Cryogenic payload for KAGRA

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Contribution

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0. Abstract

Although there are many topics, but here, I will explain

(1)Experiments in KAGRA cryostat
(2)Monolithic sapphire suspension

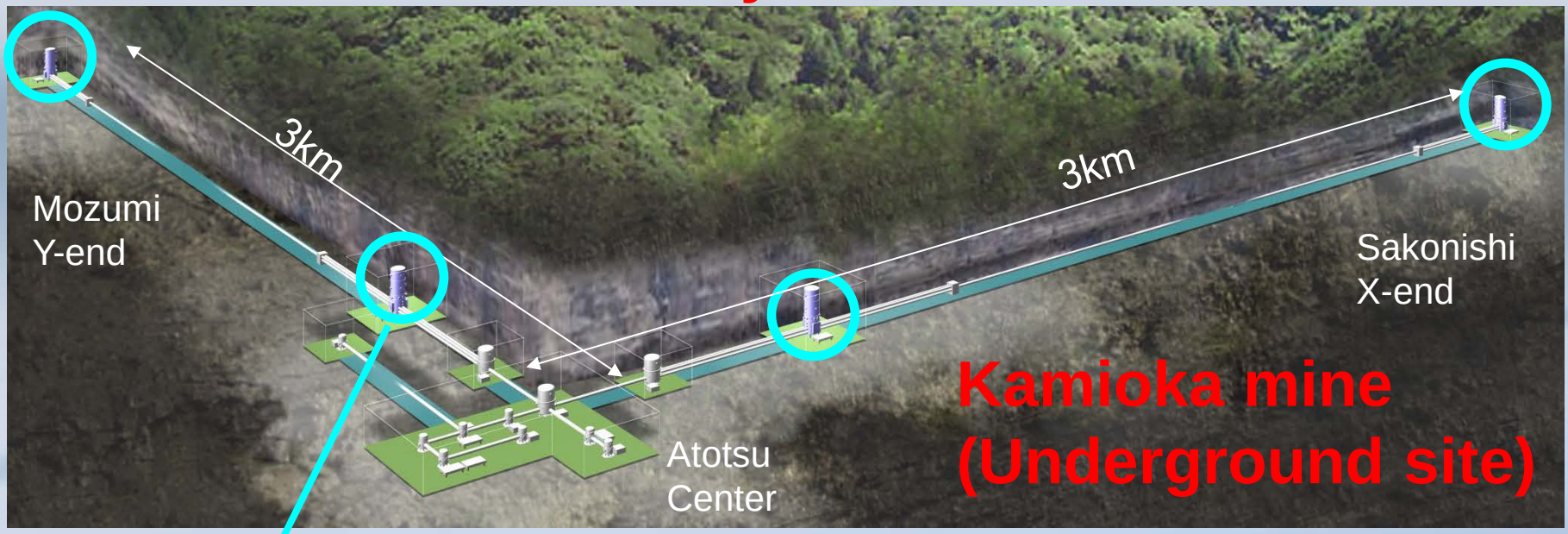
Contents

1. Introduction
2. Experiments
   in KAGRA cryostat
3. Sapphire suspension
4. Human resources
5. Summary

1. Introduction

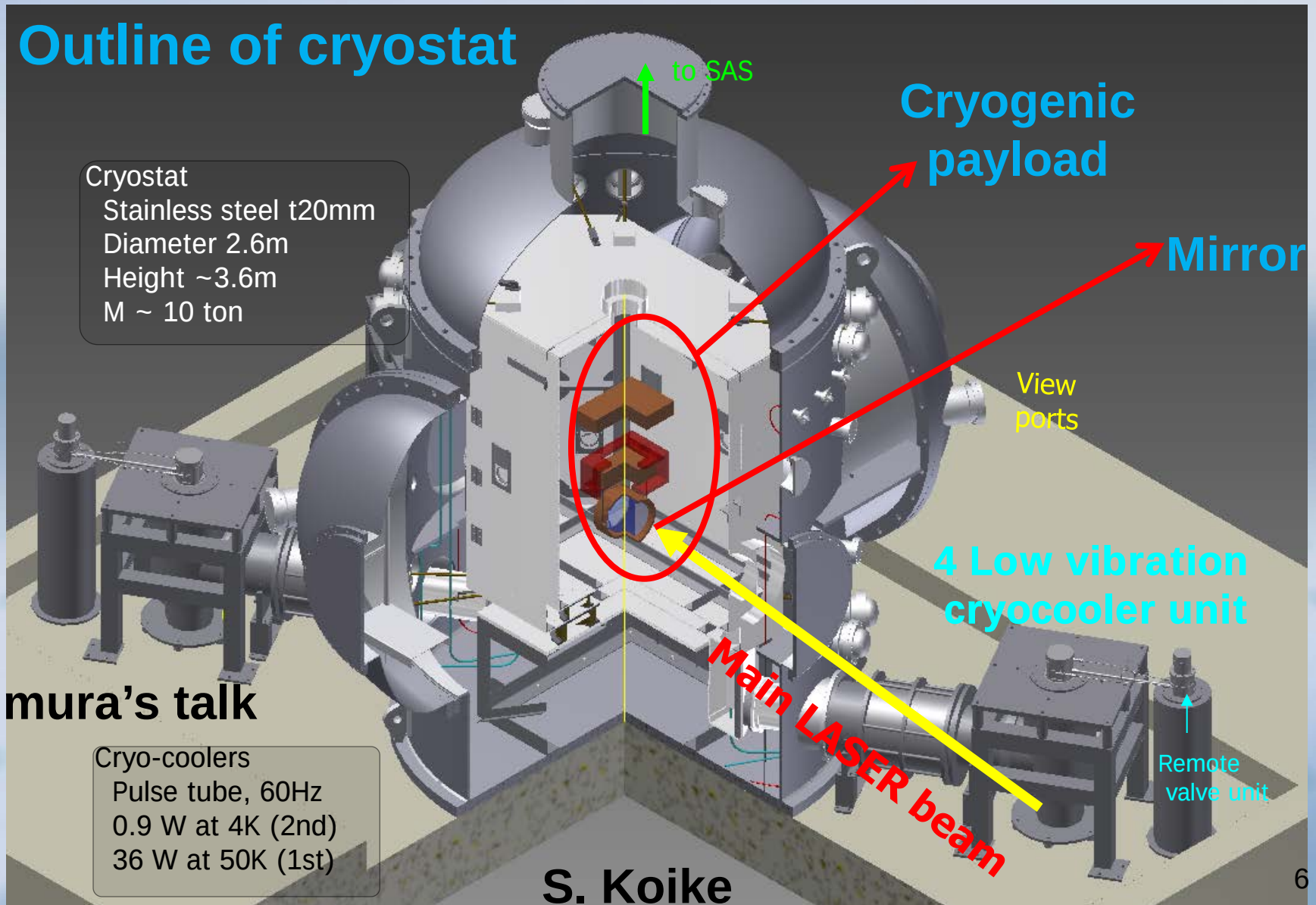
Schematic view of KAGRA interferometer
(K. Kuroda's talk)

Four mirrors of arm cavity will be cooled.



Vibration isolation system, Cryocooler unit, Cryostat, Cryogenic payload

1. Introduction

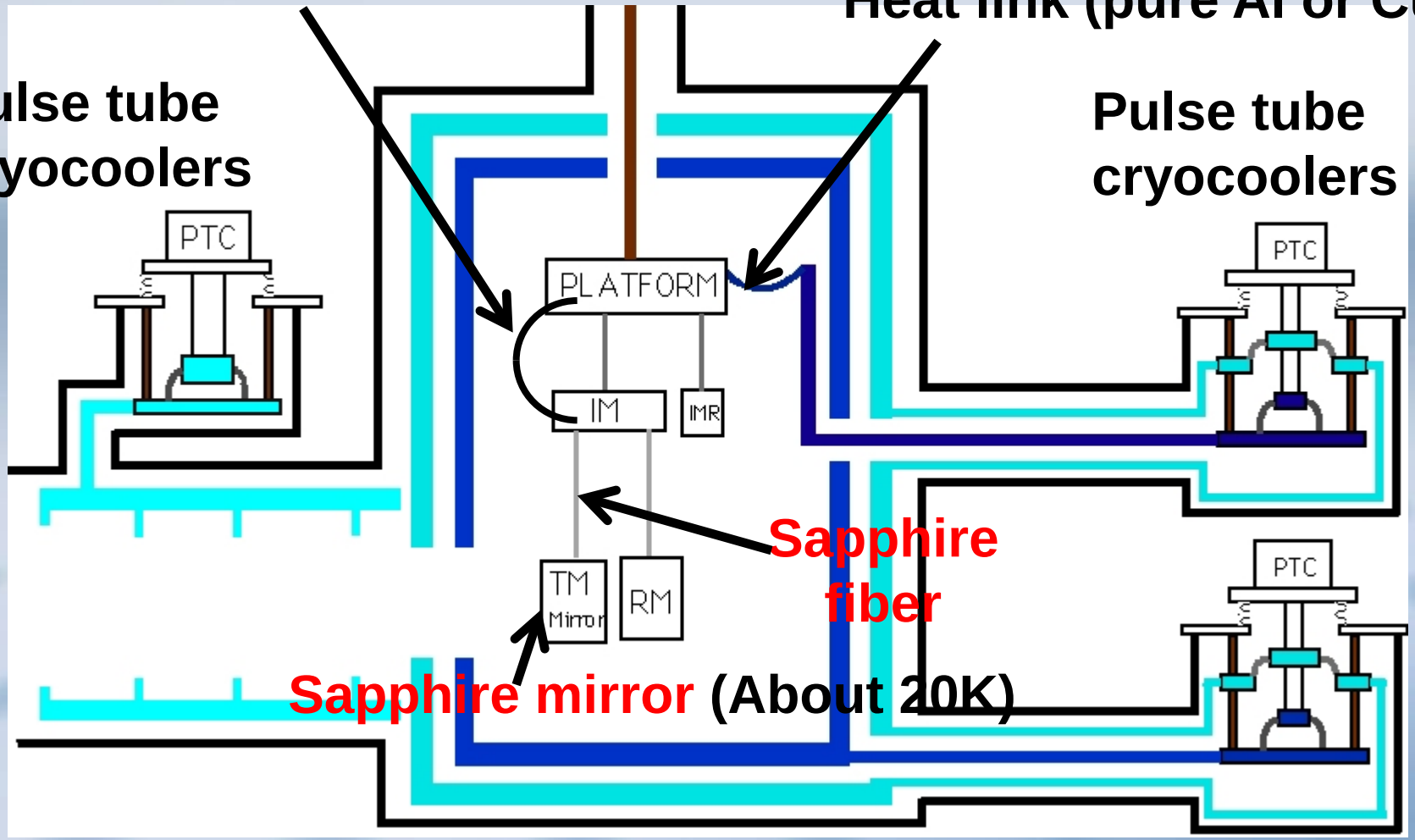


N. Kimura's talk

S. Koike

1. Introduction

Outline of vibration isolation and cryostat



1. Introduction

Main topics

Experiments in KAGRA cryostat

- **Initial cooling time**
- **Measurement of radiation vibration**

Sapphire monolithic suspension

- **Key component of KAGRA**

2. Experiments in KAGRA cryostat

KAGRA cryostats have already been assembled !

at Toshiba Keihin Product Operations

2. Experiments in KAGRA cryostat

Cooling test : Can cryostats be cooled well ?

Cooling test for all four KAGRA cryostats
January 2013 – April 2013

Cooling test for the 3rd cryostat
July 2013 – August 2013

2. Experiments in KAGRA cryostat

Experiments in cooling test of KAGRA cryostat

Experiment 1 : Initial cooling time of cryogenic payload

This initial cooling time should be short.

Experiment 2 : Measurement of shield vibration

This vibration causes motion of mirrors and scattered light noise.

Dan Chen presents poster in this meeting.

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

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

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

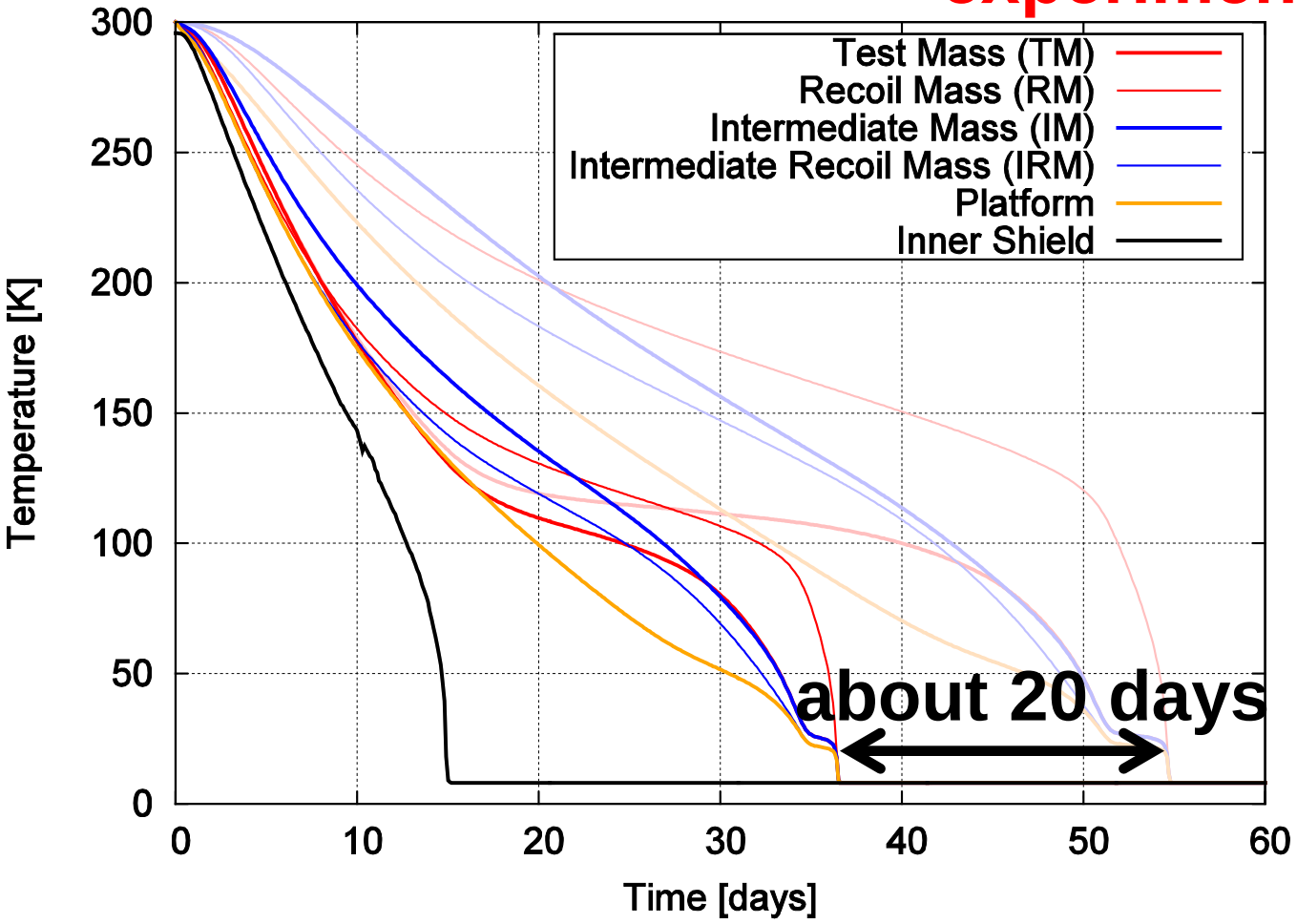
Diamond Like Carbon (DLC) coating (or SolBlack)
(High emissivity, Large radiation)
on shields and payload (except for mirror)

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

Yusuke Sakakibara's calculation

This calculation must be checked experimentally.

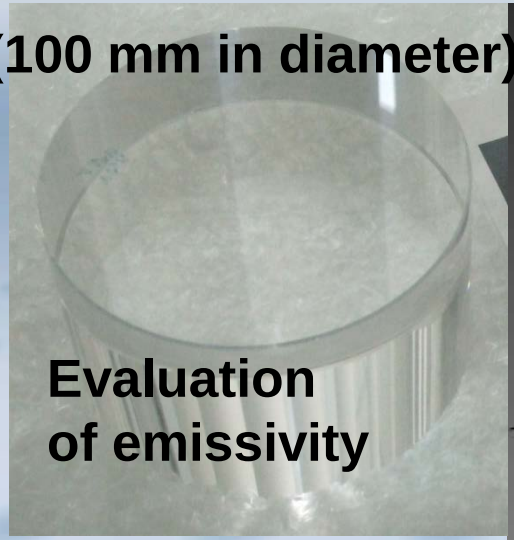


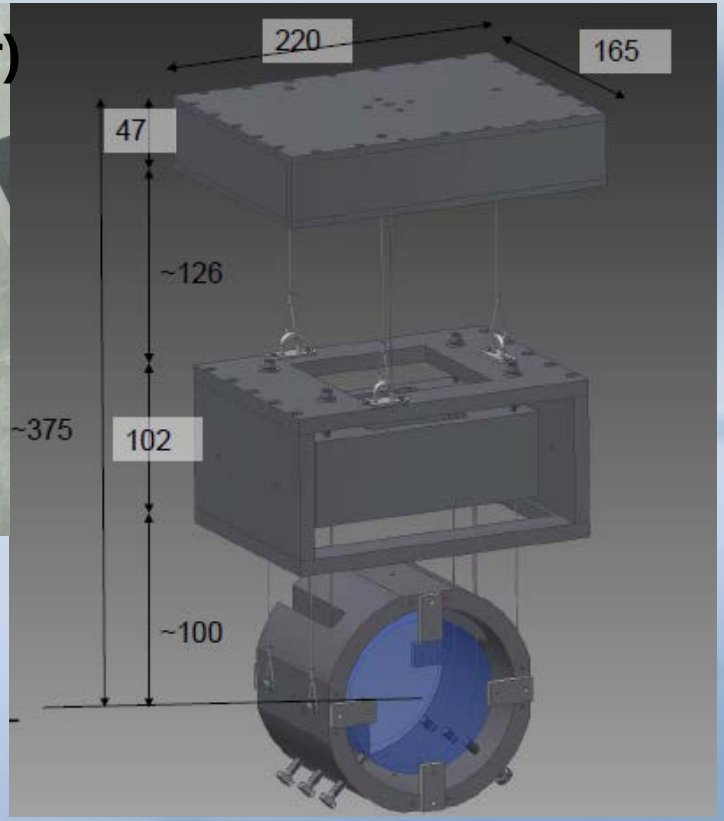
2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

Dummy payload was suspended in KAGRA cryostat.

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



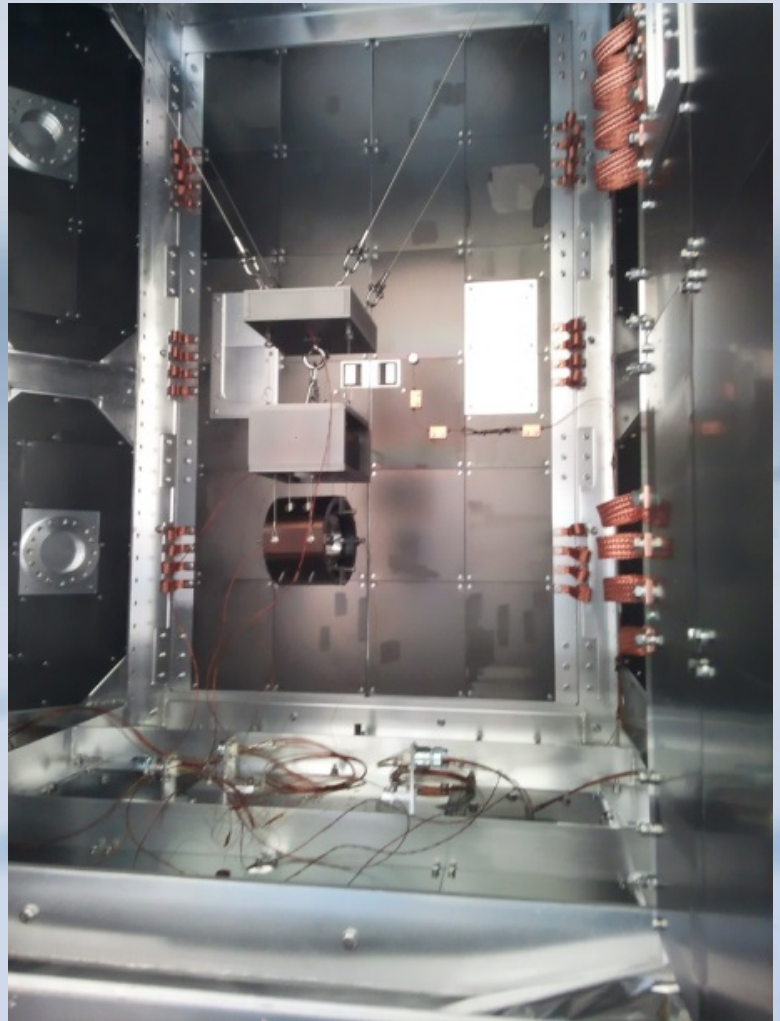


S. Koike

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

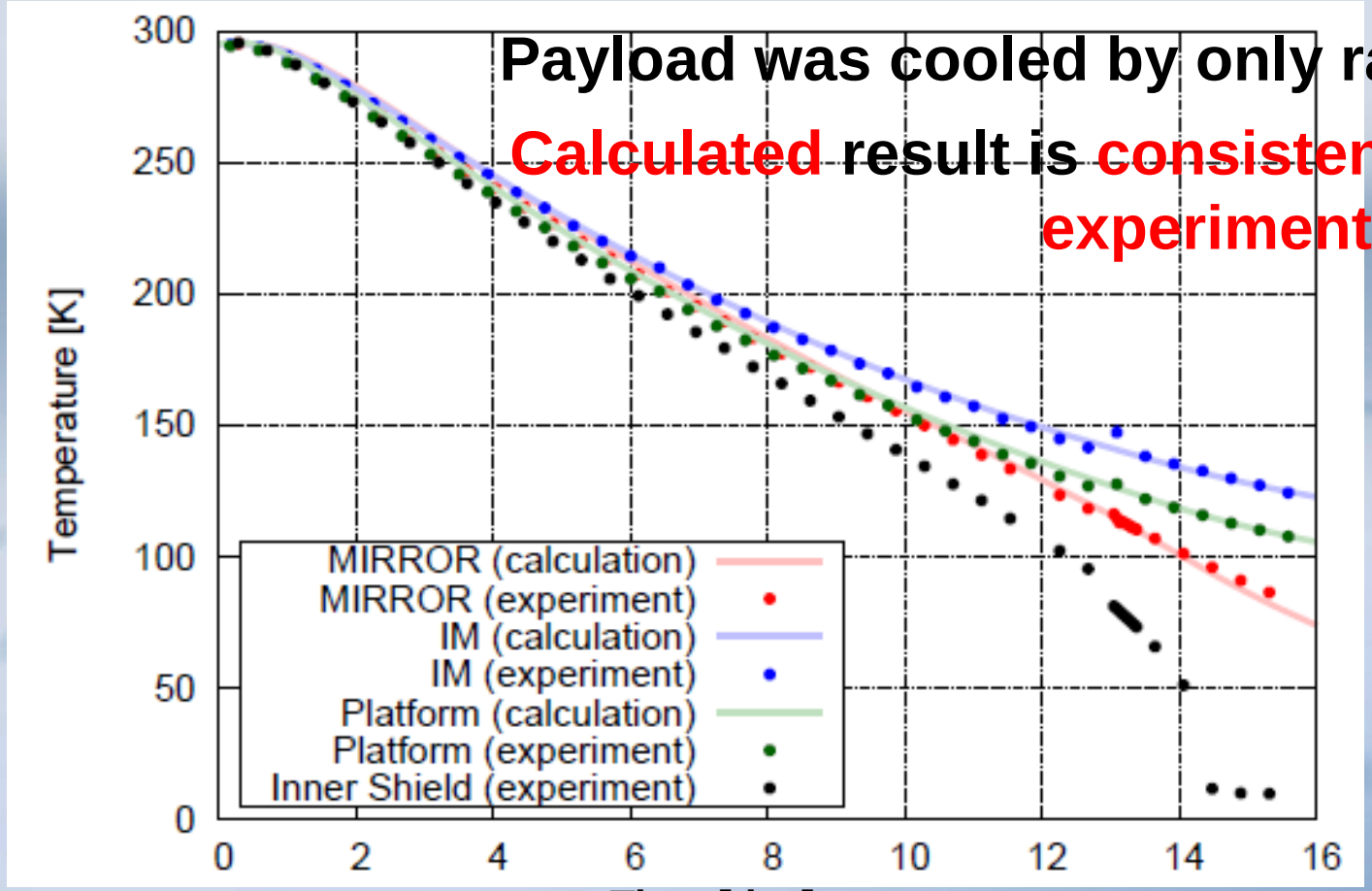
Dummy payload



2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

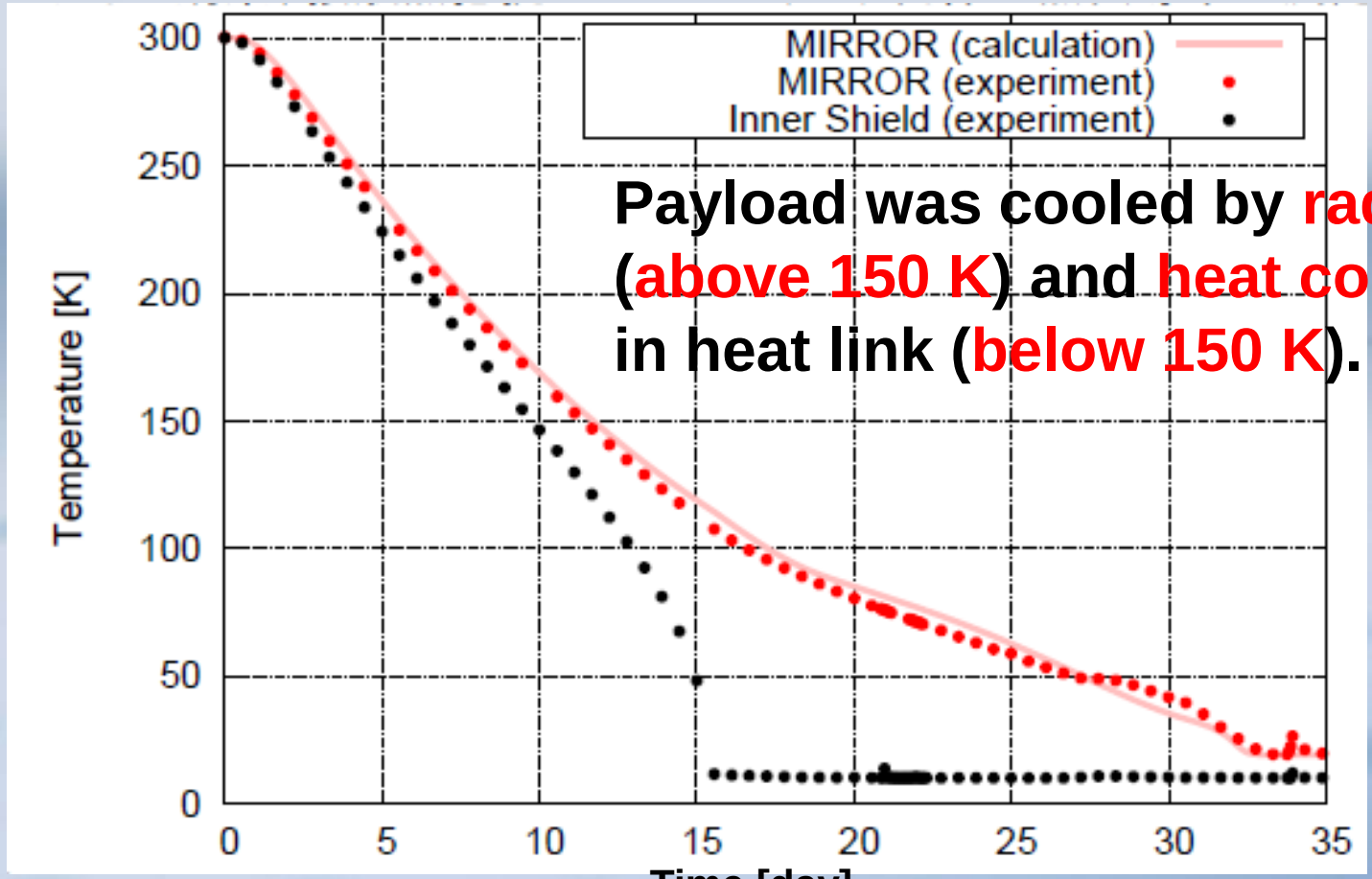
First experiment (Spring 2013) without heat link



2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

Second experiment (Summer 2013) with Cu heat link



Payload was cooled by radiation (above 150 K) and heat conduction in heat link (below 150 K).

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

Second experiment (Summer 2013) with Cu heat link

Problem (1) : One cryocooler temperature is 20 K (below 8 K in normal operation).

Problem (2) : Thermal resistance of copper heat link is a few times larger than our expectation.

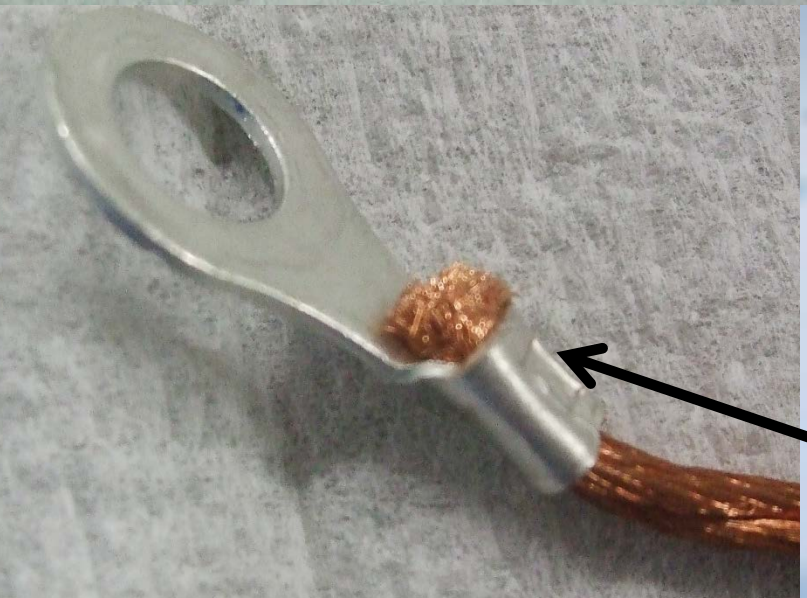
Themal resistance on the both ends (solderless terminal) ?

Size effect (this heat link many consists of thin wires) ?

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

Second experiment (Summer 2013) with Cu heat link



Size effect (this heat link many consists of thin wires) ?

Themal resistance on the both ends (solderless terminal) ?

2. Experiments in KAGRA cryostat

Experiment 1 : Initial cooling time

After second experiment (Summer 2013)

with Cu heat link ...

Plan

(1)Dummy payload cooling test in 1/4 cryostat

This 1/4 cryostat is to test performance of KAGRA cryogenic payload

(2)Measurement of thermal conductivity (or resistance) of heat link itself

2. Experiments in KAGRA cryostat

1/4 cryostat for perfomance test
of cryogenic payload

Vacuum chamber :
1.2 m in diameter, 1.6 m in height
Delivery : 27th of Sep. 2013

2. Experiments in KAGRA cryostat

Experiment 2 : Measurement of shield vibration

Vibration of shield could be problems.

Vibration via heat links, Scattered light

We must measure the vibration of shield.

This measurement is

at cryogenic temperature and in vacuum.

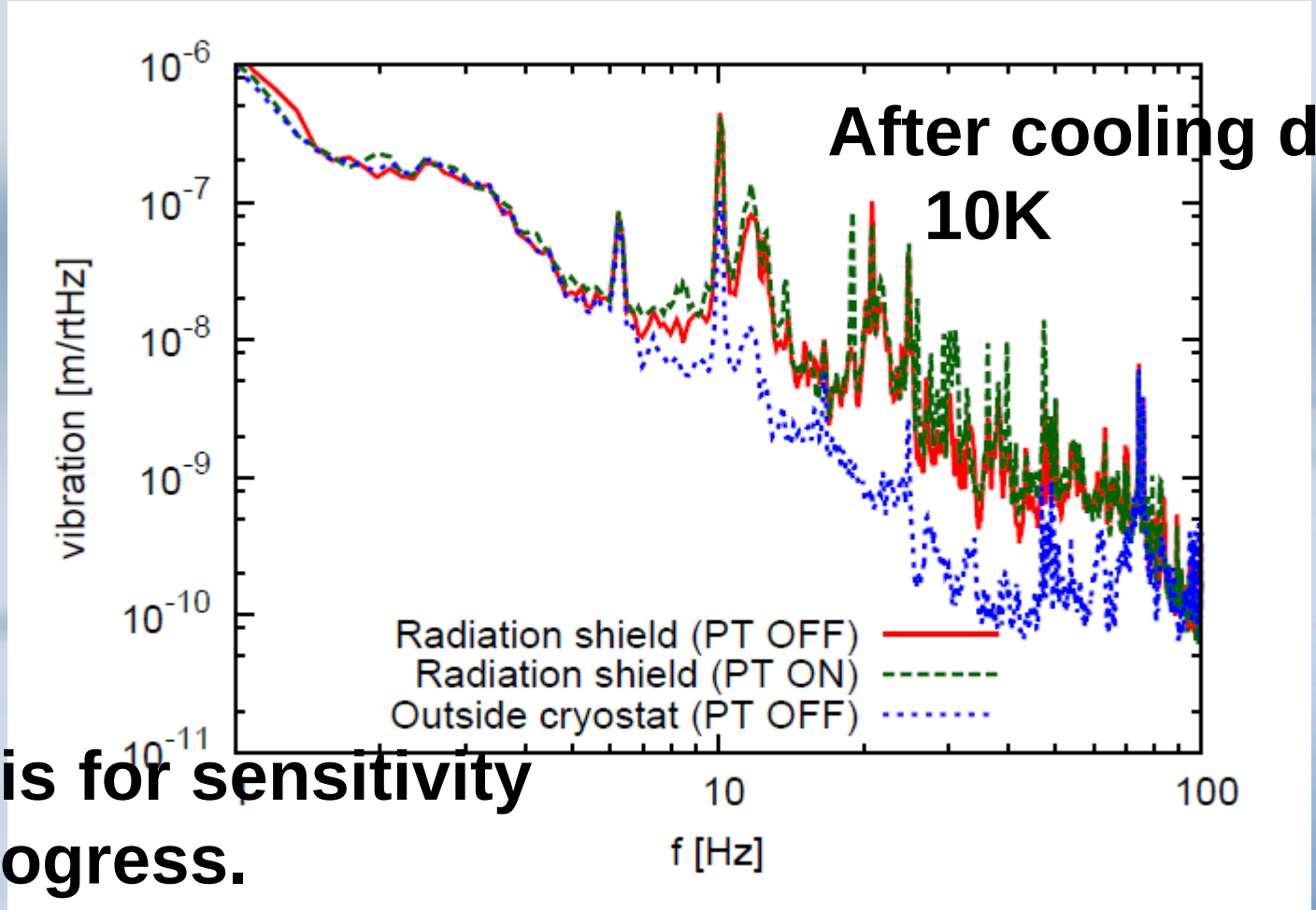
Luca Naticchioni (Rome) and Dan Chen (ICRR) will measure vertical and horizontal vibration of radiation shield of KAGRA, respectively.

Dan Chen presents poster in this meeting.

2. Experiments in KAGRA cryostat

Experiment 2 : Measurement of shield vibration

Dan Chen (horizontal motion)

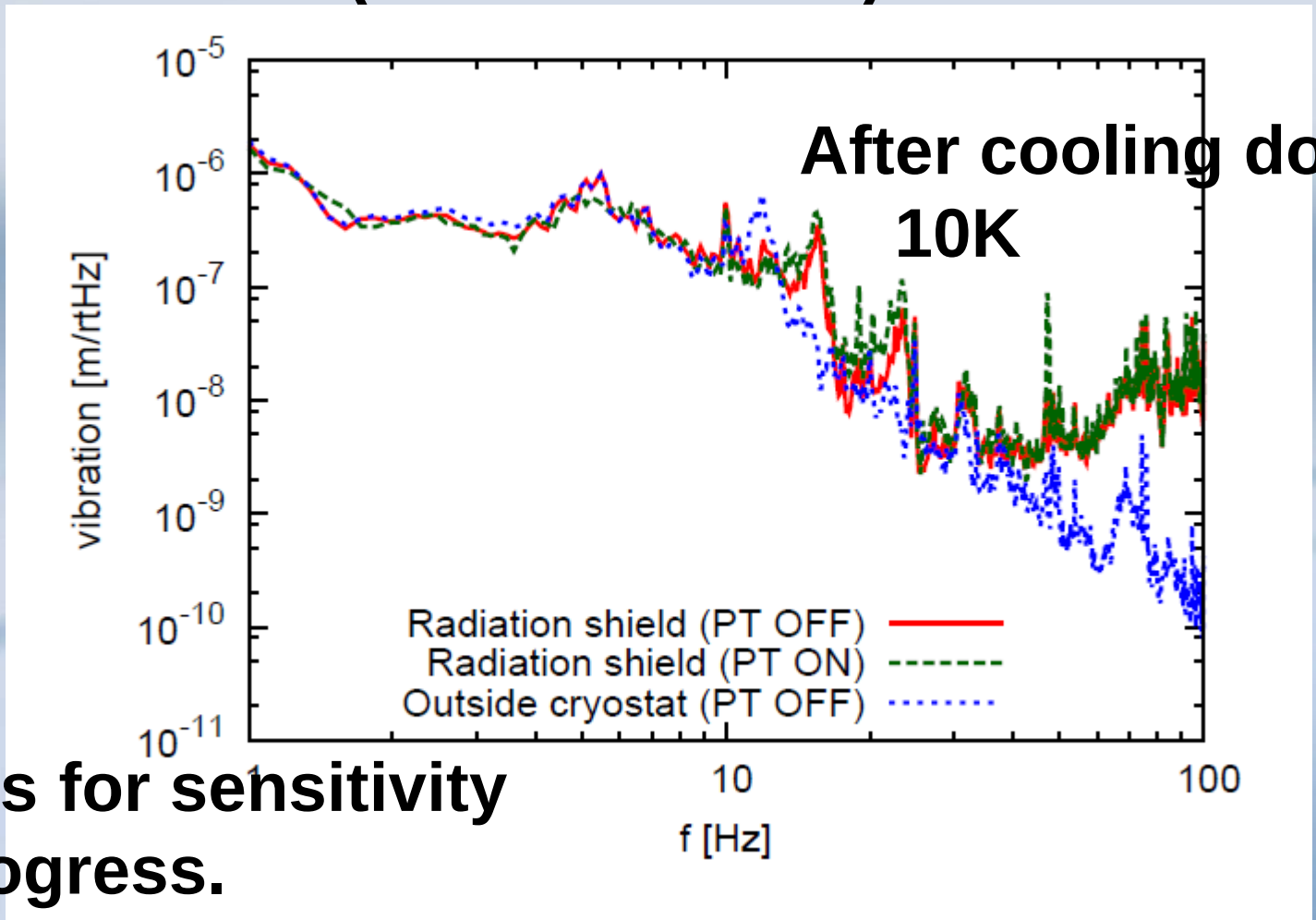


Analysis for sensitivity is in progress.

2. Experiments in KAGRA cryostat

Experiment 2 : Measurement of shield vibration

Luca Naticchioni (vertical motion)



Analysis for sensitivity is in progress.

3. Sapphire suspension

Sapphire monolithic suspension

Sapphire mirror is suspended by sapphire fibers.

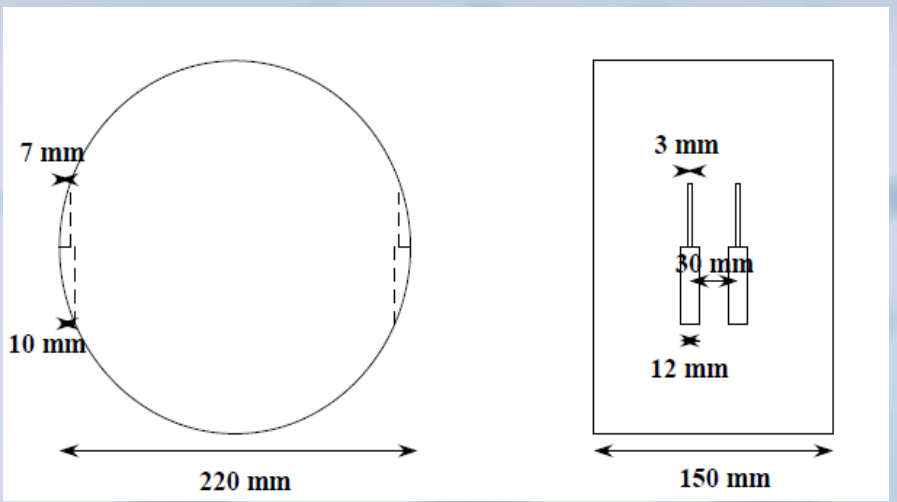
Key component of KAGRA

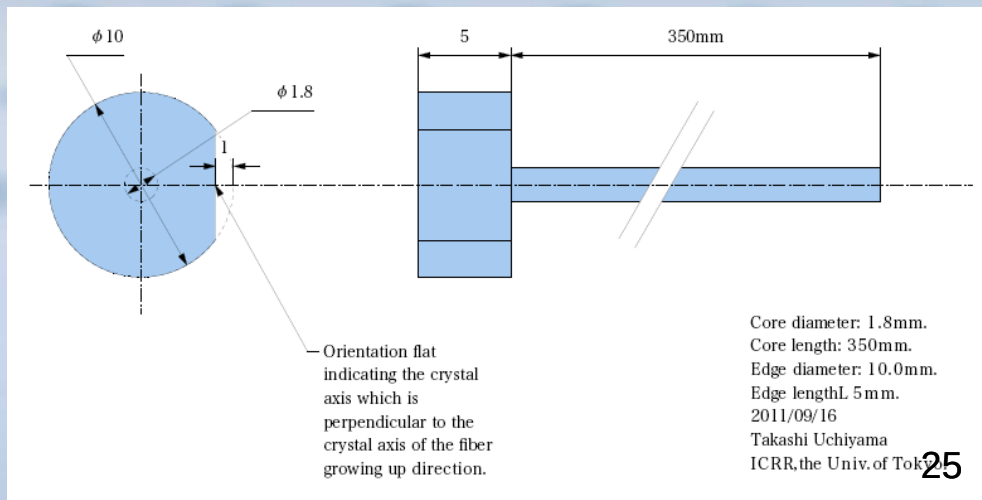
We need

(a)Drilled sapphire mirror

(b)Sapphire fibers with nail heads

(c)Bonding between bulk and fibers

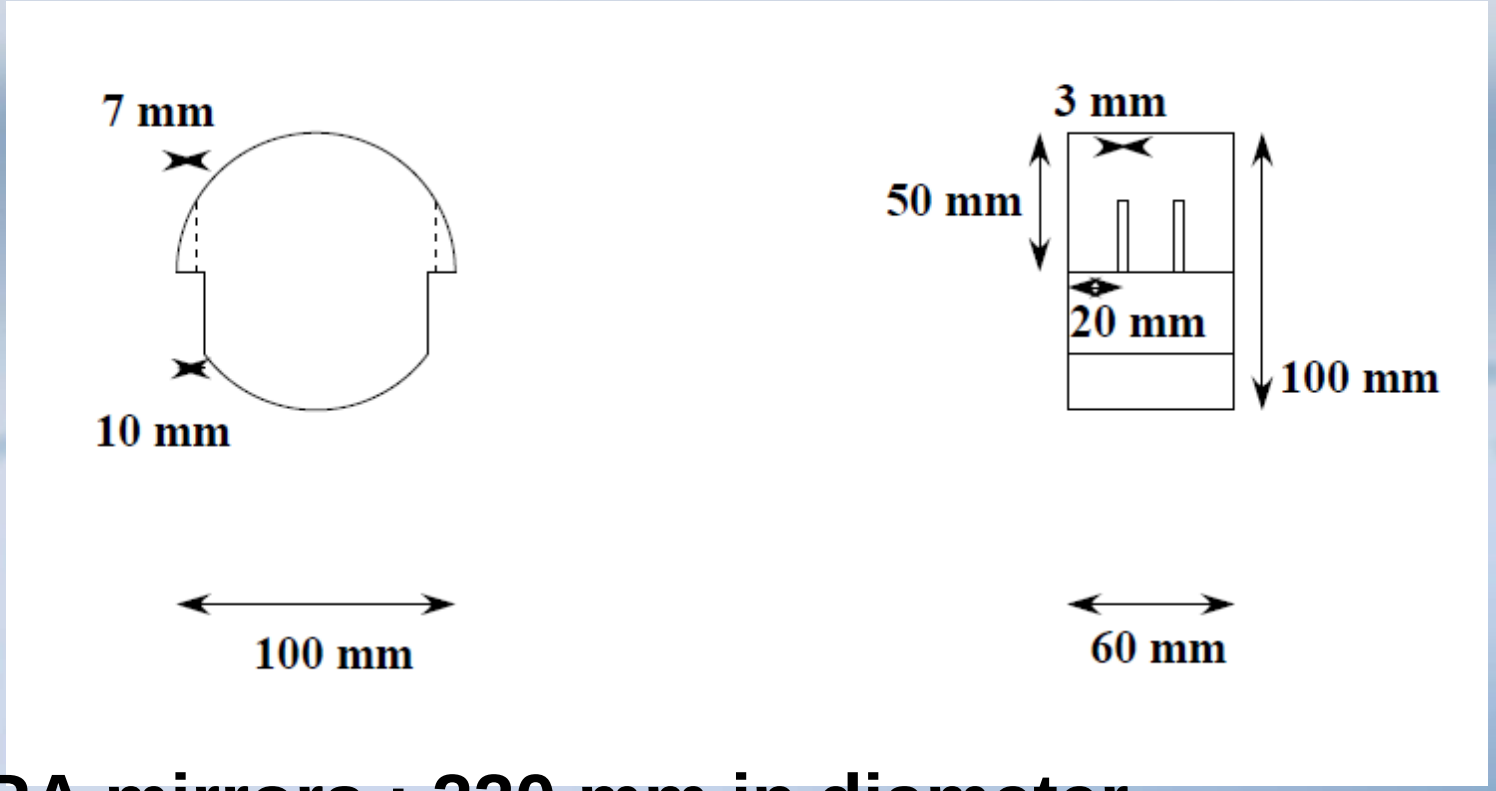




3. Sapphire suspension

Drilled sapphire bulk

We ordered Shinkosha (test sample).



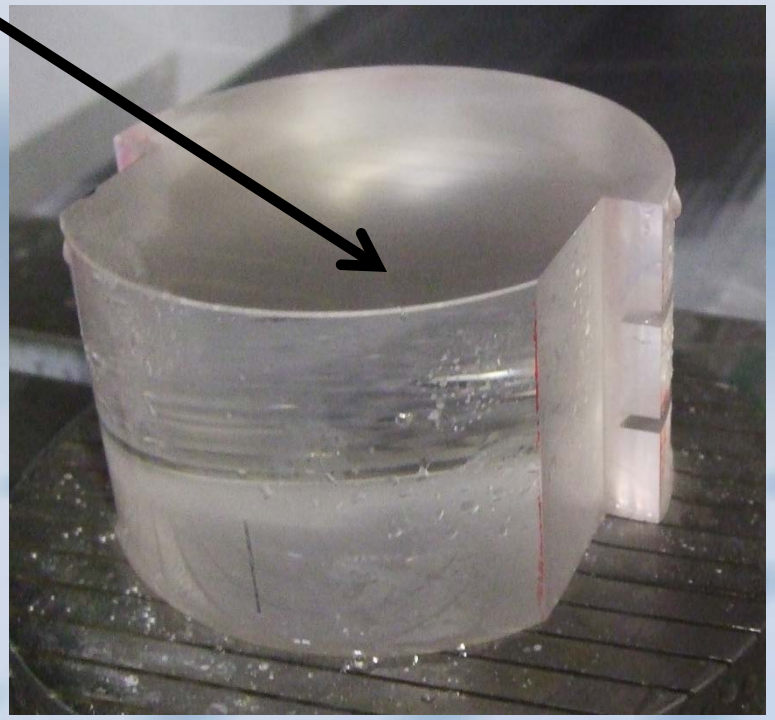
KAGRA mirrors : 220 mm in diameter

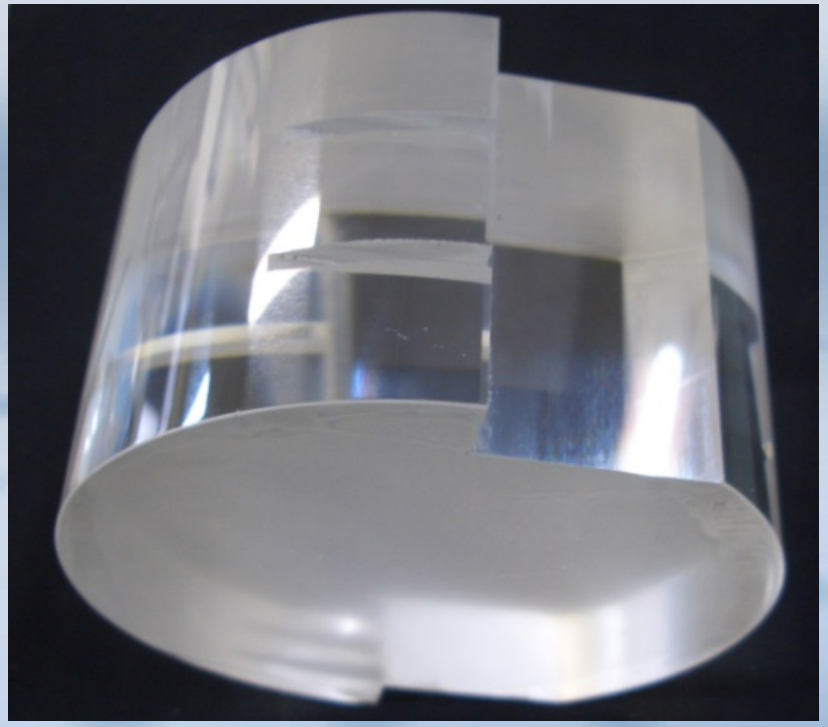
3. Sapphire suspension

Drilled sapphire bulk

We ordered Shinkosha (test sample).

It was delivered on the 1st of October.



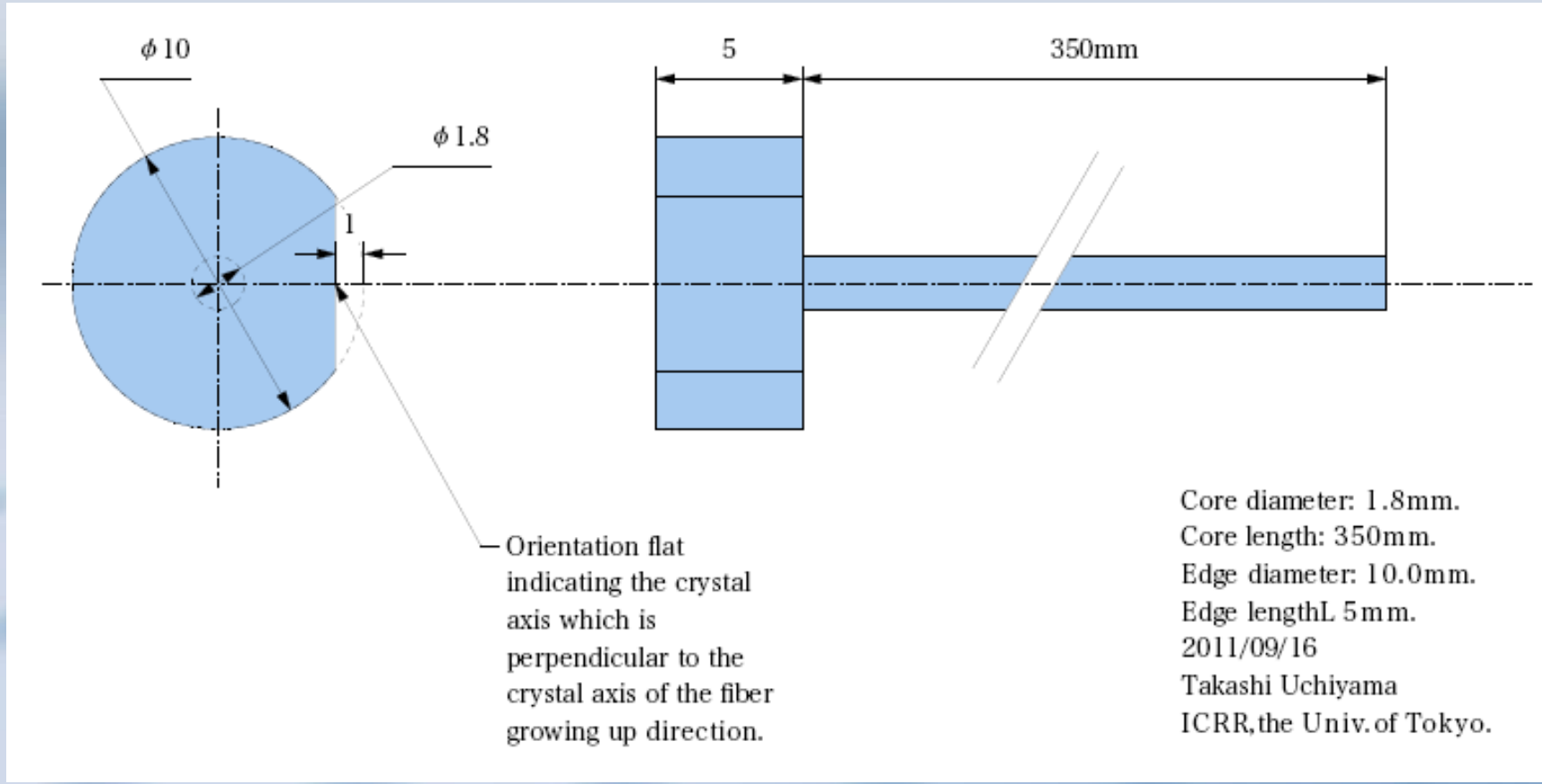


Second sample is being made.

3. Sapphire suspension

Sapphire fibers with nail heads are necessary to suspend mirrors.

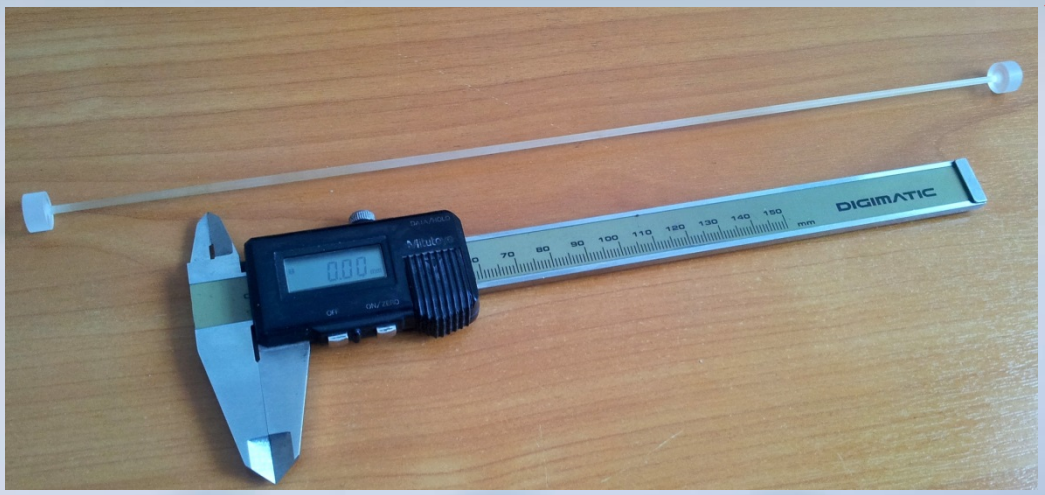
Test sample (T. Uchiyama)



3. Sapphire suspension

Sapphire fibers with nail heads

MolTech GmbH (Germany) and IMPEX HighTech GmbH (Germany) have already delivered !



Although the size is similar to that of KAGRA, quality check is necessary.

3. Sapphire suspension

Sapphire fibers with nail heads

Quality check under collaboration with ET (ELiTES)

Q-value

Measurement in Glasgow, Jena, Rome and Tokyo

Thermal conductivity

Measurement in Jena, Rome and Tokyo

Strength

Measurement in Glasgow

3. Sapphire suspension

Sapphire fibers with nail heads

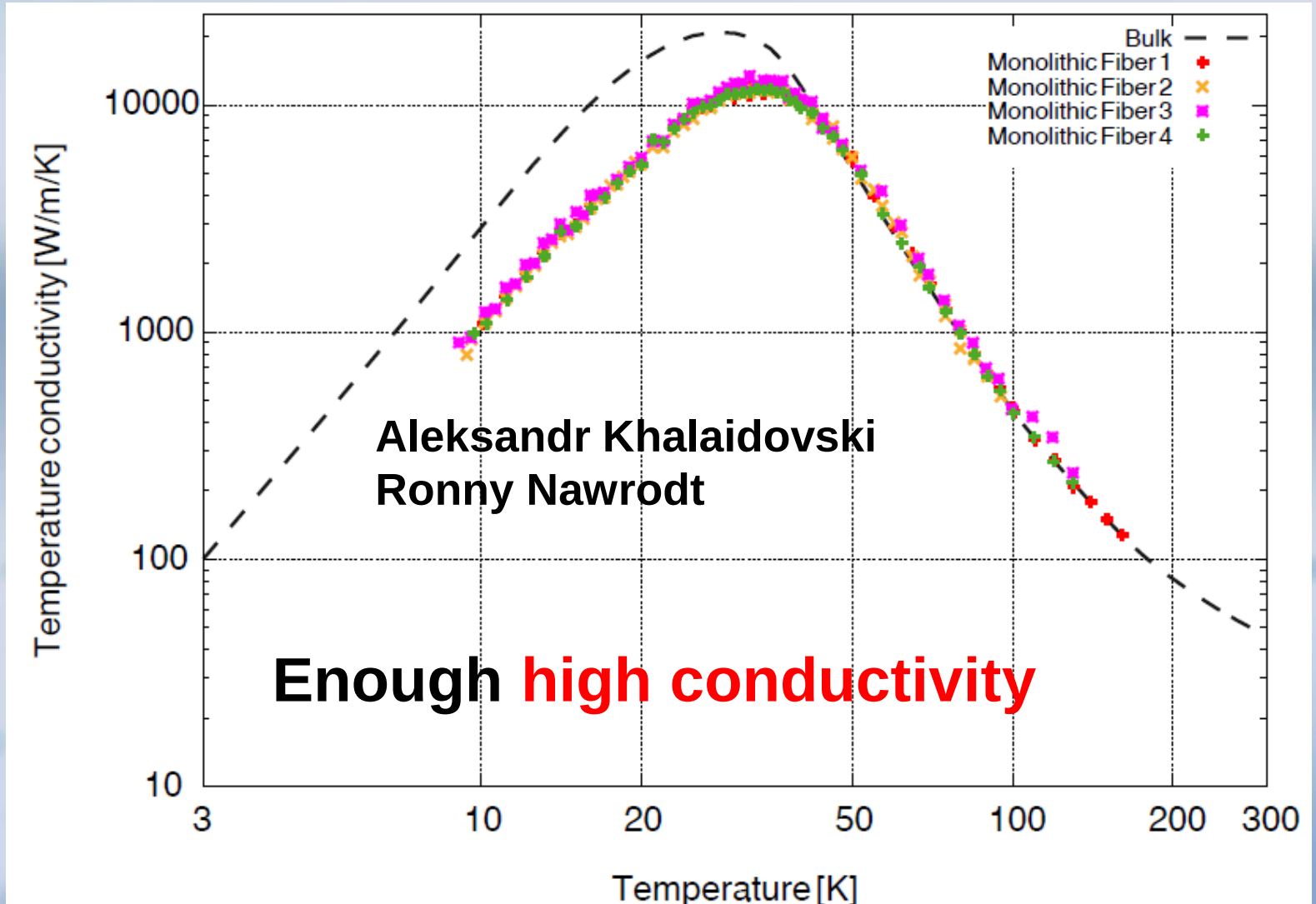
Latest summary

	Moltech	IMPEX	KAGRA requirement
Q-value at 20K	10^7	$1*10^6$ - $6*10^6$	$5*10^6$
Thermal Conductivity at 20K [W/m/K]	3000	5000 -9000	5000

Although IMPEX fiber satisfies requirement (Details are in D. Chen's poster), further investigation is necessary (polish of nail head surface …).

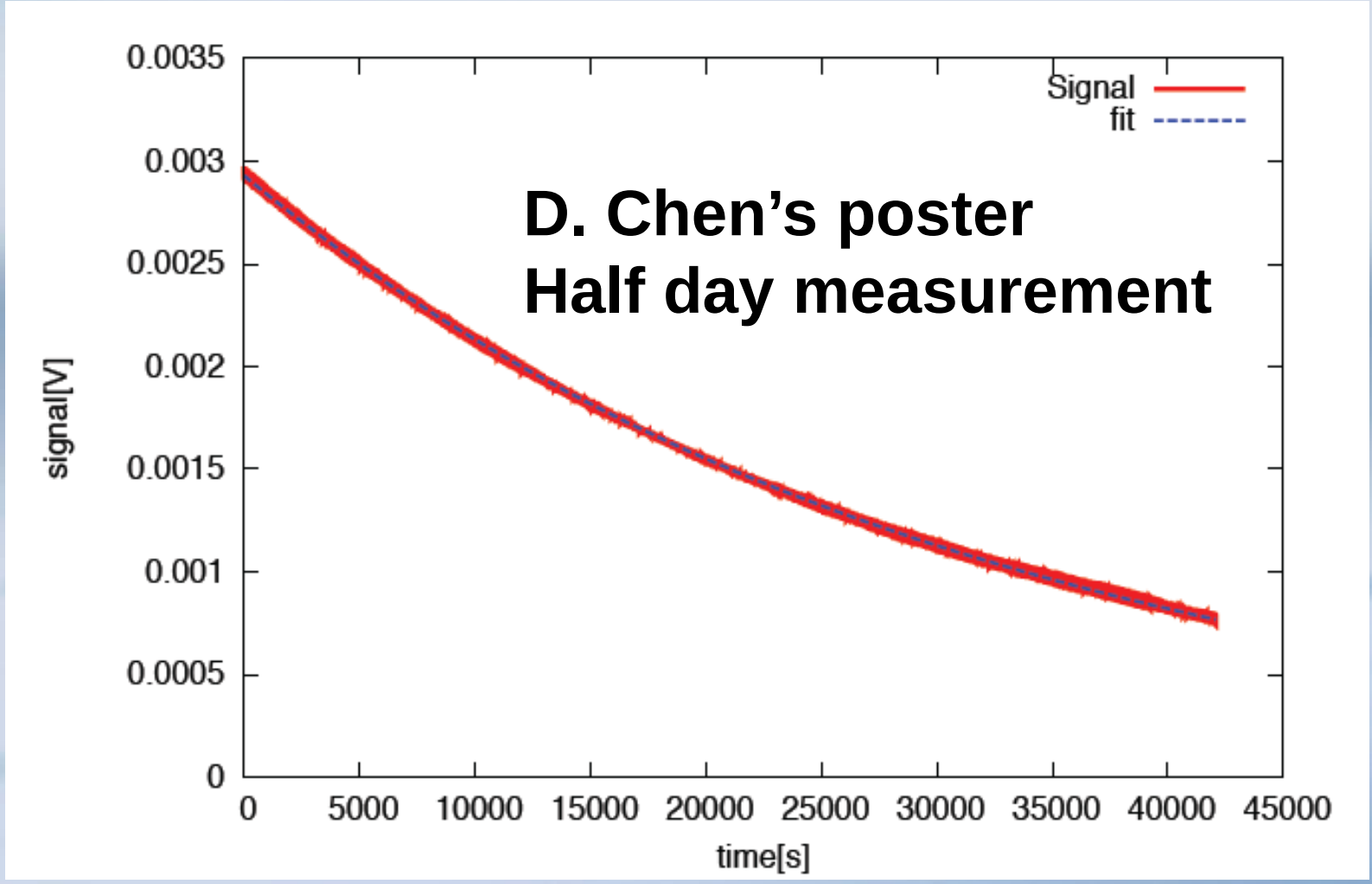
3. Sapphire suspension

Thermal conductivity of four IMPEX fibers



3. Sapphire suspension

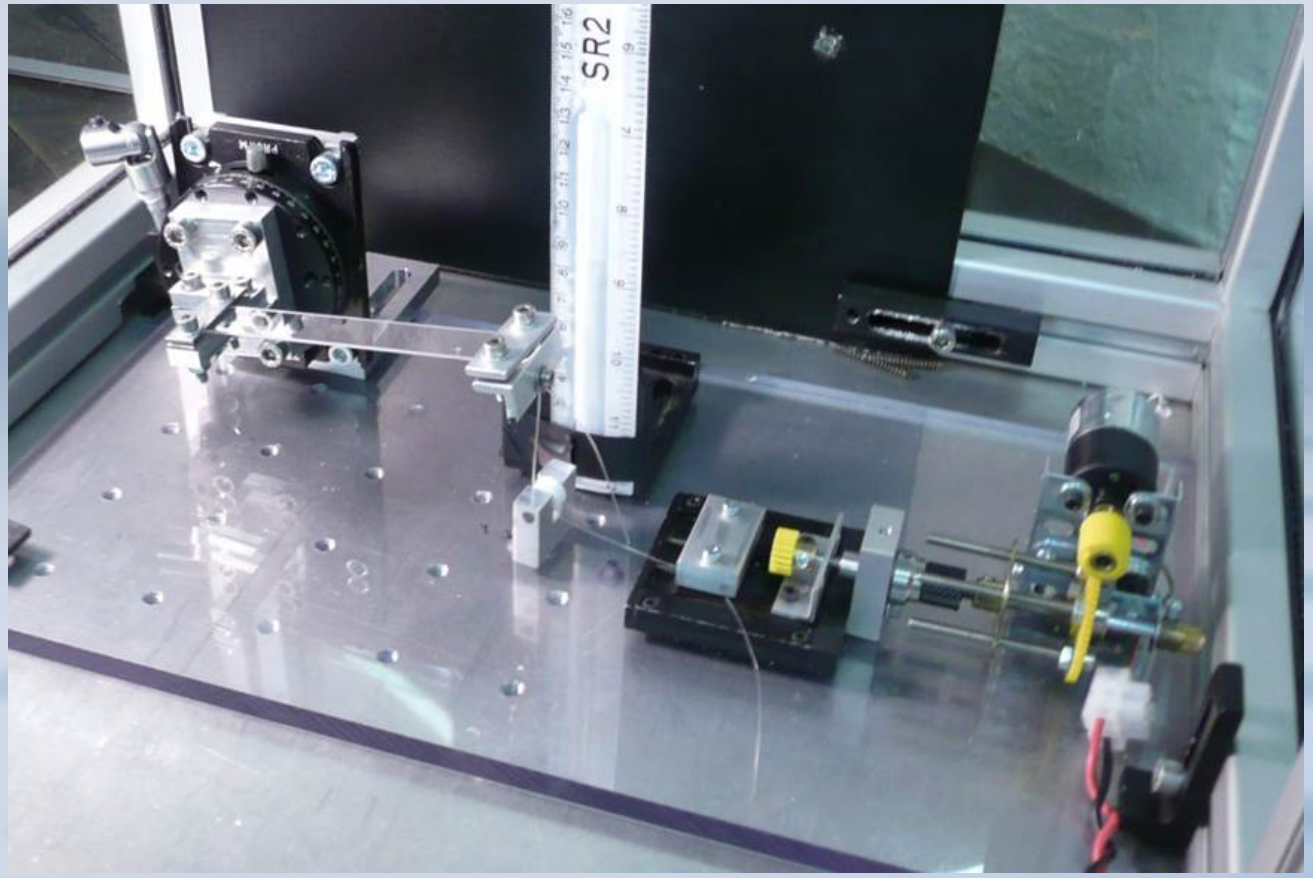
Decay motion of IMPEX fibers



3. Sapphire suspension

Strength test

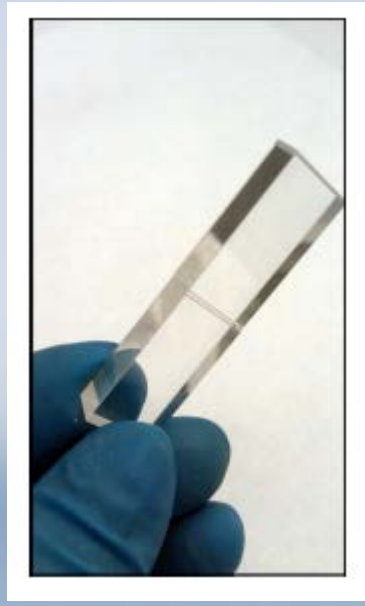
Test for sapphire fibers and blades is in progress (Glasgow).



Bending strength 268 MPa

Alan V. Cumming' talk

3. Sapphire suspension



Bonding between sapphire fibers and sapphire mirror

Investigation of Hydroxide Catalysis Bonding is in progress in Glasgow. (Rebecca Douglas, GWADW2013).

Strength (about 60 MPa) measured by her is 10 times larger than those of previous papers.

T. Suzuki et al., Journal of Physics; Conference Series 32(2006)309.
A. Dari et al., Classical and Quantum Gravity 27(2010)045010.

Other measurement (thermal resistance and so on) are necessary. Rebecca Douglas and Karen Haughian will stay in Japan (November).

3. Sapphire suspension

Assembled sapphire monolithic suspension

Performance of assembled monolithic sapphire pendulum must be checked.

Before that, sapphire bulk is suspended by sapphire fibers using indium as thermal and mechanical contact (some kinds of "glue" instead of bonding) between sapphire bulk and fibers.

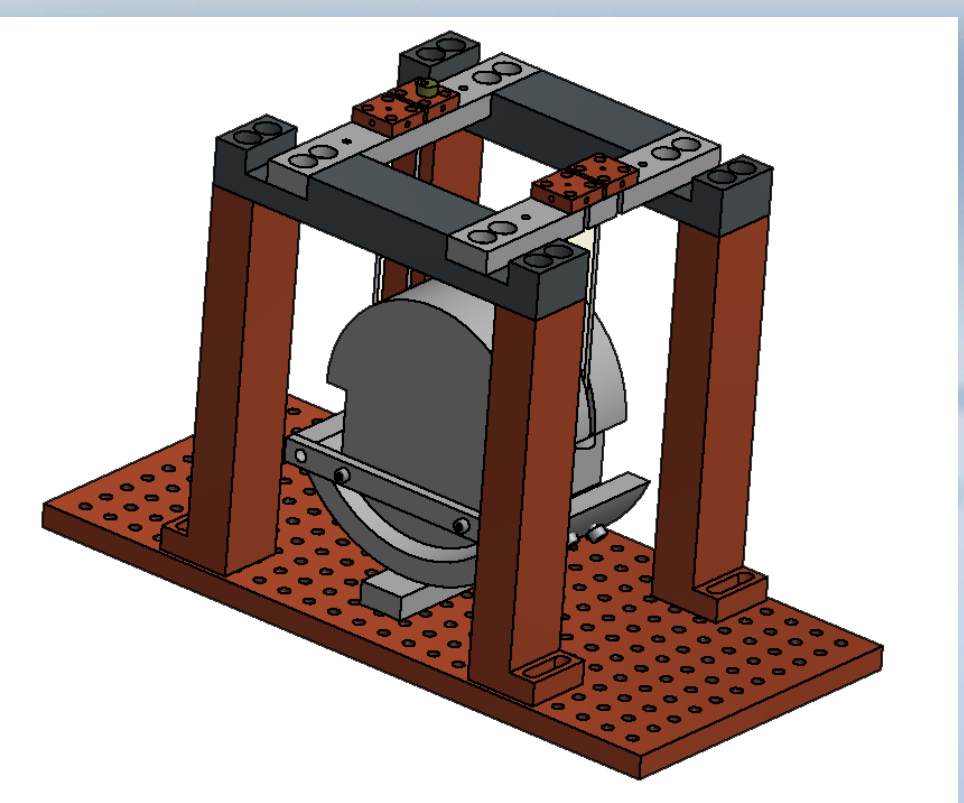
We will investigate performance and obtain expertise for the monolithic pendulum test as first step.

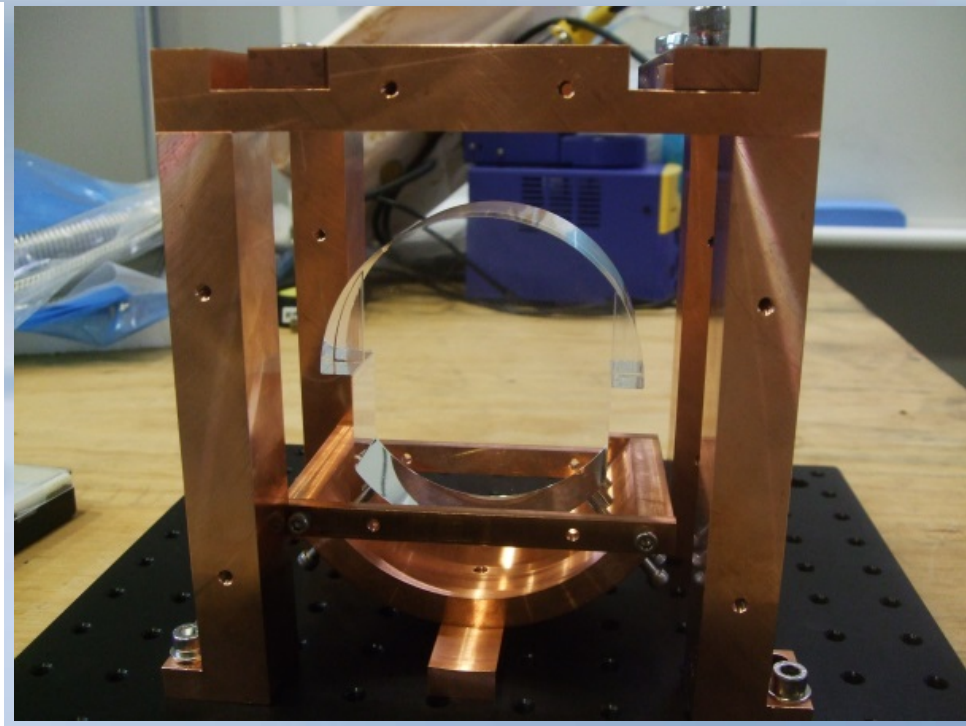
3. Sapphire suspension

Assembled sapphire monolithic suspension

A. Khalaidovski designed the frame for this first step. This frame was delivered.

Experiment will be started soon.





4. Human resources

3 fresh persons from Europe

Dr. Aleksandr Khalaidovski
from Hannover, June 2013-May 2014
Sapphire monolithic suspension

(Dr. Fabián Erasmo Peña Arellano
from Birmingham, May 2013 – April 2016
Cryogenic sensor)

Dr. Rahul Kumar
from Glasgow, September 2013 – August 2014
Simulation and development of payload

4. Human resources

ELiTES: ET-LCGT interferometric Telescope Exchange of Scientists

Grant for collaboration about cryogenic between KAGRA and ET

European 7th Framework Programme
Marie Curie action (Mar. 2012 - Feb. 2016)

European people can visit Japan for KAGRA.

4. Human resources

7 visitors supported by ELiTES
in the first three quaters of 2013

Christian Schwarz, Gerd Hofmann, Ronny Nawrodt (Jena)
Automatic systems to measure Q-values
and thermal conductivity of sapphire fibers

Luca Naticchioni, Maurizio Perci, Ettore Majorana (Rome)
Measurement of KAGRA radiation shield
at cryogenic temperature

Kieran Craig (Glasgow)
Measurement of coating mechanical dissipation

4. Human resources

13 visitors supported by ELiTES
in the last quater of 2013

Gerd Hofmann, Julius Komma, Ronny Nawrodt (Jena)
Cryogenic experiment

Silvio Savoia, Massimo Moccia, Adele Fusco,
Innovenzo Pinto (Sannio)
Cryogenic experiment, Coating

Rebecca Douglas, Karen Haughian (Glasgow)
Sapphire bonding

4. Human resources

13 visitors supported by ELiTES
in the last quater of 2013

Joris Van Heijningen, Kazuhiro Agatsuma (NIKHEF)
Vibration isolation system

Gerald Bergmann, Manuela Hanke (Hannover)
Cryogenic payload and so on

5. Summary

KAGRA cryostat

Experiment : Initial cooling time of payload
Radiation shield vibration

Initial cooling time of payload

(1) DLC coating reduces initial cooling time as our calculation.

(2) Thermal resistance of Cu heat link is a few times lareger than our expectation.
Investigation is in progress.

Radiation shield vibration

We measured. Analysis is in progress.

5. Summary

Sapphire monolithic suspension

Drilled test bulk was delivered on 1st of October.

Experiments for sapphire fiber
and sapphire bonding are in progress
but the results are promising.
Thermal conductivity and Q-value of IMPEX
fibers are larger than KAGRA reuqirement.

We are preparing the first step experiment
of monolithic sapphire suspension.

5. Summary

Human resources

Three brilliant fresh persons came from Europe.

Strong support from ELiTES

In the first three quaters of 2013 : 7 visitors

In the last quater of 2013 : 13 visitors

Thank you for your attention !