Development of cryogenic payload for KAGRA I

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0. Abstract

Progress of development
and near future plans
of cryogenic payload
(and cryostat and cryocooler unit)
for KAGRA in the last half year

Contents

1. *Introduction*
2. *Cryocooler unit*
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1. Introduction

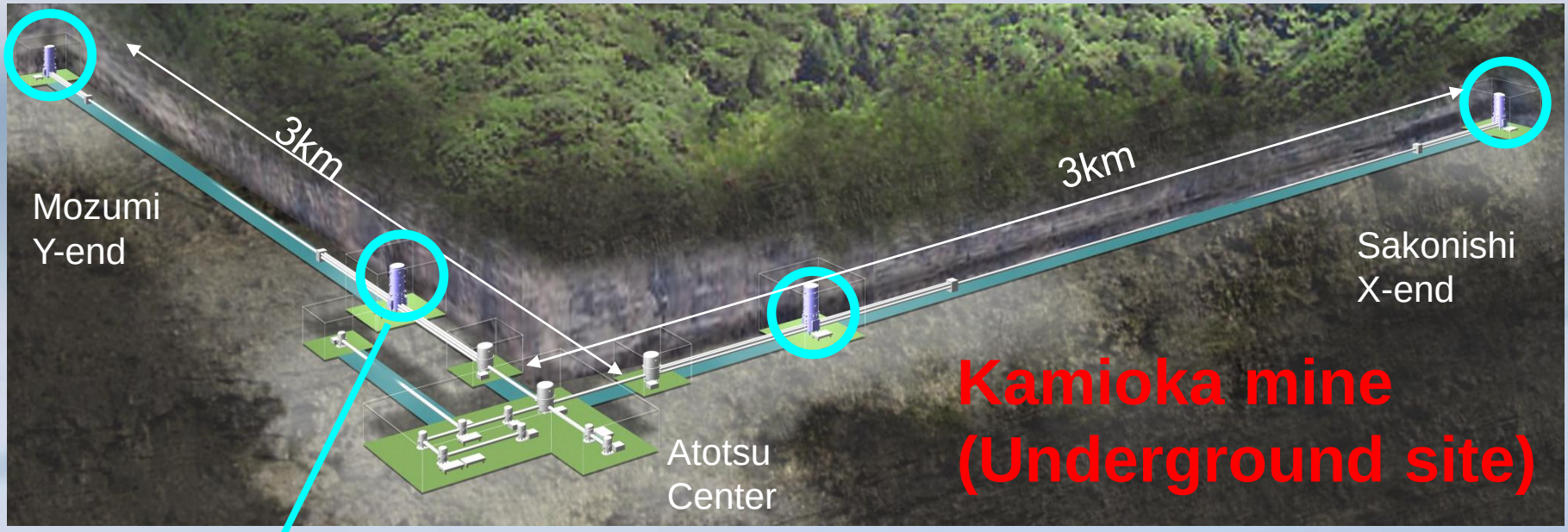
KAGRA :
2nd generation interferometric
gravitational wave detector in Japan

Key features of KAGRA project
Silent underground site (Kamioka) :
Small seismic motion
Cryogenic system : Reduction of thermal noise
and so on

1. Introduction

Schematic view of KAGRA interferometer

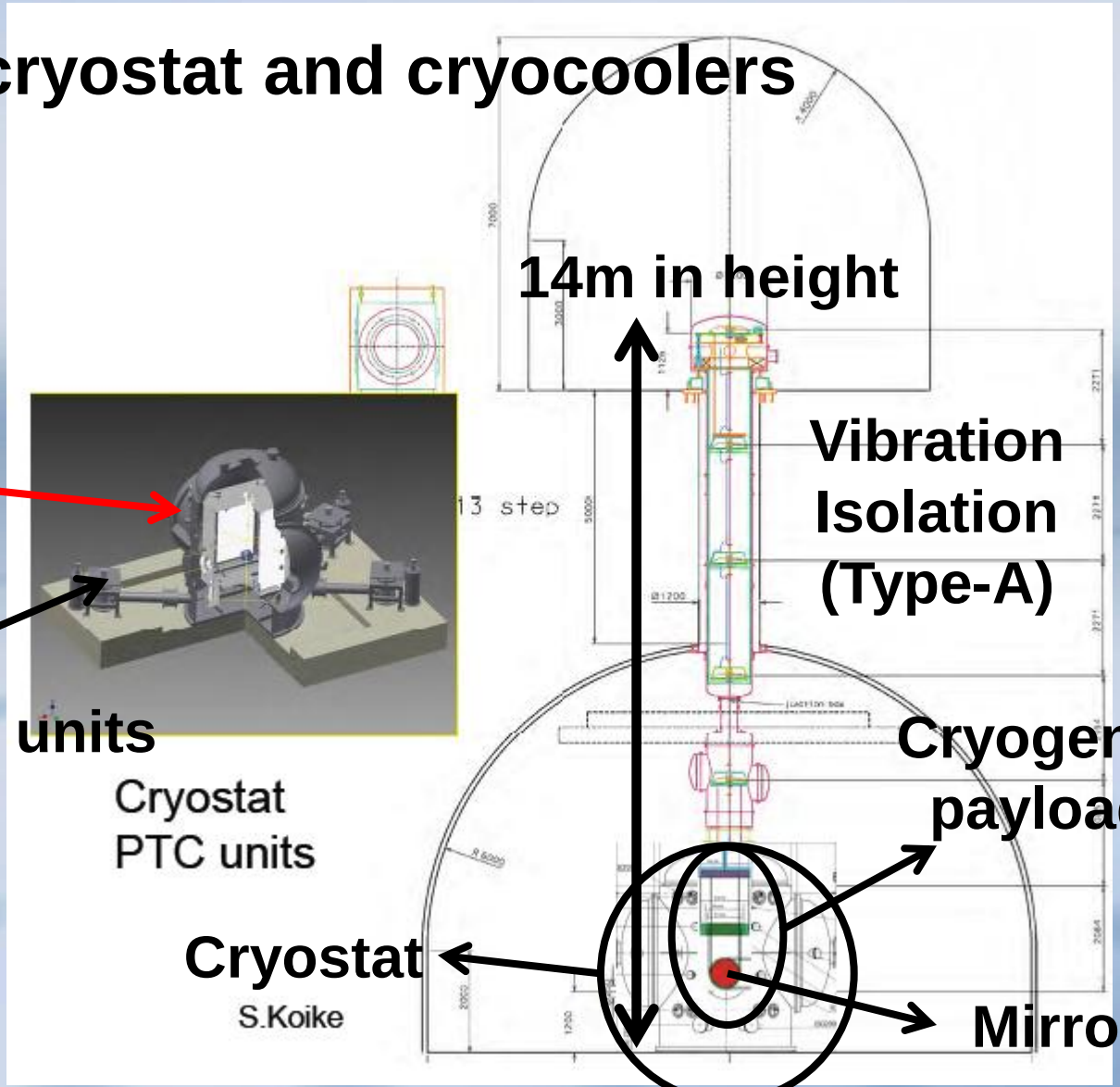
Four mirrors of arm cavity will be cooled.



Vibration isolation system, Cryostat, Cryocooler unit, Cryogenic payload

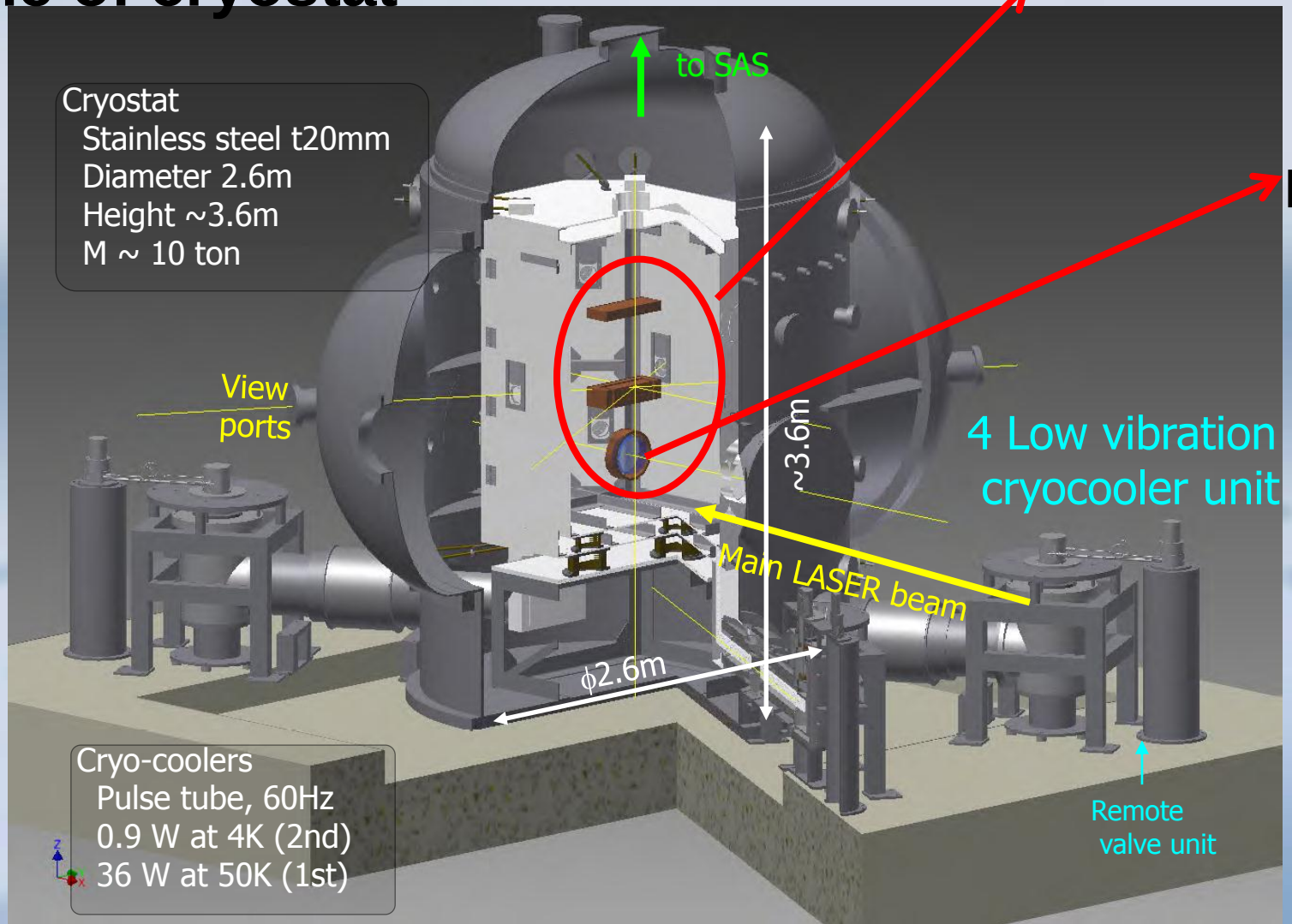
1. Introduction

Outline of cryostat and cryocoolers



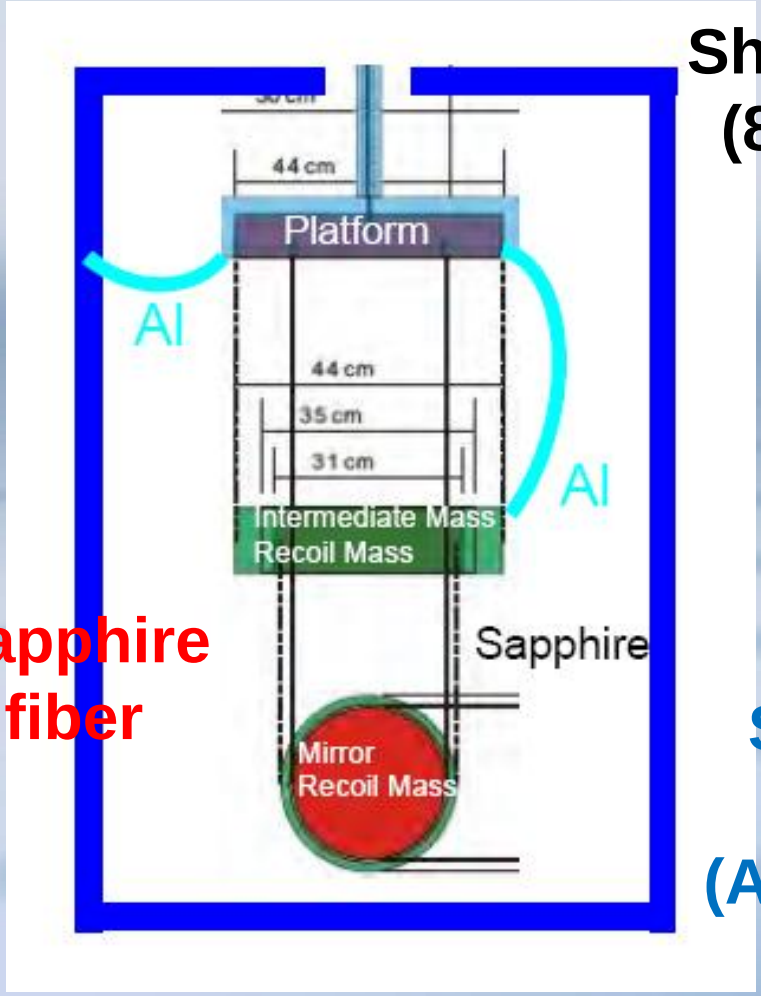
1. Introduction

Outline of cryostat



1. Introduction

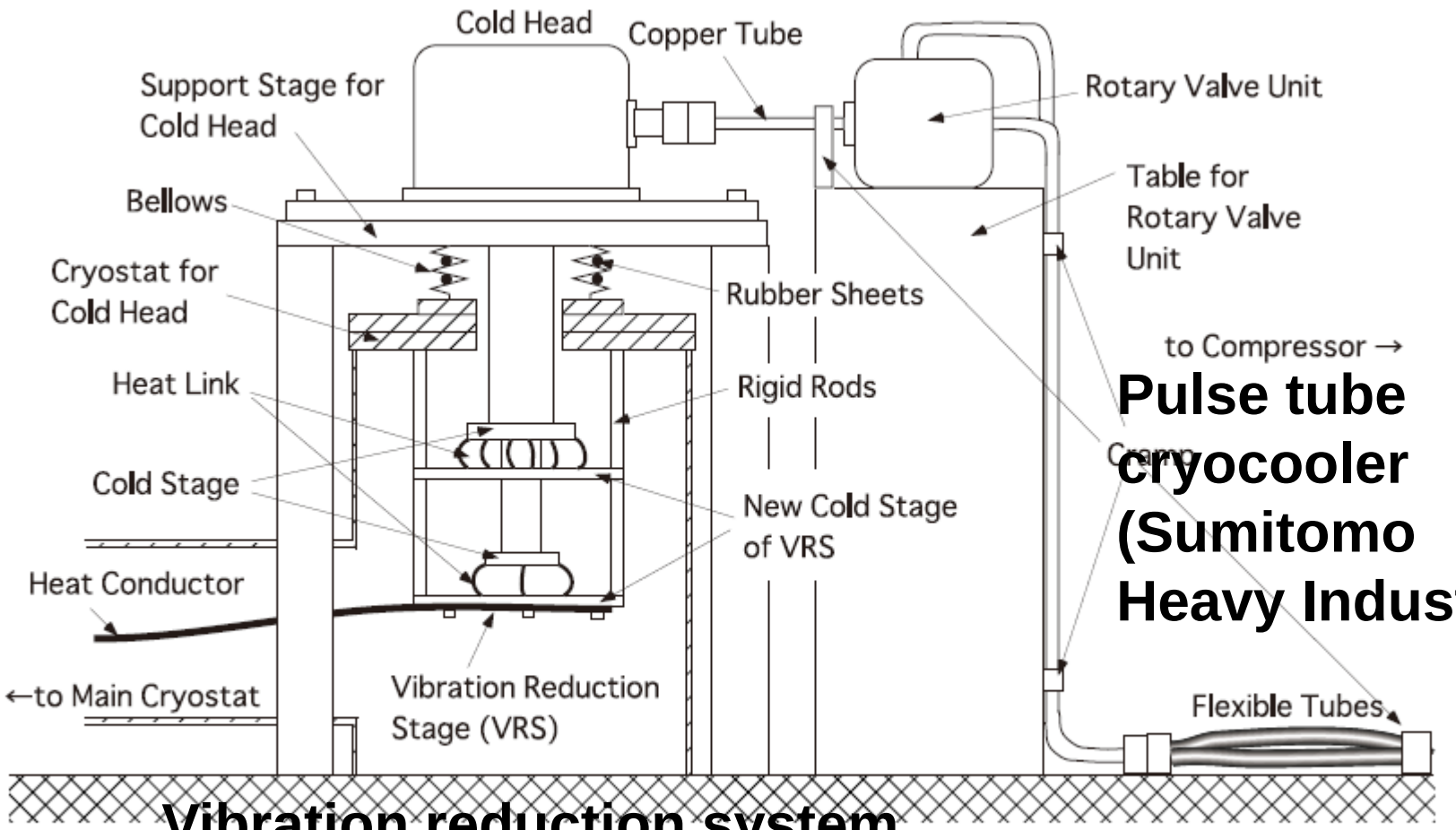
Outline of cryogenic payload



2. Cryocooler unit

1. Outline

Class. Quantum Grav. **21** (2004) S1005–S1008



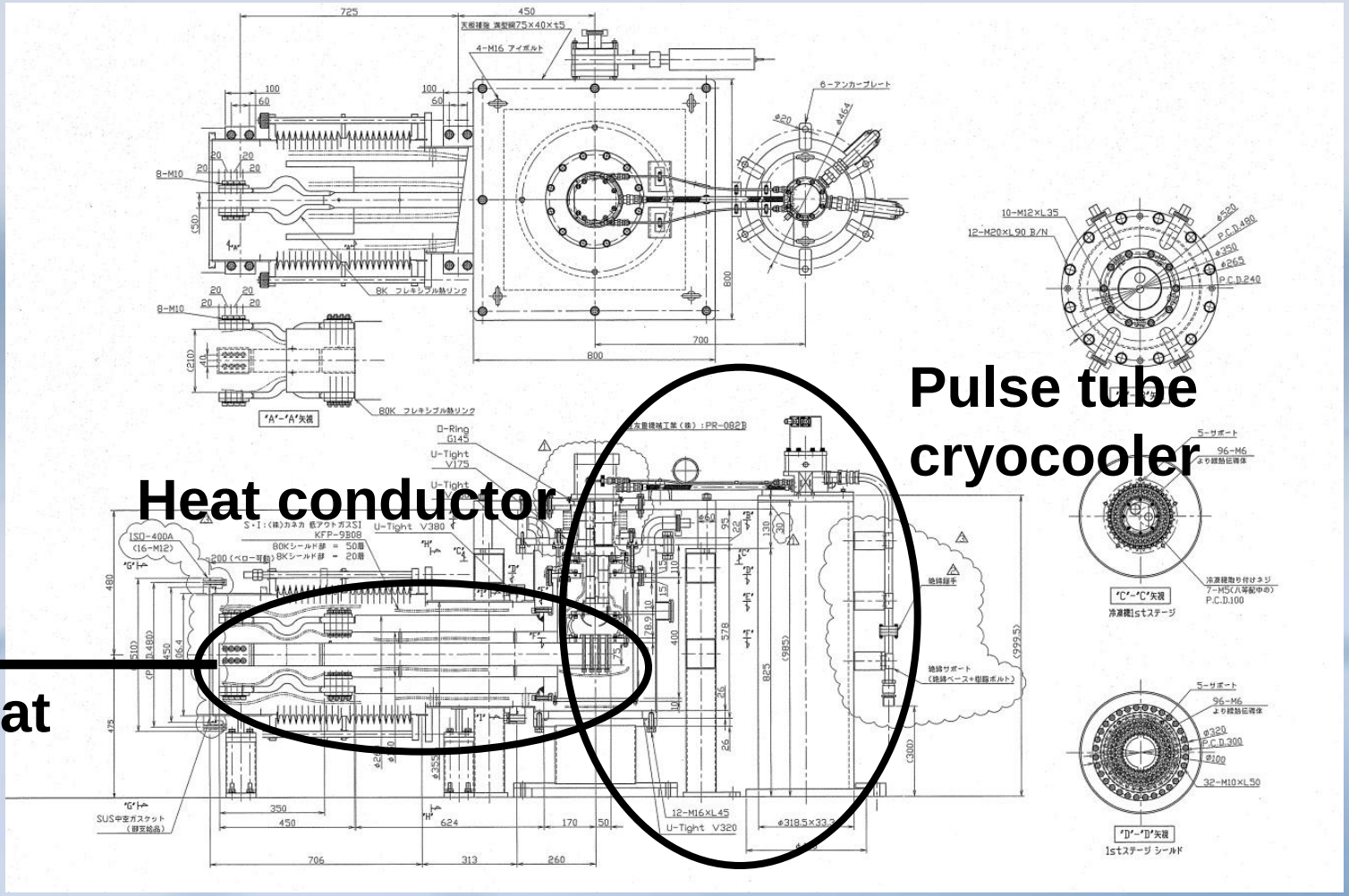
Pulse tube cryocooler (Sumitomo Heavy Industries)

Vibration reduction system

Figure 3. Vibration-reduction system we have been developing for the PT cryocooler.

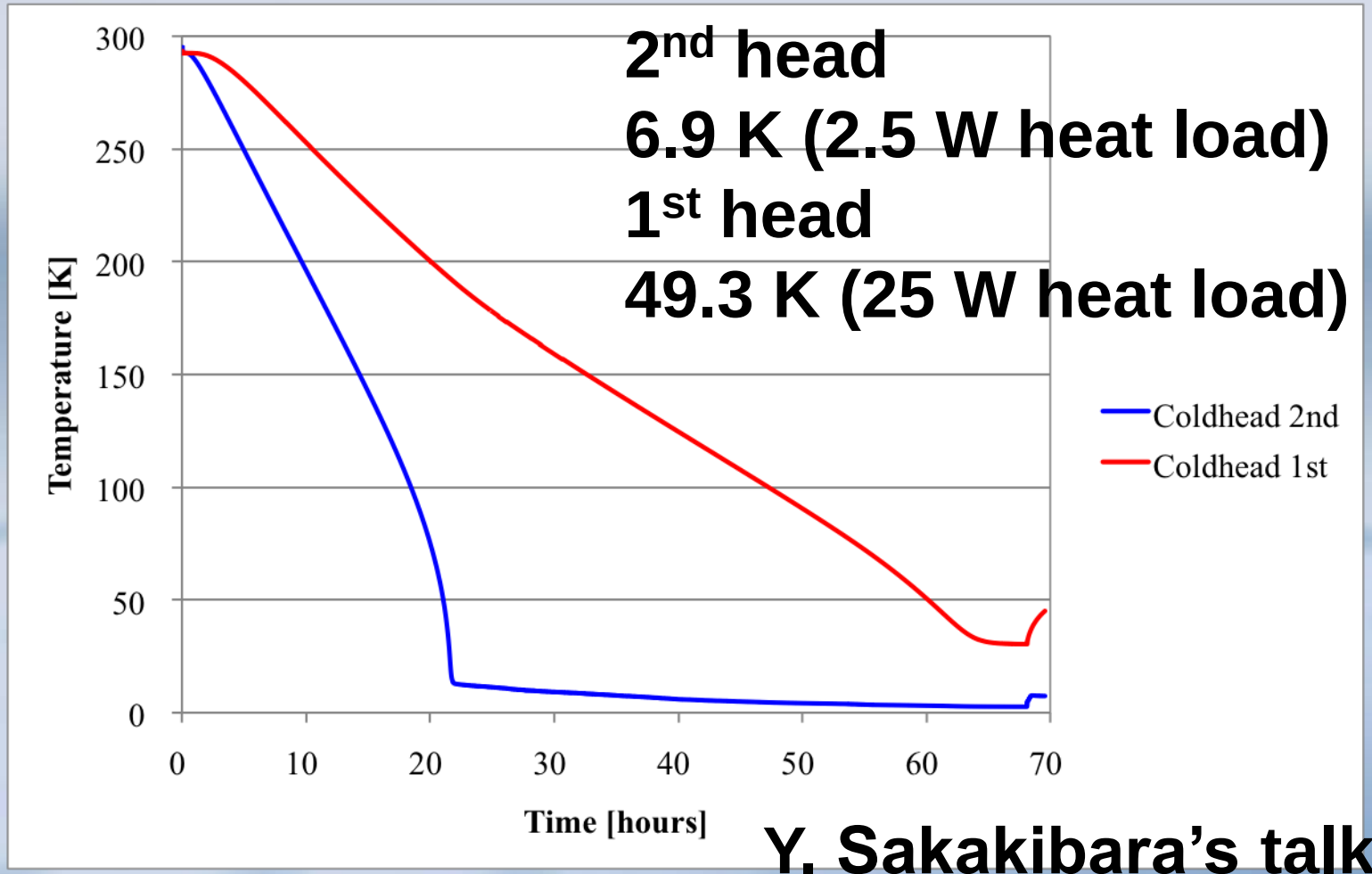
2. Cryocooler unit

2. Drawing by Jecc Torisha



2. Cryocooler unit

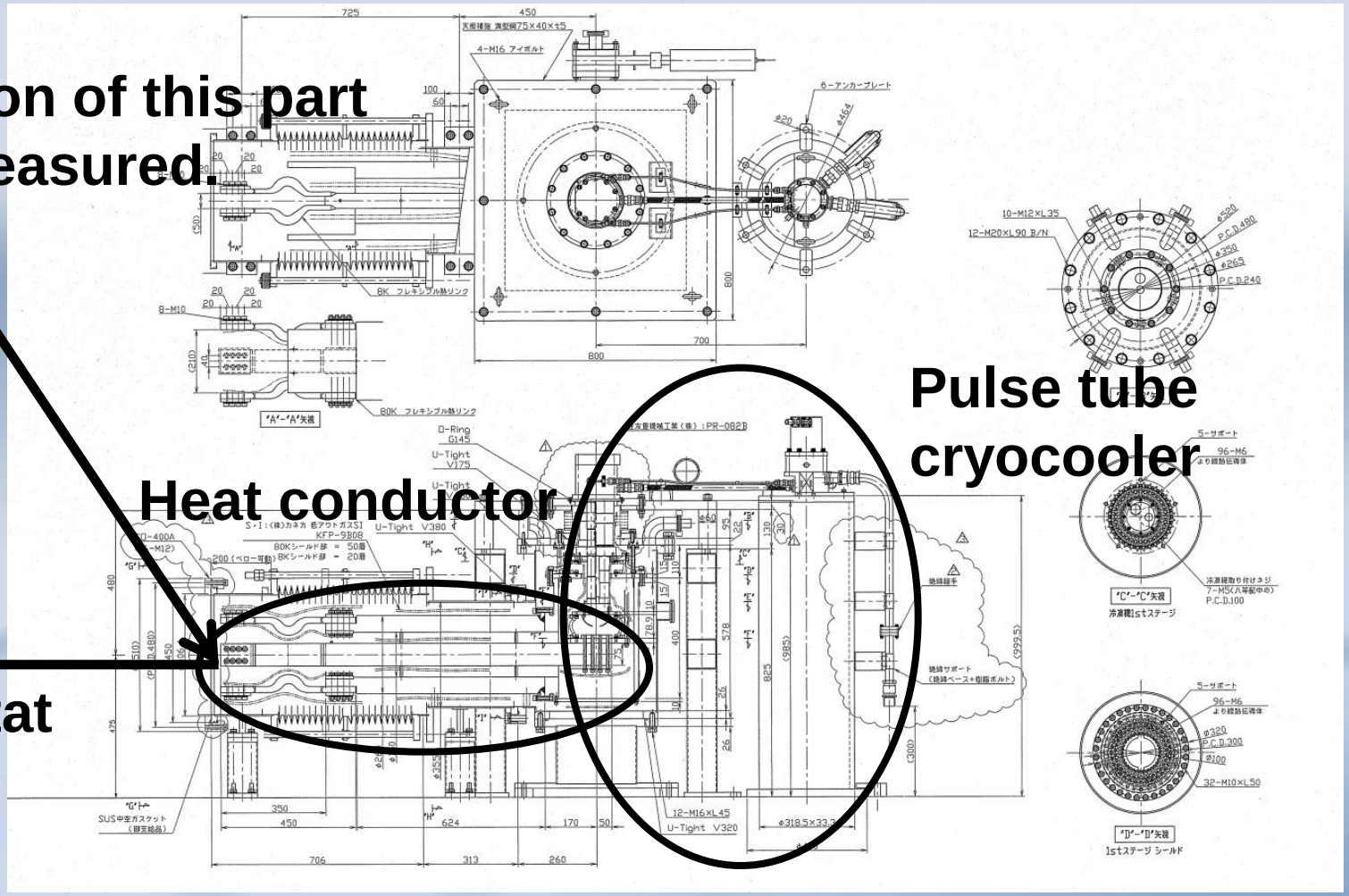
3. Cooling test : Cryocooler works well.



Y. Sakakibara's talk

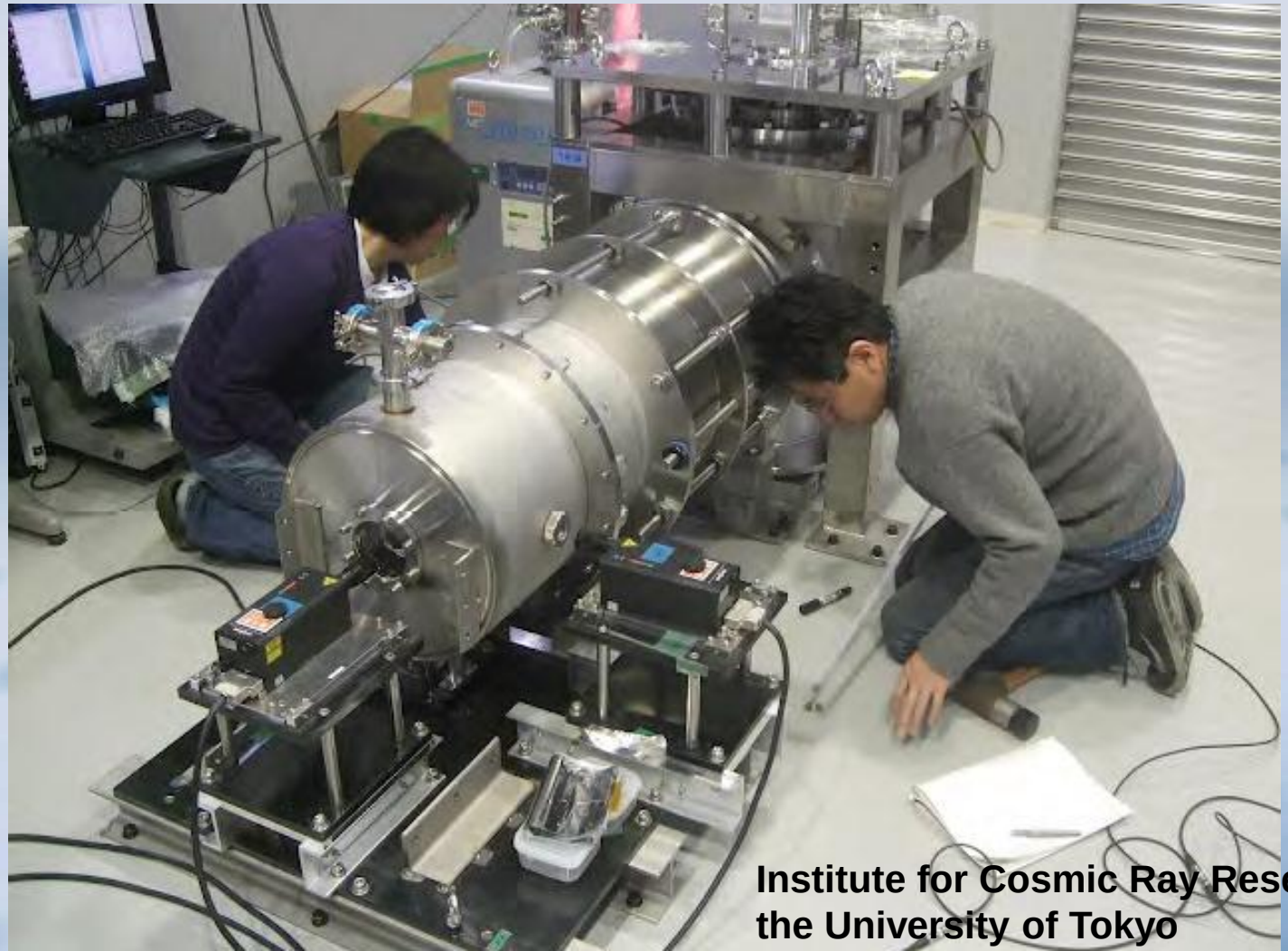
2. Cryocooler unit

4. Vibration measurement



2. Cryocooler unit

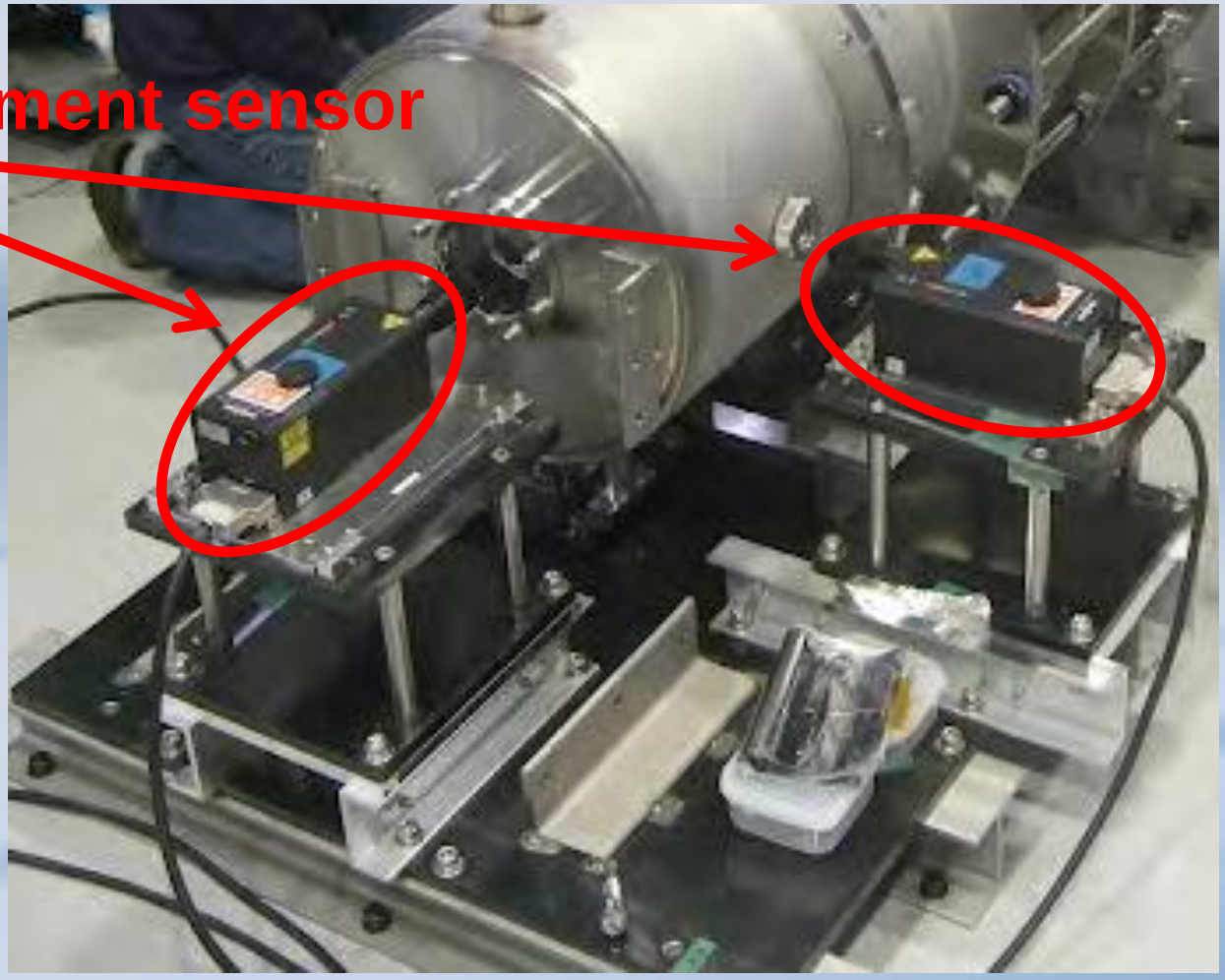
4. Vibration measurement



Institute for Cosmic Ray Research,
the University of Tokyo

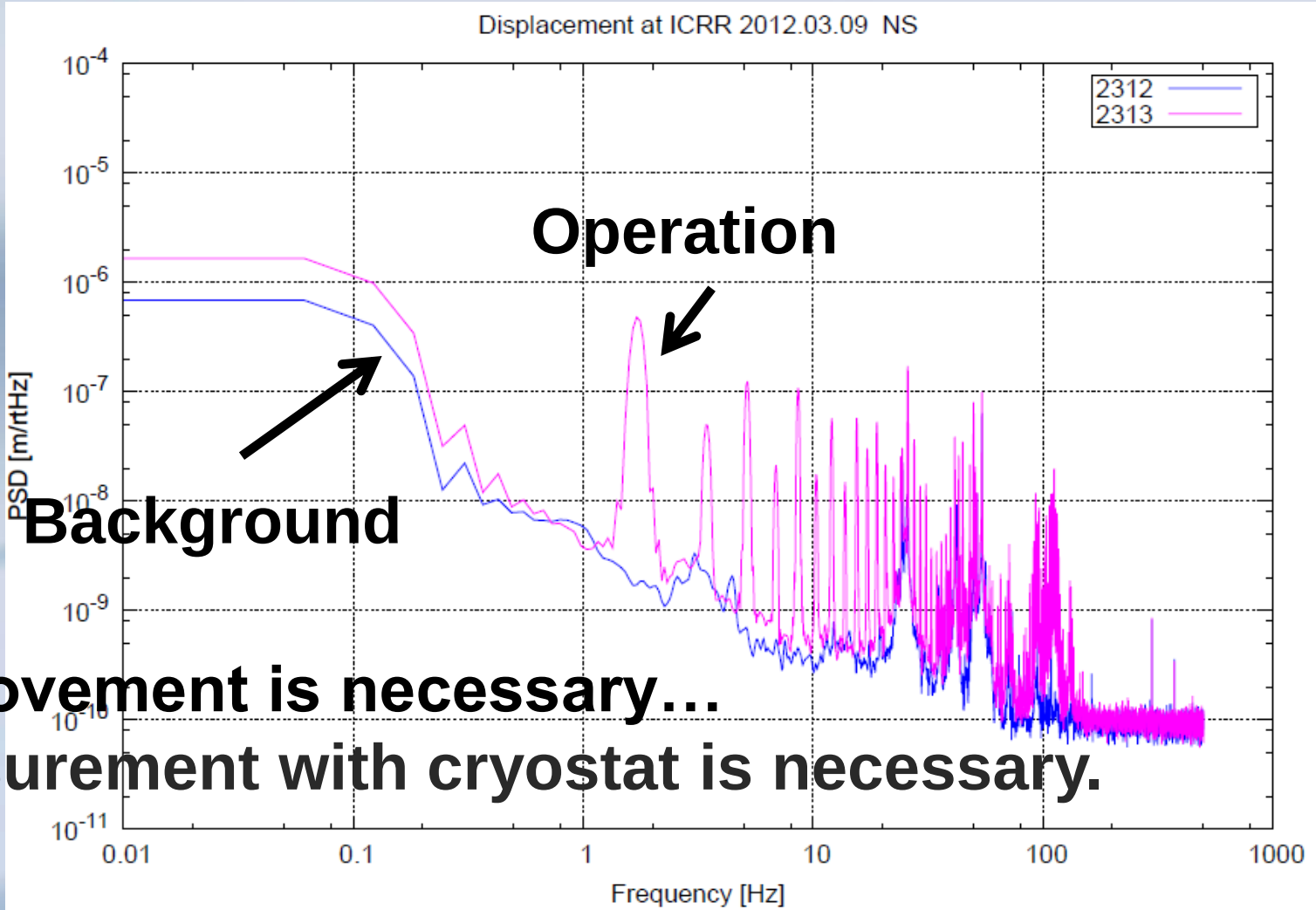
2. Cryocooler unit

4. Vibration measurement



2. Cryocooler unit

4. Vibration measurement

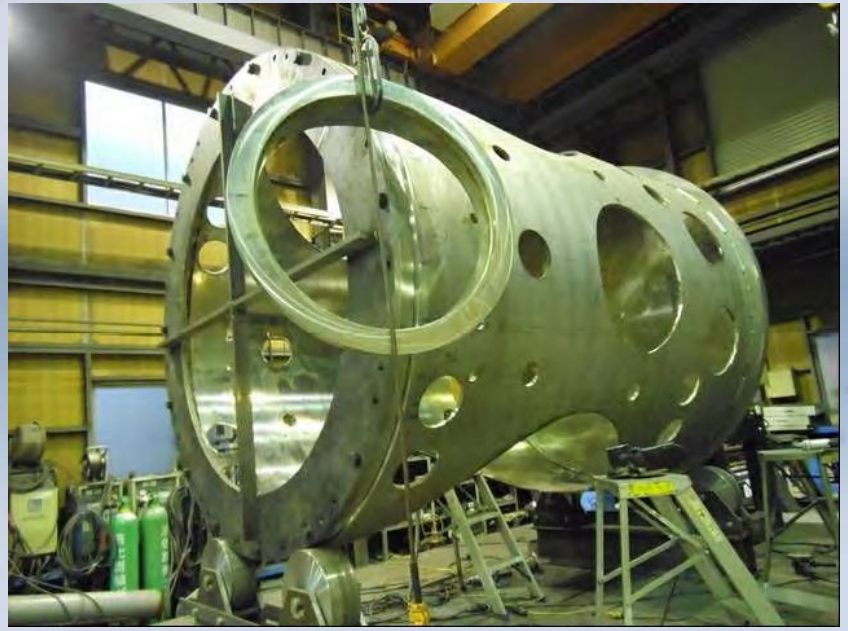


Improvement is necessary…

Measurement with cryostat is necessary.

3. Cryostat

1. Assembly



Main body (Φ2.6m, H3.6m)

at Toshiba Keihin Product Operations

3. Cryostat

1. Assembly

at Toshiba Keihin Product Operations

Vacuum chamber

3. Cryostat

1. Assembly

at Toshiba Keihin Product Operations

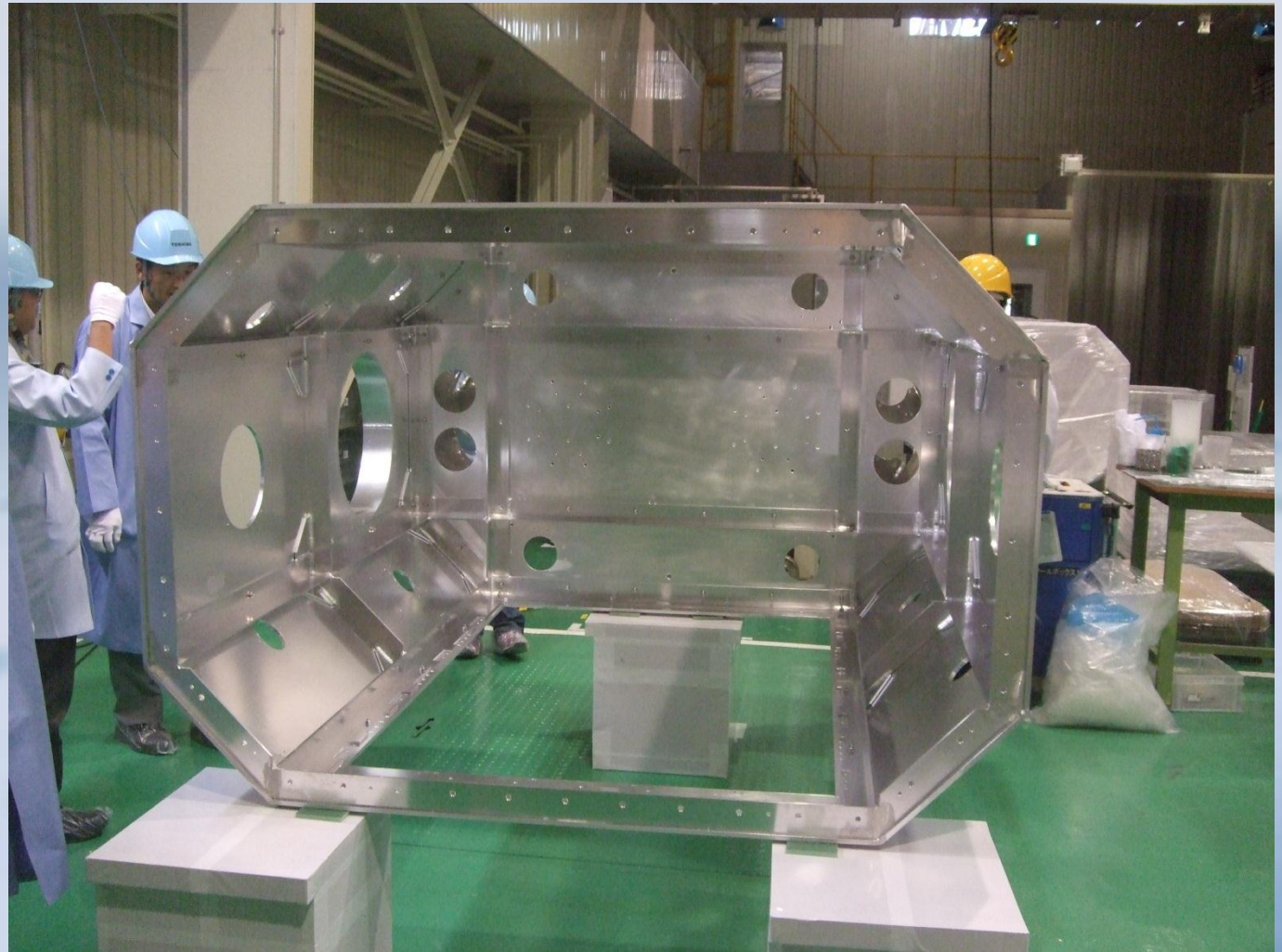
Vacuum Chamber

3. Cryostat

1. Assembly

at Toshiba Keihin Product Operations

Shield



3. Cryostat

2. Experimental plans in Toshiba

In this autumn, there will be cooling test of shileds in Toshiba Keihin Product Operations.

At the same time, we have experimental plans in Toshiba.

(1) Heat load test
(2) Measurement of vibration of shield
(3) Measurment of initial cooling time

3. Cryostat

2. Experimental plans in Toshiba

(2) Measurement of vibration of shield

This measurement is

at cryogenic temperature and in vacuum.

Luca Naticchioni (Rome) and Dan Chen will measure vertical and horizontal vibration of radiation shield of KAGRA, respectively.

D. Chen's talk

3. Cryostat

2. Experimental plans in Toshiba

(2) Measurement of vibration of shield

Luca Naticchioni's accelerometer

3. Cryostat

2. Experimental plans in Toshiba

(3) Measurment of initial cooling time

Initial cooling time for cryogenic payload is about 2 months (if no tricks).

At beginning of initial cooling, heat transfer is dominated by radiation.

Diamond Like Carbon (DLC) coating (High emissivity, Large radiation) on shields and payload (except for mirror)

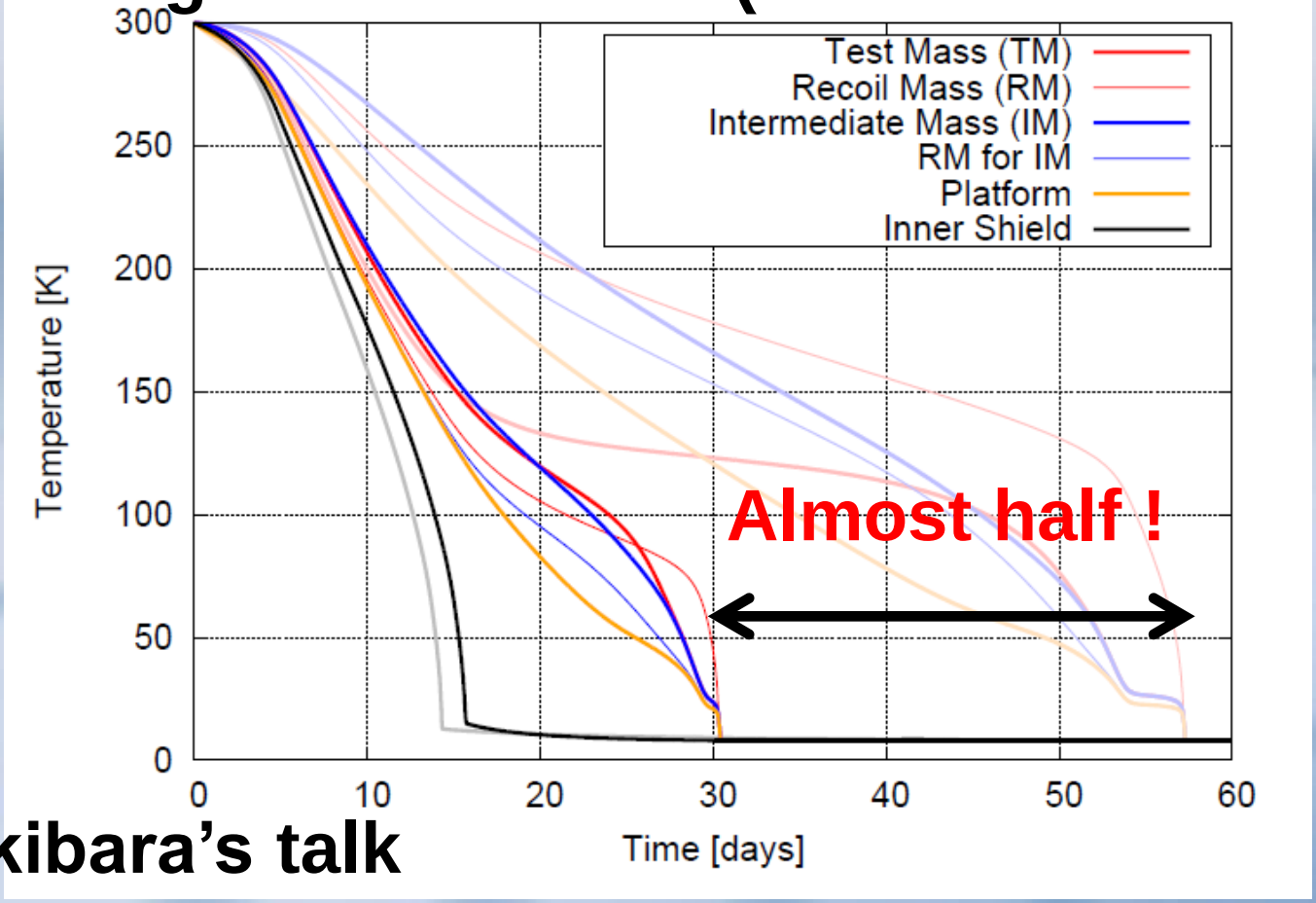
Y. Sakakibara's talk

3. Cryostat

2. Experimental plans in Toshiba

(3) Measurment of initial cooling time

Initial cooling time with DLC (shield and mass)



Y. Sakakibara's talk

3. Cryostat

2. Experimental plans in Toshiba

(3) Measurment of initial cooling time

We must check the effect of radiation (and DLC coating) on the initial cooling time experimentally.

We suspend something without heat link inside shield and monitor the temperature of something in shiled during cooling test.

What is something ?

Sample 1 : Sapphire and metal hollow sphere

Sample 2 : Dummy payload (hollow masses)

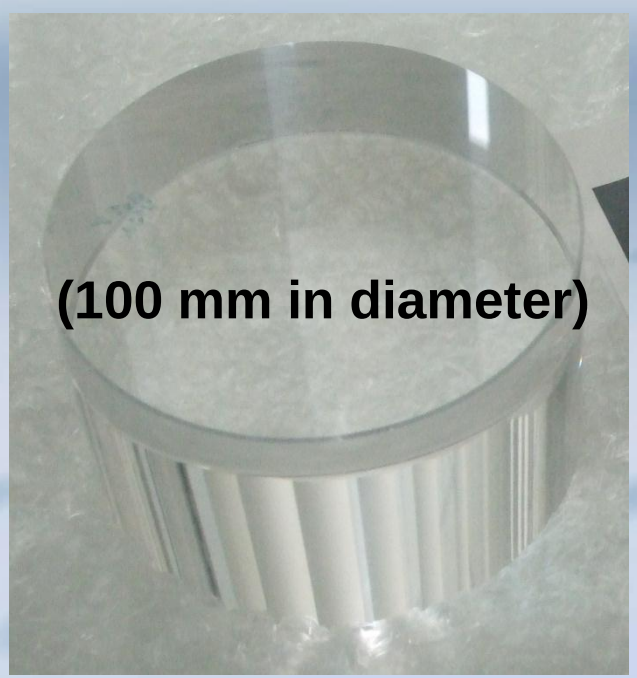
3. Cryostat

2. Experimental plans in Toshiba

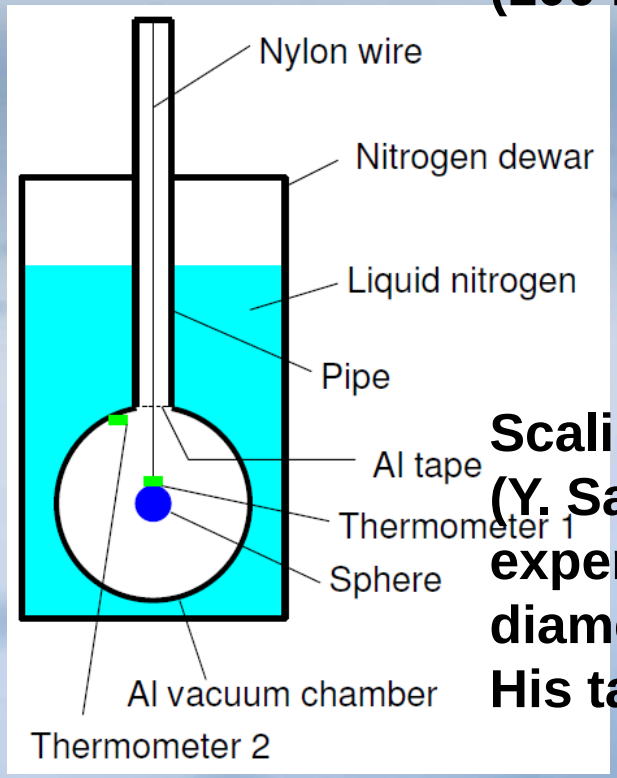
(3) Measurment of initial cooling time

Sample 1 : Sapphire and metal hollow sphere

(100 mm in diameter)



Evaluation of emissivity



Scaling law
(Y. Sakakibara's small experiment: 30 mm in diameter)
His talk

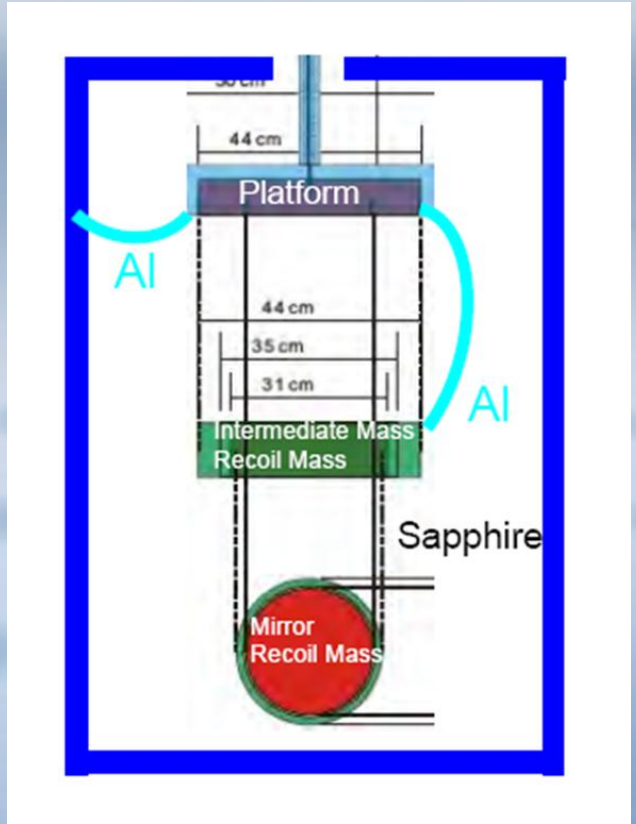
3. Cryostat

2. Experimental plans in Toshiba

(3) Measurment of initial cooling time

Sample 2 : Dummy payload (hollow masses)

Half size
Hollow masses
(~5 kg)
DLC coating
Sapphire bulk as dummy mirror



Preparation is in progress.

4. Cryogenic payload

1. **Mechanical simulation**

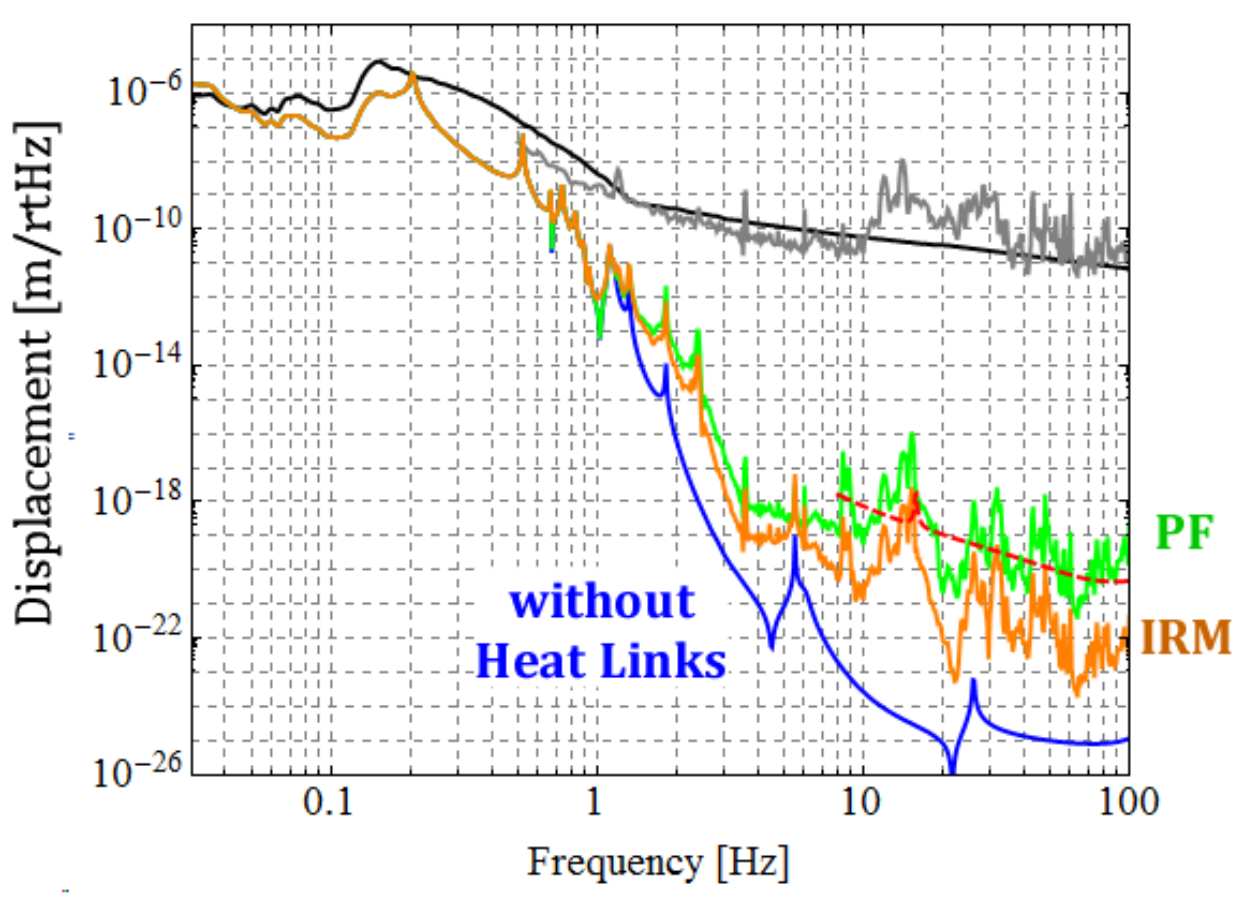
T. Sekiguchi is developing.

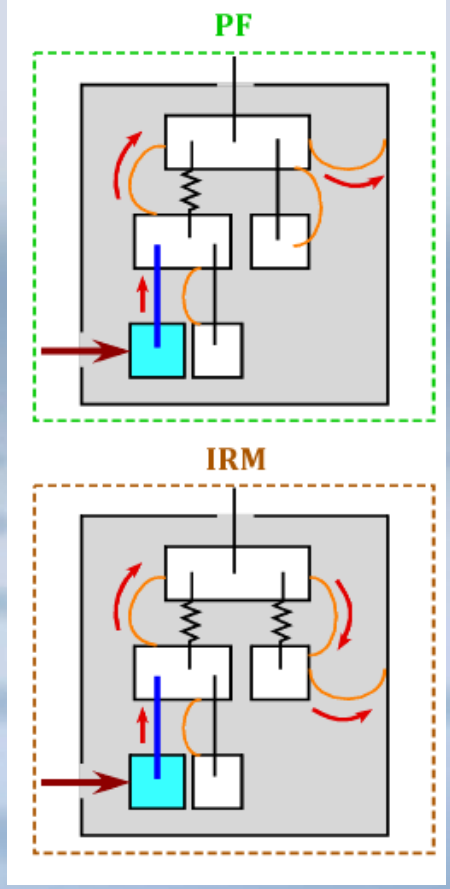
(1) Vibration via heat links (above 1 Hz)
(2) Thermal noise (above 10Hz)
(3) Control scheme
(Investigation started recently)

4. Cryogenic payload

1. Mechanical simulation

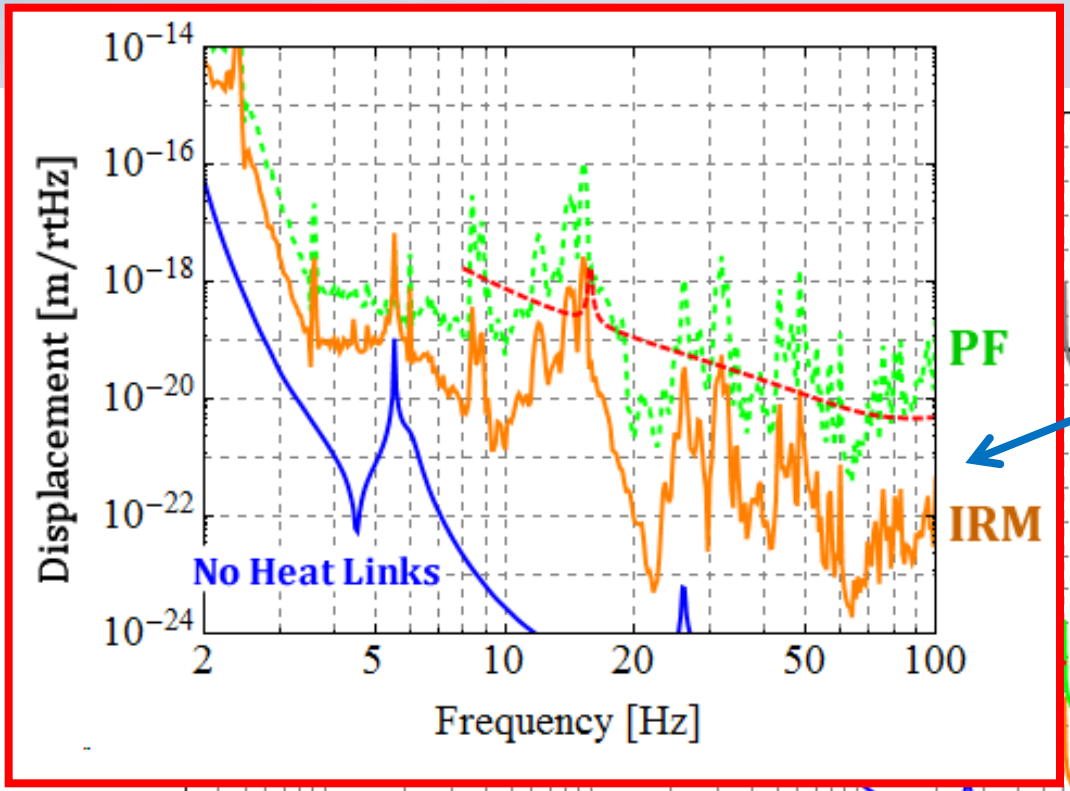
(1) Vibration via heat links

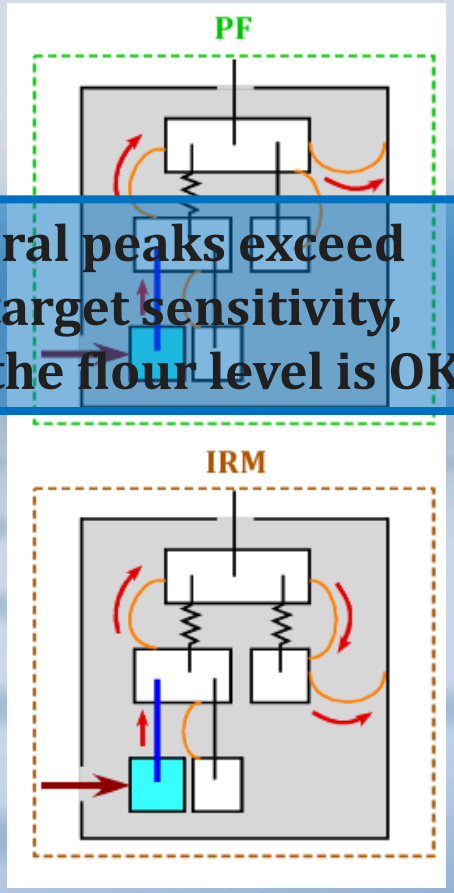




4. Cryogenic payload

1. Mechanical simulation





Several peaks exceed the target sensitivity, but the flour level is OK.

Investivation (for safty margin) is in progress.

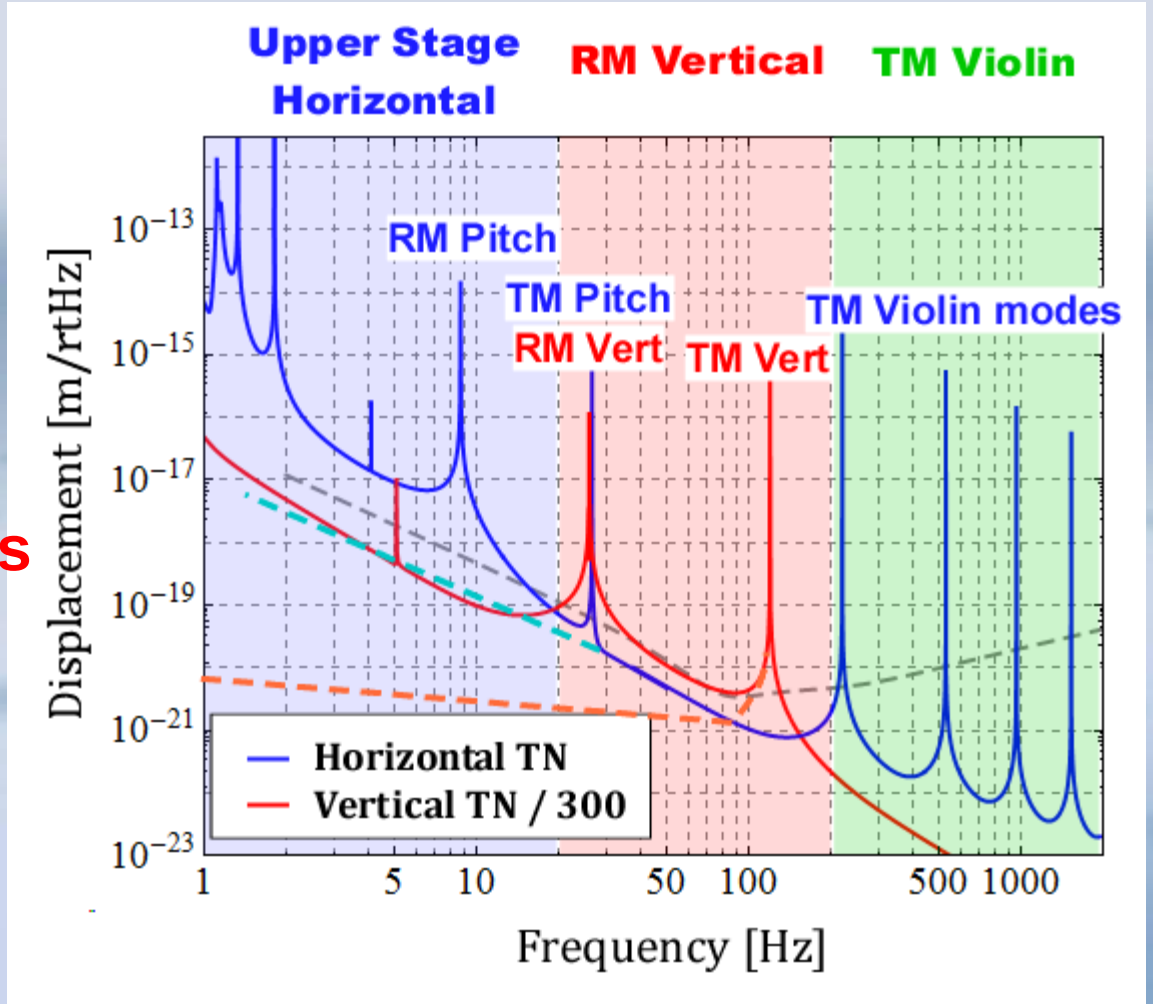
4. Cryogenic payload

1. Mechanical simulation
   (2) Thermal noise

Now, we can calculate thermal noise.

Not only sapphire mirror and fibers but also the other parts must be consider carefully.

We must proceed with investiation.



4. Cryogenic payload

2. Sapphire fibers with nail heads

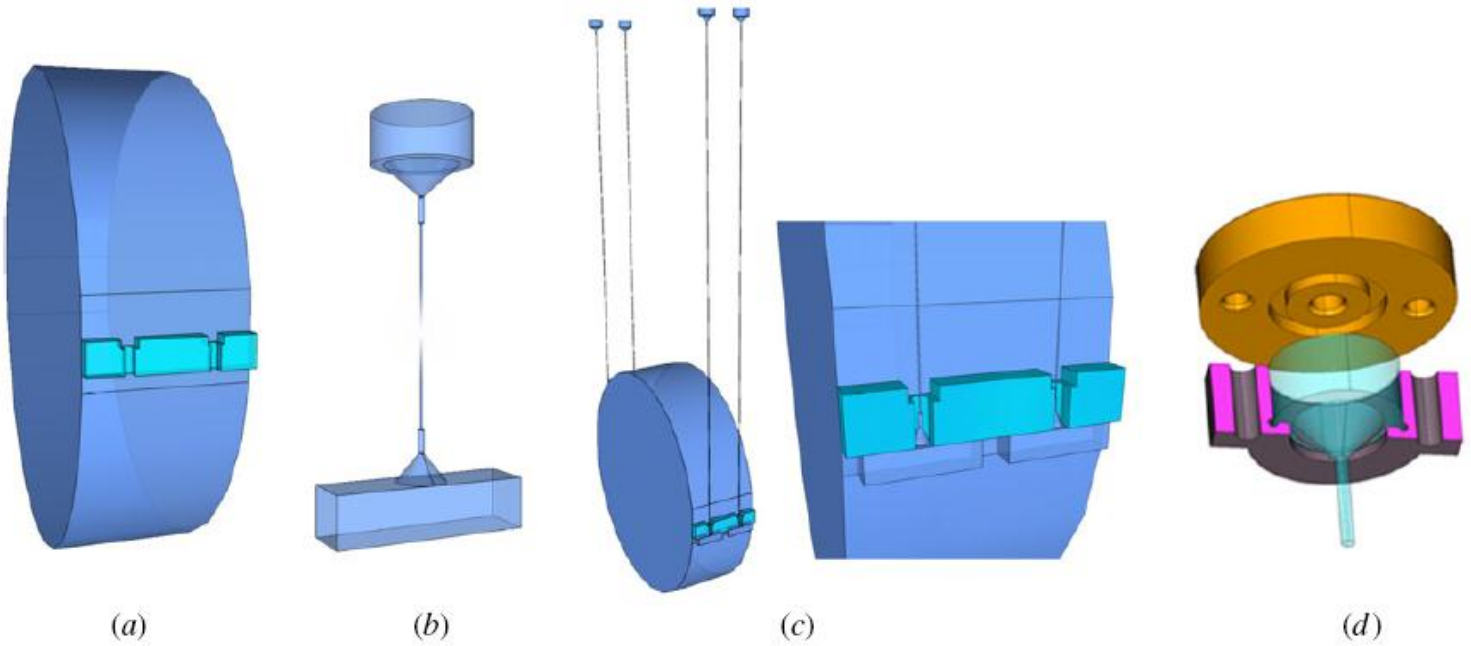
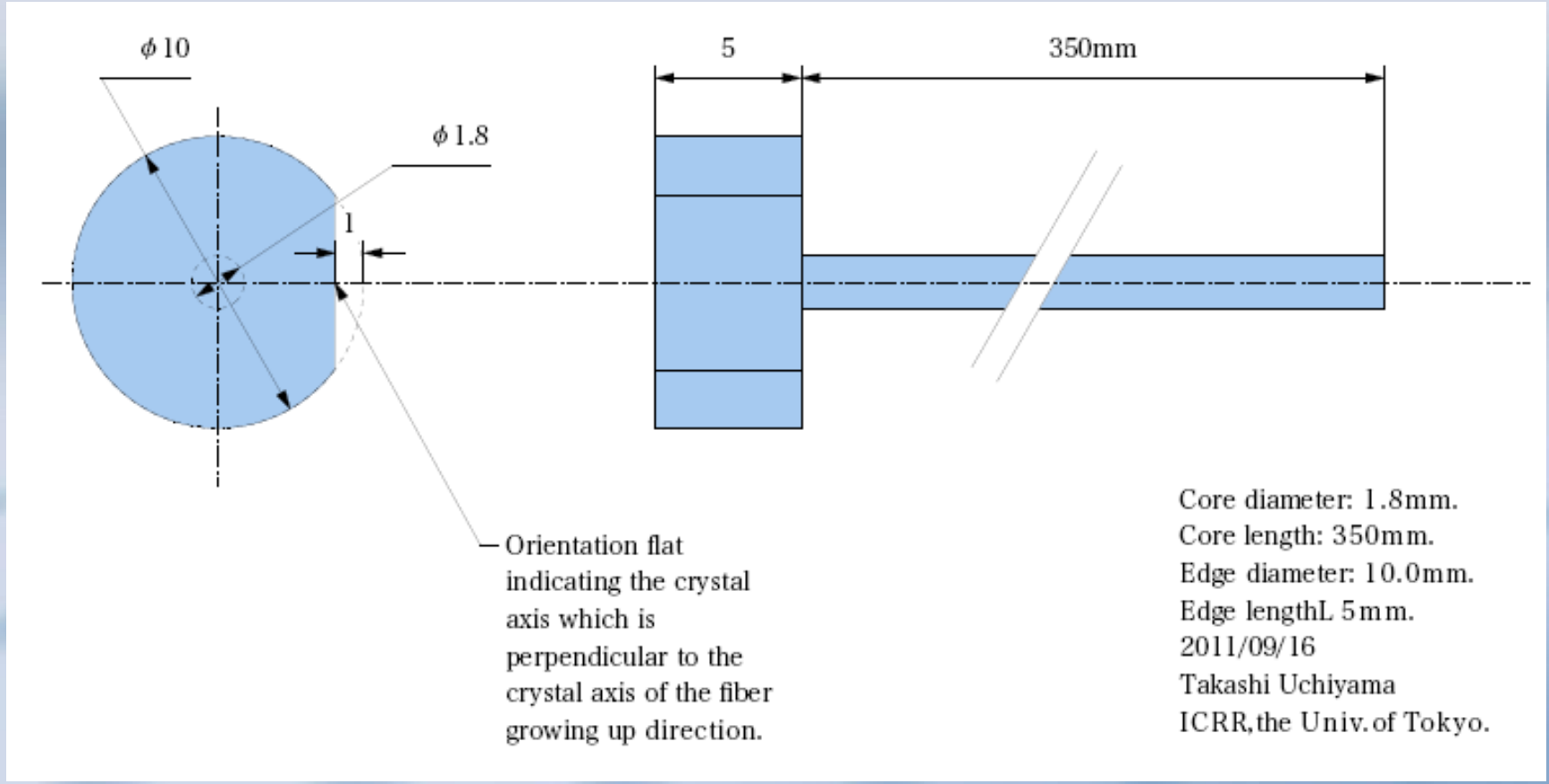


Figure 2. Sketch of the steps followed to realize a monolithic suspension, as detailed in the text.

4. Cryogenic payload

2. Sapphire fibers with nail heads

Test sample (T. Uchiyama)



4. Cryogenic payload

2. Sapphire fibers with nail heads

Sapphire fibers to suspend sapphire mirrors
Sapphire fibers from MolTech GmbH (Germany)

Length = 350 mm diameter = 1.8 mm
Almost as needed in bKAGRA.
Need to check the quality and improvement (T. Ushiba, K. Shibata).

4. Cryogenic payload

2. Sapphire fibers with nail heads

Ettore Majorana asked IMPEX HighTech GmbH (German company).

They can make similar fibers (nail heads on the both ends).

Shoter fibers (about 100 mm in length) is coming soon.

4. Cryogenic payload

2. Sapphire fibers with nail heads

Thermal conducutivity measurement : T. Ushiba

Q-value measurement in this autumn:
K. Shibata and Y. Sakakibara

5. Summary

1. Tests for cryocooler unit
   Cooling : OK
   Vibration : Almost OK
   (some improvement is necessary)

2. Cryostat
   Assembly is in progress in Toshiba.
   In this autumn,
   there will be cooling test of shileds.
   In this test, we will try these experiments
   (1) Heat load test
   (2) Measurement of vibration of shield
   (3) Measurment of initial cooling time

5. Summary

3. Cryogenic payload

Simulation tool

Vibration via heat link

Thermal noise

Control scheme

Investigation using simulation tool is in progress.

Sapphire fibers with nail heads

Moltech and IMPEX

Measurement of thermal conductivity and Q-values is in progress.

Thank you for your attention !