evaluated maximum range :
36 mrad > 20 mrad
Resolution :
0.45 urad < 9 urad

Sapphire suspension

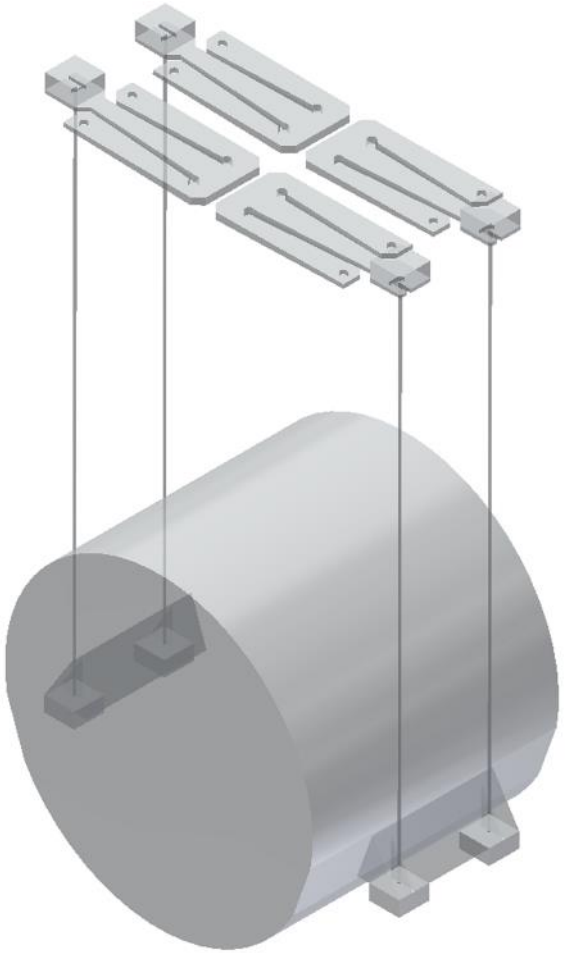
Test mass obtains large heat during the operation.
→ Thick sapphire fibers are used for heat extraction (~1.6 mm).

Problems:

- How to compensate length difference of sapphire fibers
  →using sapphire blade spring.

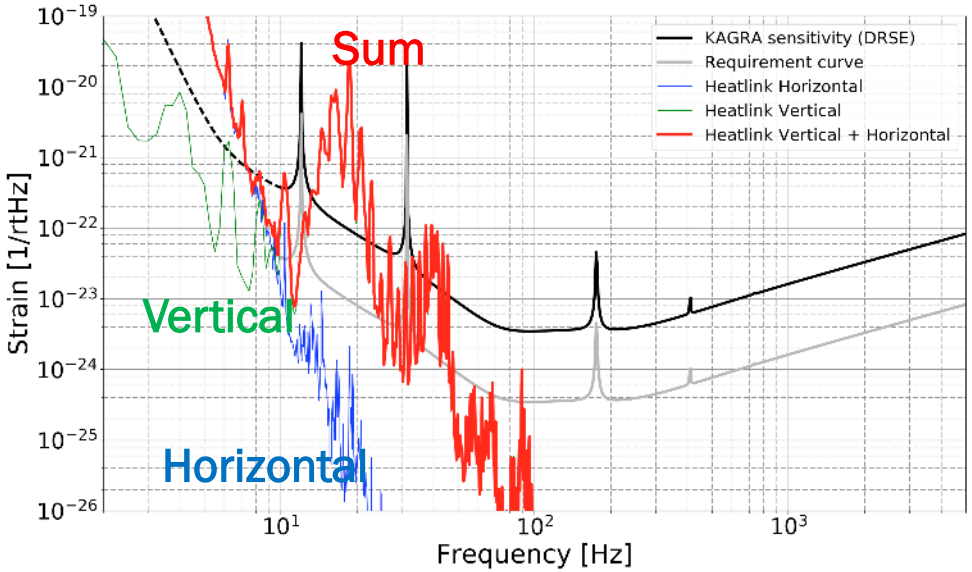
- How to suspend the sapphire mirror.
  →using ears and fibers with nail head

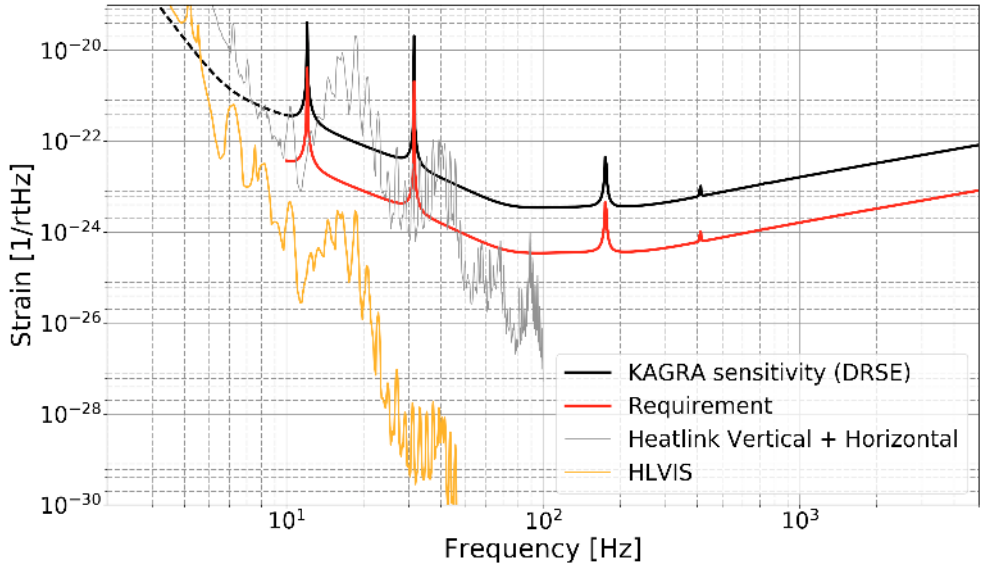
- How to make their thermal contact well:
  →using Ga bonding and Hydroxide catalysis bonding



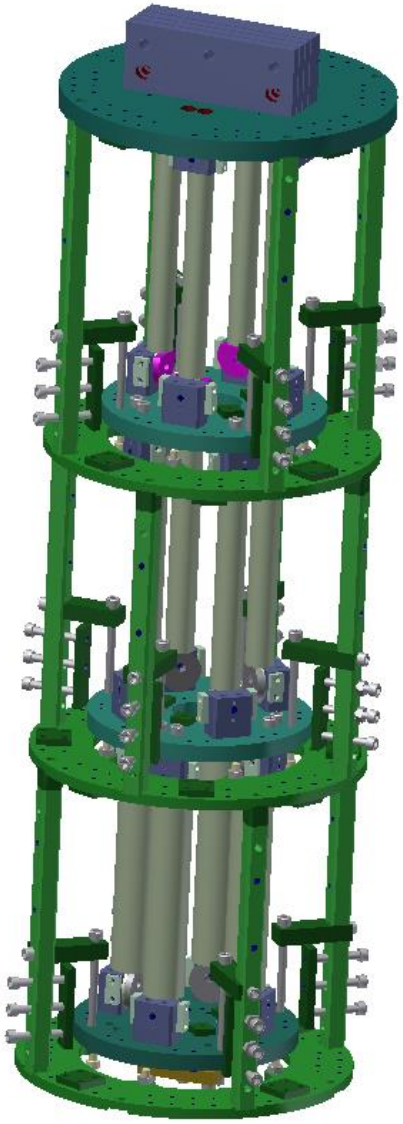
Heatlink Vibration isolation system

Three-stage VIS with tension spring was installed into the cryostat.





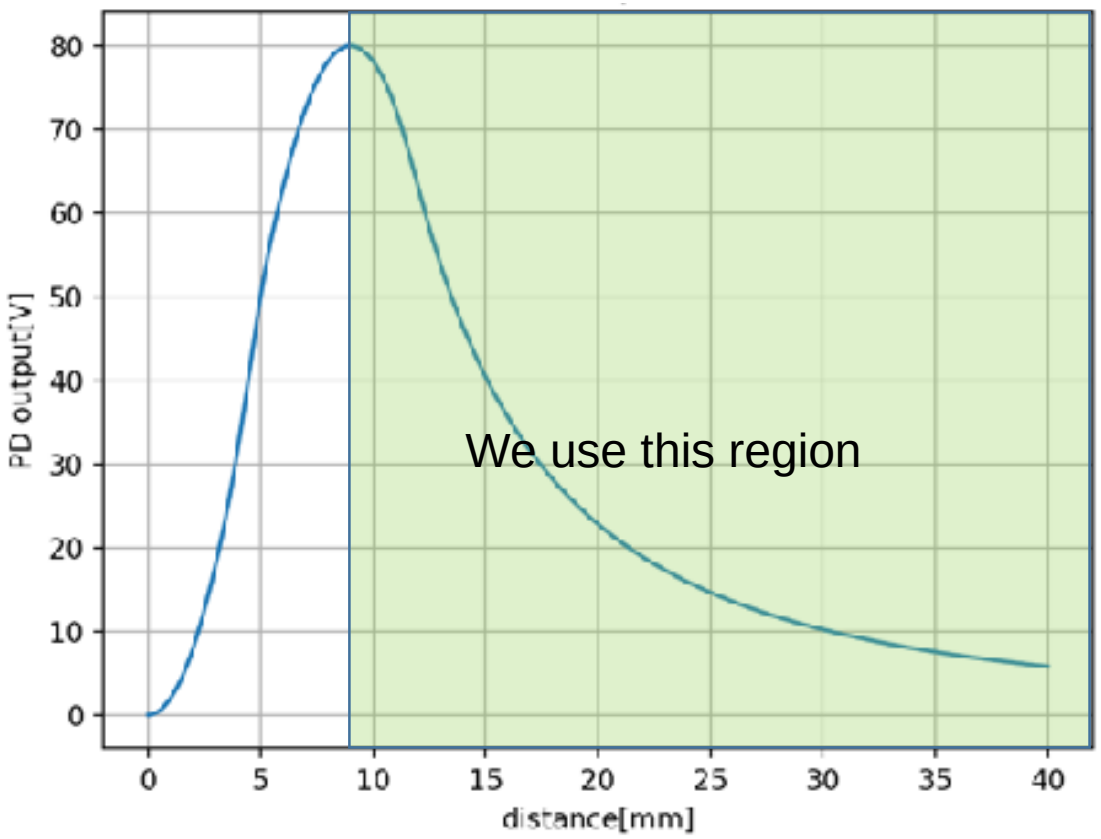
Improved by HLVIS



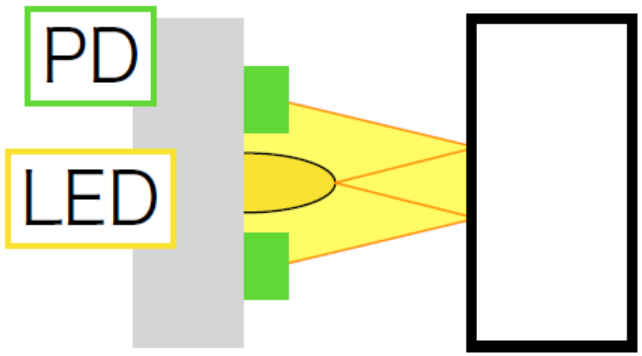
Reflective-type photosensor in KAGRA

Unexpected thermal contraction can move suspensions drastically.
So, we use reflective-type photosensors (large dynamic range).
For saving space on the payload, we designed a photosensor module, which consists of a coil, LED, and PDs

Typical response of the photosensors



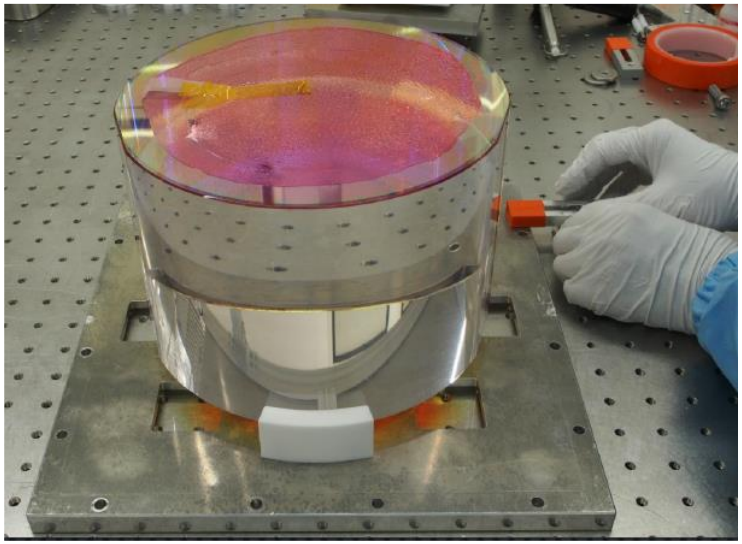
Schematic view and photo



Installation and Performance evaluation

Hydroxide Catalysis Bonding

Hydroxide Catalysis Bonding technique is used for the ear bonding as well as LIGO and VIRGO



・Members for HCB mission
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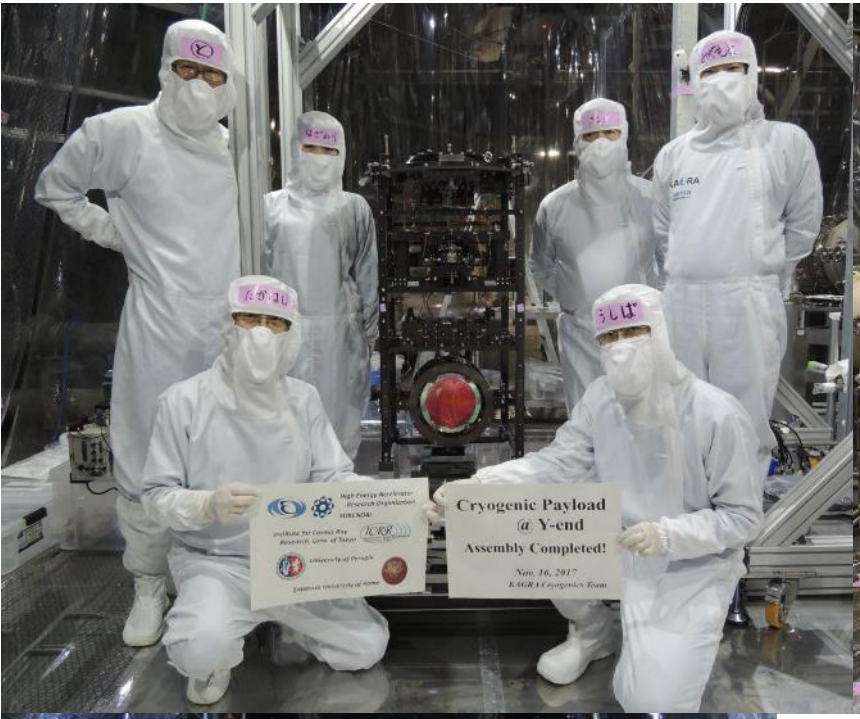
Tomohiro Yamada(Utokyo)
Masashi Fukunaga(UTokyo)
Toshiya Yoshioka(Toyama)
Yuki Kuromiya(Toyama)
Kieran Craig(ICRR)
Helios Vocca(Perugia)
Flavio Travasso(Perugia)
Kazuhiro Yamamoto(Toyama)

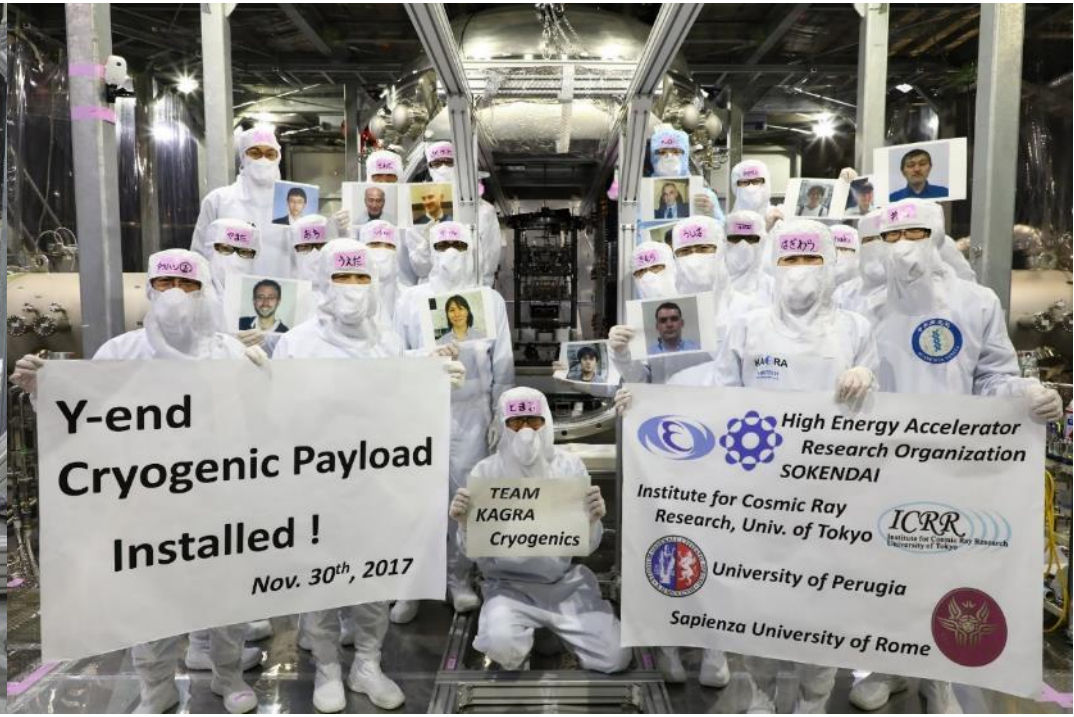
The last mirror was sent to KAGRA site in the end of last Nobember.

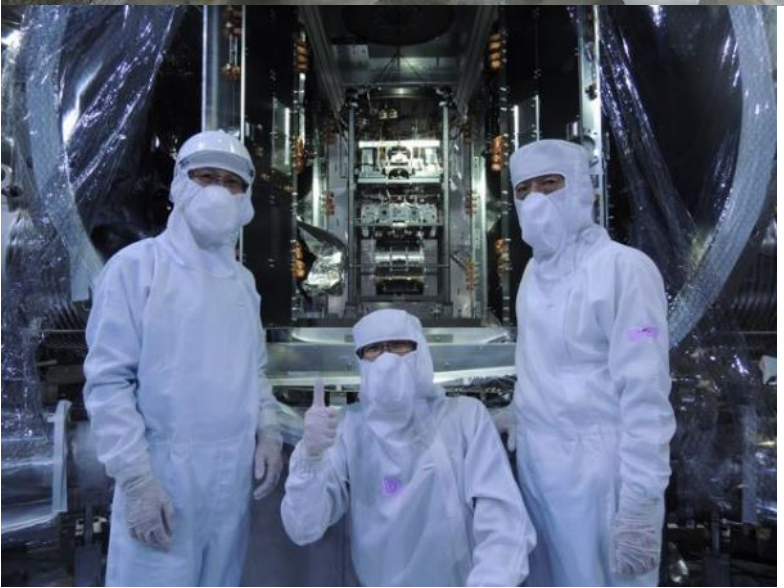
All mirrors have already suspended and no serious problem has been occurred so far.

HCB mission was successfully over!

Installation







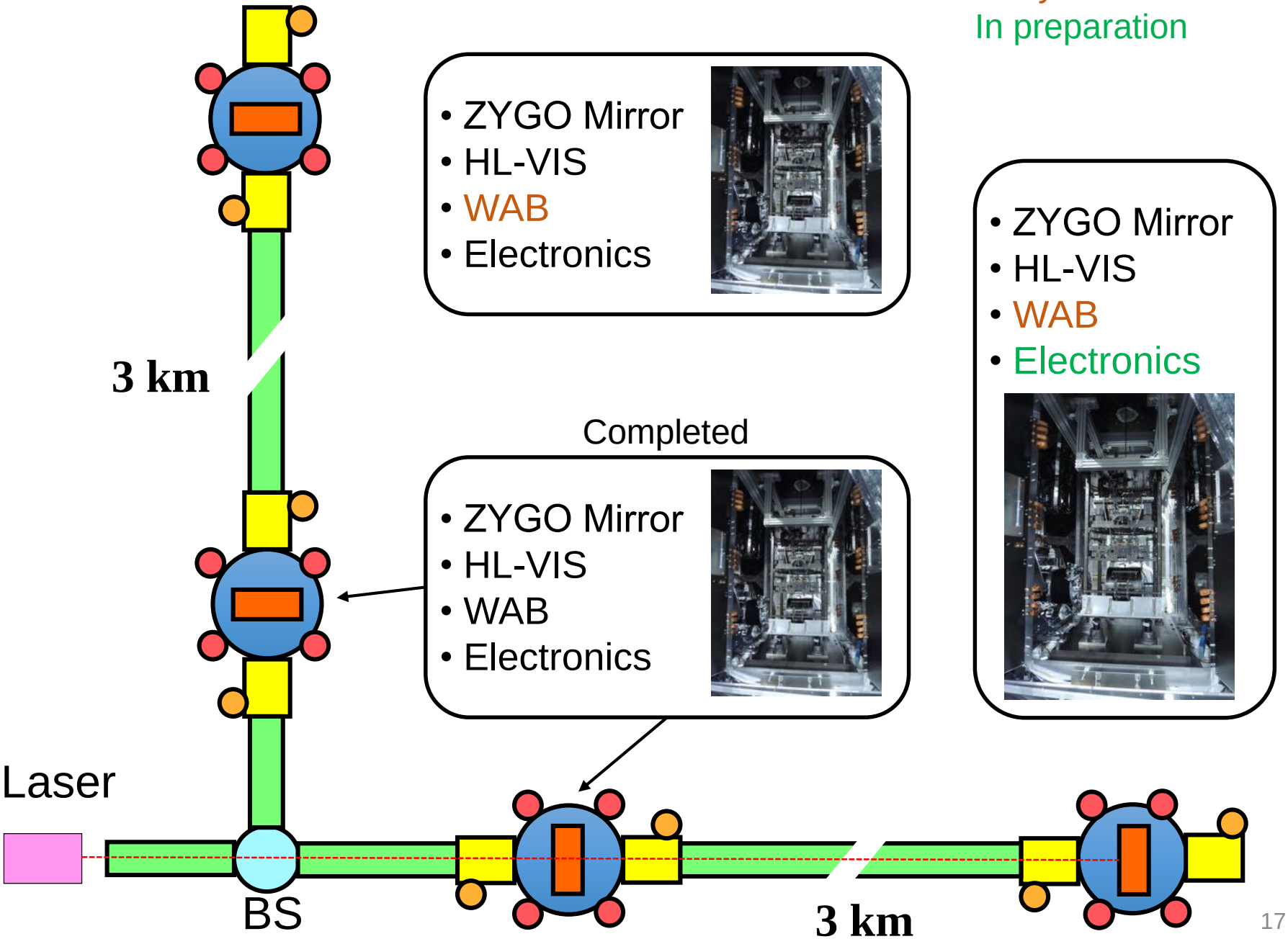
All sapphire mirrors have been installed in the cryostat.

All sapphire mirror has been suspended by 13.5-meter suspension.

Ready to start commissioning!

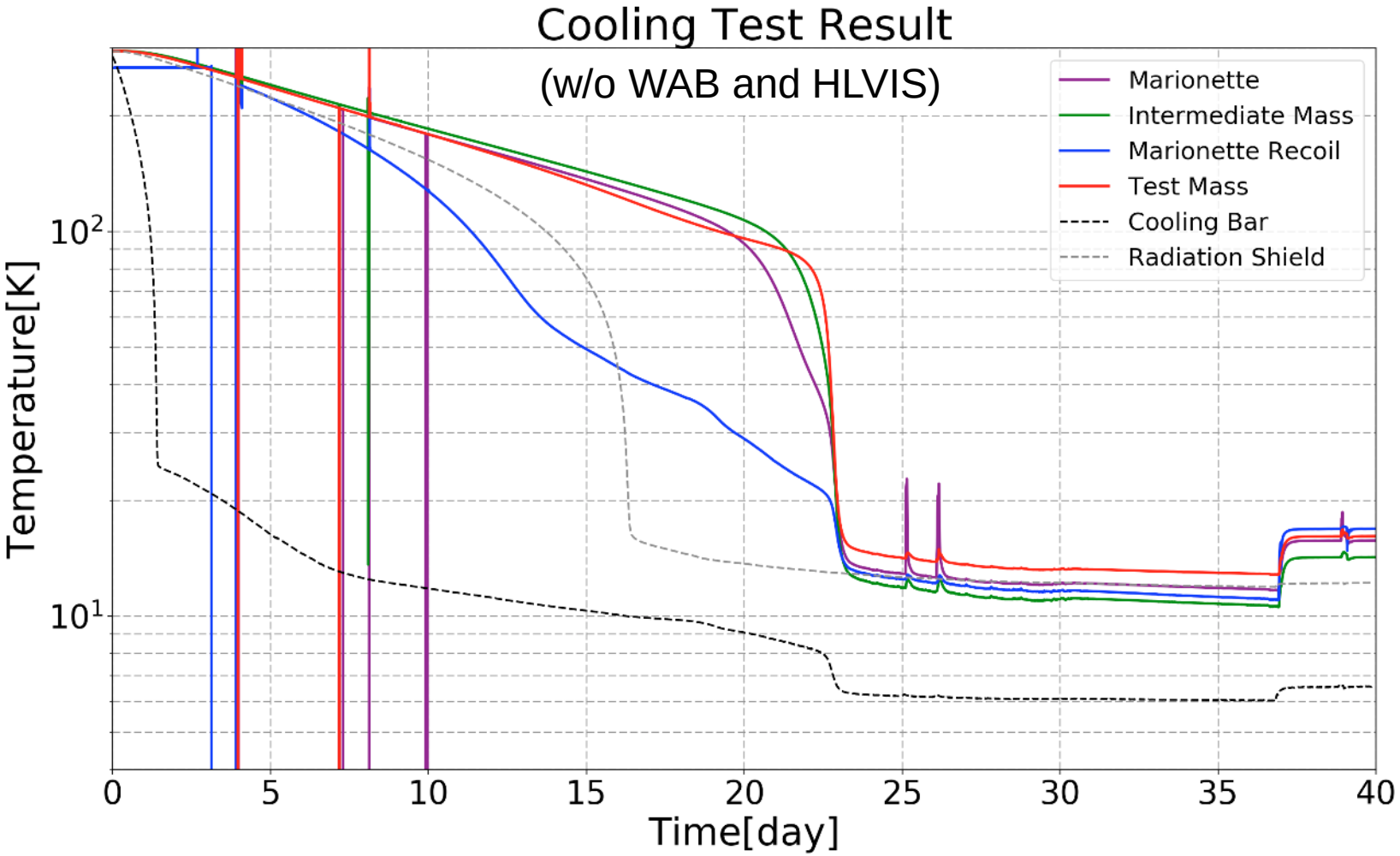
Preparation status summary

Not yet finalized
In preparation



Cooling Performance

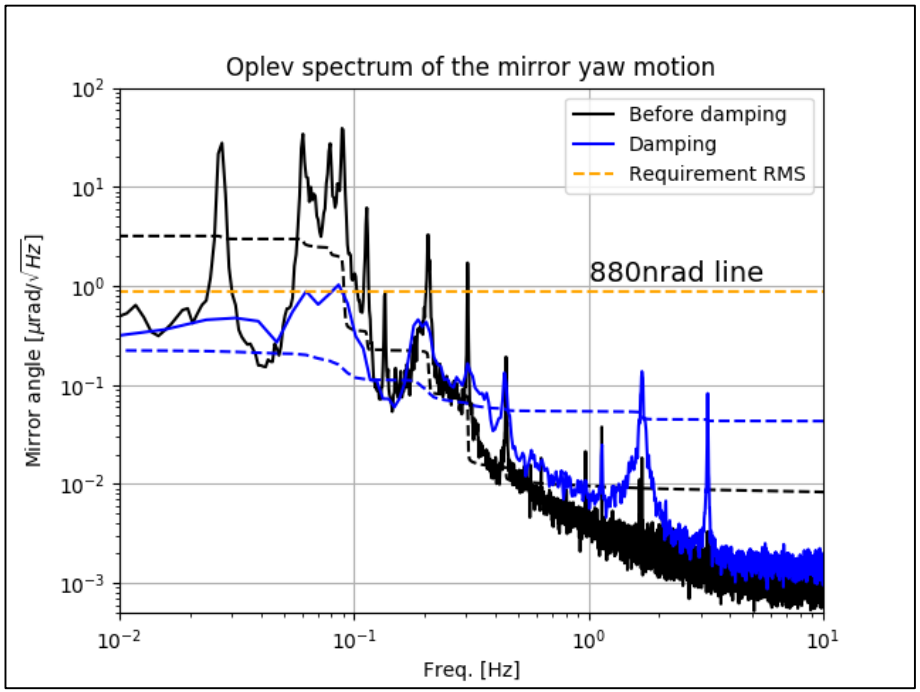
We cooled payloads three times and achieved to reach below 20 K every time.



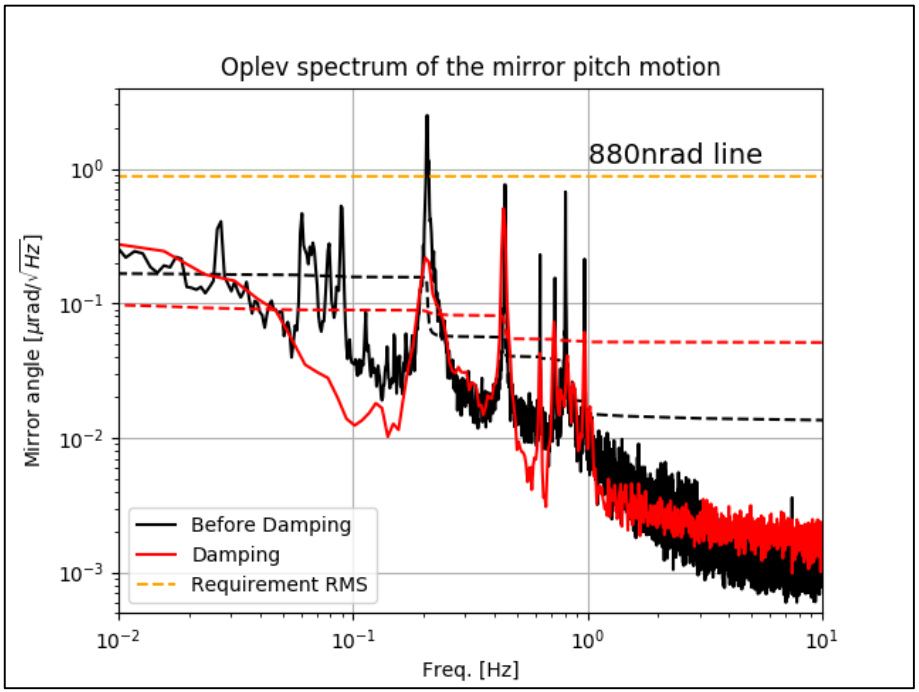
We can reach below 20 K within about 3 weeks.
We will check WAB and HLVIS affects the cooling performance or not soon.

Damping control at cryogenic temperature

Angular control for initial alignment of 3-km arm Fabry-Perot cavity



Yaw motion



Pitch motion

Achievement
200 nrad for Yaw motion RMS, 100 nrad for Pitch motion RMS.

We satisfied the angular motion requirement for local damping (200 nrad for each).

Summary

- We succeeded in the installation into the cryostat and suspension of all four cryogenic payloads.
- So, commissioning of the full configuration interferometer will start soon.
- Cooling performance is well enough to reach below 20 K within three weeks.
- Angular control at cryogenic temperature was tested, and we achieved that 200 nrad RMS and 100 nrad RMS for Yaw and Pitch motion, respectively.
- This result satisfies the requirement of local control of angular motion.

ありがとうございました
Thank you for your attention