Lessons from CLIO

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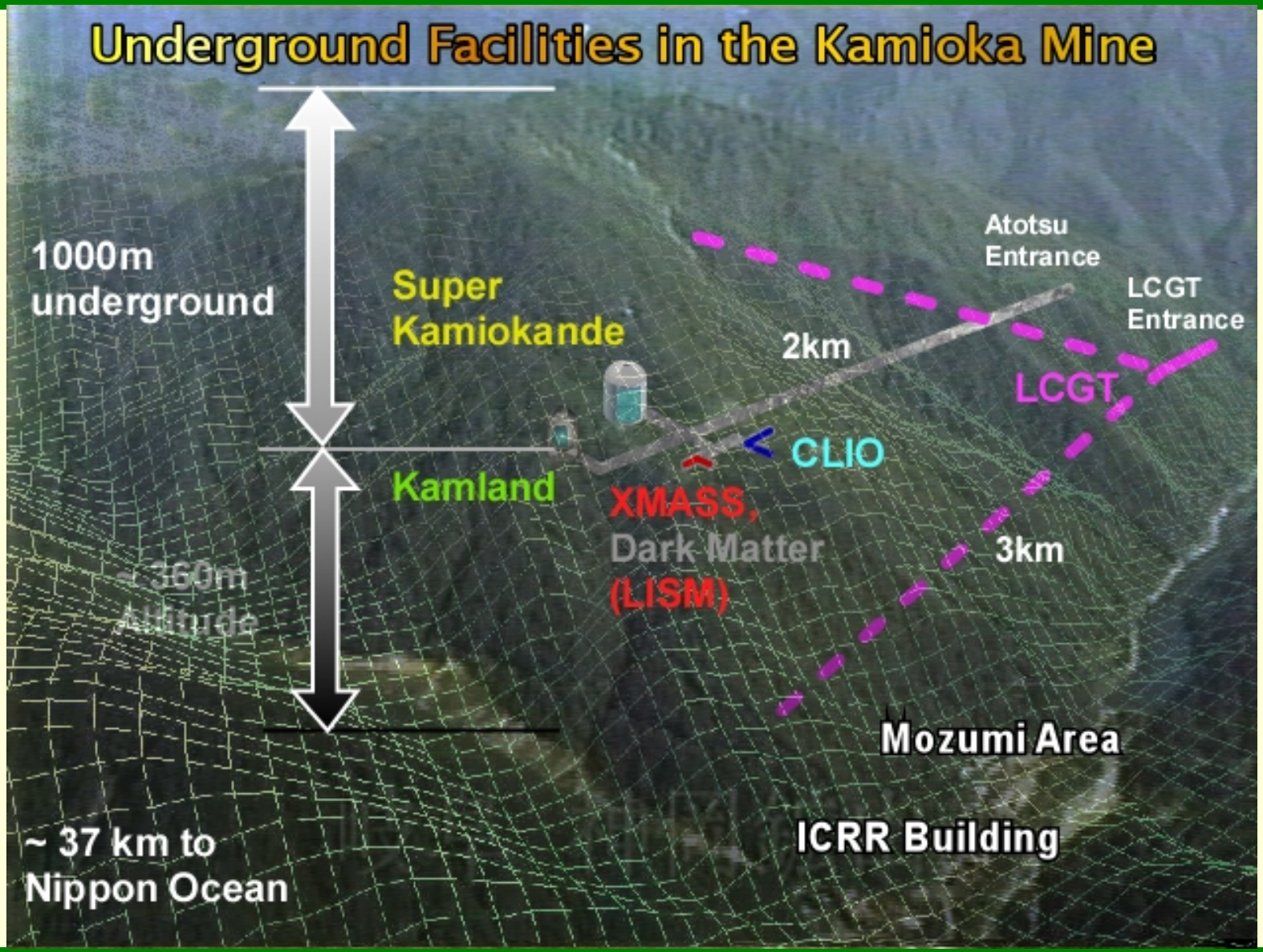
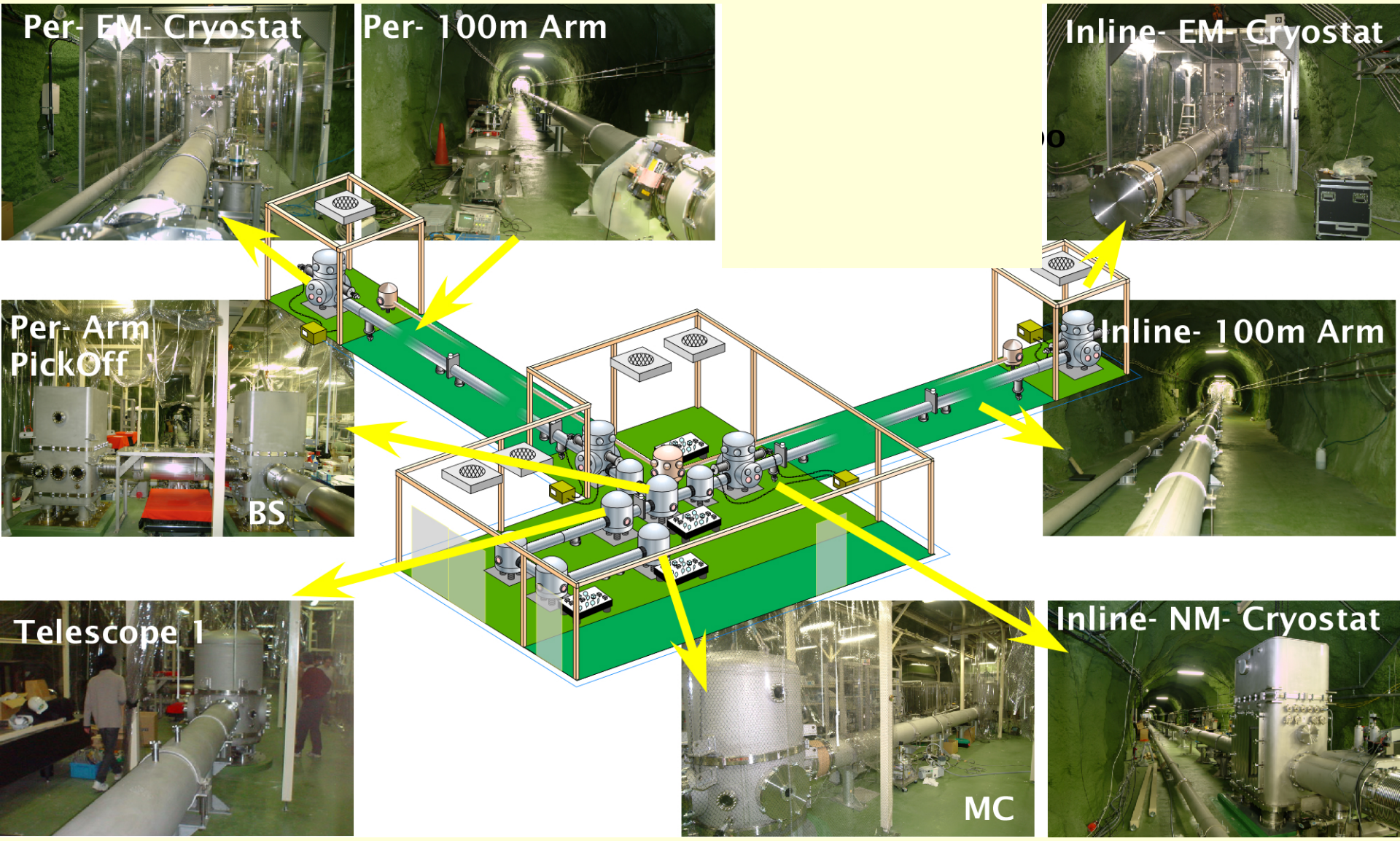
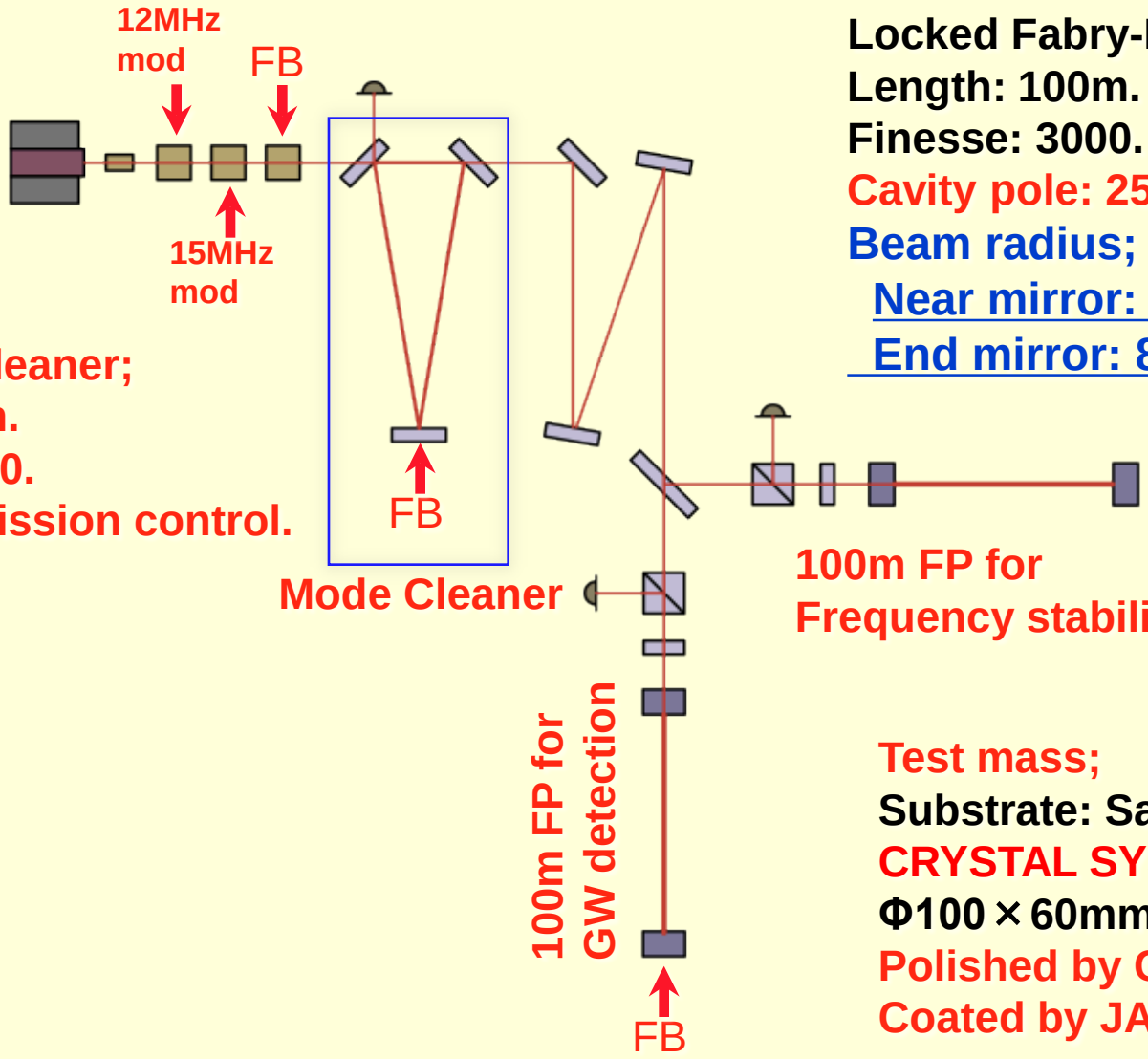
CLIO: Prototype for KAGRA



Overview of CLIO



CLIO Optical configuration



Innolight
MEPHISTO
1064nm, 2W

One Mode Cleaner;
Length: 9.5m.
Finesse: 1800.
Mod. transmission control.

Locked Fabry-Perot IFO
Length: 100m.
Finesse: 3000.
Cavity pole: 250Hz.
Beam radius;
Near mirror: 4.9mm.
End mirror: 8.5mm.

100m FP for
Frequency stabilization

Test mass;
Substrate: Sapphire.
CRYSTAL SYSTEMS
Φ100×60mm, 1.8kg.
Polished by CANON
Coated by JAE

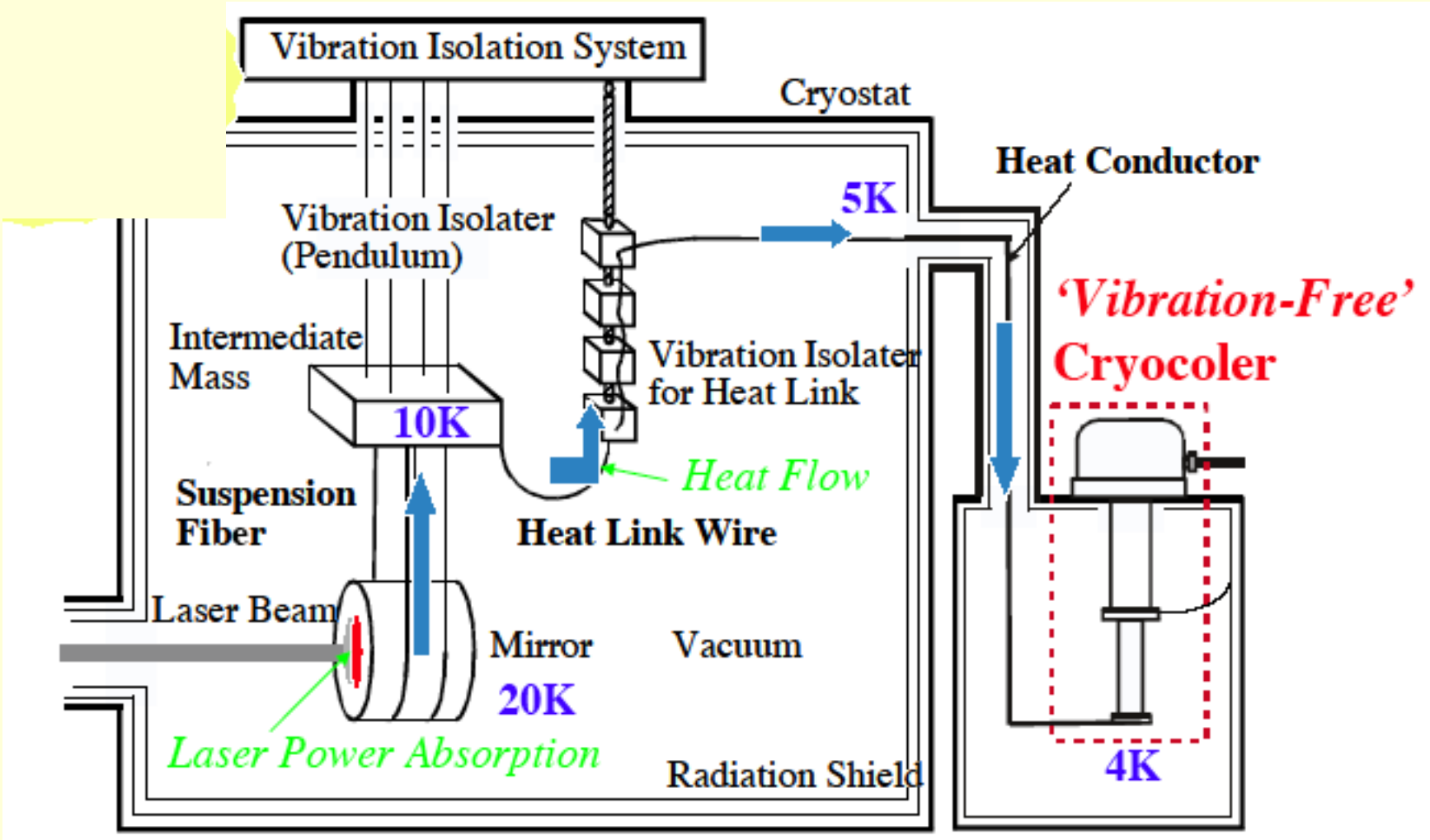
Lesson 1

1. It was not easy to cool the mirrors.

Difficulties of cooling

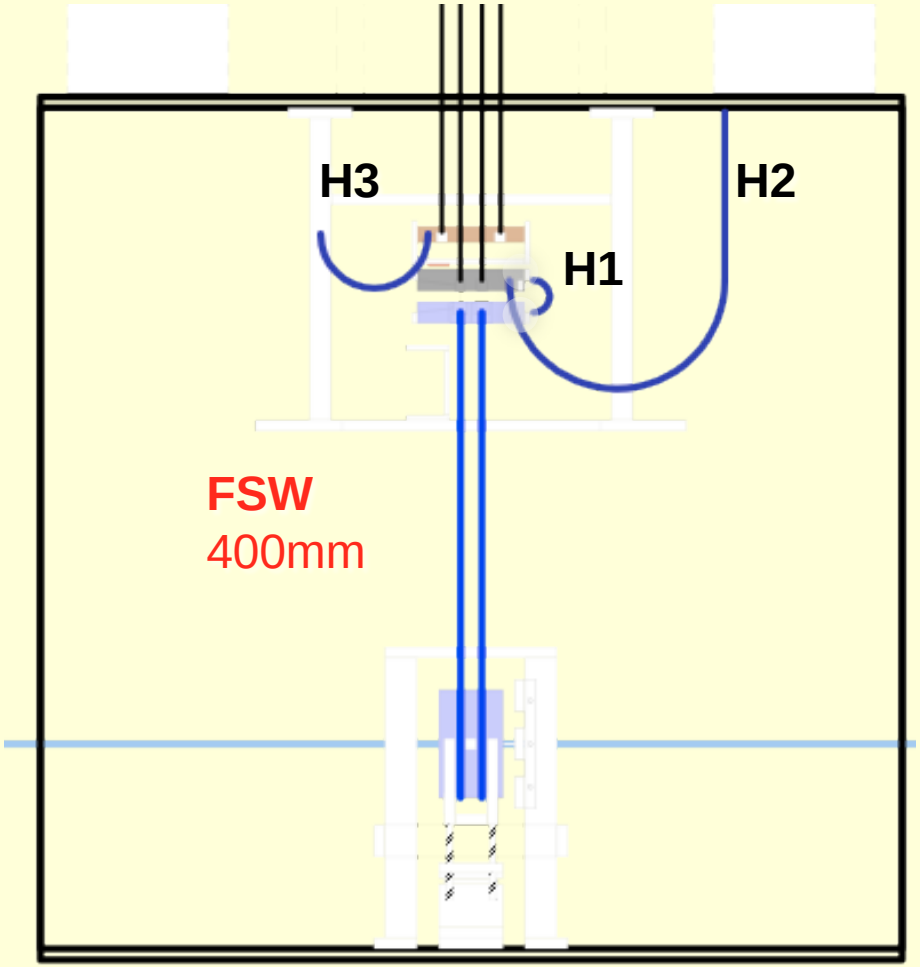
- Thermal conduction is the only method for cooling.
  - Mirrors are in high vacuum (10^{-5}Pa) and low temperature.
  - No convection and no radiation for heat transfer.
- Mirrors are vibration isolated.
- Low suspension thermal noise is necessary.

Cooling method by a cryocooler

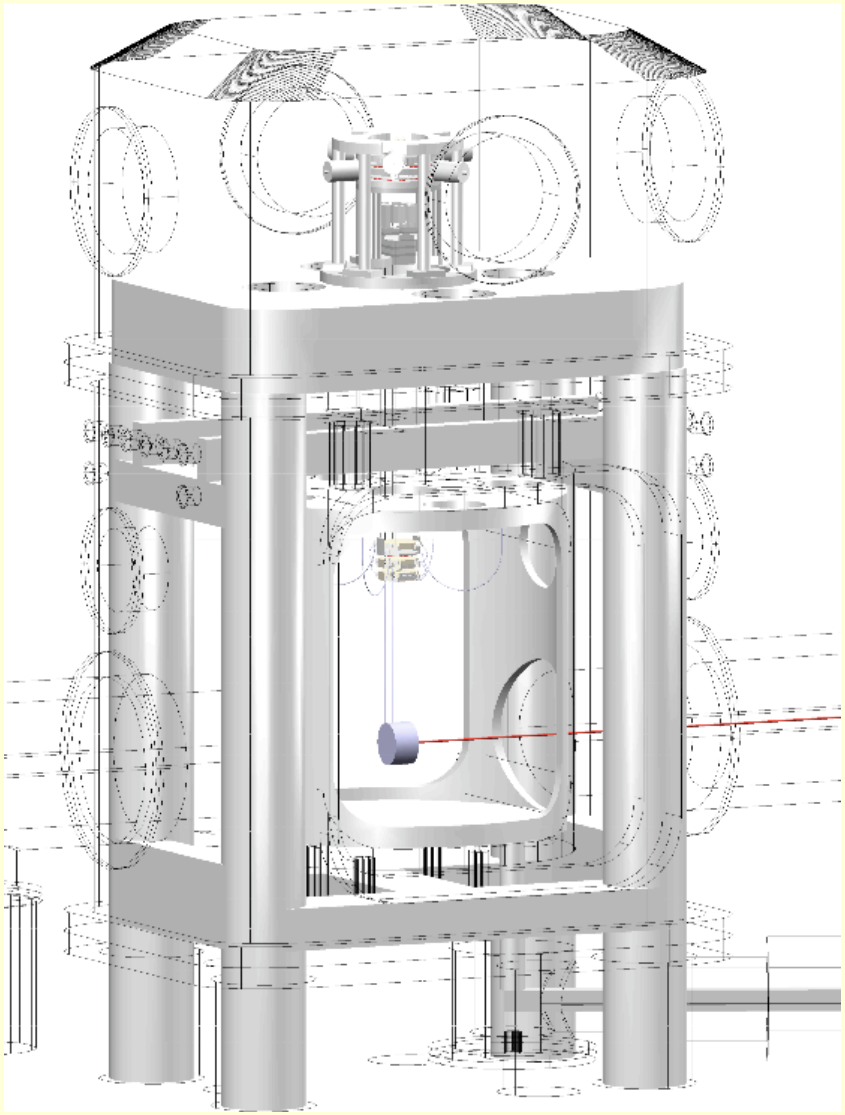


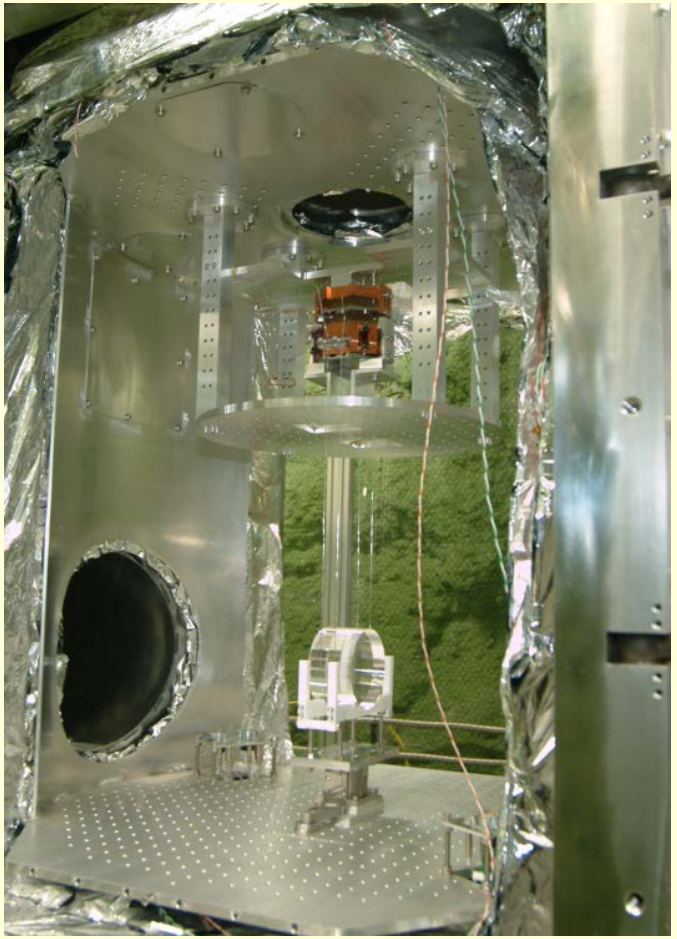
Suspension for cooling

- **Final suspension wire(FSW).**
  - **300K: Bolfur of Φ0.05.**
  - **Cryogenic: Al wire of Φ0.5.**
- **Three heat link wires(H1-3).**
  - **Cryogenic: Al wire of Φ0.5.**
- Two thermometers for monitoring.
  - Attached on clamping points of H1.
- Suspended mirror was housed in a cage prevent from radiation heat.

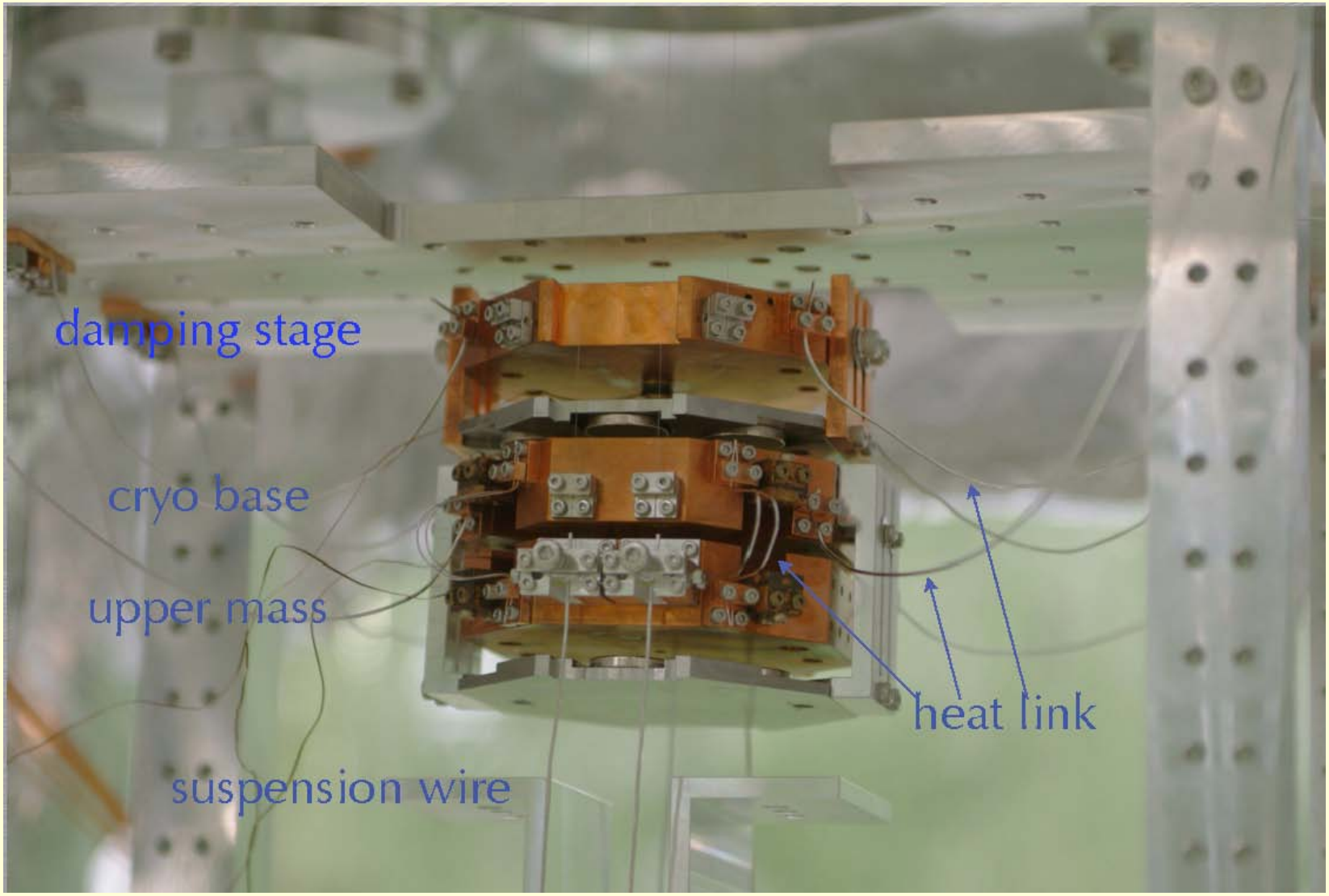


Cryogenic suspension





Intermediate Mass



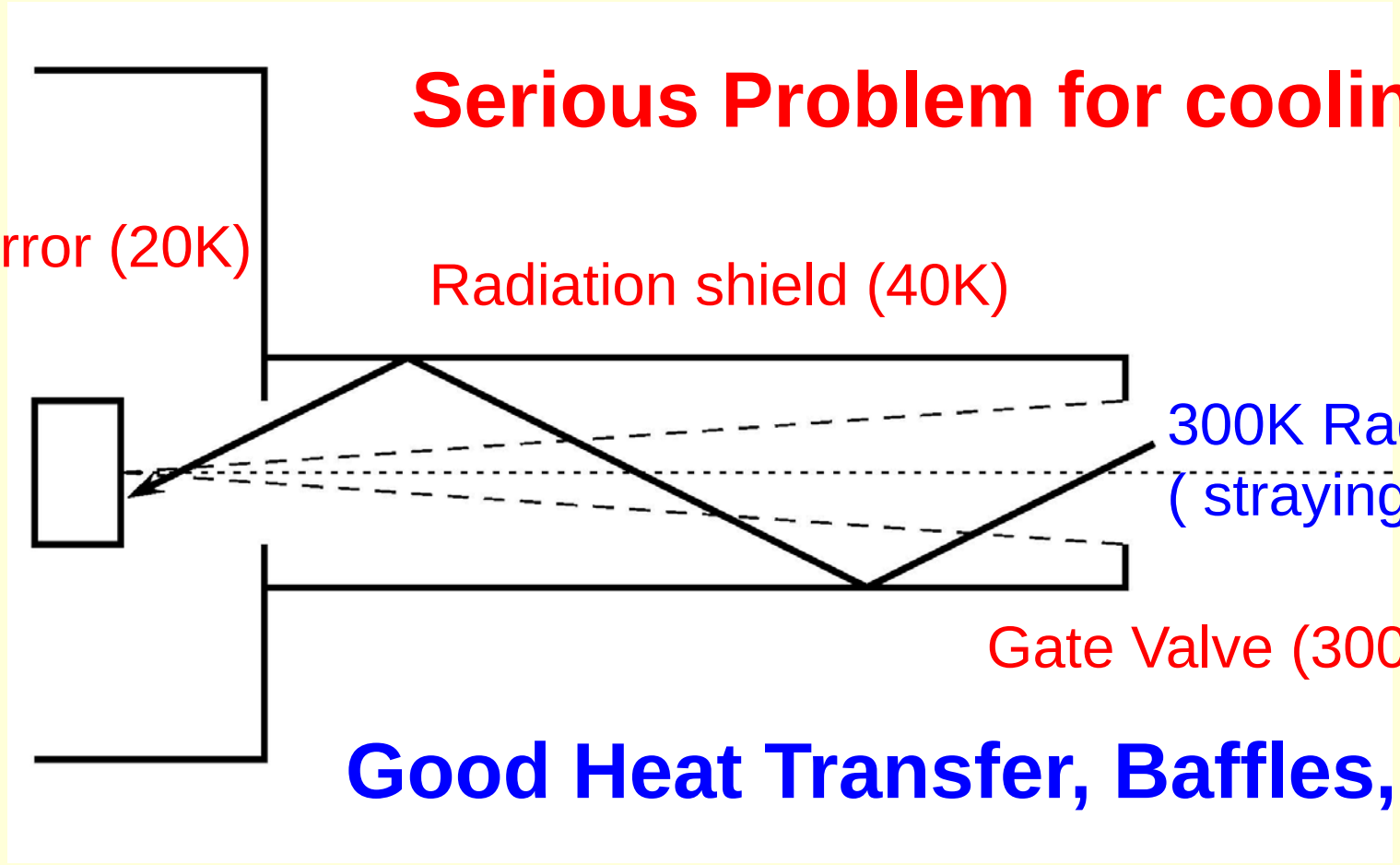
Lesson 1

1. It was not easy to cool the mirrors.

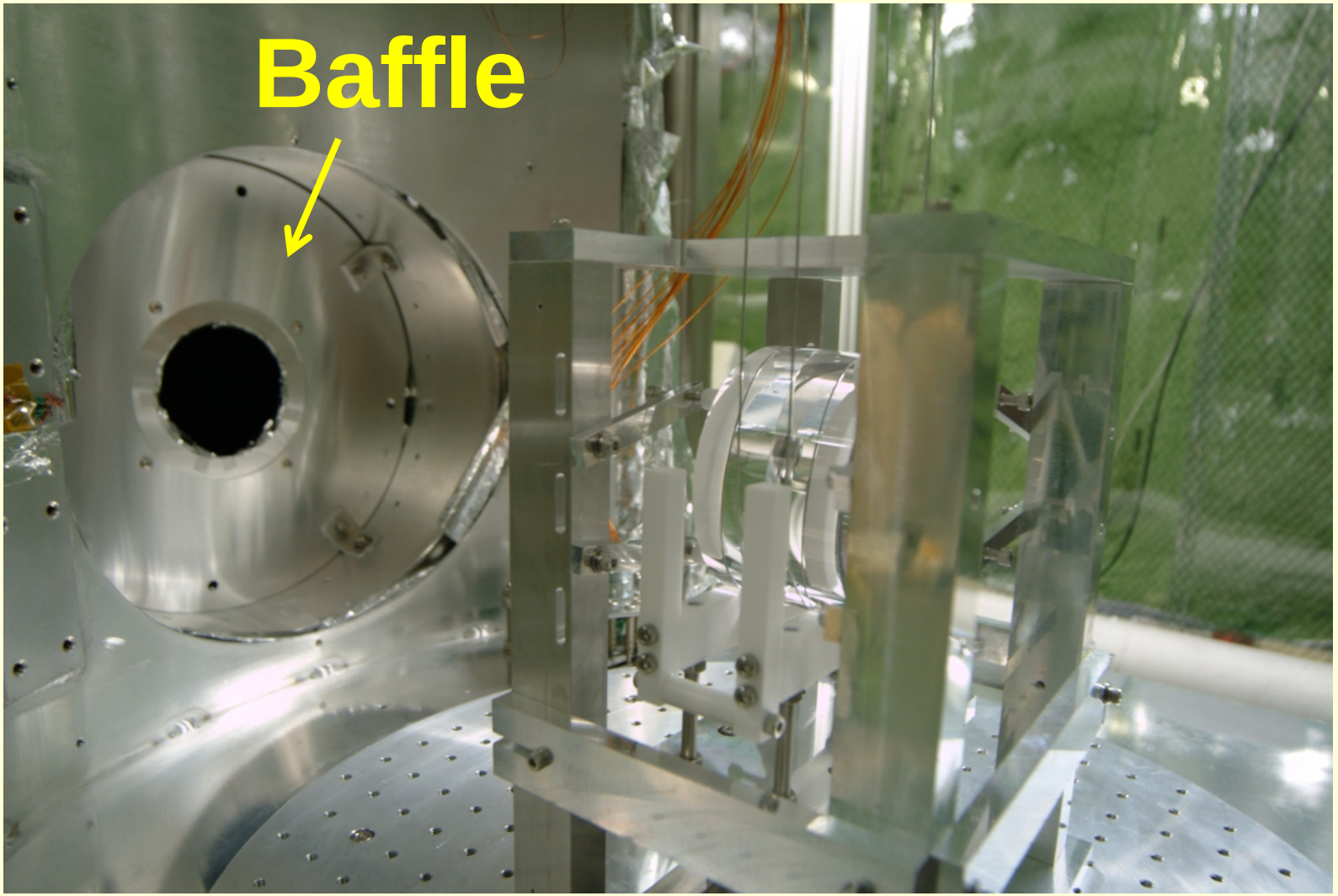
2. It was difficult to cool the mirrors.

300K Radiation

300K Radiation from window of Gate Valve warms mirrors



Radiation Shields 1



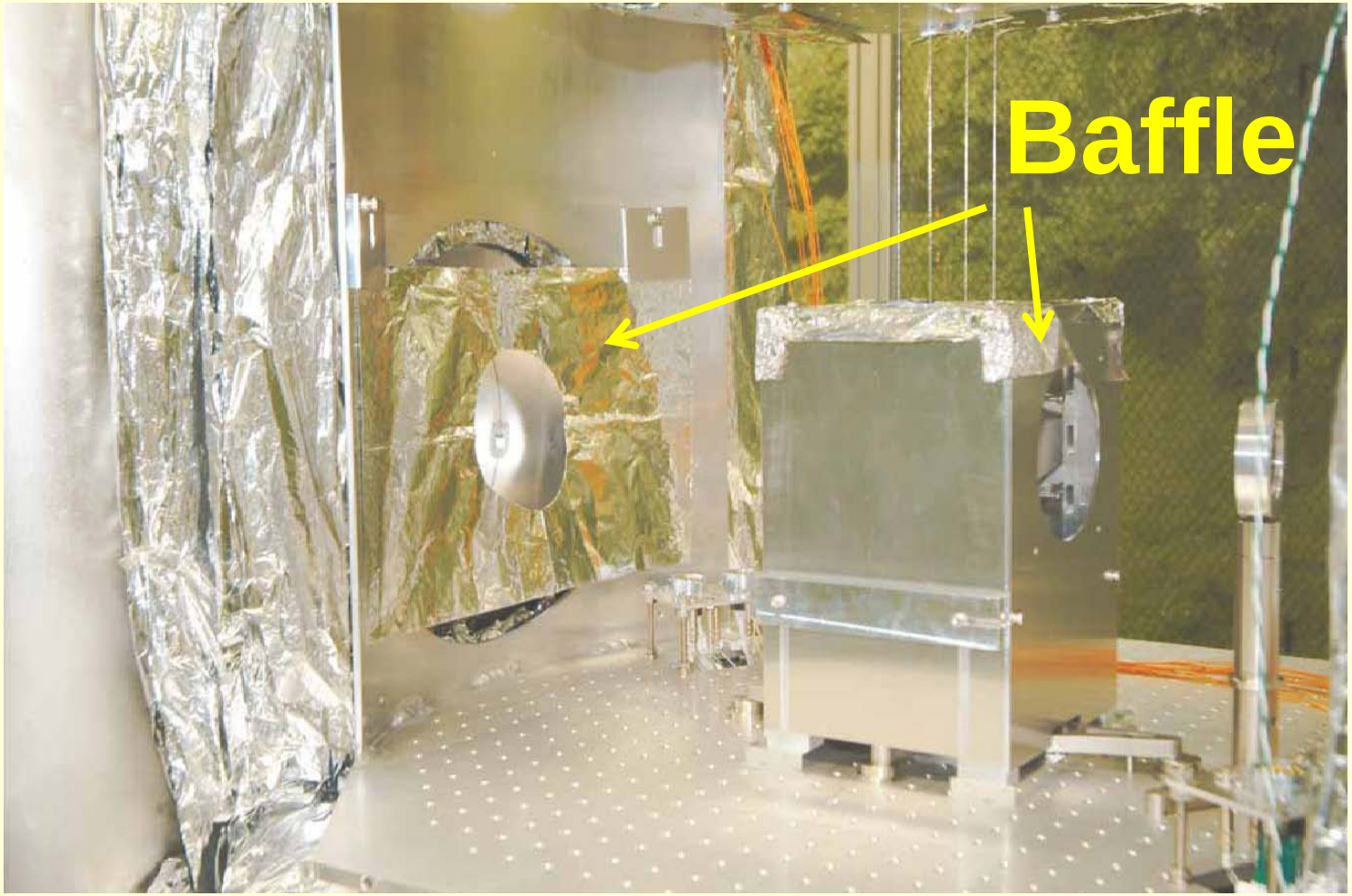
Lesson 1

1. It was not easy to cool the mirrors.

2. It was difficult to cool the mirrors.

3. It seemed almost impossible
   to cool the mirrors to 20K.

Radiation Shields 2



Lesson 1

1. It was not easy to cool the mirrors.

2. It was difficult to cool the mirrors.

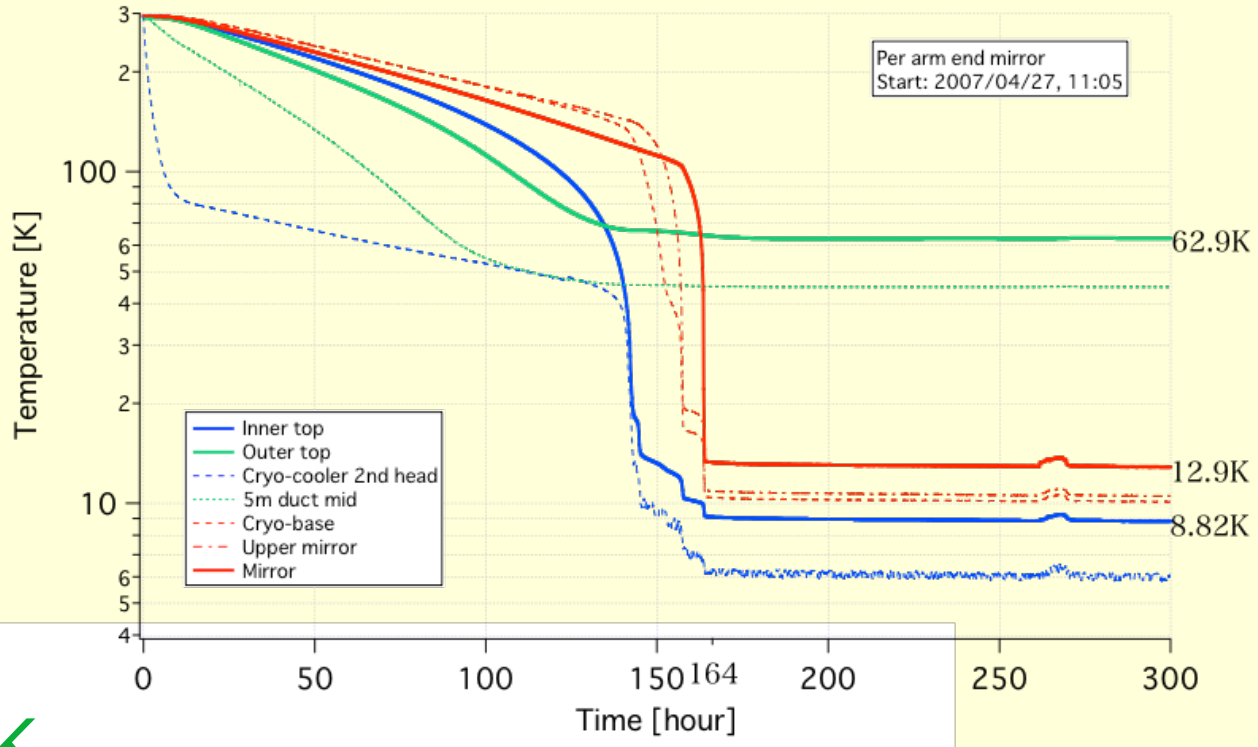
3. It seemed almost impossible to cool the mirrors to 20K.

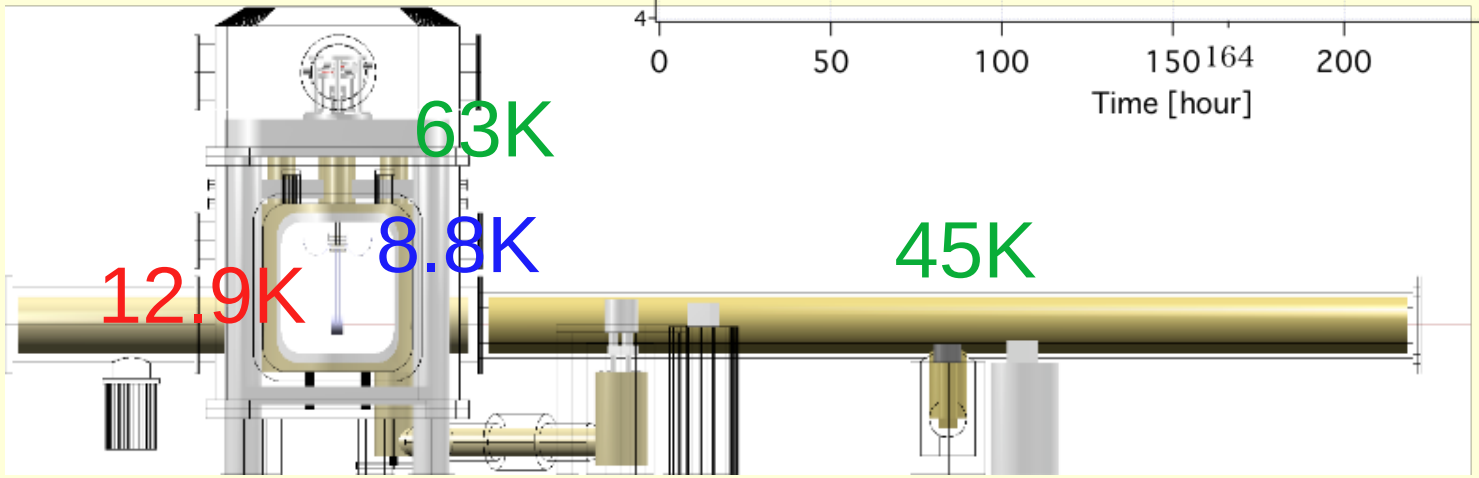
Radiation shield is essential for cooling.

Lesson 2

1. It takes long to cool mirrors.

Cooling test and achieved temperature





Cooling summary

	Cooling time	Mirror temp	Heat in the suspension	Heat at the 1st cooling 2006/02
Inline end	176hour start 07/06/22,10:00	13.5K	40mW	N/A
Inline near	174hour start 07/06/22,10:00	13.4K	36mW	N/A
Per arm end	164hour start 07/04/27,11:05	12.5K	62mW[#1]	116mW
Per arm near	193hour start 07/08/16,12:30	13.8K	29mW	109mW

#1; No shield for radiation from the outer shield at 63K.

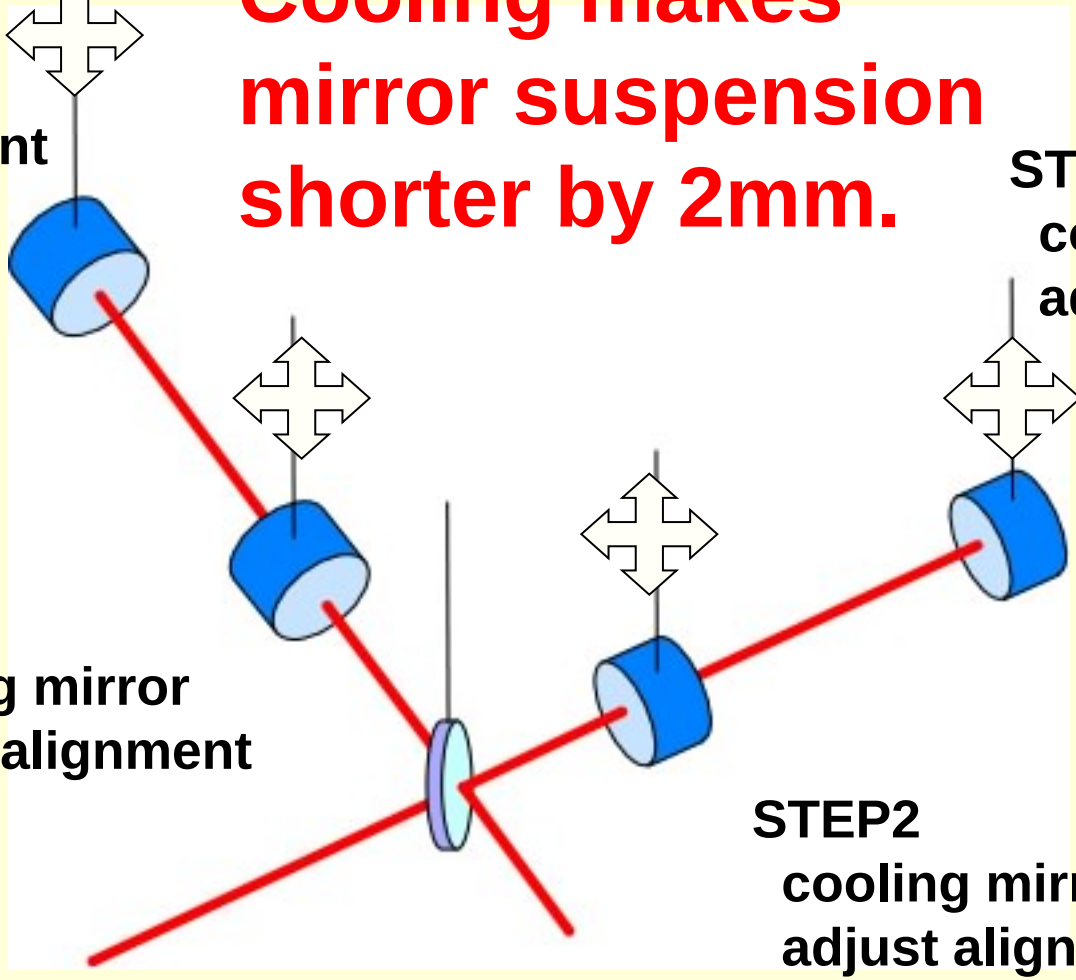
Lesson 2

1. It takes long to cool mirrors.

2. It is important to keep alignment.
   If we loose alignment, we have to warm up mirrors and adjust.

Cooling procedure (for example)

Cooling makes mirror suspension shorter by 2mm.



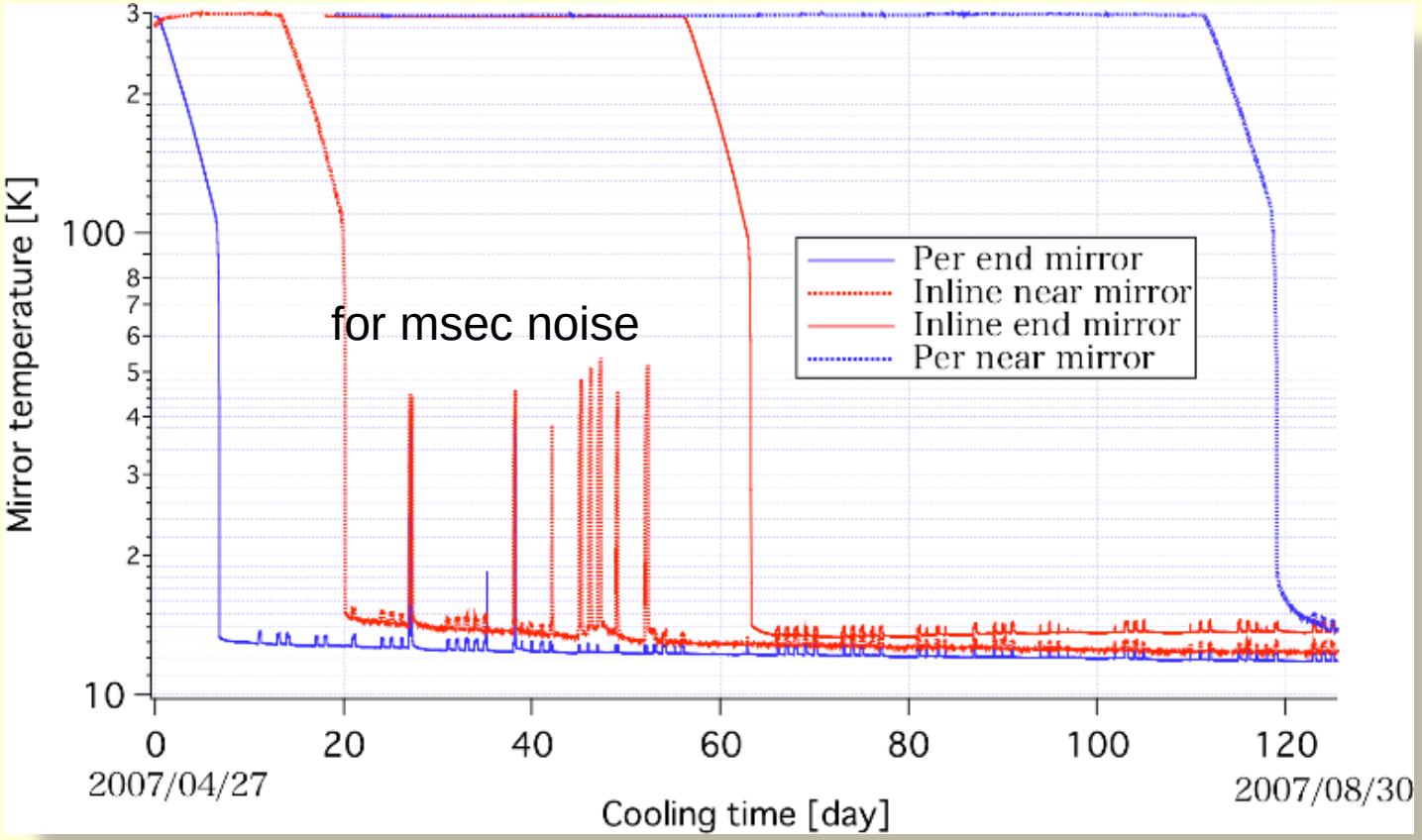
STEP3
cooling mirror
adjust alignment

STEP1
cooling mirror
adjust alignment

STEP4
cooling mirror
adjust alignment

STEP2
cooling mirror
adjust alignment

Cooling in 2007



- All mirrors are suspended by Φ0.5 Al wire.
- All mirrors are cooled at 12K -14K.
- Only inline near mirror was cooled during 07/03/16 - 04/24 using Φ1.0 Al wire.
- This is the first sensitivity trial with cryogenic cooled 4 mirrors.

Lesson 2

1. It takes long to cool mirrors.

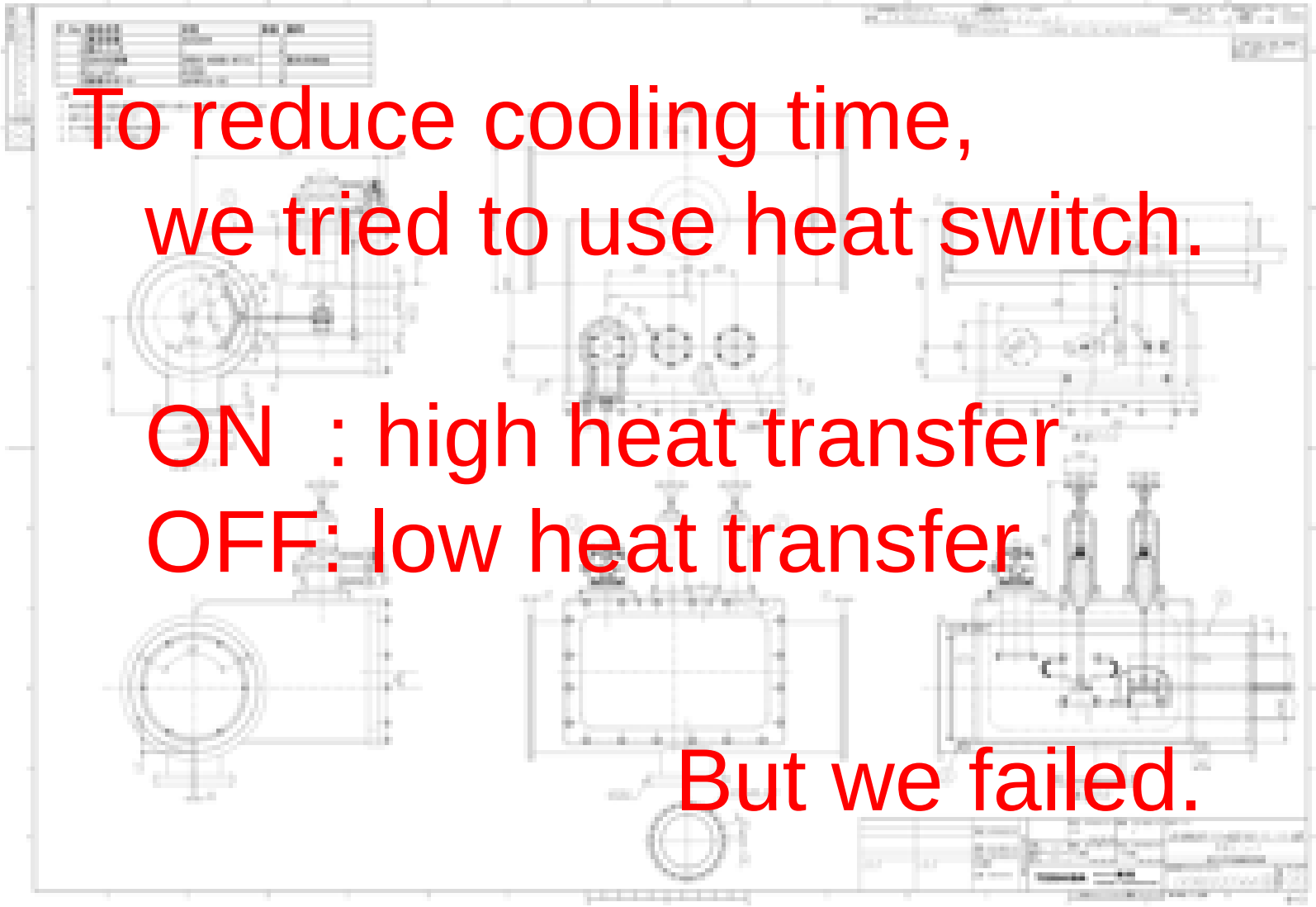
2. It is important to keep alignment.

Wave Front Sensor is necessary.

Lesson 3

How about heat switch system ?

Heat switch

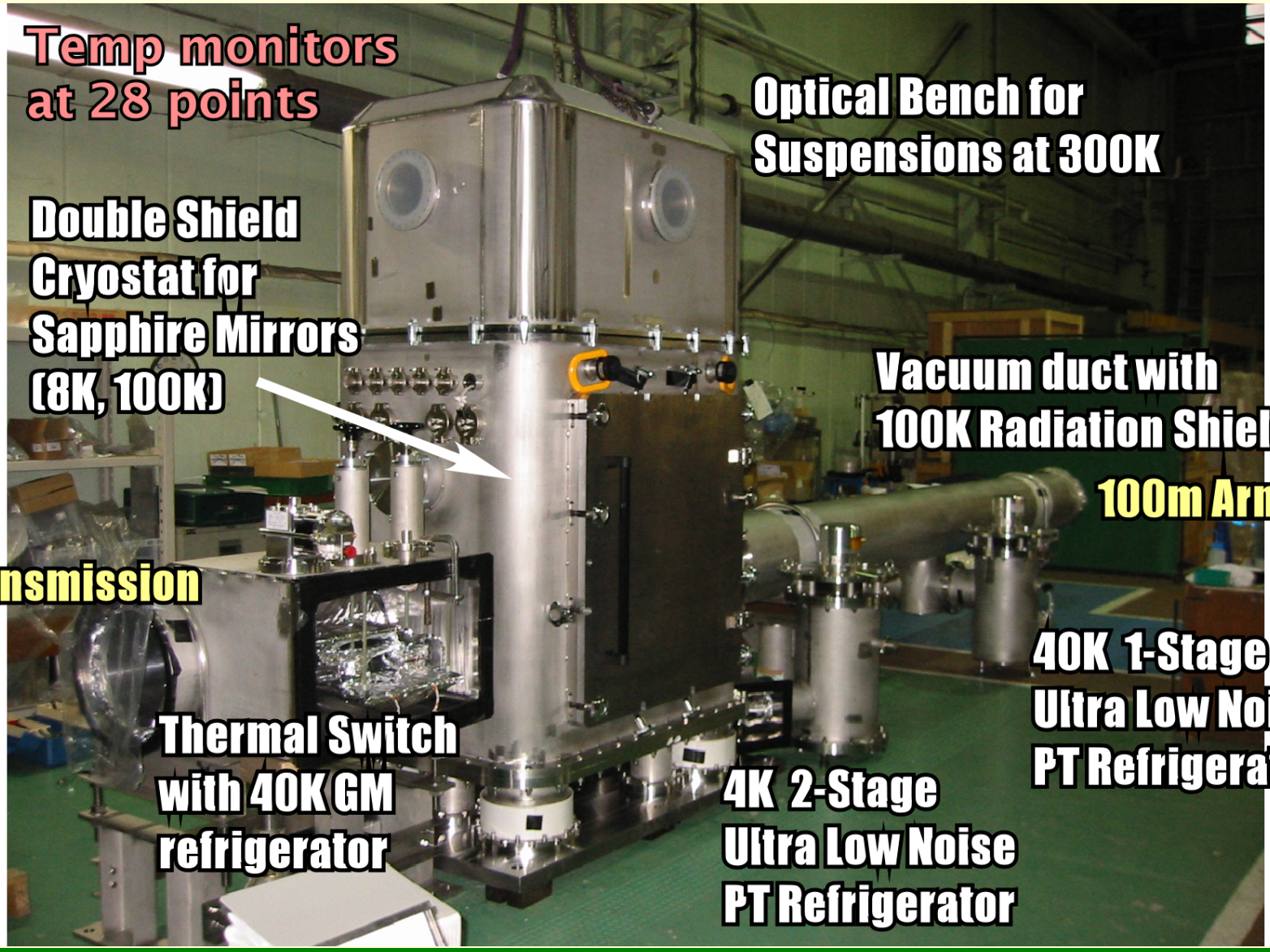


To reduce cooling time,
we tried to use heat switch.

ON : high heat transfer
OFF: low heat transfer

But we failed.

Cryostat for an end mirror



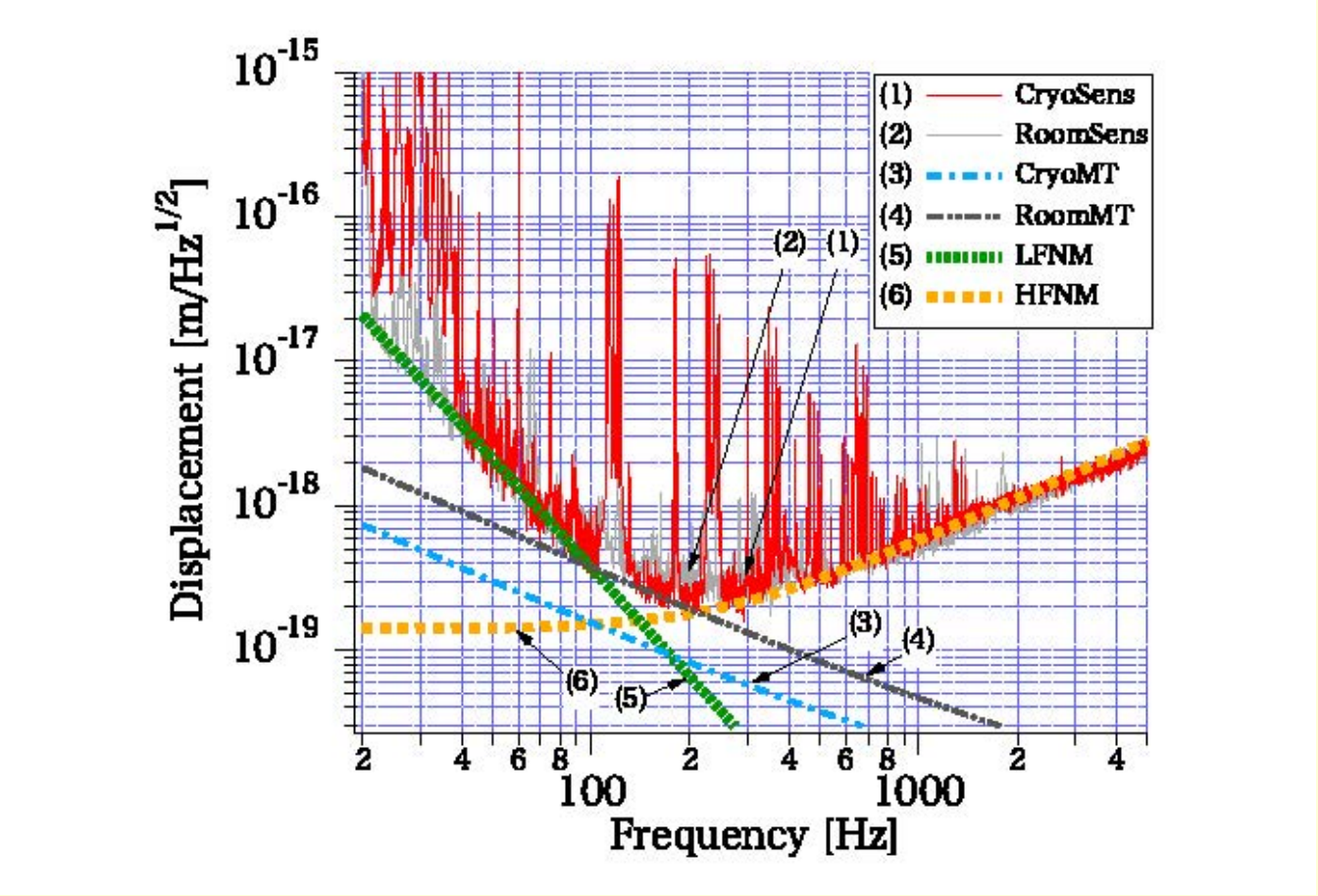
Lesson 3

How about heat switch system ?

Low heat flow is essential.

Status of CLIO

CLIO noise spectrum with cryogenic mirror became below that with room-temperature mirror.



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SUMMARY

- **We demonstrated to operate interferometer with cryogenic mirrors by CLIO, but careful setup is necessary for cooling.**