Status of KAGRA Cryogenics

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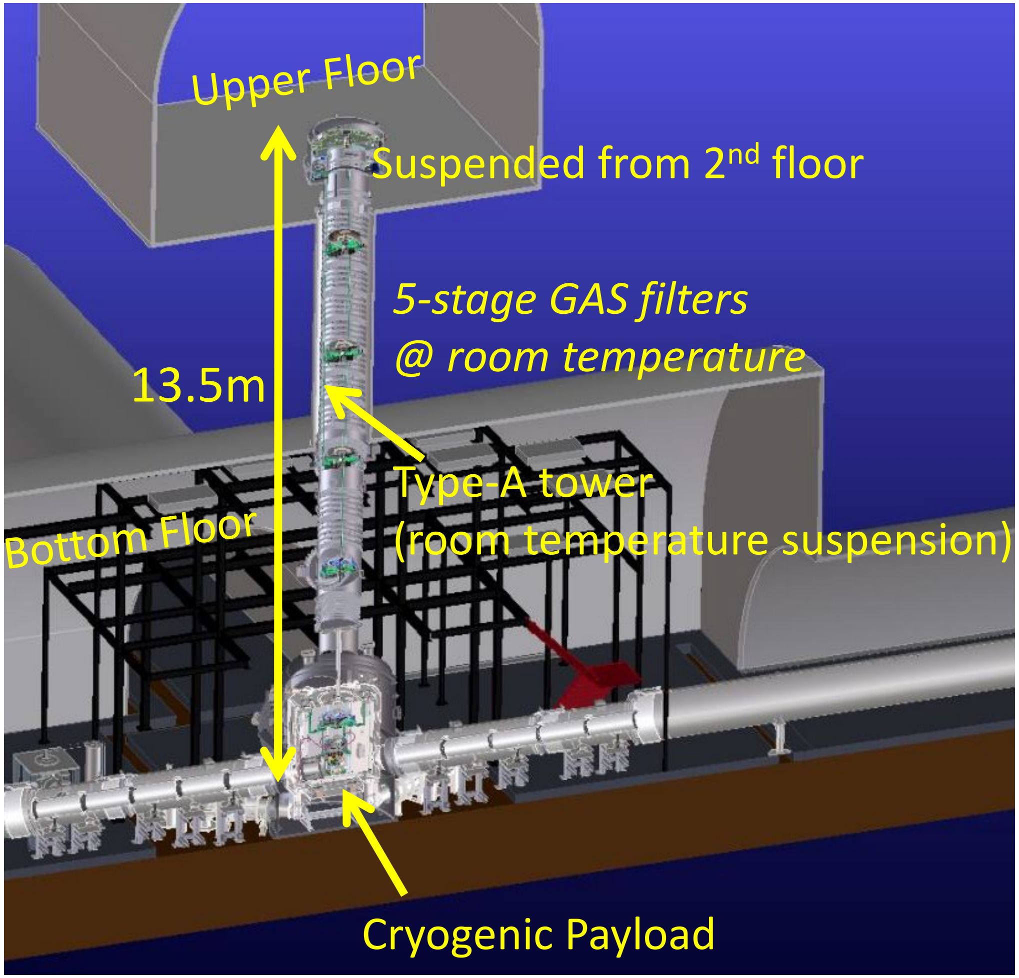
ICRR, KAGRA Collabration

July 7, 2021, KAGRA International Workshop with online style

KAGRA Cryogenics

Cryogenics is one of key features of KAGRA.

Sapphire mirror is suspended by four stage cryogenic pendulum.



Type-A suspension

Cryogenic payload

Detail of the payload can be seen in the paper (Class. Quantum Grav. **38** (2021) 085013)

Recent update of KAGRA cryogenics

- Cooling System

— Cooling performance of KAGRA cryogenic system

— Performance evaluation of Heat Link Vibration Isolation System (HLVIS)

— Establishment of cooling scheme without frost problem

- Suspension update for O4 observing run

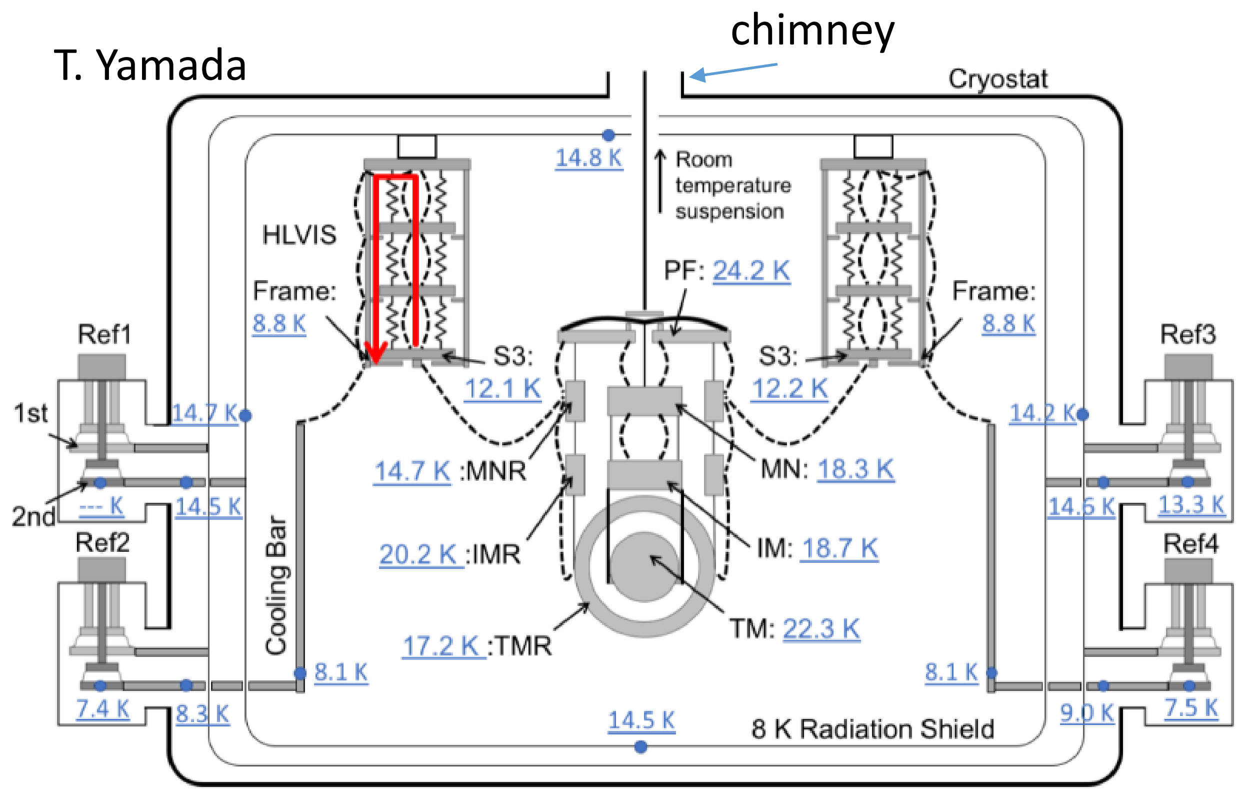
— Actuator modification and additional optical sensor installation

— New moving mass system development

— New baffle installation between the cryogenic payload and Type-A tower.

Cooling system update

Cooling performance of KAGRA cryogenic system

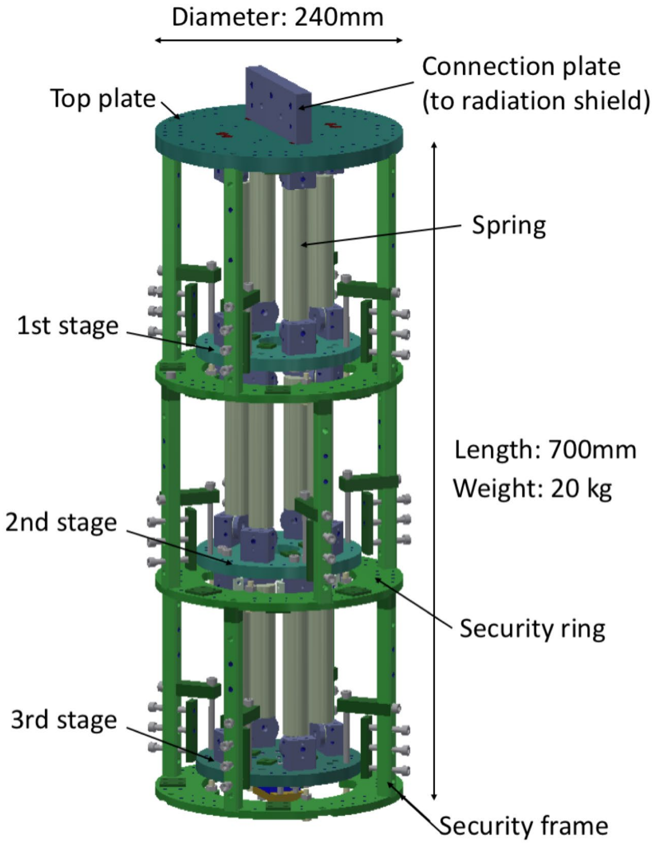


- Assuming that above temperature distribution is due to the heat flow, heat flow from the payload to cryostat is about 2 W.
- That heat flow is larger than we expected and one of possibility for the extra heat is thermal radiation from chimney on the radiation shield.
- So, we installed the additional baffles between PF and Type-A tower for reducing thermal radiation from upper room-temperature area.

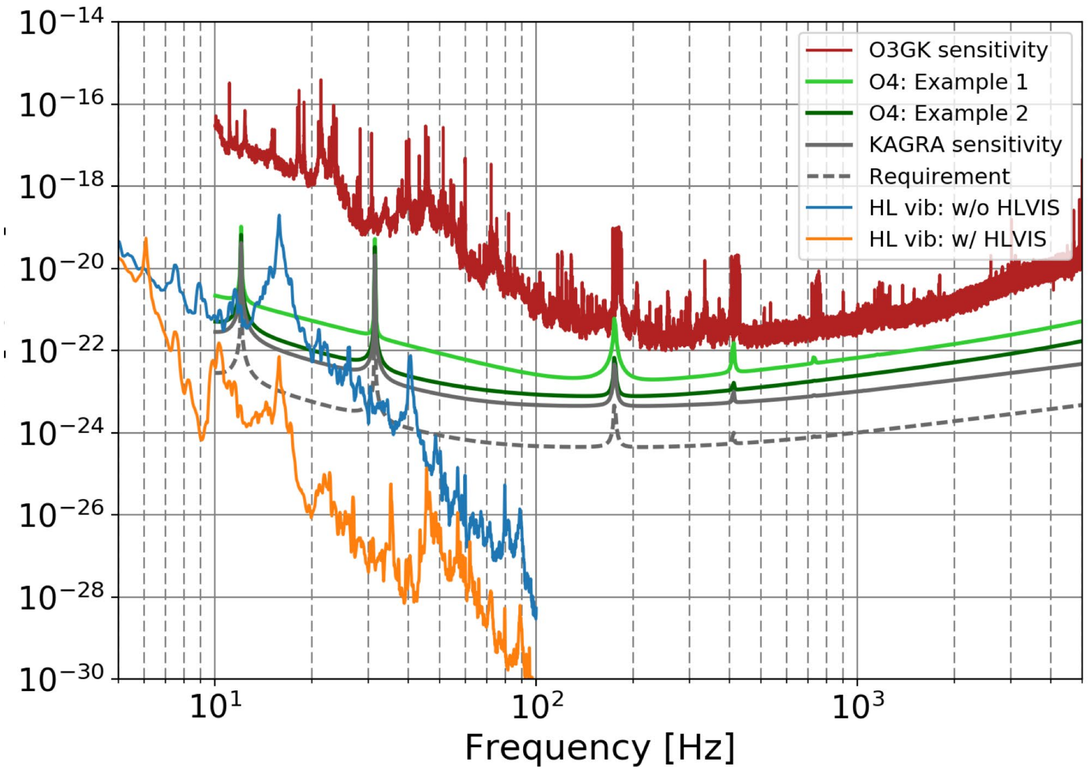
Performance evaluation of HLVIS

6N pure aluminum heat links are connected to the cryogenic payload from cryocooler.
→ Vibration can be induced and HLVIS is necessary.

Transfer function of HLVIs and spring constant of heat links are measured.
→ Effect on heat links is evaluated.



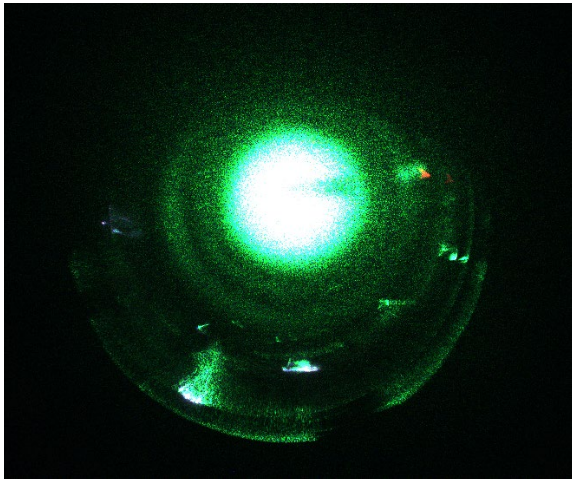
Schematic of HLVIS



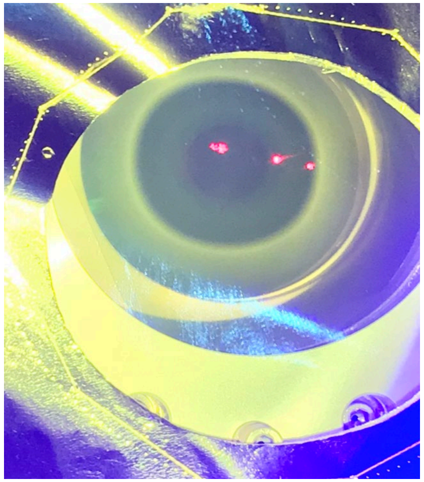
Estimation of heat link effect

New cooling scheme

One of the issues we faced during cooling is forming frost on the mirror and viewport surface.

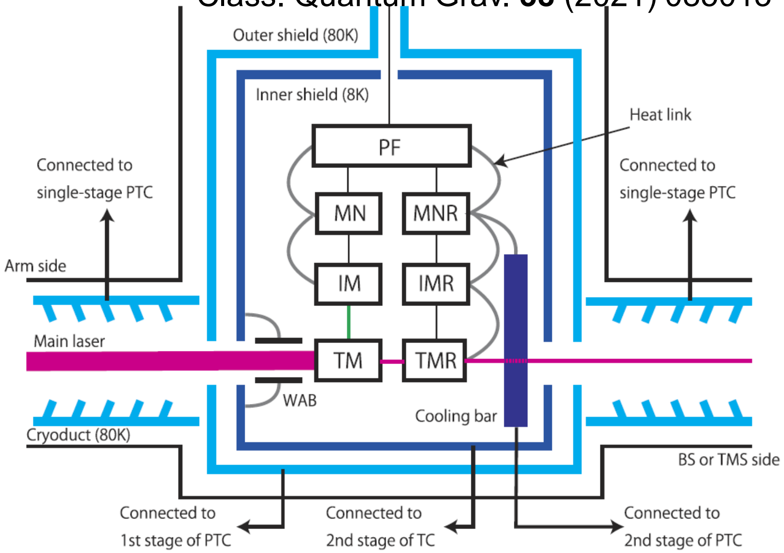


Mirror surface at cryo temp.



Viewport for an OpLev

Class. Quantum Grav. **38** (2021) 085013

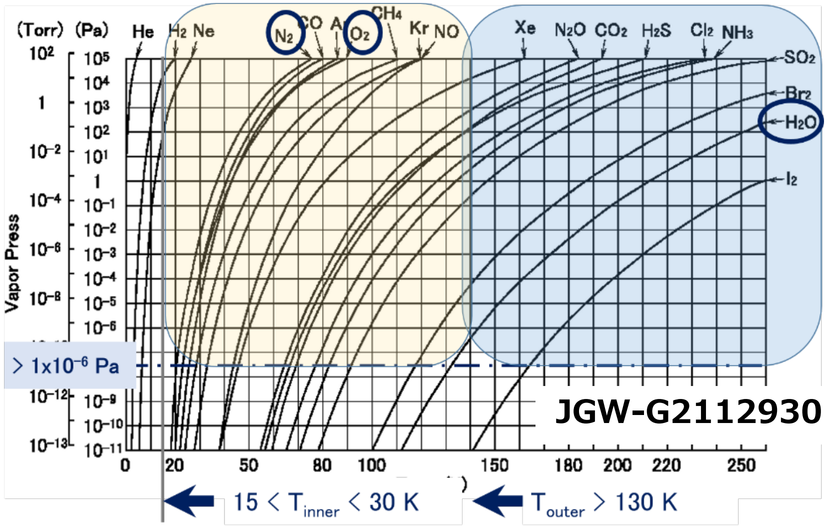


Schematic of cooling system

New procedure:

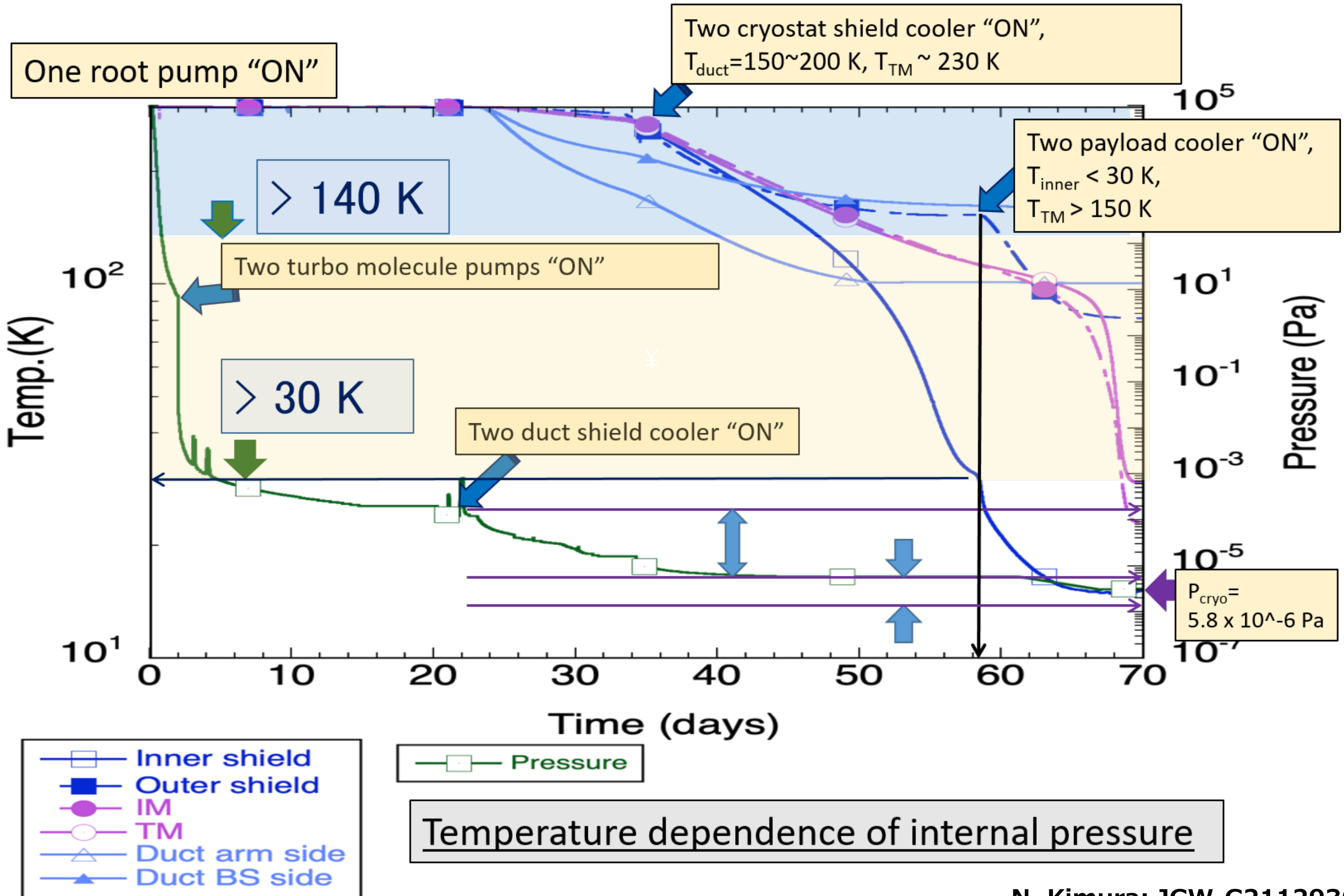
1. Pumping until pressure inside cryostat reaches below 10^{-4} Pa. (3 weeks)
2. Start only duct shield cryocoolers to trap H_2O at the duct shields. (2 weeks)
3. Start cryocoolers for radiation shields to trap N_2 and O_2 at the radiation shield. (3.5 weeks)
4. Start cryocoolers for the payload to cool the mirror at 20 K. (1.5 weeks)

→ Total 2.5 months to complete the cooling.



JGW-G2112930

Test of new cooling scheme



Temperature dependence of internal pressure

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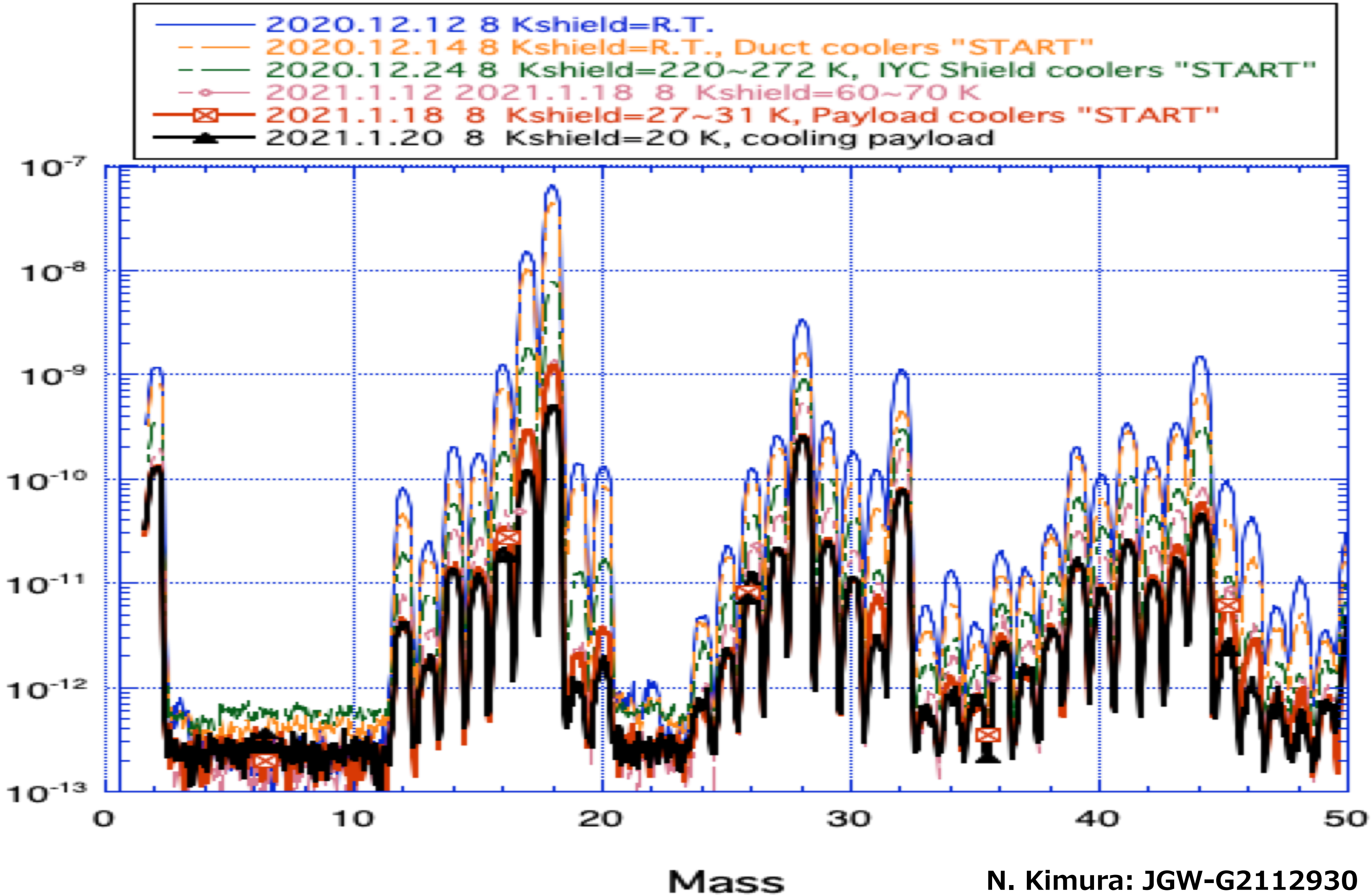
Test of new cooling scheme



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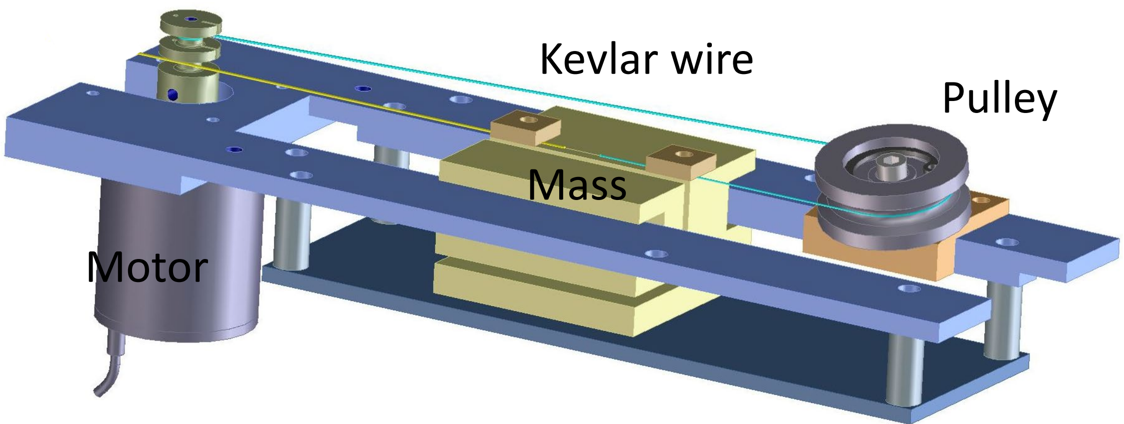
Even after the completion of cooling, a mirror and viewports don’t seem to be covered by frost.

Suspension update

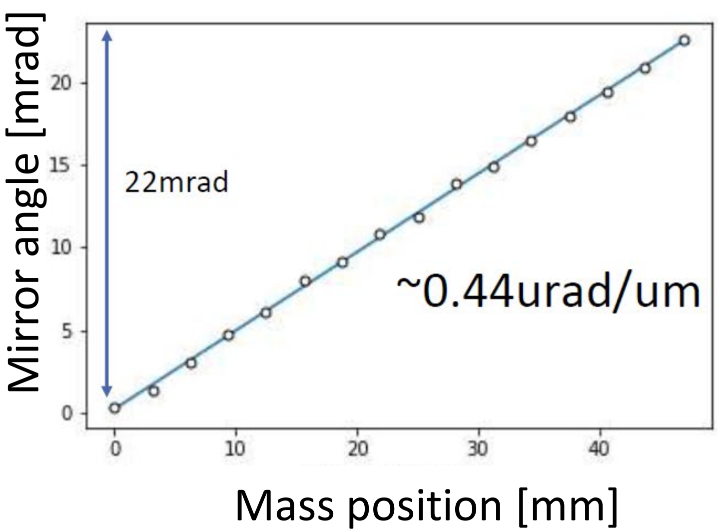
New moving mass

Since old (initial design of) moving mass has a problem on long-term reliability, we developed a new moving mass for control mirror inclination

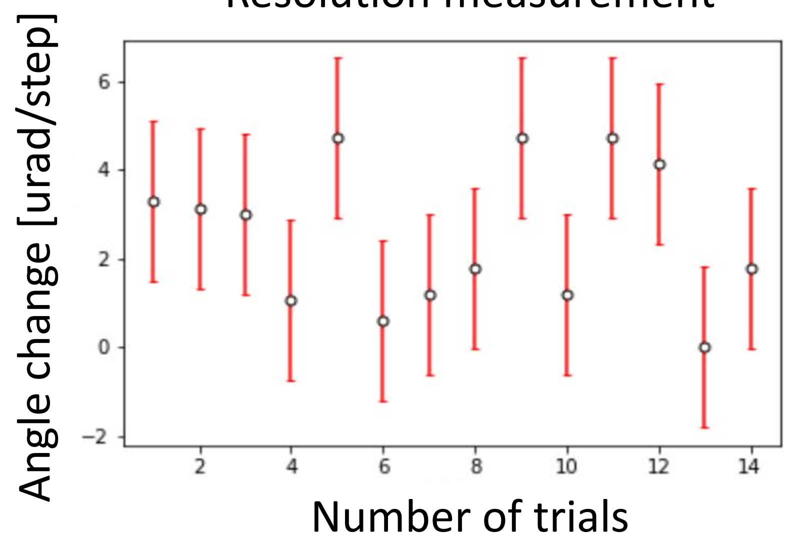


Mass: 300 g
Moving range: 50 mm
Control range: $\pm$11 mrad
Resolution: ~3 urad

Range measurement



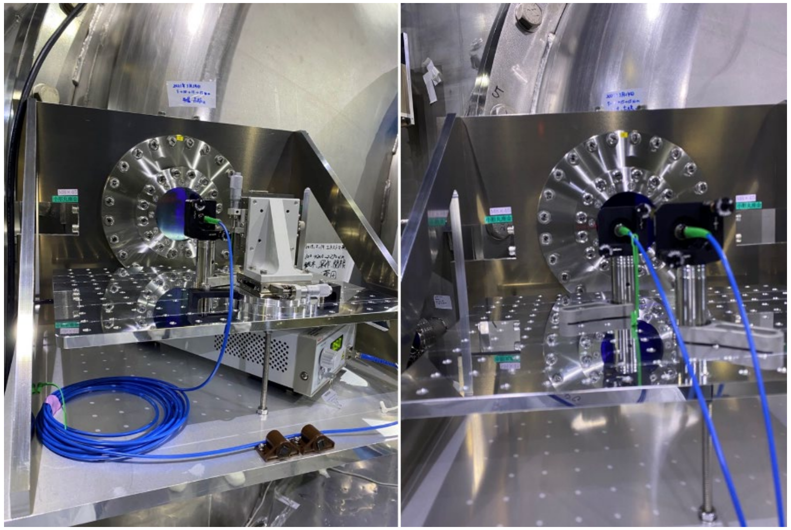
Resolution measurement



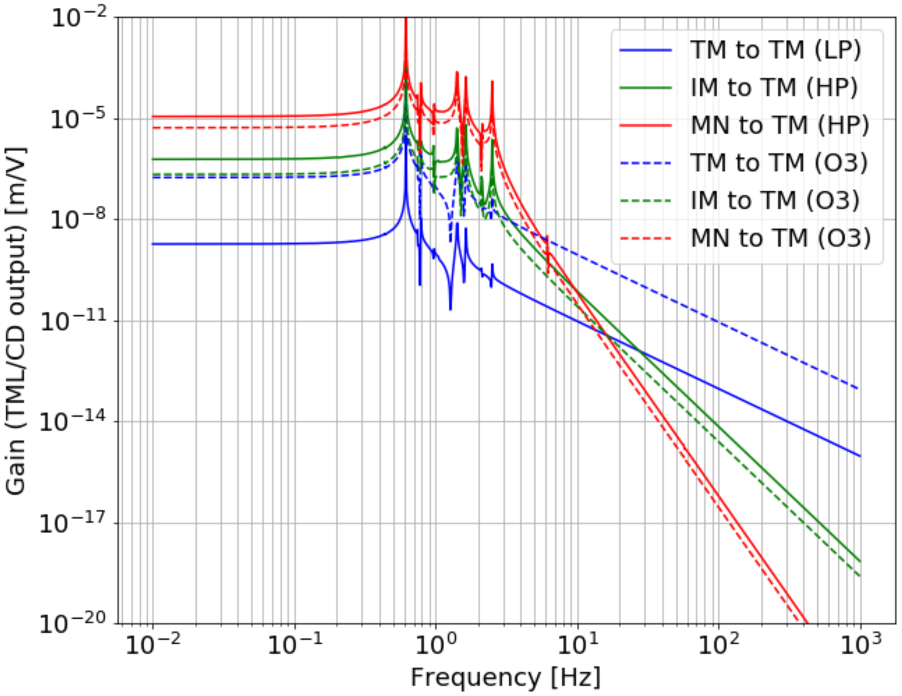
Sensors and actuators update

Issues during O3GK:

1. The sensitivity at low frequencies (< 50 Hz) is limited by control noise of the payload.
   → Optical levers and optical length sensing sensors are newly installed.
2. DAC noise of TM actuators is very close to the sensitivity.
   → Electronics will be replaced to the lower power's one.
3. Interferometer locking sometimes becomes difficult when ground motion is large.
   → Magnets on MN and IM are replaced to larger ones.

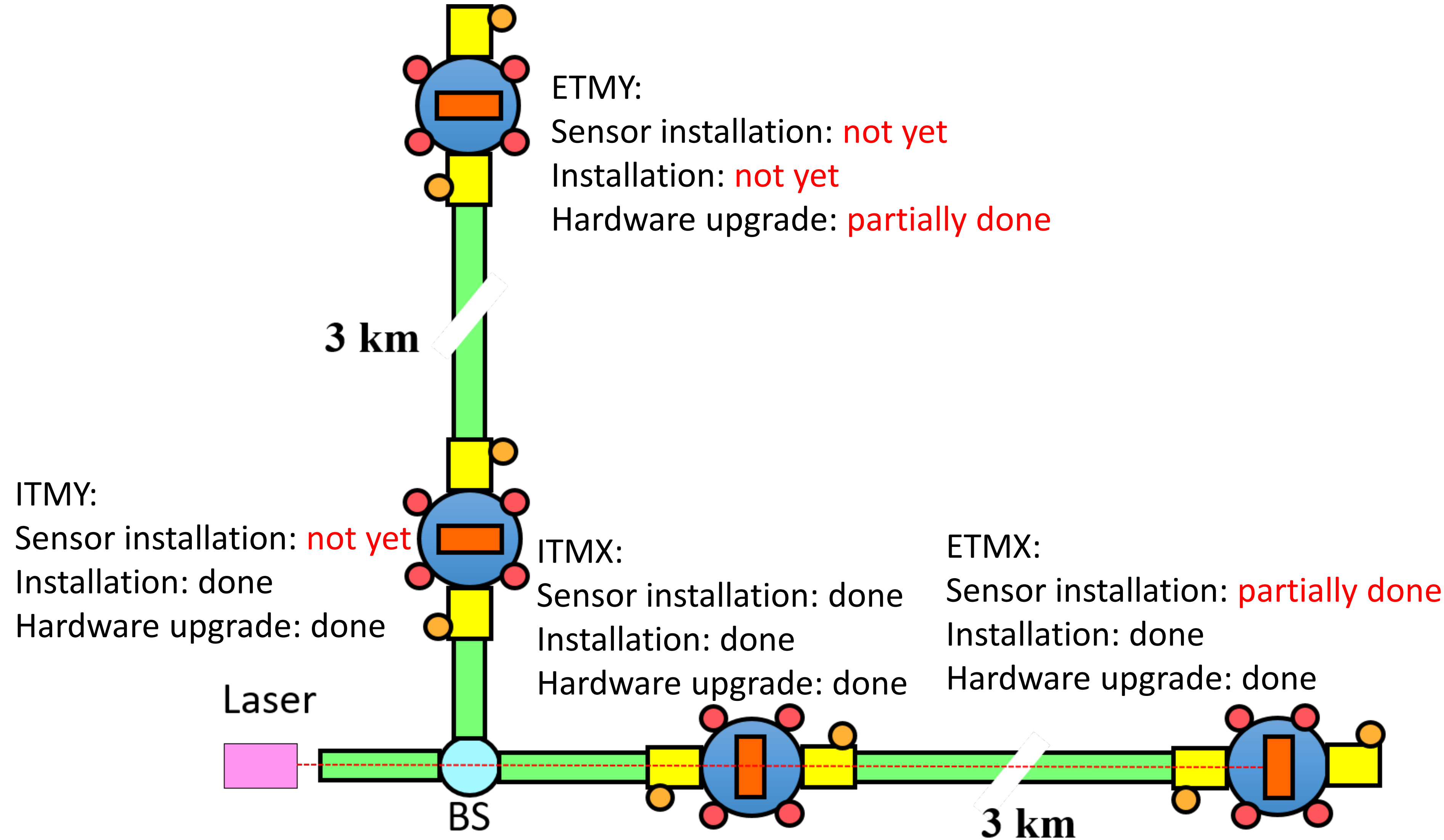


Newly installed optical sensors (light source side)



Actuator efficiency

Current progress



Installation for ETMX will be finished by the end of July.
Preparation for ITMY and ETMY will be done by the end of September.

Summary

- Towards O4 observing run, we are proceeding both hardware upgrade and cryogenic strategies.

- Cooling scheme was discussed and cooling was demonstrated.

— It will take 2.5 months for cooling from atmospheric pressure.

— No serious frost problem was not observed.

- Hardware update is ongoing.

— X-arm payload will be ready soon.

— Y-arm payload will be ready at the end of September.