KAGRA

Large-scale cryogenic gravitational-wave telescope in Japan:

KAGRA

Tomotada Akutsu *National Astronomical Observatory of Japan*

for the KAGRA Collaboration

LISA Symposium X, University of Florida, Gainesville (May 21, 2014)

Good news

KAGRA

Tunnel excavation completed as planned in March 2014.

Leading-edge Research Infrastructure Program
Large-scale Cryogenic Gravitational Wave Telescope Project

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Excavation of KAGRA's 7 km Tunnel Now Complete

Excavation of KAGRA's 7 km Tunnel Now Complete
March 31, 2014

On March 31, 2014, the team of the Large-Scale Cryogenic Gravitational Wave Telescope (KAGRA) completed the excavation of its L-shaped tunnel with two 3 km arms. Including two access tunnels, a total length of 7,697 m has been hollowed out 200 m below the surface of Mt. Ikenoyama in Kamioka—beside the site of Super-Kamiokande—where the construction of a 3-km-scale cryogenic interferometer will soon begin. This interferometer has been designed to directly detect gravitational waves for the first time ever.

KAGRA is an international project involving 231 scientists from 31 institutions, principally operated by ICRR(Institute for Cosmic Ray Research) with two main joint-research institutions, KEK (High energy accelerator research organization) and NAOJ (National Astronomical Observatory). Its aim is to construct 3-km-scale Fabry-Perot Michelson Interferometer underground at Kamioka to detect gravitational waves. Gravitational waves, derived from Einstein's general theory of relativity, are ripples in the curvature of spacetime that propagate at the speed of light. The first indirect proof of their existence was proposed by Dr. Hulse and Dr. Taylor in 1974 who found a binary system of neutron stars, whose decrease in orbital period was well described by the loss of energy through gravitational radiation. In addition, the astronomers of the BICEP2 experiment at the South Pole recently reported that they had found the signature of primordial gravitational waves imprinted in the B-mode polarization of the Cosmic Microwave Background—further evidence of gravitational waves if confirmed. However, gravitational waves have yet to be detected directly in a form in which their waveforms are evident. The direct detection of gravitational waves will not only validate our understanding of gravity and spacetime but also open up a whole new field of gravitational wave astronomy by enabling the physics of strong gravitational fields to be tested, and enabling direct observations of mysterious objects such as black holes, which are not possible through the

News Category

- Back Number
- Events
- KAGRA news introduced in mass communication media
- Latest News

Archives

- Mar 2014
- Dec 2013
- Nov 2013
- Oct 2013
- Jul 2013
- Jun 2013
- May 2013
- Apl 2013
- Jan 2013

http://gwcenter.icrr.u-tokyo.ac.jp/en/archives/1075

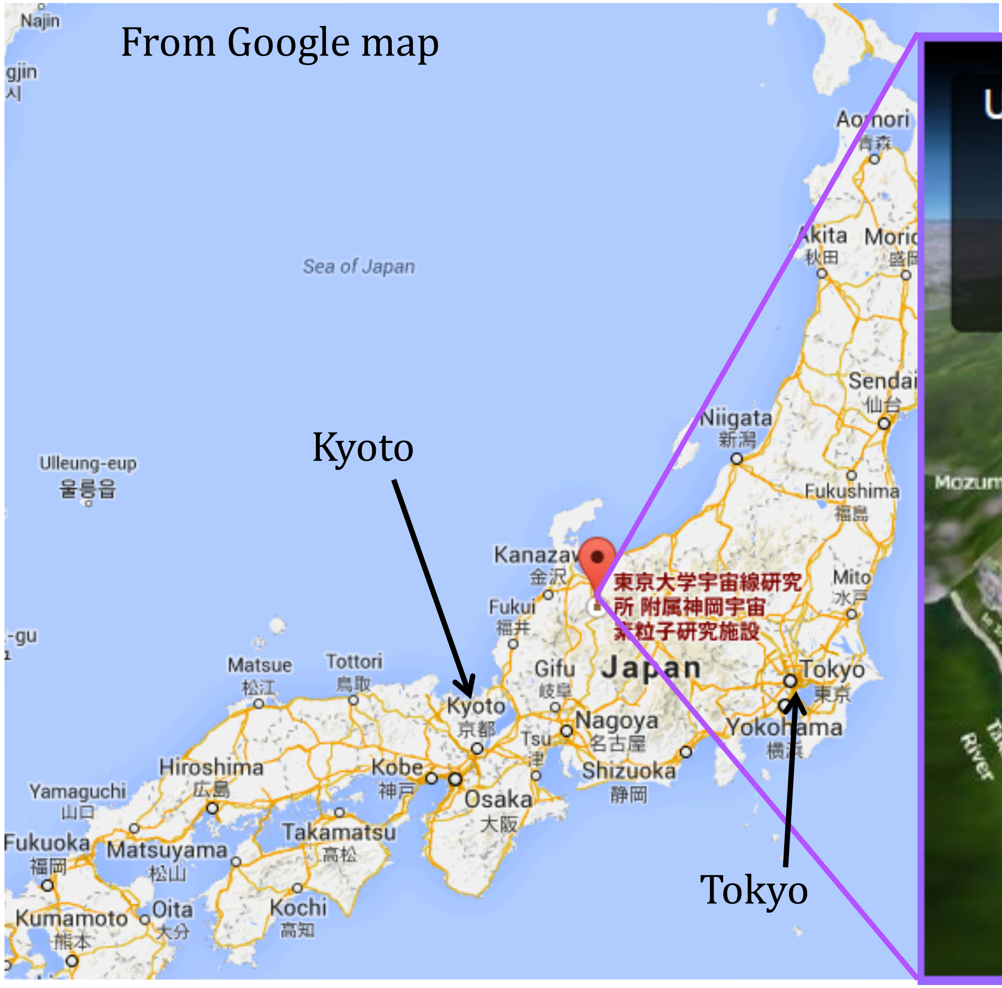
Contents

- Overview of KAGRA
- Real work
- Summary

KAGRA project

Previously known as LCGT

- Laser interferometric gravitational-wave detector with 3-km arms
- Now under construction in the Kamioka mine, Gifu, Japan
- Facility of Institute for Cosmic Ray Research (ICRR), Univ. of Tokyo



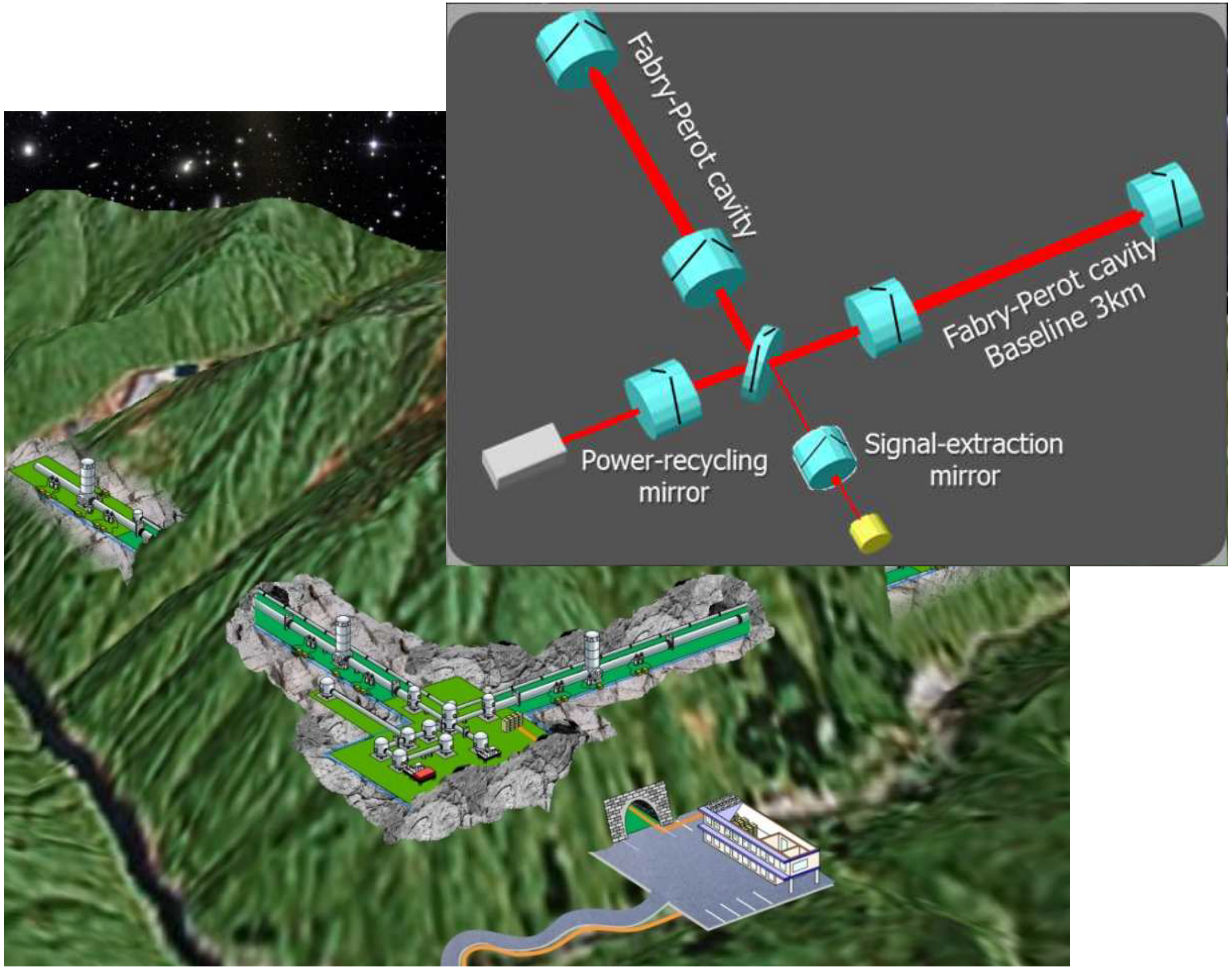
In collaboration

KAGRA

- Host: ICRR, Univ. of Tokyo
- Co-Hosts: KEK and NAOJ
- Over 200 collaborators from more than 60 universities and institutes in Japan and abroad.

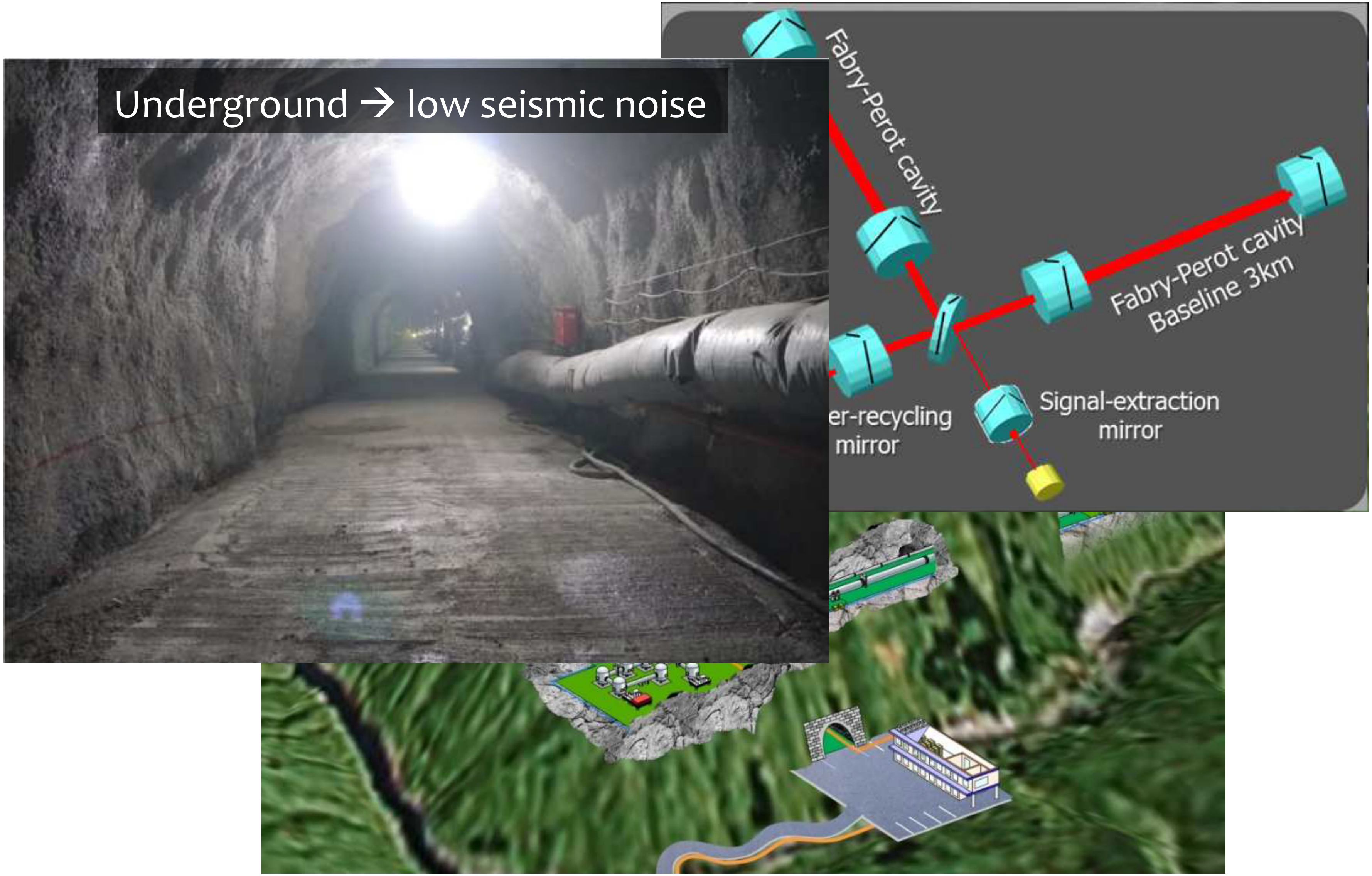
Main Features

Main Features

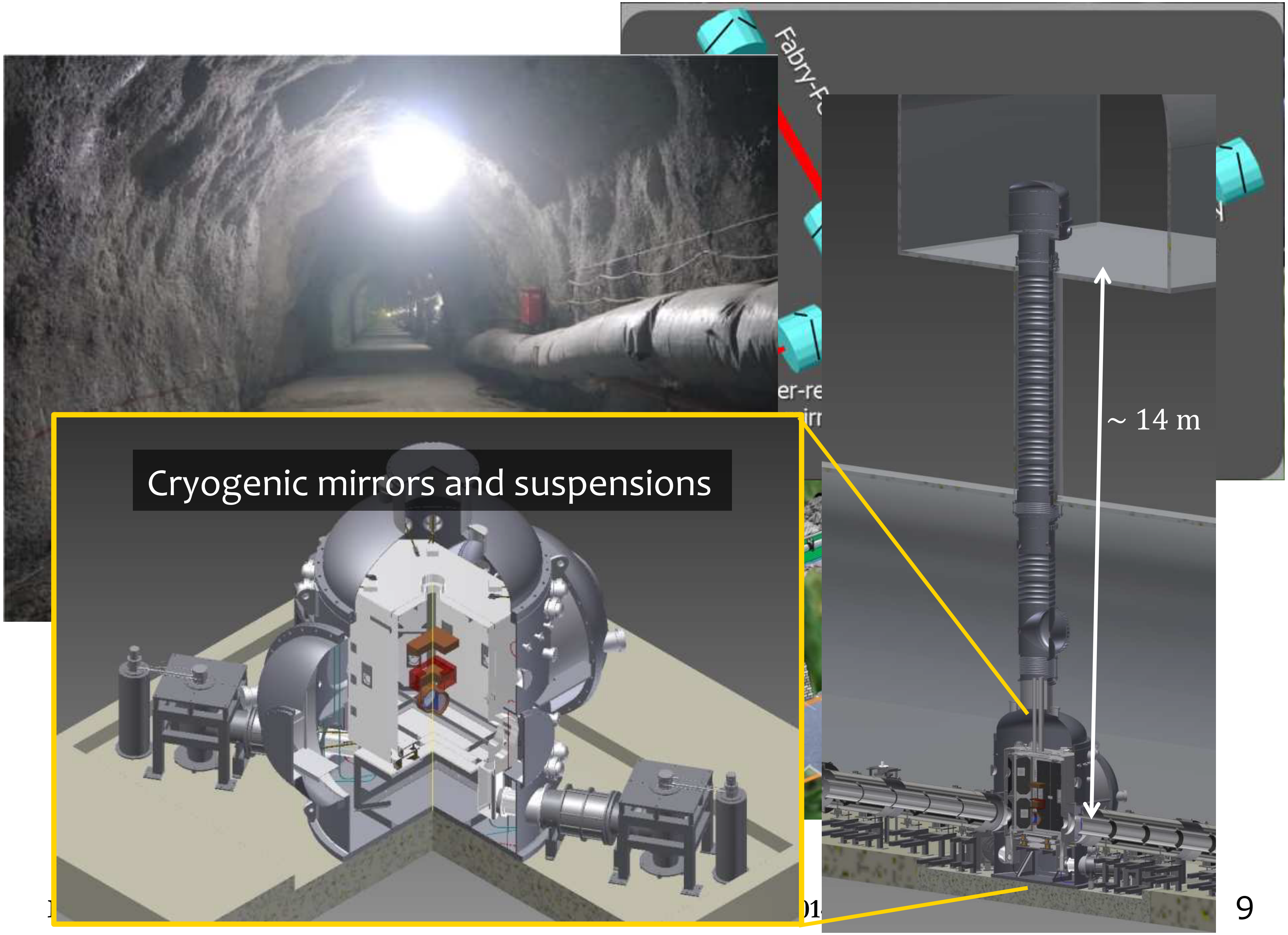


Main Features

KAGRA

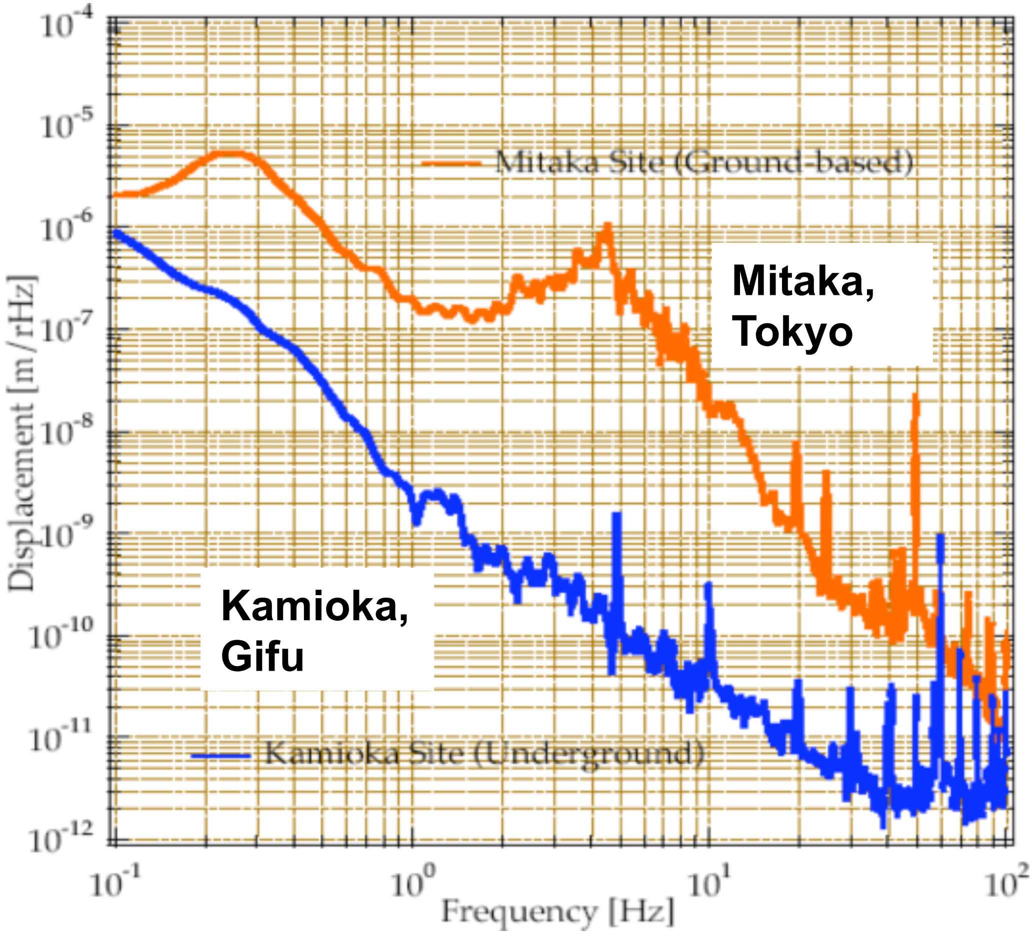


Main Features



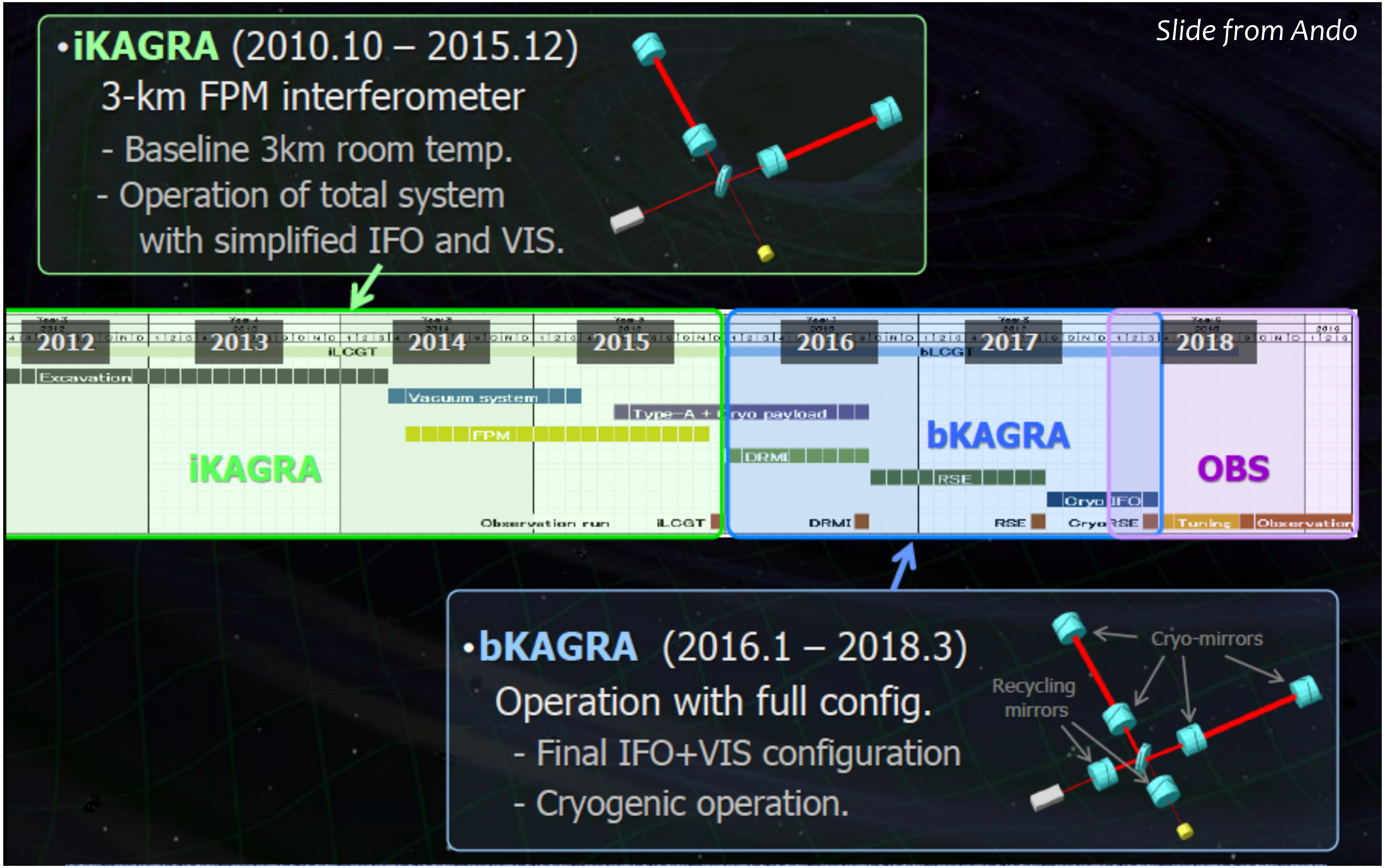
Back to the past...

Seismic noise



KAGRA's basic features were proofed.

Overall plan



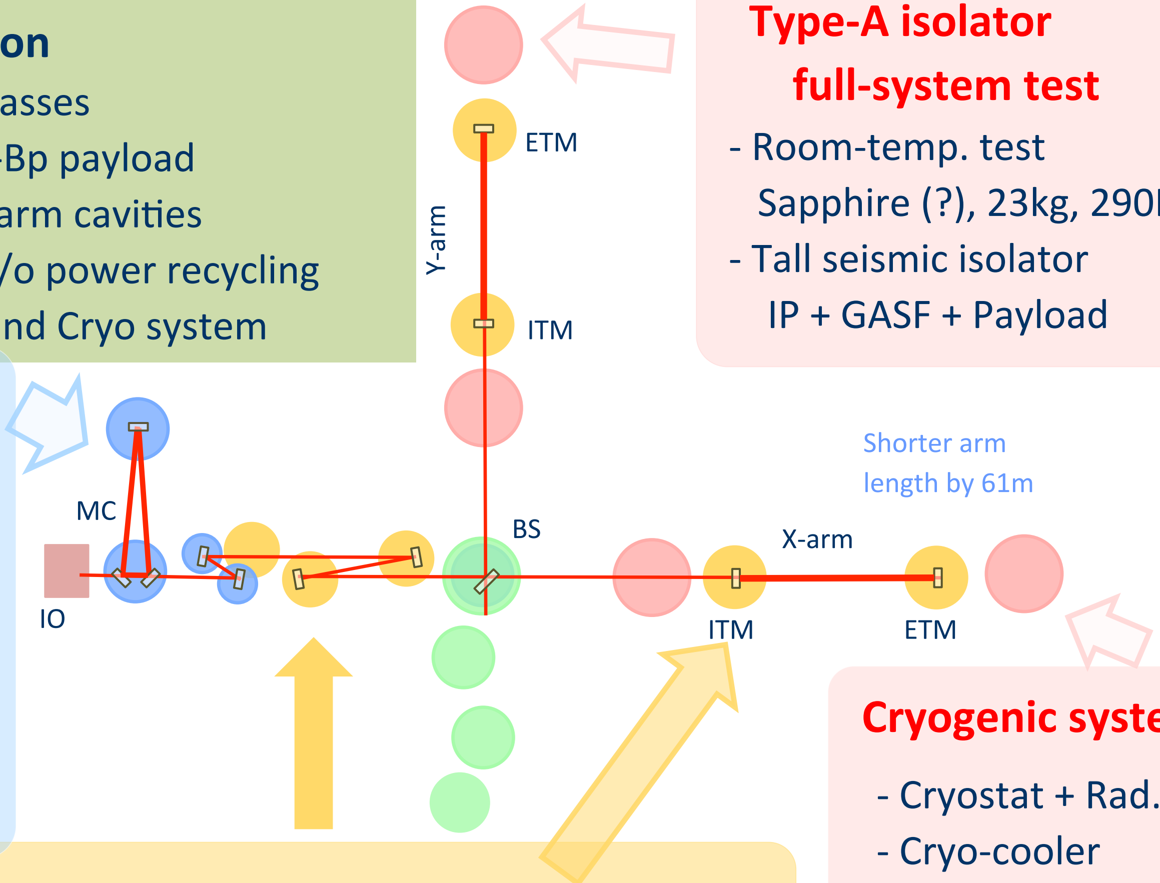
iKAGRA configuration

Slide from Y.Saito

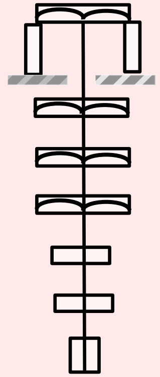
iKAGRA obs. Run in **Dec. 2015** ~1 month

iKAGRA configuration

- Room-temp. test masses suspended by Type-Bp payload
- FPMI with 2.94 km arm cavities
- Low laser power, w/o power recycling
- On-site test of VIS and Cryo system

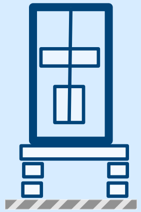


Type-A isolator full-system test



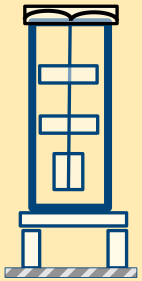
- Room-temp. test
  Sapphire (?), 23kg, 290K
- Tall seismic isolator
  IP + GASF + Payload

Type-C system



- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

Type-Bp payload



- Test mass and Core optics (BS, FM,..)
  Silica, 10kg, 290K
- Seismic isolator
  Table + GASF + Type-B Payload

Cryogenic system test

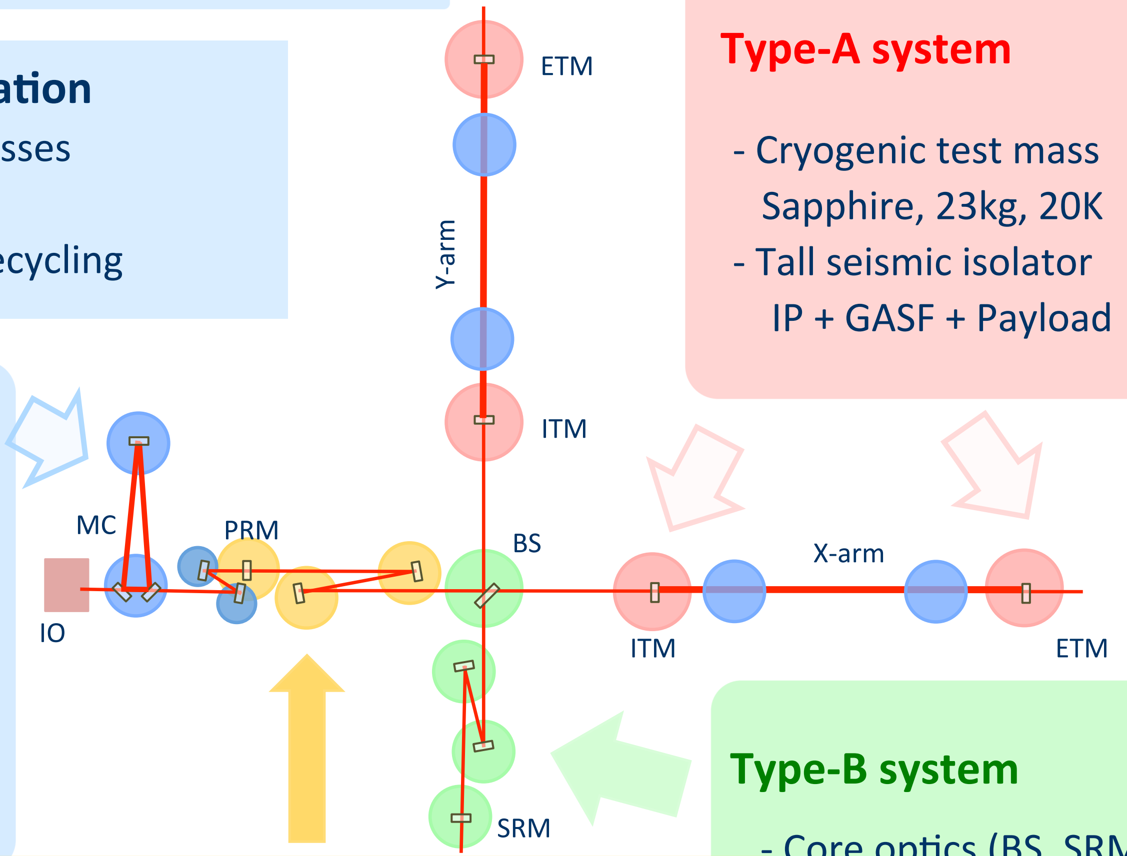
- Cryostat + Rad. shield duct
- Cryo-cooler
- Cryogenic payload
- Fixed Type-A SAS

bKAGRA configuration

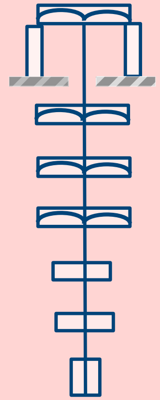
Slide from Y.Saito

first science run in **FY2017**

bKAGRA configuration
- Cryogenic test masses
- 3 km arm cavities
- RSE with power recycling

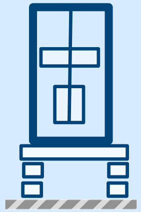


Type-A system



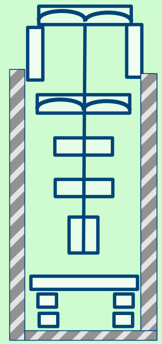
- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload

Type-C system



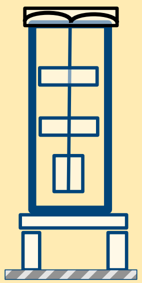
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

Type-B system



- Core optics (BS, SRM,...)
  Silica, 10kg, 290K
- IP + GASF + Payload
- Stack for aux. optics

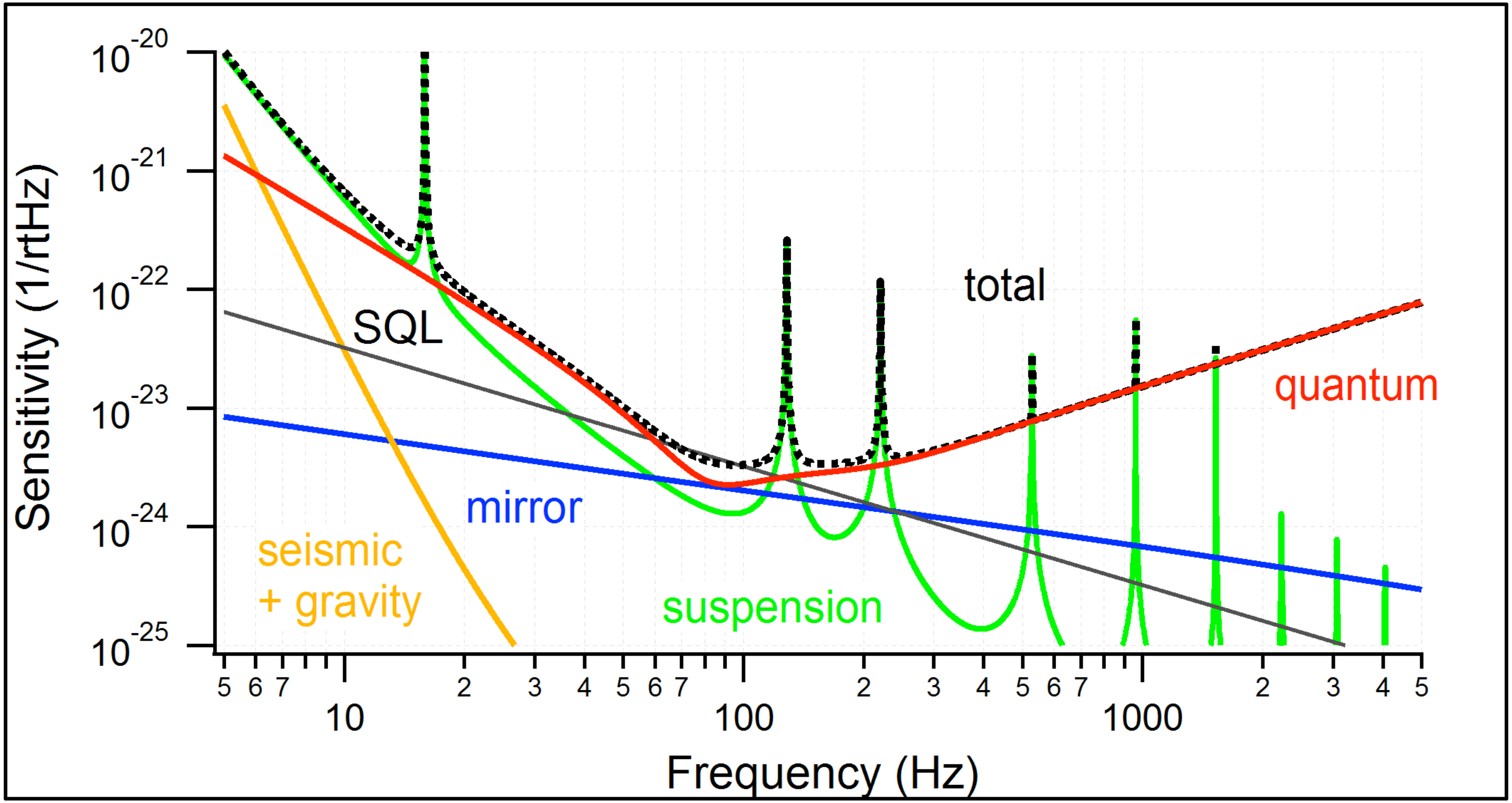
Type-Bp payload



- Test mass and Core optics (BS, FM,..)
  Silica, 10kg, 290K
- Seismic isolator
  Table + GASF + Type-B Payload

Design sensitivity of bKAGRA

KAGRA



http://gwcenter.icrr.u-tokyo.ac.jp/researcher/parameters

Data sharing for “GW astronomy”

By Kajita

Collaboration with LIGO/LSC and Virgo (An update)

- In MOU/Attachment B “Agreement for data sharing and analysis during the KAGRA construction and commissioning period”, there is a sentence; “*The KAGRA spokesperson will appoint a liaison person to coordinate data analysis activities with the LSC and VIRGO data analysis coordinators, who may attend meetings of the LSC-Virgo Data Analysis Council.*”

➔ KAGRA EO appointed Nobuyuki Kanda and Hideyuki Tagoshi to the liaison person(s).

- KAGRA will really start collaborative data analysis activities with LIGO/LSC and Virgo.

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Data sharing for "GW astronomy"

KAGRA

Collaboration with LIGO/LSC and Virgo (An update)

19-Sep-12

Memorandum of Understanding

between

KAGRA, LIGO and Virgo Scientific Collaborations

A. Purpose of the agreement:

The purpose of this Memorandum of Understanding (MOU) is to establish a collaborative relationship between the signatories who are seeking to discover gravitational waves and pursue the new field of gravitational wave astronomy. The main scientific motivation is that the maximum return from gravitational wave observations is through simultaneous joint measurements by several instruments.

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Tunnel movie 1

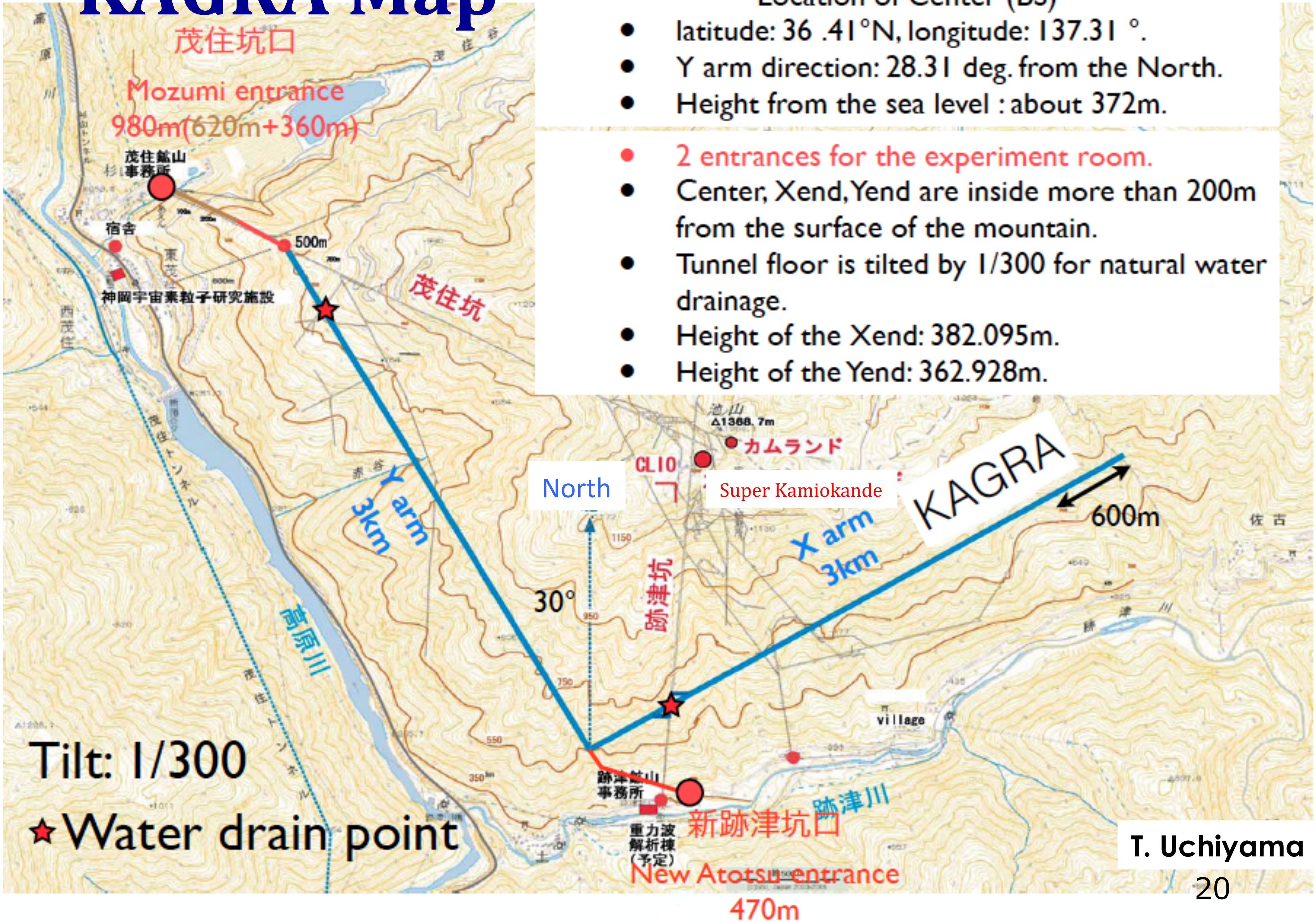
Tunnel movie 2

KAGRA Map

Location of Center (BS)

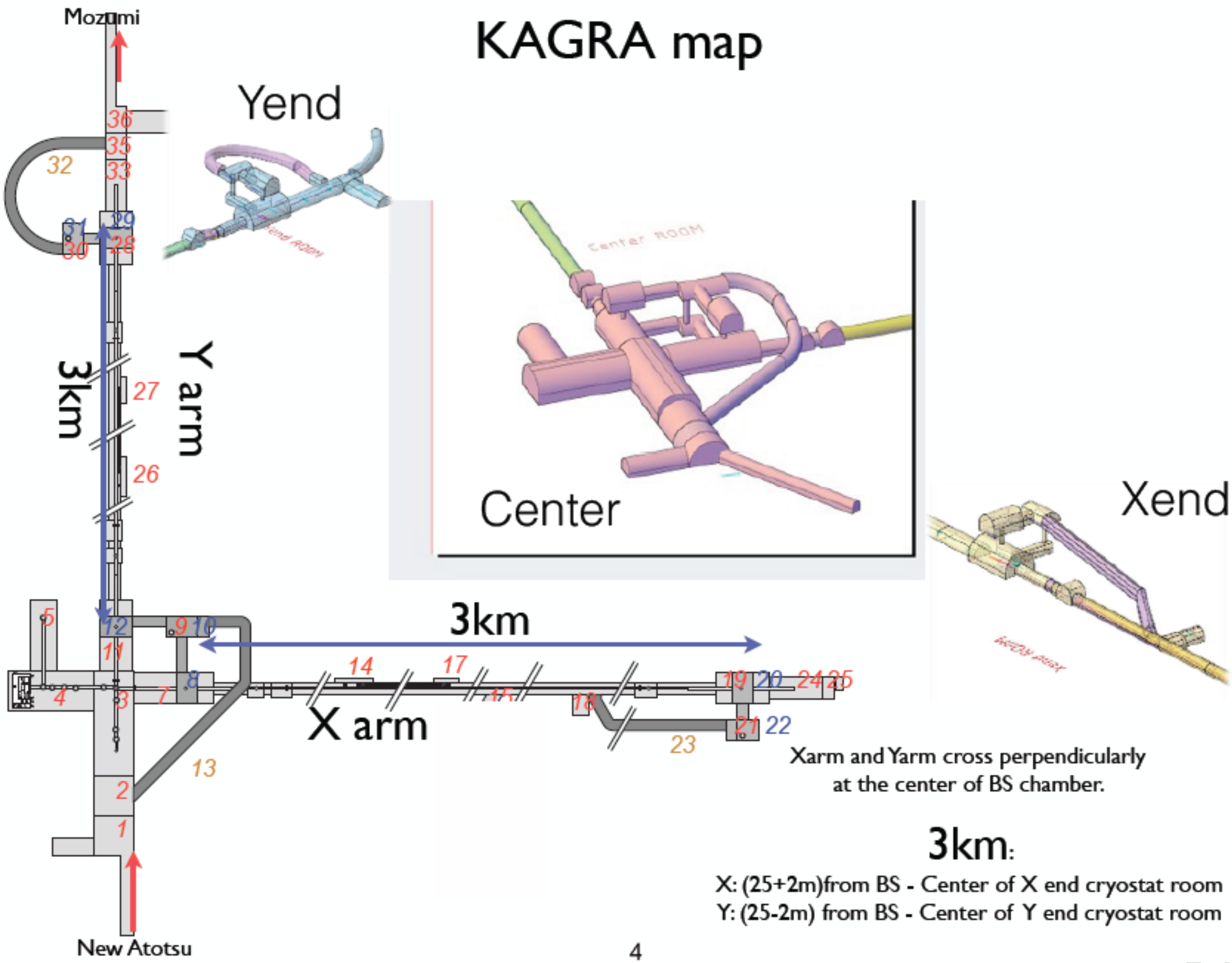
- latitude: 36 .41°N, longitude: 137.31 °.
- Y arm direction: 28.31 deg. from the North.
- Height from the sea level : about 372m.

- 2 entrances for the experiment room.
- Center, Xend, Yend are inside more than 200m from the surface of the mountain.
- Tunnel floor is tilted by 1/300 for natural water drainage.
- Height of the Xend: 382.095m.
- Height of the Yend: 362.928m.



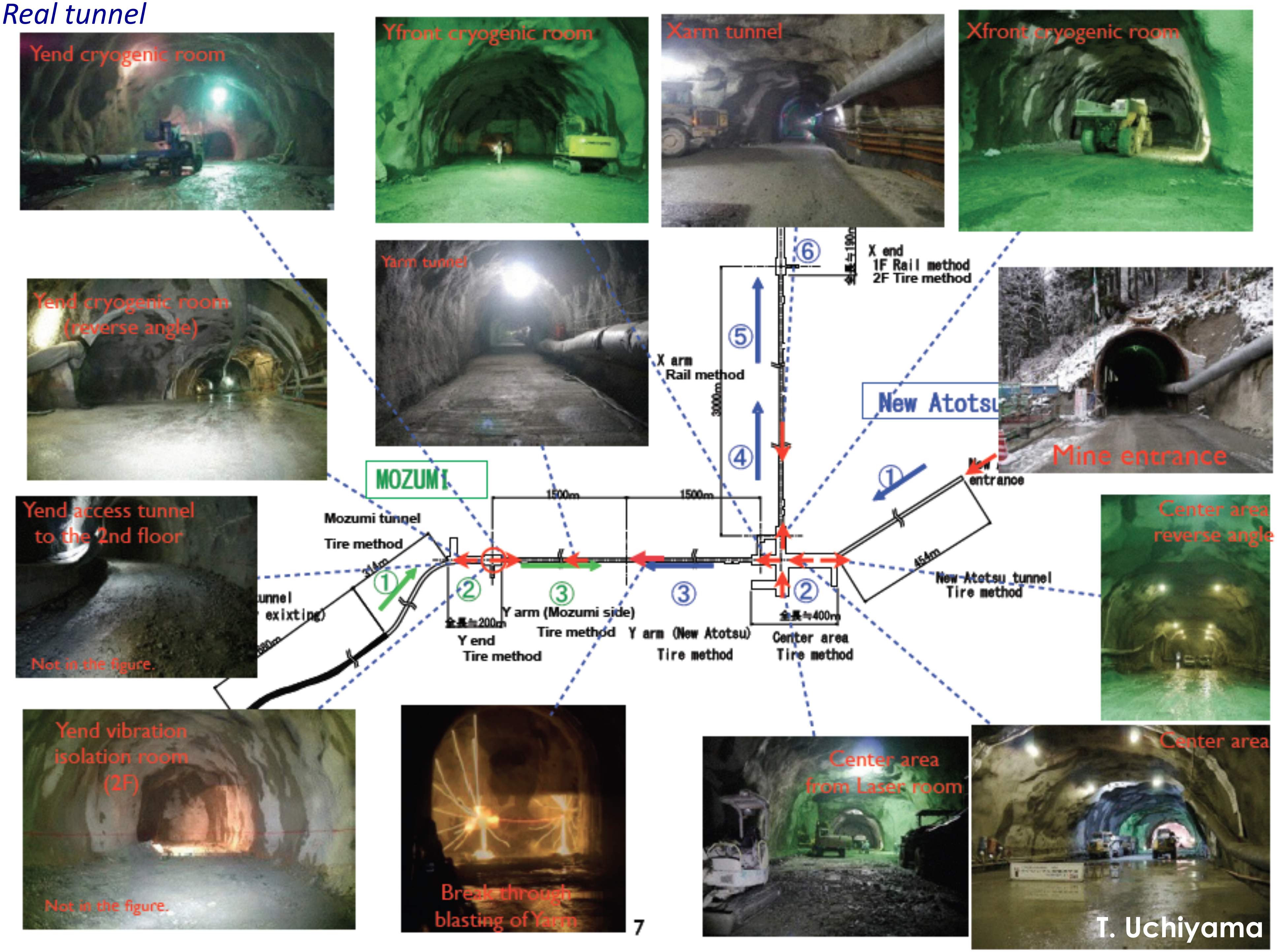
T. Uchiyama

Schematic of the KAGRA tunnel



T. Uchiyama

Real tunnel



T. Uchiyama

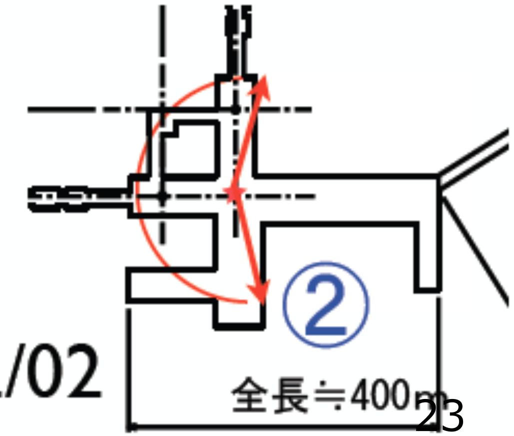
Panorama photo from BS position.

Direction of Yarm

Direction of Xarm

Direction of Laser booth
&
Mode Cleaner

2012/12/02



Vacuum system

- One chamber for one mirror, basically.
- Cryostat chambers: 2.6 m dia.
- Other chambers: 1.5~1.2 m dia.

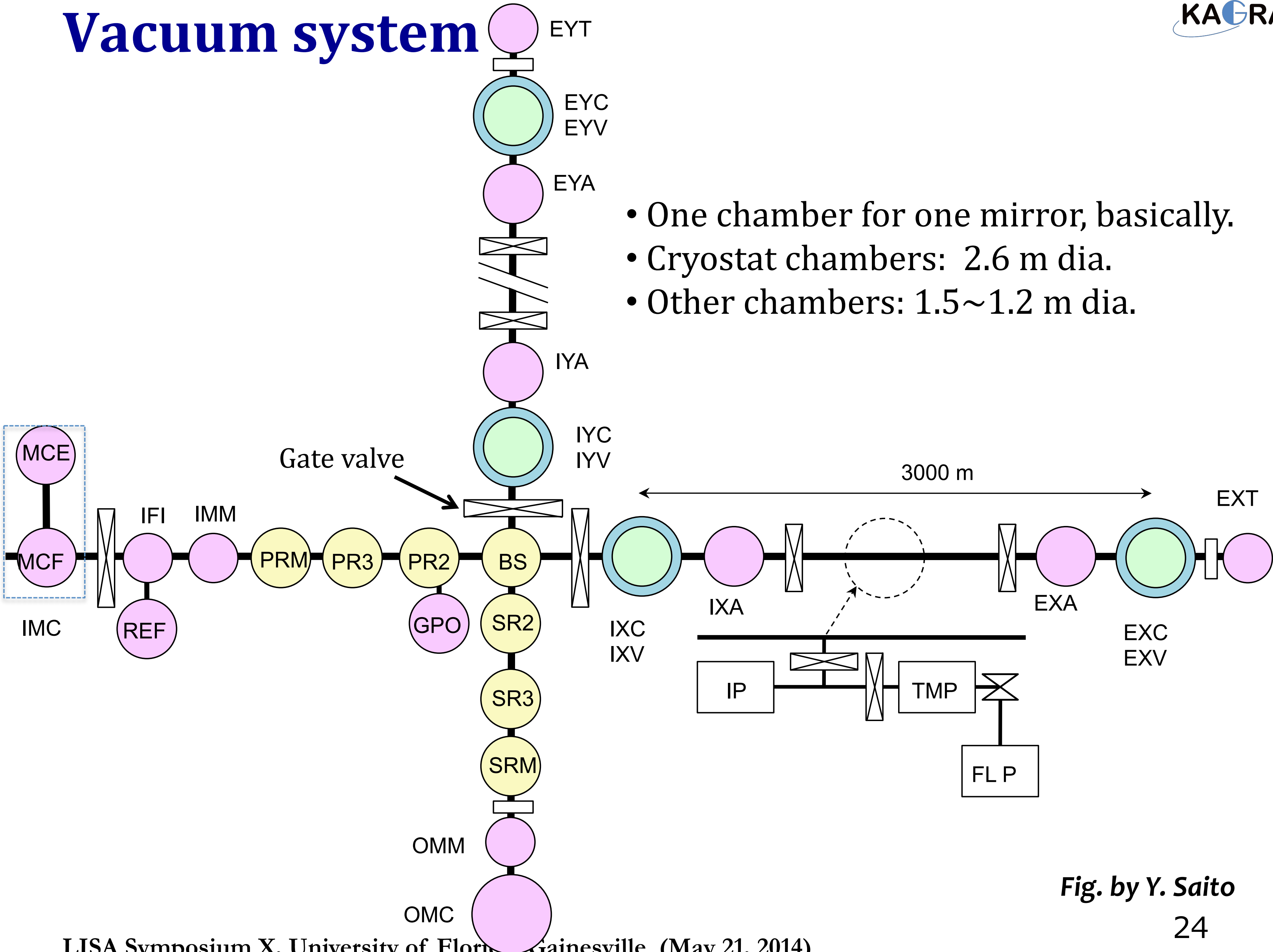
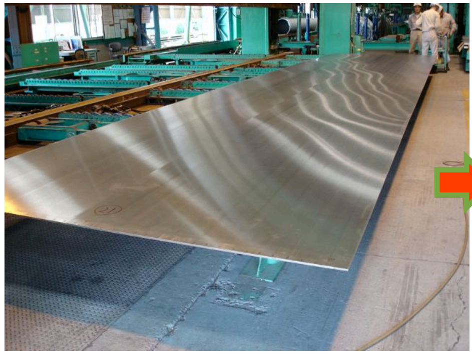


Fig. by Y. Saito

Vacuum ducts for 3-km arms

- 12 m long each, 800 mm diameter
- All 478 pcs of the ducts were delivered to Kamioka.



Vacuum chambers

Height of the beam line

Most of the chambers are delivered.
Installation in 2014.

Clean booth around chambers

Before the installation of optics

Example: clean booth around a cryostat

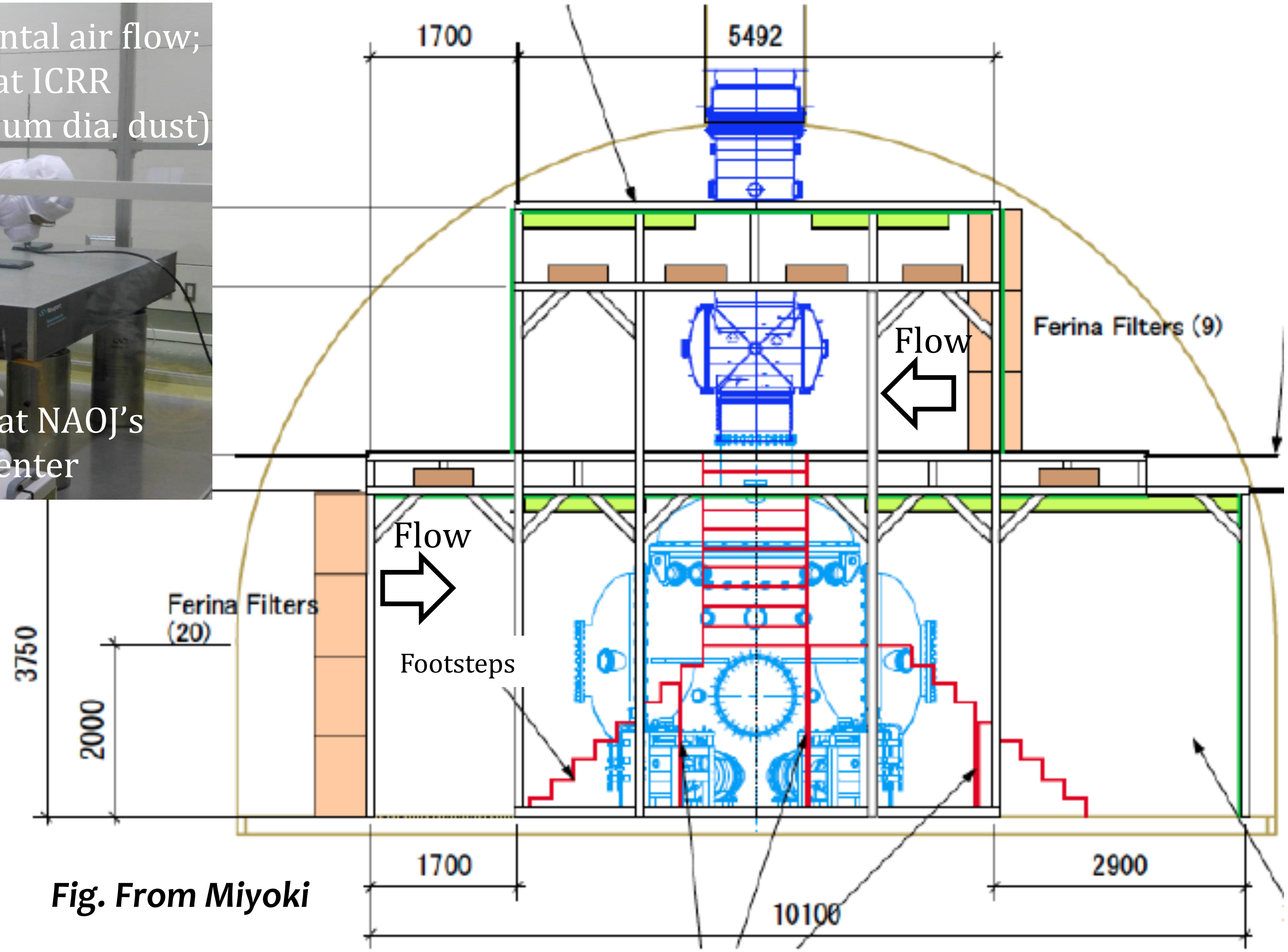


Fig. From Miyoki

Mirrors

- Cryogenic test masses: sapphire in the bKAGRA phase
- Other mirrors: silica

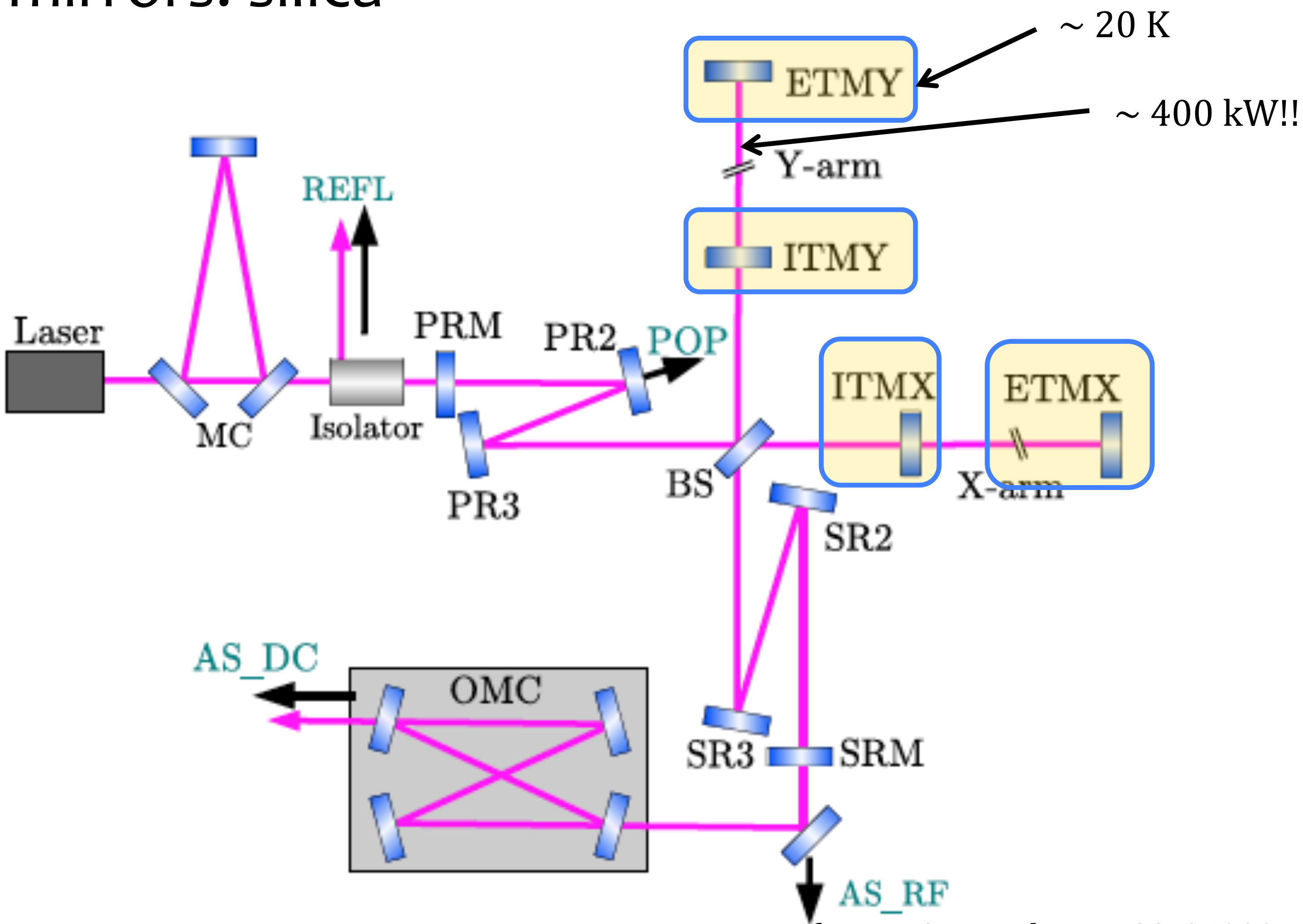
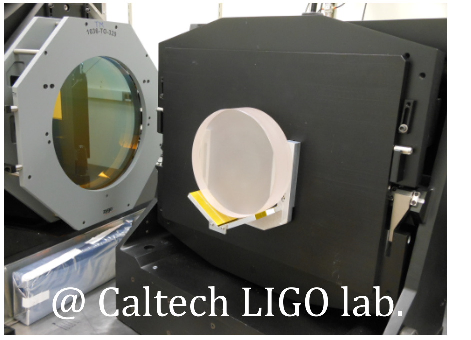


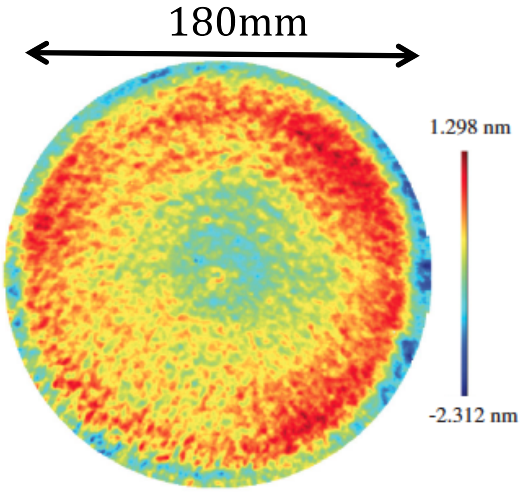
Fig. from Y. Aso et al., PRD 88, 043007 (2013)

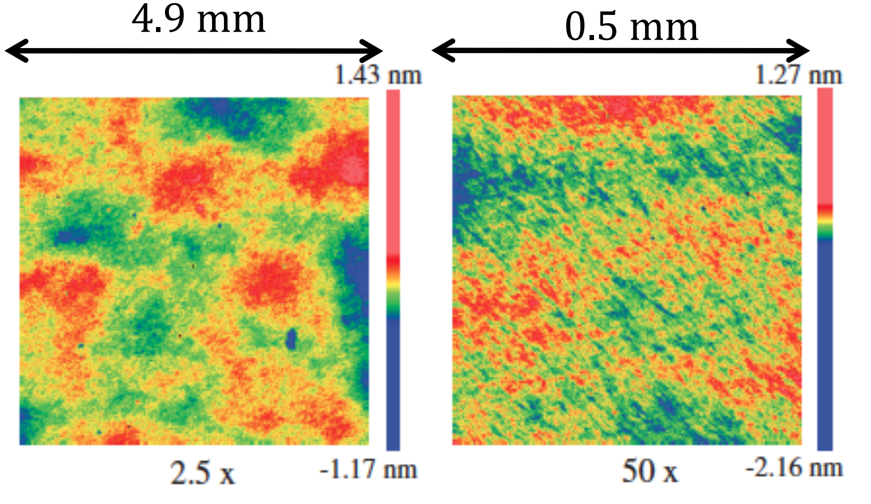
Sapphire substrate

- Higher thermal conductivity at ~ 20K: > 1000 W/m/K
- But needs R&D.



Results of a test polish Hirose et al., PRD 89, 062003 (2014)





Sapphire substrate

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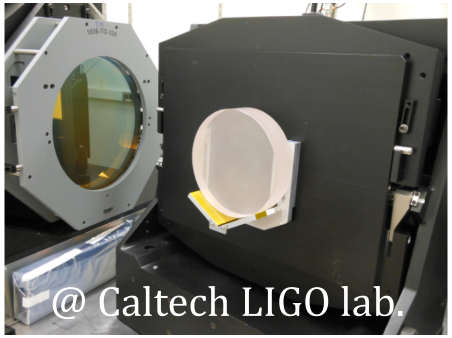
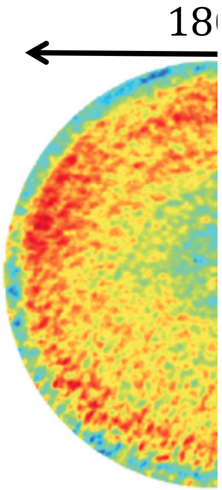
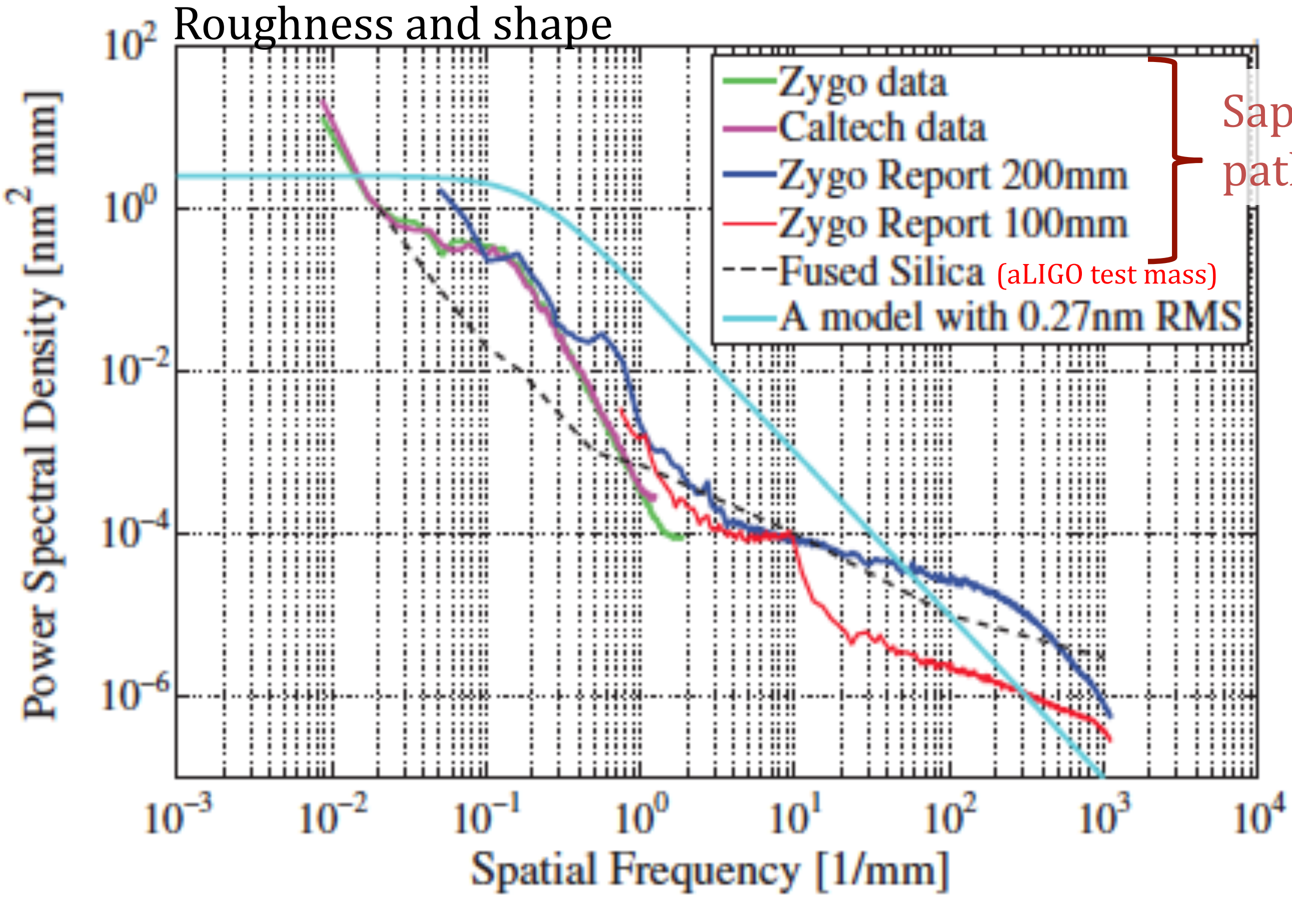
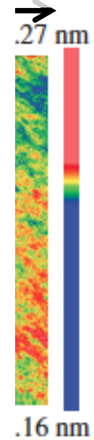


Results of a test polish Hirose et al., PRD 89, 062003 (2014)





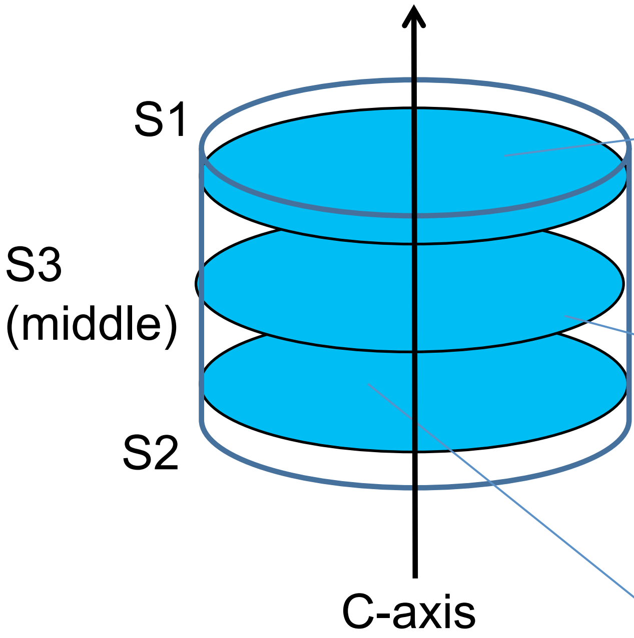


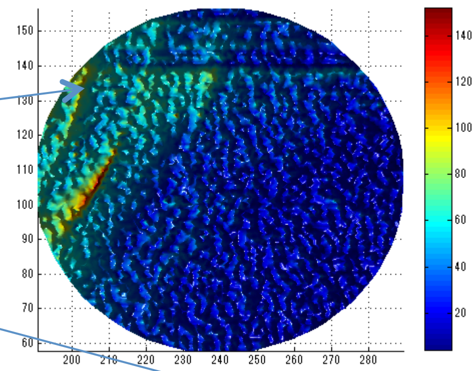
Absorption meas. at Caltech (bulk#1)

KAGRA

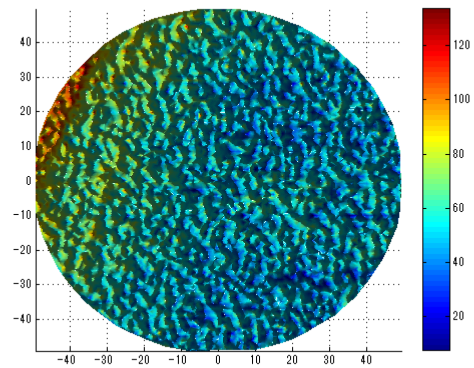
Slide by Hirose

Liyuan Zhang, GariLynn Billingsley (LIGO lab), E. Hirose

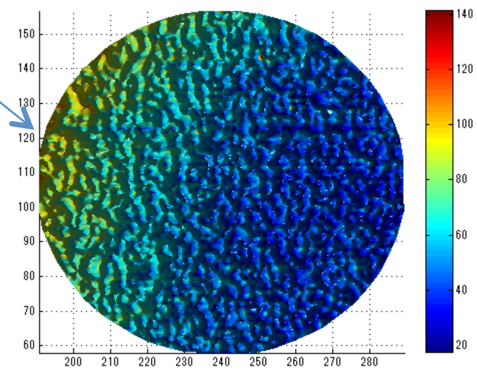




mean
35.1ppm/cm



mean
55.5ppm/cm



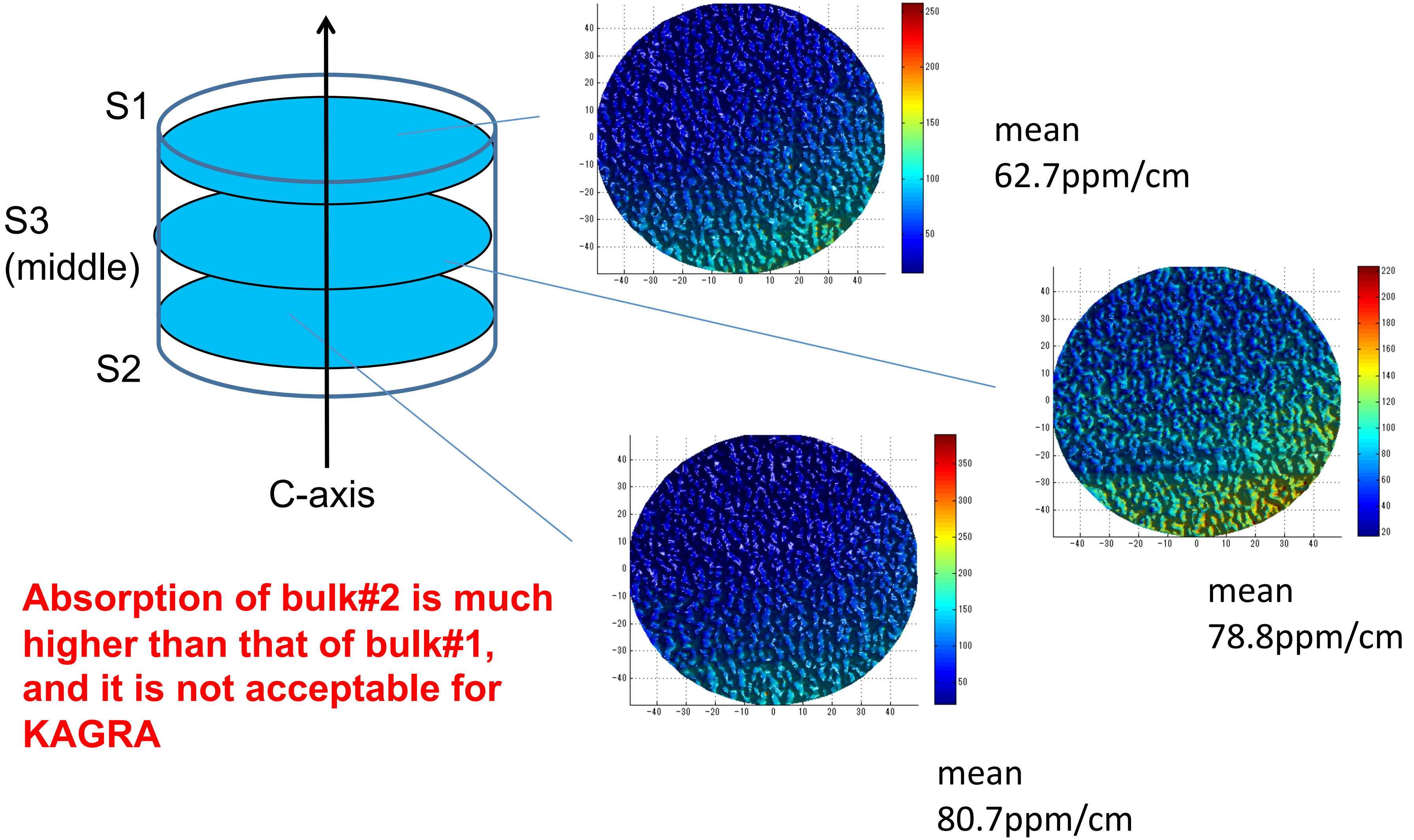
mean
55.1ppm/cm

Structure of how absorption is distributed is not as simple as we expected. It seems higher part is biased in one side (bottom of A-axis?)

Absorption meas. at Caltech (bulk#2)

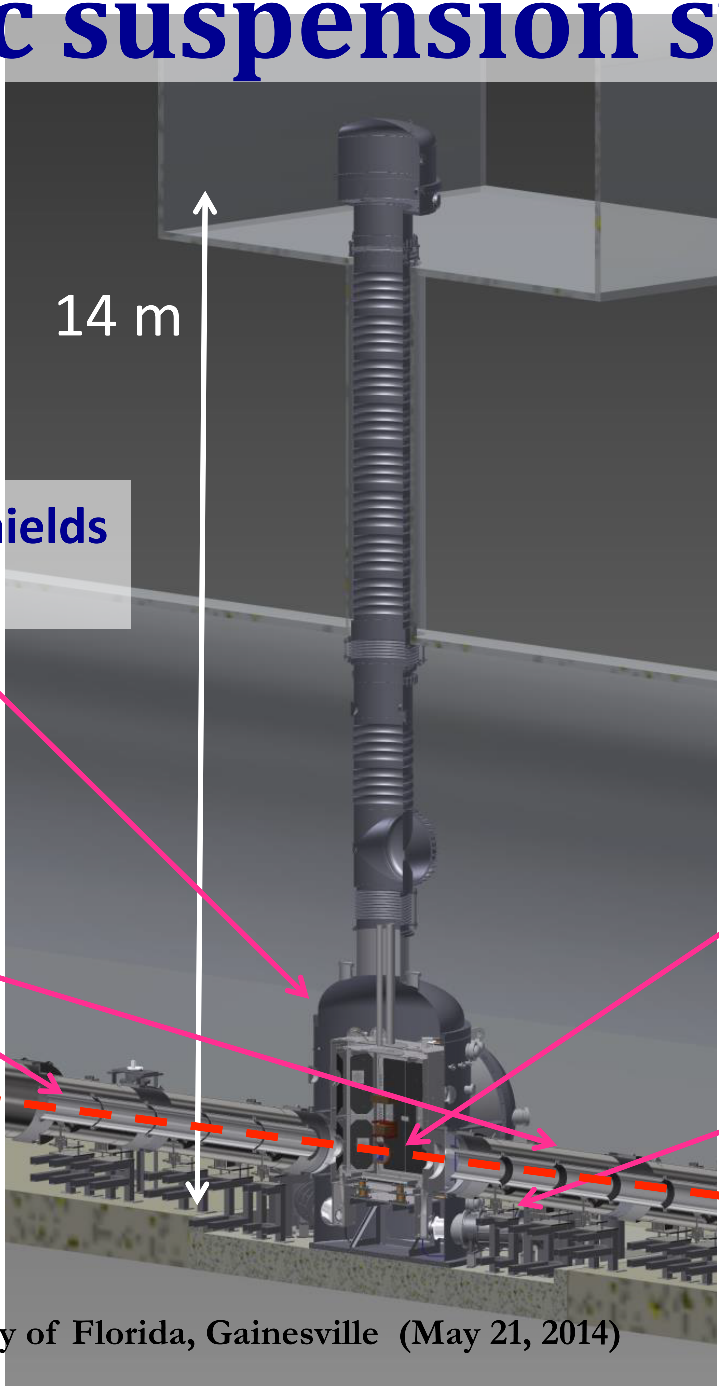
KAGRA

Slide by Hirose

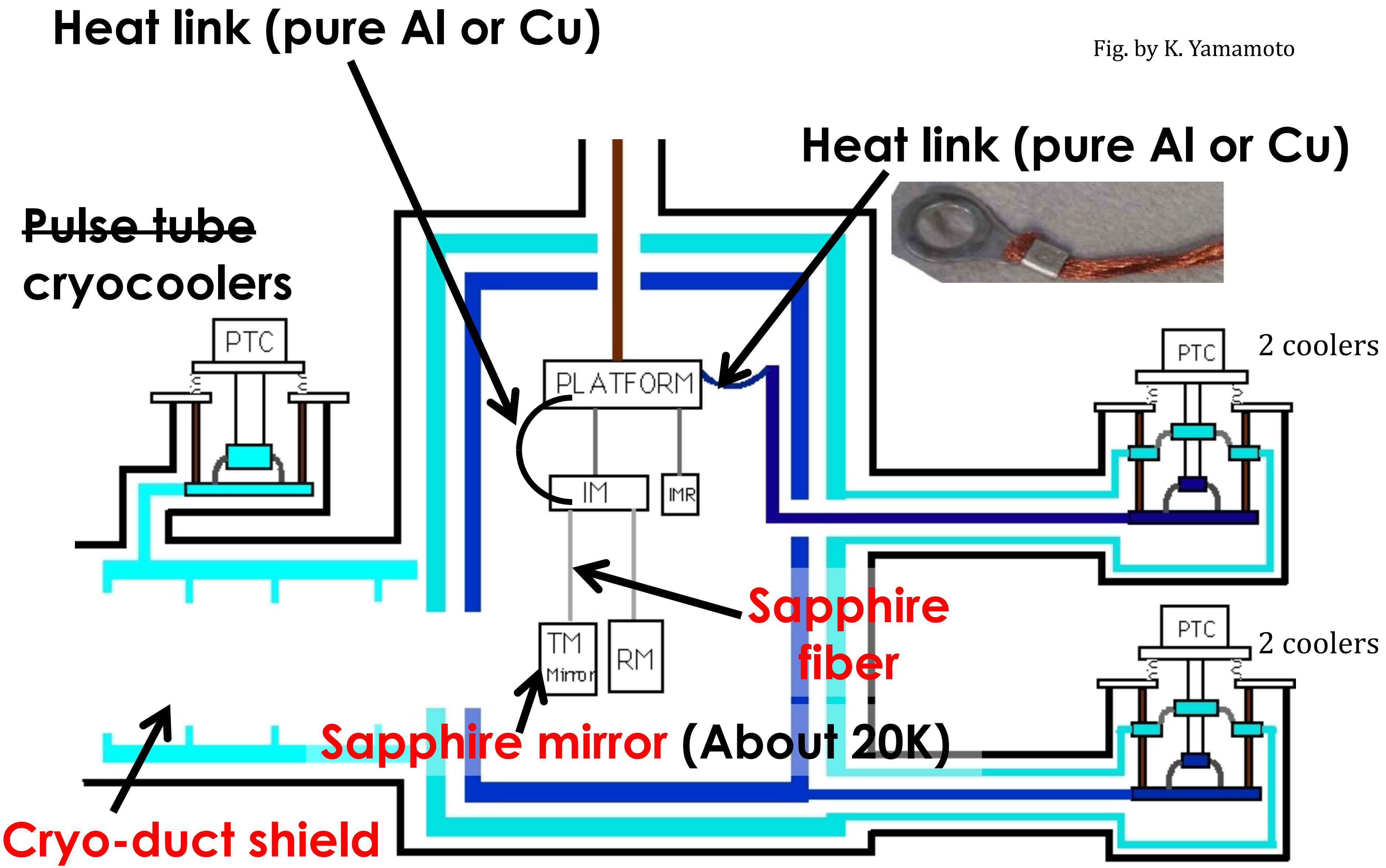


Absorption of bulk#2 is much higher than that of bulk#1, and it is not acceptable for KAGRA

Cryogenic suspension system

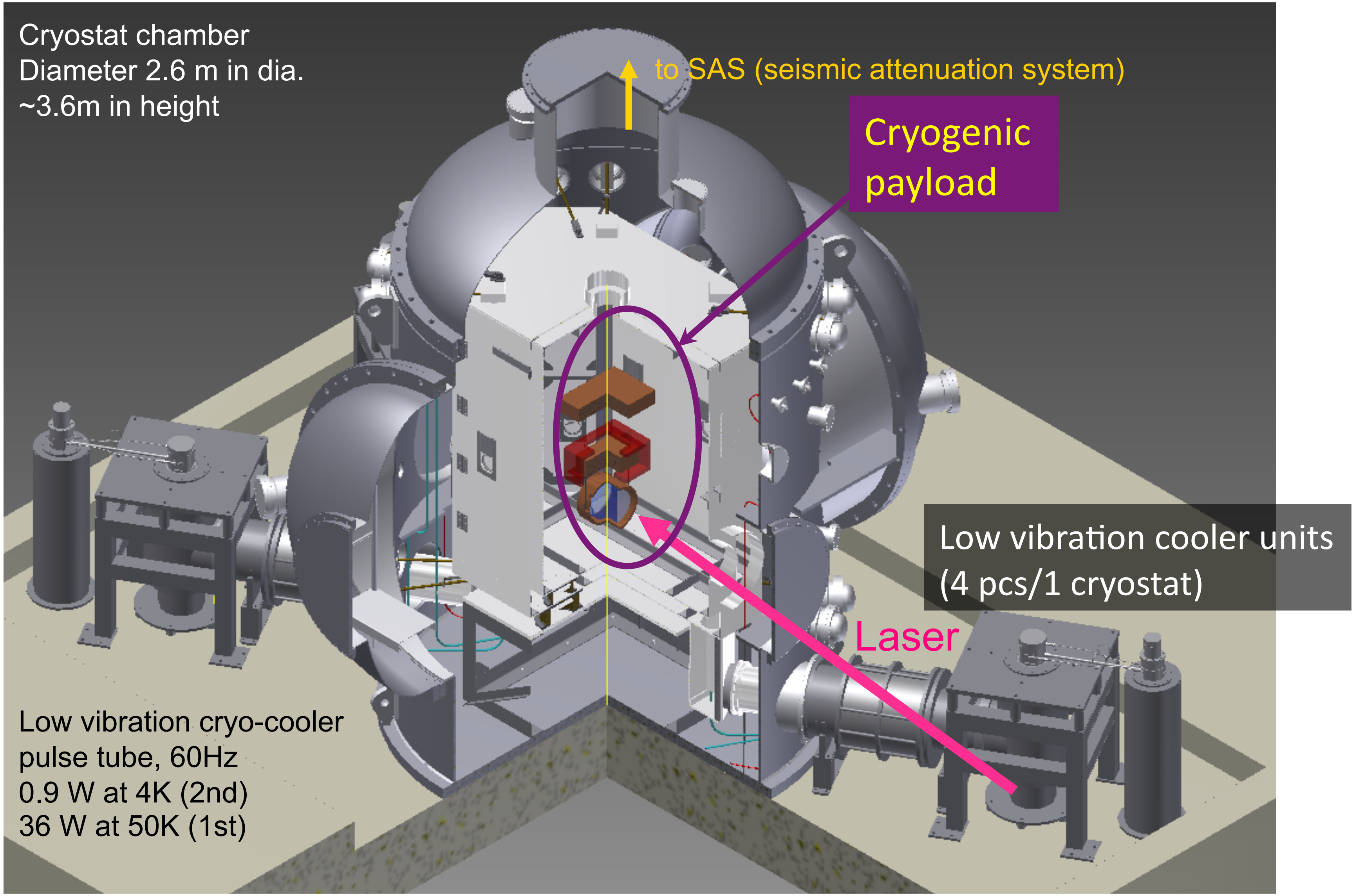


Schematic of cryogenic system



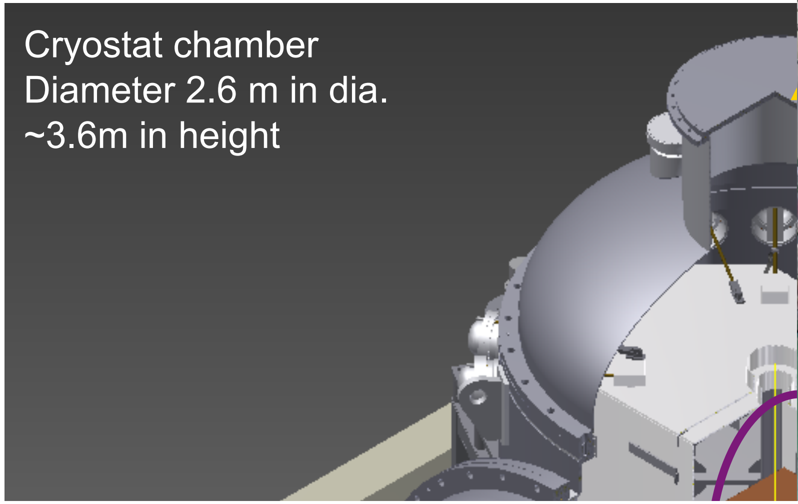
Reducing the solid angle of 300K radiation subtended by the mirror

Cryostat

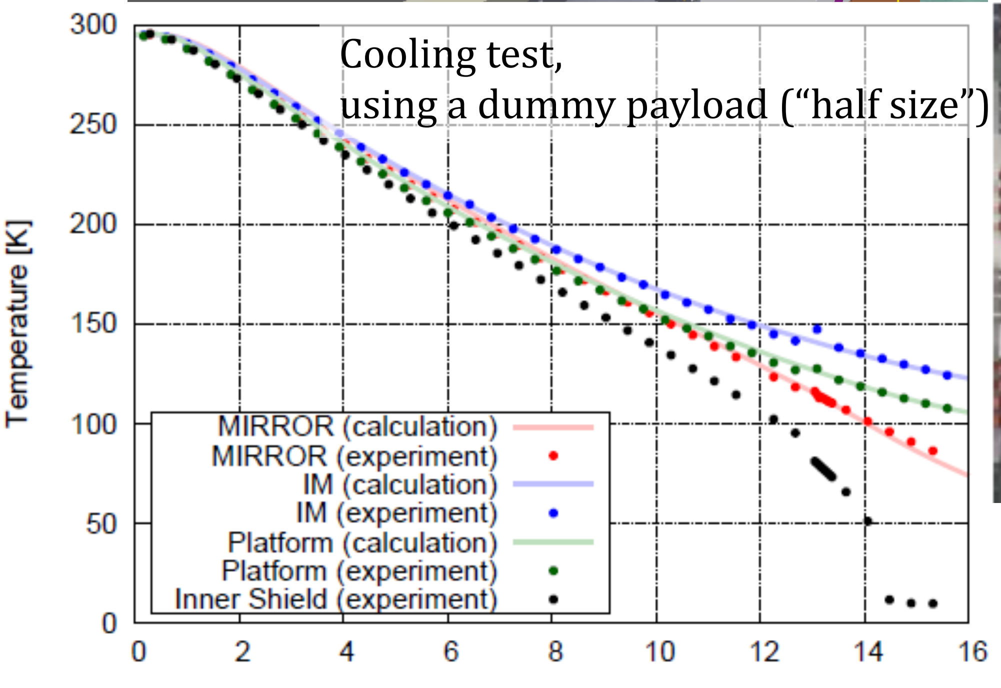


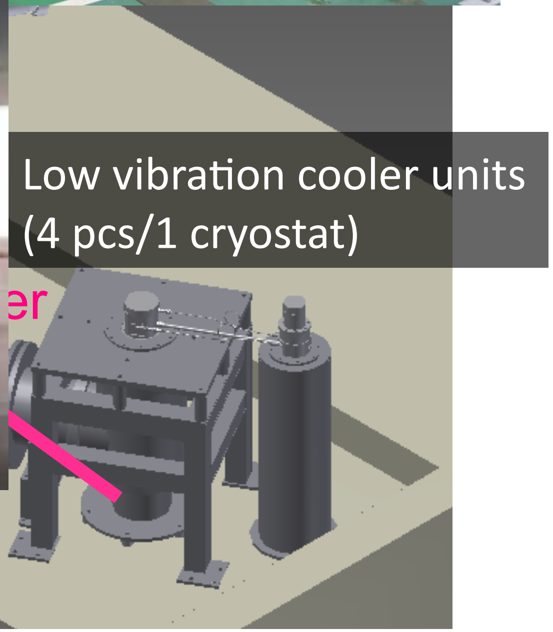
Cryostat chamber
Diameter 2.6 m in dia.
~3.6m in height
to SAS (seismic attenuation system)
Cryogenic payload
Low vibration cooler units
(4 pcs/1 cryostat)
Laser
Low vibration cryo-cooler
pulse tube, 60Hz
0.9 W at 4K (2nd)
36 W at 50K (1st)

Cryostat


Cryostat chamber
Diameter 2.6 m in dia.
~3.6m in height


4 cryostats, made in Toshiba

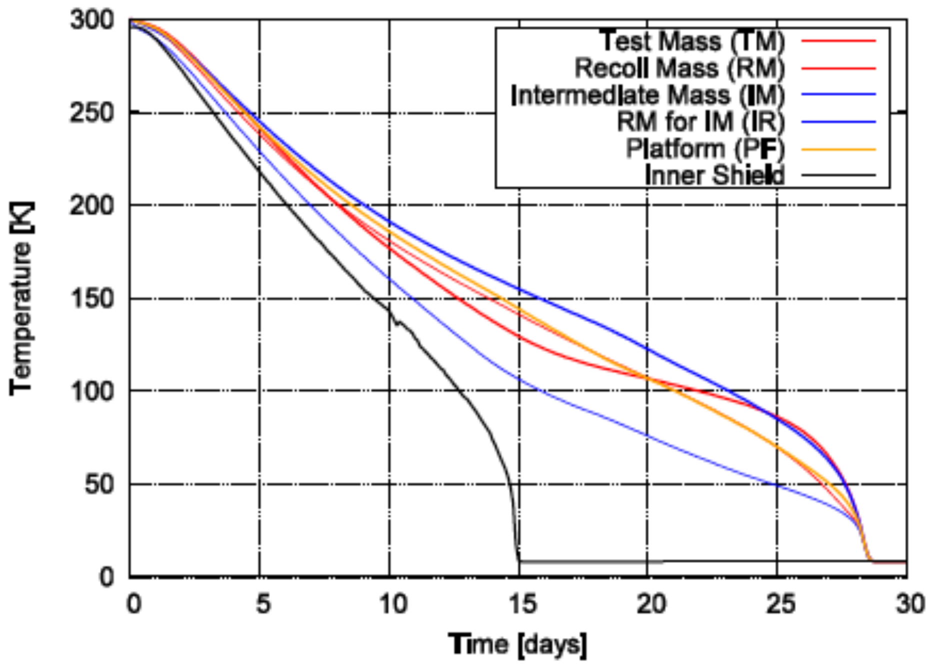

Cooling test,
using a dummy payload ("half size")
Temperature [K]
days
MIRROR (calculation)
MIRROR (experiment)
IM (calculation)
IM (experiment)
Platform (calculation)
Platform (experiment)
Inner Shield (experiment)
0
50
100
150
200
250
300
0
2
4
6
8
10
12
14
16

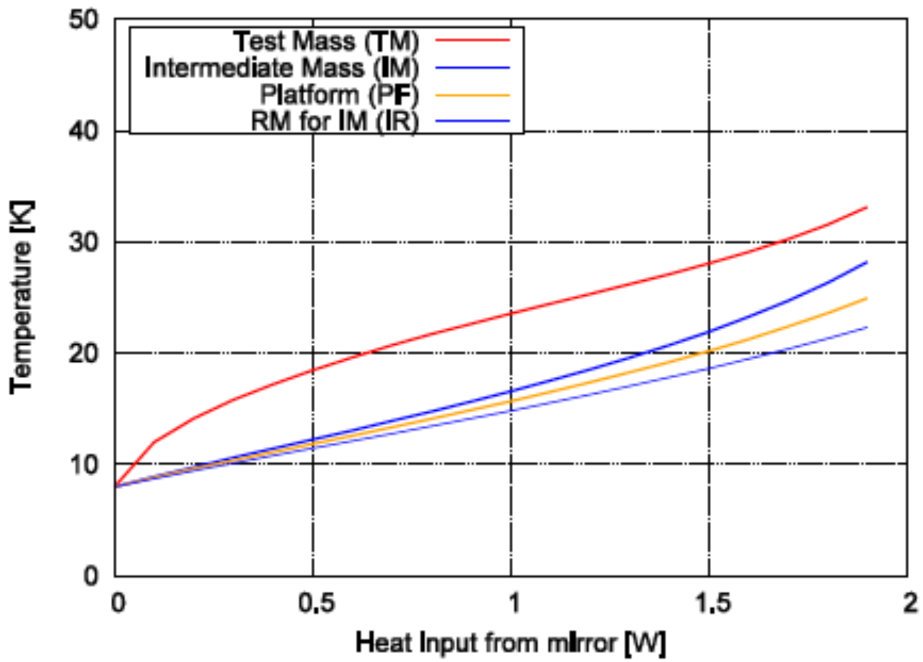

Low vibration cooler units
(4 pcs/1 cryostat)

Time for mirror cooling

By Y. Sakakibara

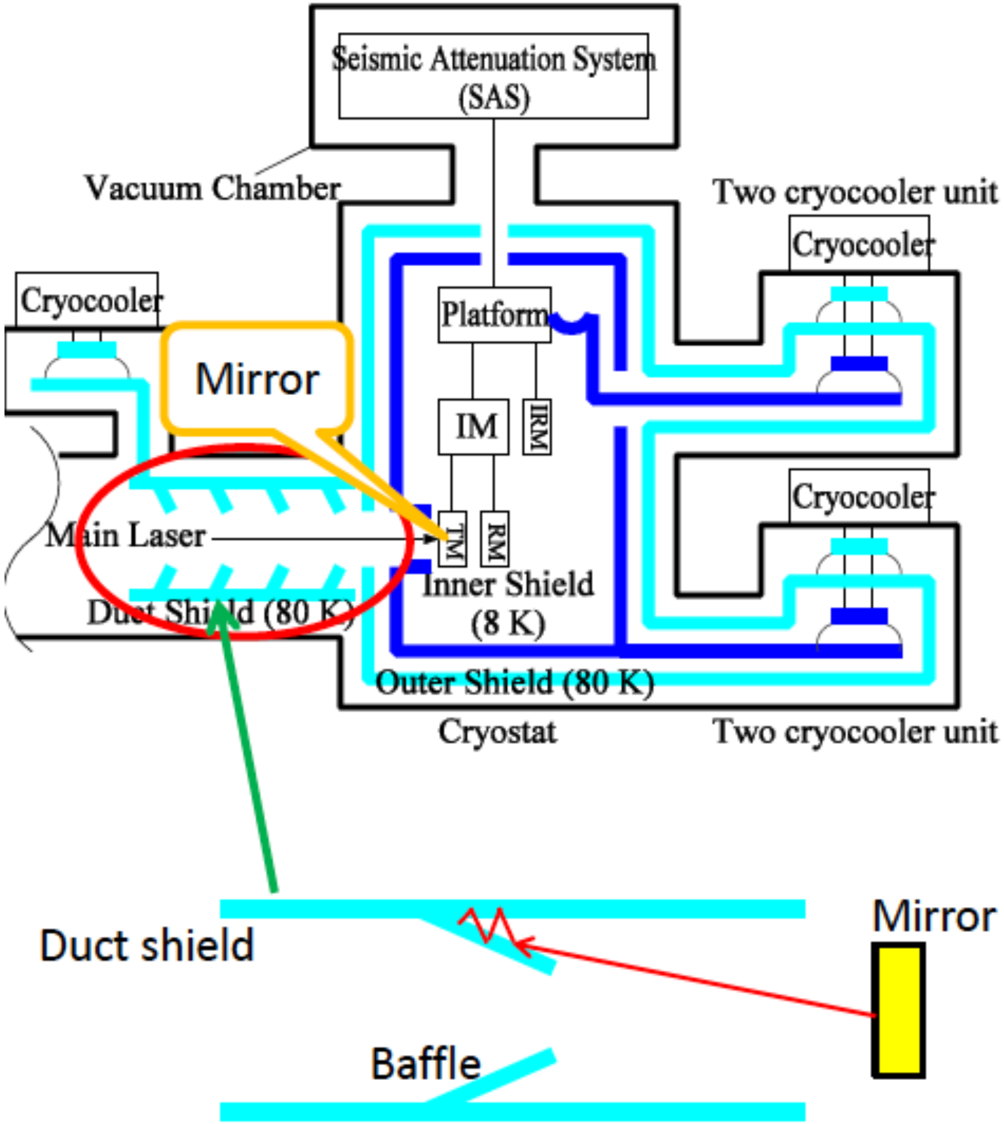
- Expected cooling time: 1 month
- Calculated mirror temperature: 23 K (mirror absorption: 1 W)
  - No contact resistance is included
  - Depending on contact resistance, number of heat links should be increased





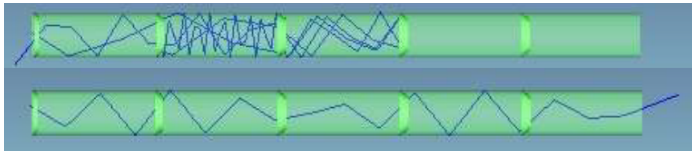
Cryo-duct shield

To catch a 300K radiation mostly before it reaches the sapphire mirror.

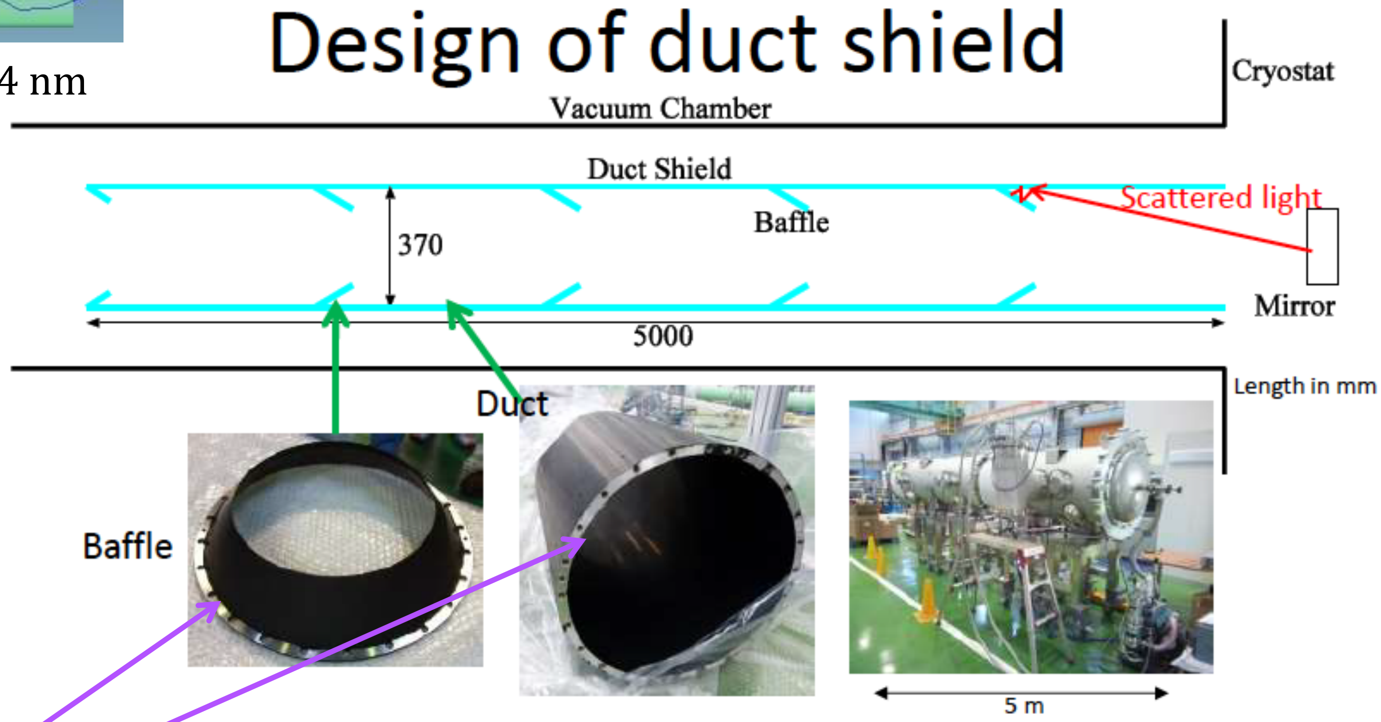


Figs by Y. Sakakibara

Cryo-duct shields



Simulation: scattering of 1064 nm and 300K radiation.



“Solblack” (black plating)

From measurement: the sapphire mirror would see 10 mW of 300K radiation.
Could fulfill the KAGRA requirement (preliminary)!

Figs by Y. Sakakibara

Cryo-duct shield (face-on)

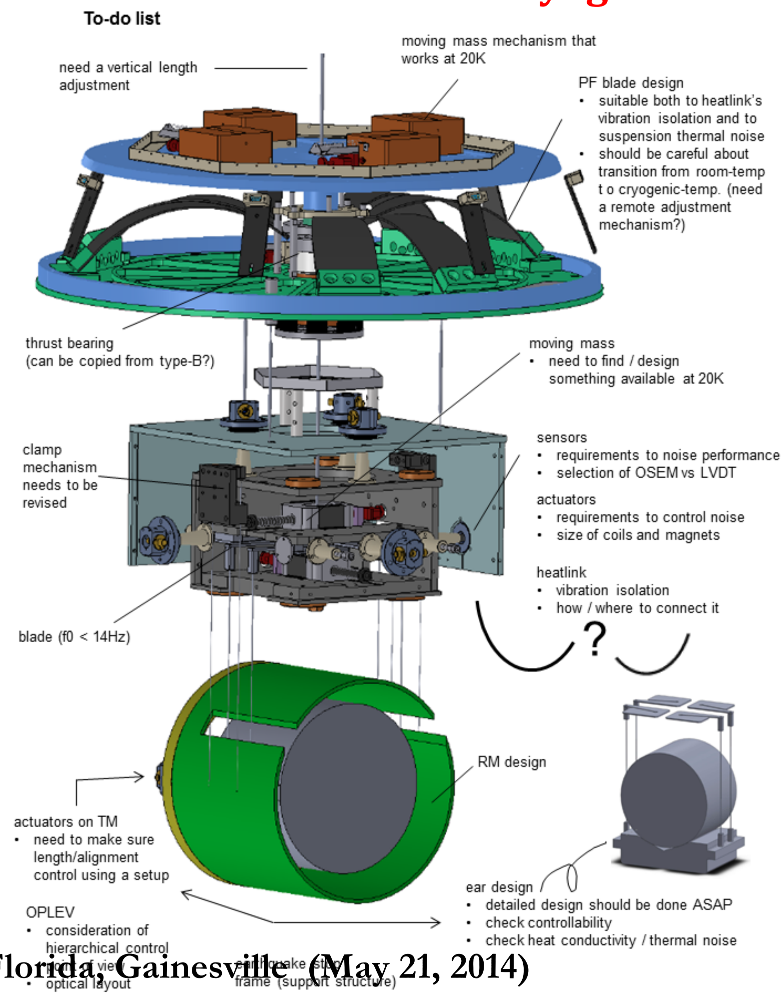
Close-up view with LED illumination

Cryogenic suspension system

- Mirror cooling
- Also isolating vibrations from heat links
- Several designs under discussion

Challenging system!!
Cryogenics and Suspensions at once!

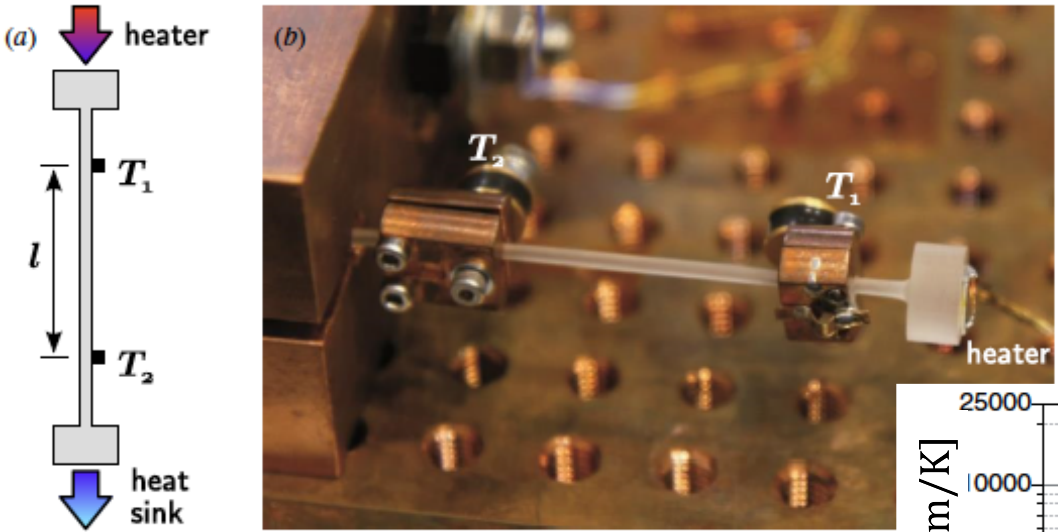
A strawman design→



Sapphire wires with nail heads

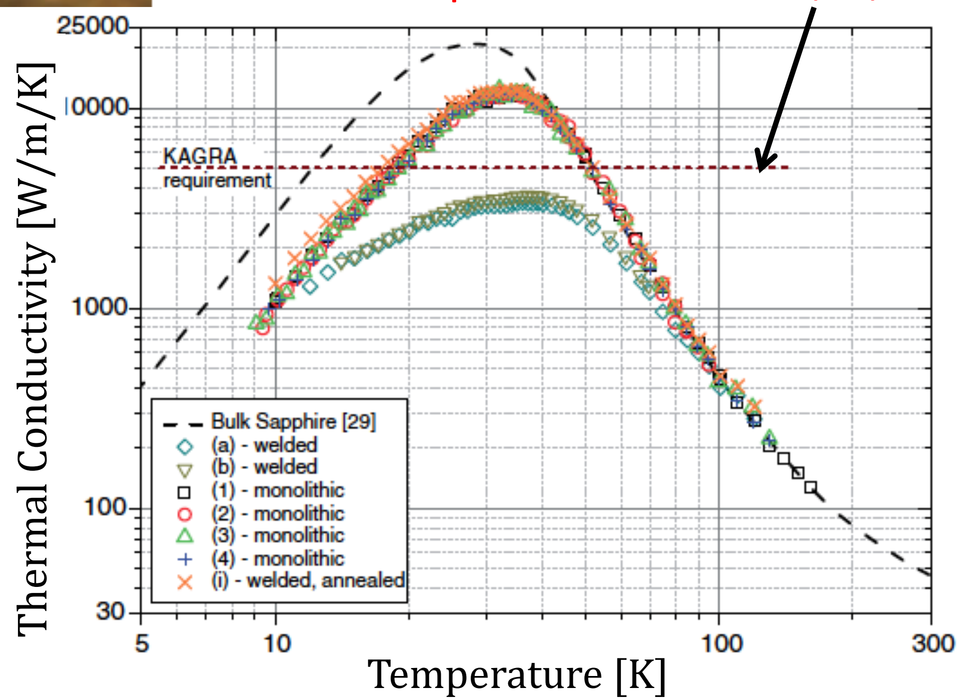
KAGRA

A. Khalaidovski et al., CQG 31, 105004 (2014)



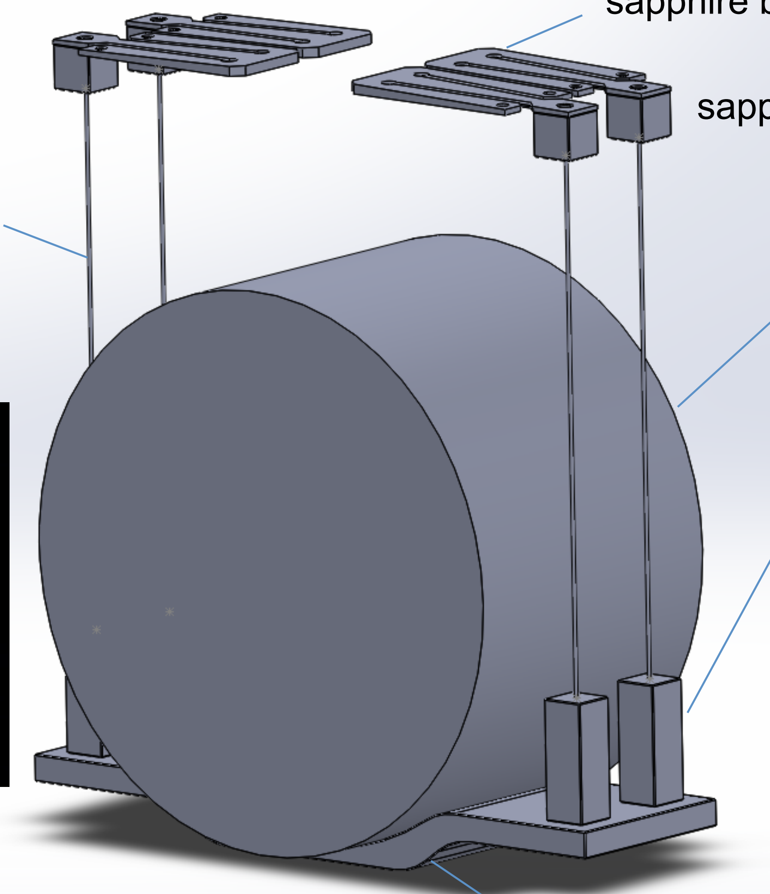
Nail heads for hooking or bonding

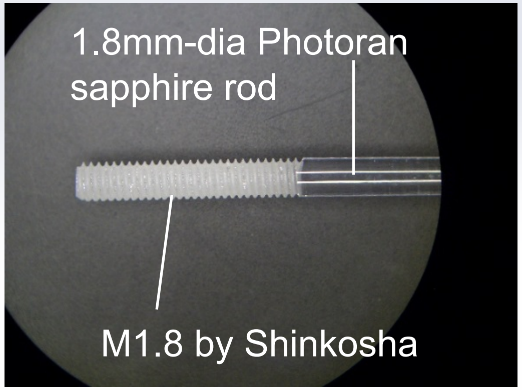
Requirement: 5000 W/m/K



Sapphire suspension Prototype

By Hirose et al.

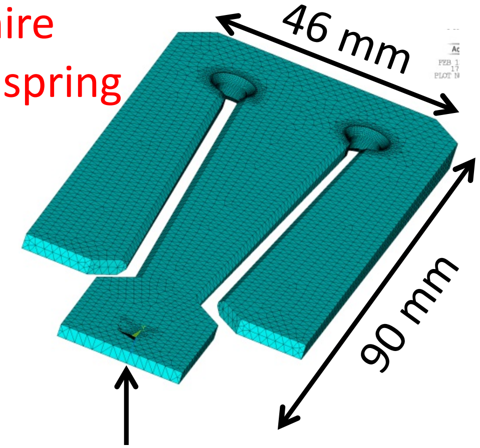




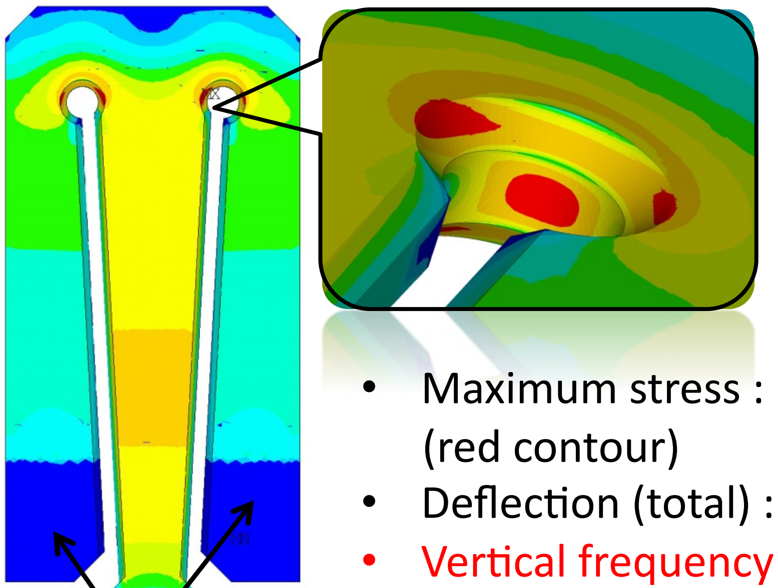
(Cont'd)

By R. Kumar

Sapphire blade spring



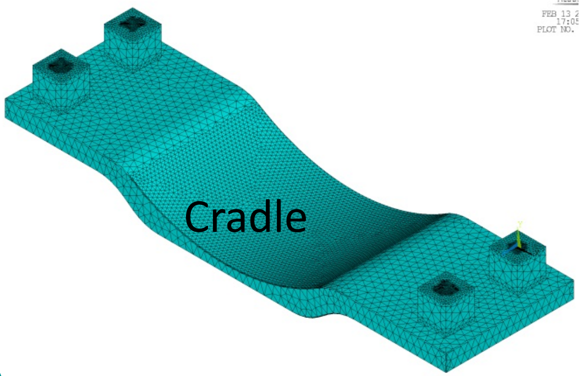
Sapphire fibre attached here

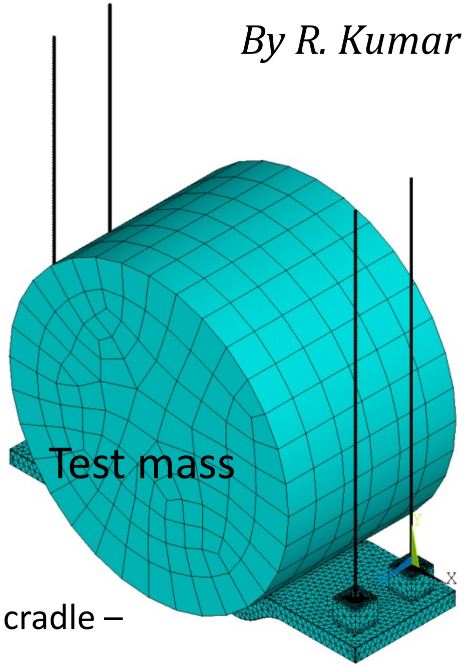


Clamped here

- Maximum stress : 160 Mpa (red contour)
- Deflection (total) : 7.94 mm
- Vertical frequency : 14.5 Hz

Cradle sapphire pendulum

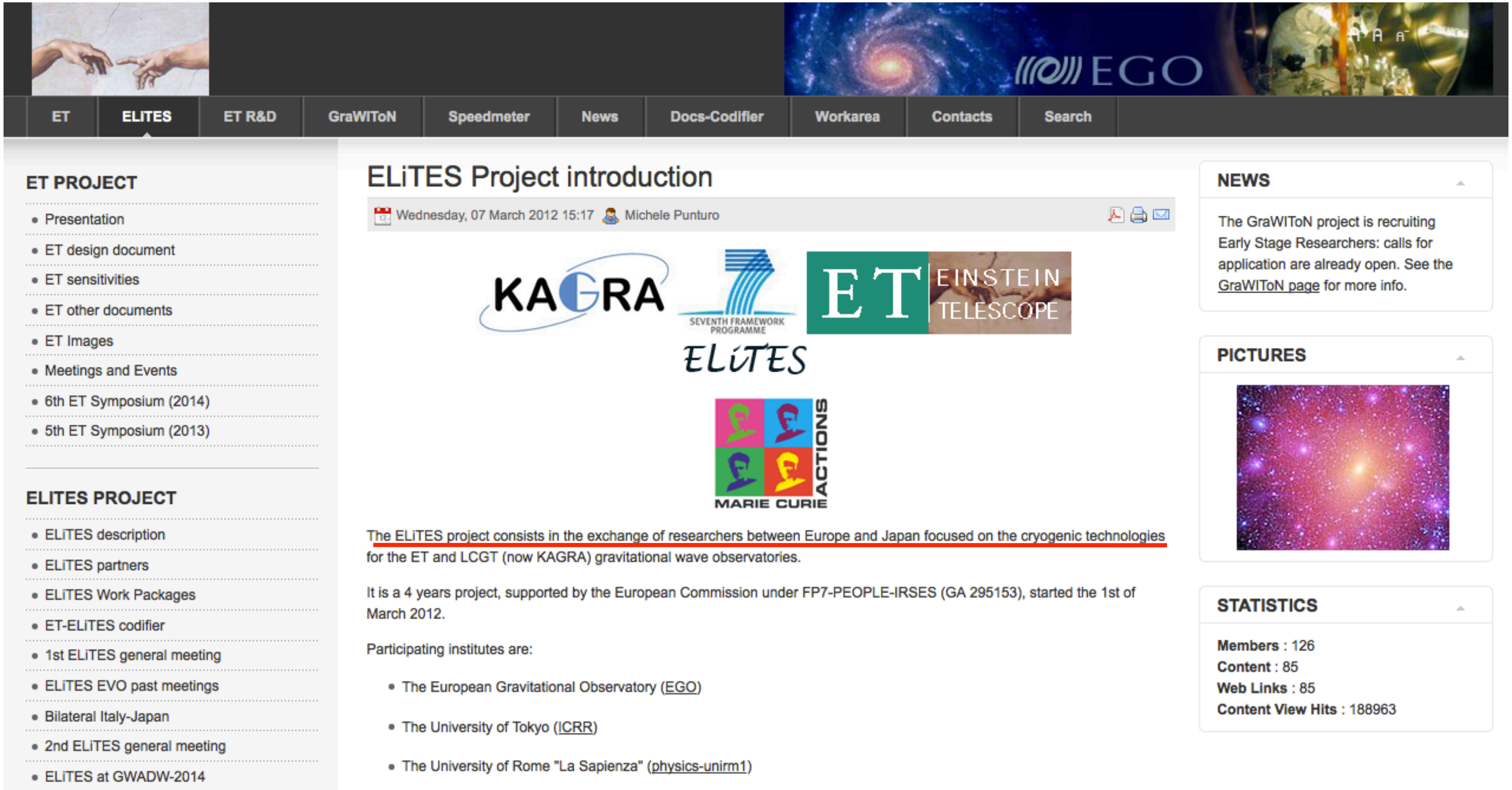




- Maximum deformation of cradle – 1.4 microns

Mode shape	Frequency, Hz
Pendulum	1.06
Pitch	6.03
Bounce (vertical)	14.5
1st Violin	211
2nd Violin	505

ELiTES program


ET | ELITES | ET R&D | GraWITON | Speedmeter | News | Docs-Codifier | Workarea | Contacts | Search

ET PROJECT

- Presentation
- ET design document
- ET sensitivities
- ET other documents
- ET Images
- Meetings and Events
- 6th ET Symposium (2014)
- 5th ET Symposium (2013)

ELITES PROJECT

- ELiTES description
- ELiTES partners
- ELiTES Work Packages
- ET-ELiTES codifier
- 1st ELiTES general meeting
- ELiTES EVO past meetings
- Bilateral Italy-Japan
- 2nd ELiTES general meeting
- ELiTES at GWADW-2014

ELiTES Project introduction

Wednesday, 07 March 2012 15:17 Michele Punturo

The ELiTES project consists in the exchange of researchers between Europe and Japan focused on the cryogenic technologies for the ET and LCGT (now KAGRA) gravitational wave observatories.

It is a 4 years project, supported by the European Commission under FP7-PEOPLE-IRSES (GA 295153), started the 1st of March 2012.

Participating institutes are:

- The European Gravitational Observatory (EGO)
- The University of Tokyo (ICRR)
- The University of Rome "La Sapienza" (physics-unirm1)

NEWS

The GraWITON project is recruiting Early Stage Researchers: calls for application are already open. See the GraWITON page for more info.

PICTURES

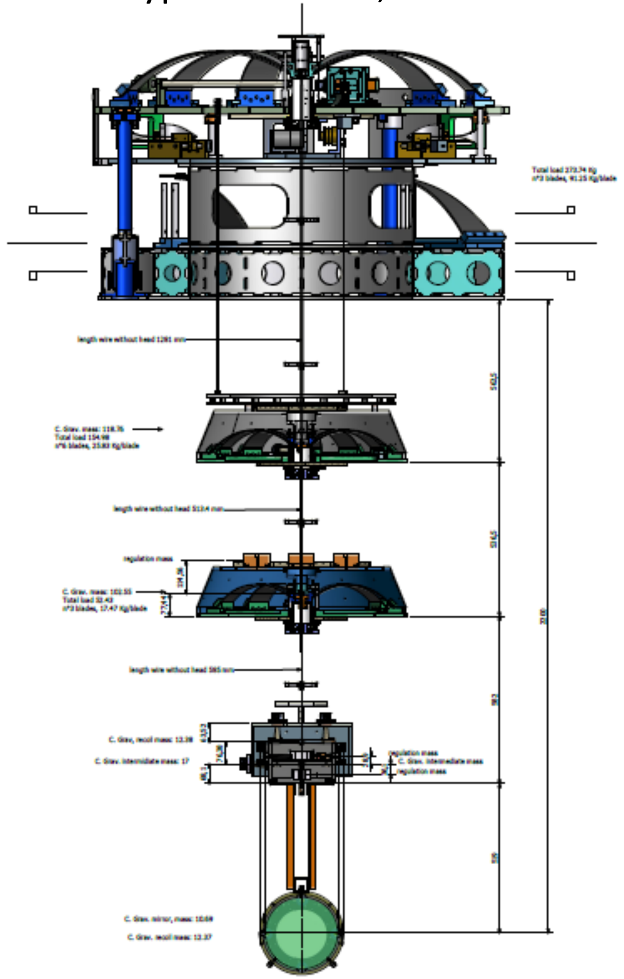
STATISTICS

Members : 126
Content : 85
Web Links : 85
Content View Hits : 188963

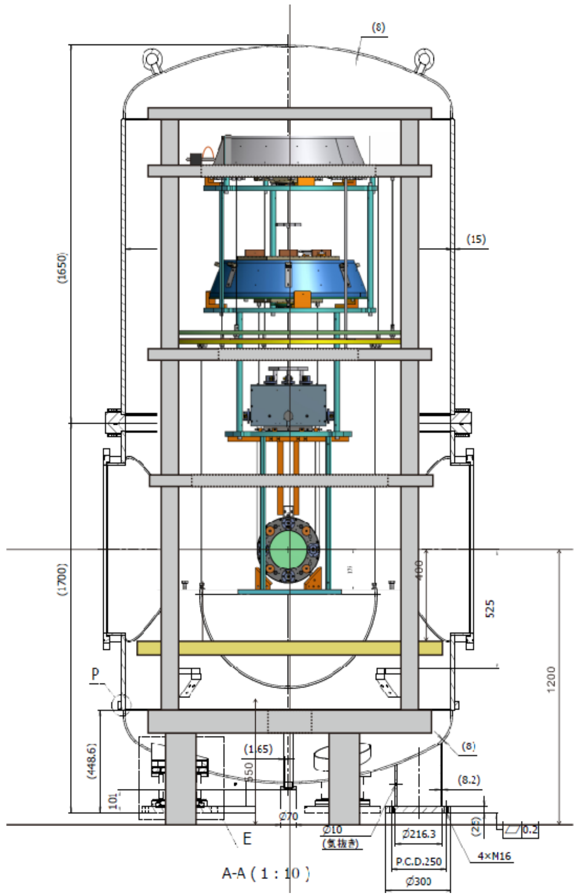
Suspensions in room temperature

SAS: seismic attenuation system

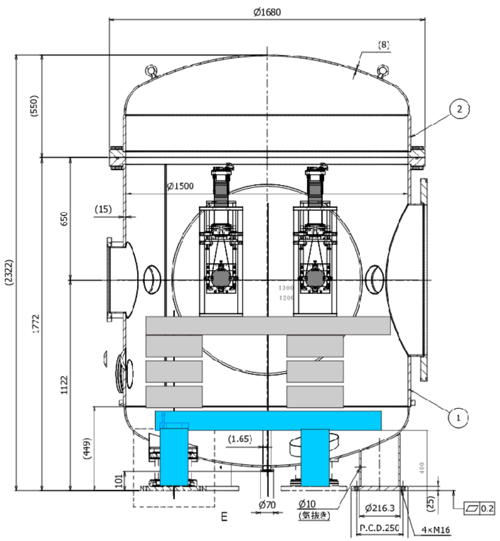
Type-B SAS: BS, SR-mirrors



Type-Bp SAS: PR-mirrors



Type-C suspension for other mirrors; several designs



Type-B is supported by an outer frame outside the chamber.

Suspensions status

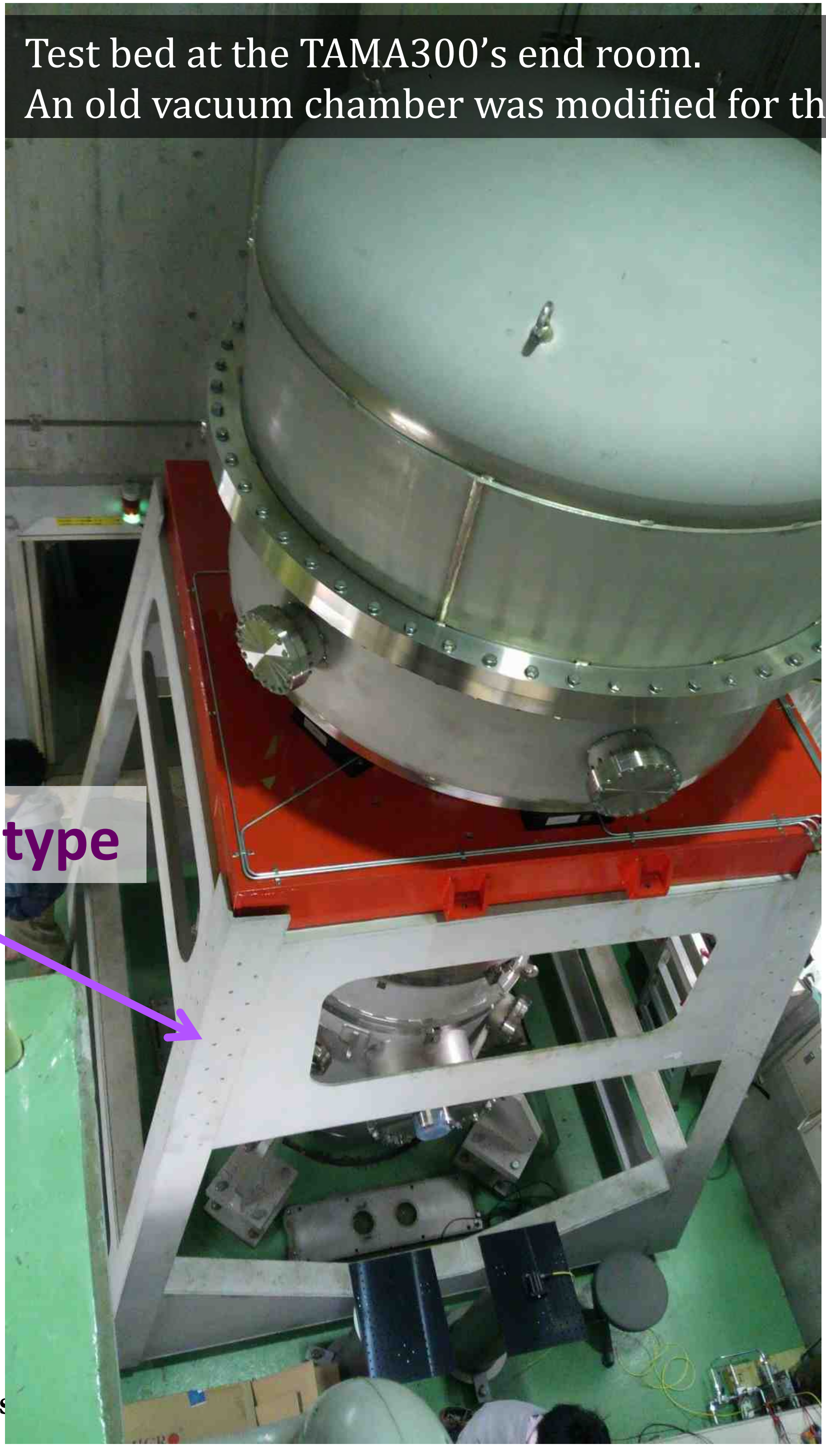
- Prototyping at NAOJ
- A test bed in TAMA300 site


Test of a pre-isolator part at ICRR


Test of a payload part at NAOJ (old 20 m interferometer site)

Test bed at the TAMA300's end room.
An old vacuum chamber was modified for this purpose.

For type-B SAS prototype

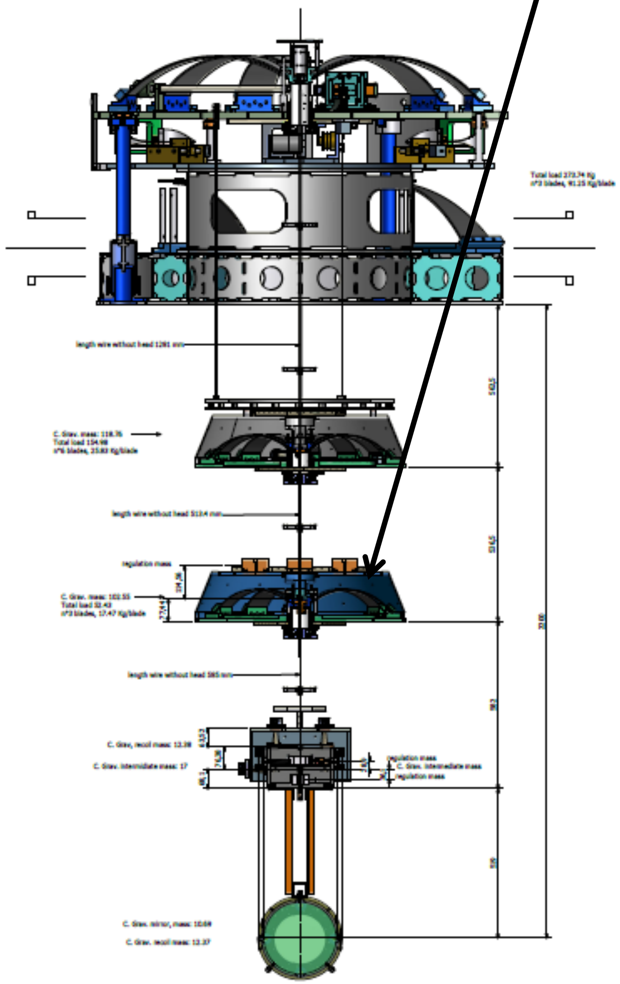


Outer frame prototype

Blade spring prototype

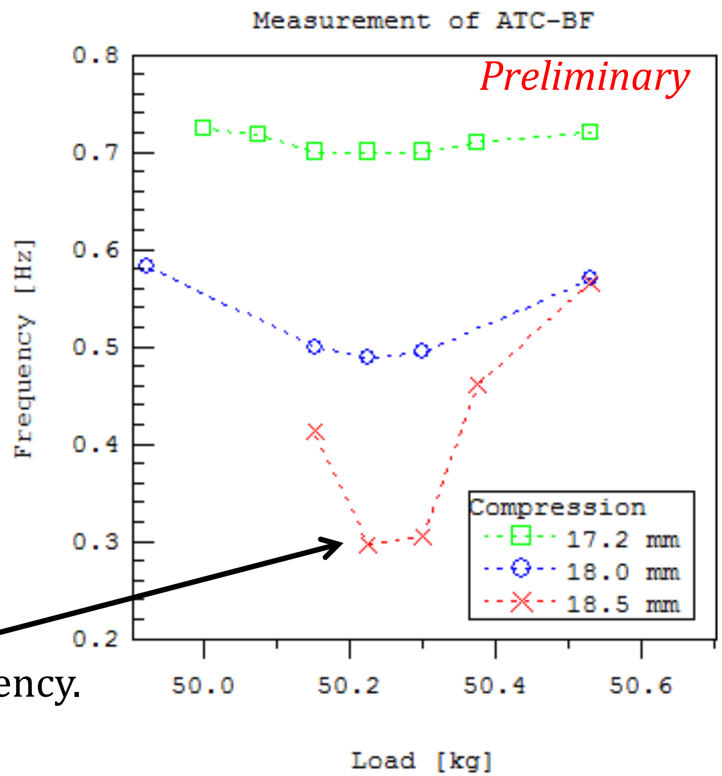
Some of blade springs of maraging steel

by Advanced Technology Center of NAOJ



"MAS1C" from Daido die&mold steel solutions

Made a GAS filter, measured working frequencies



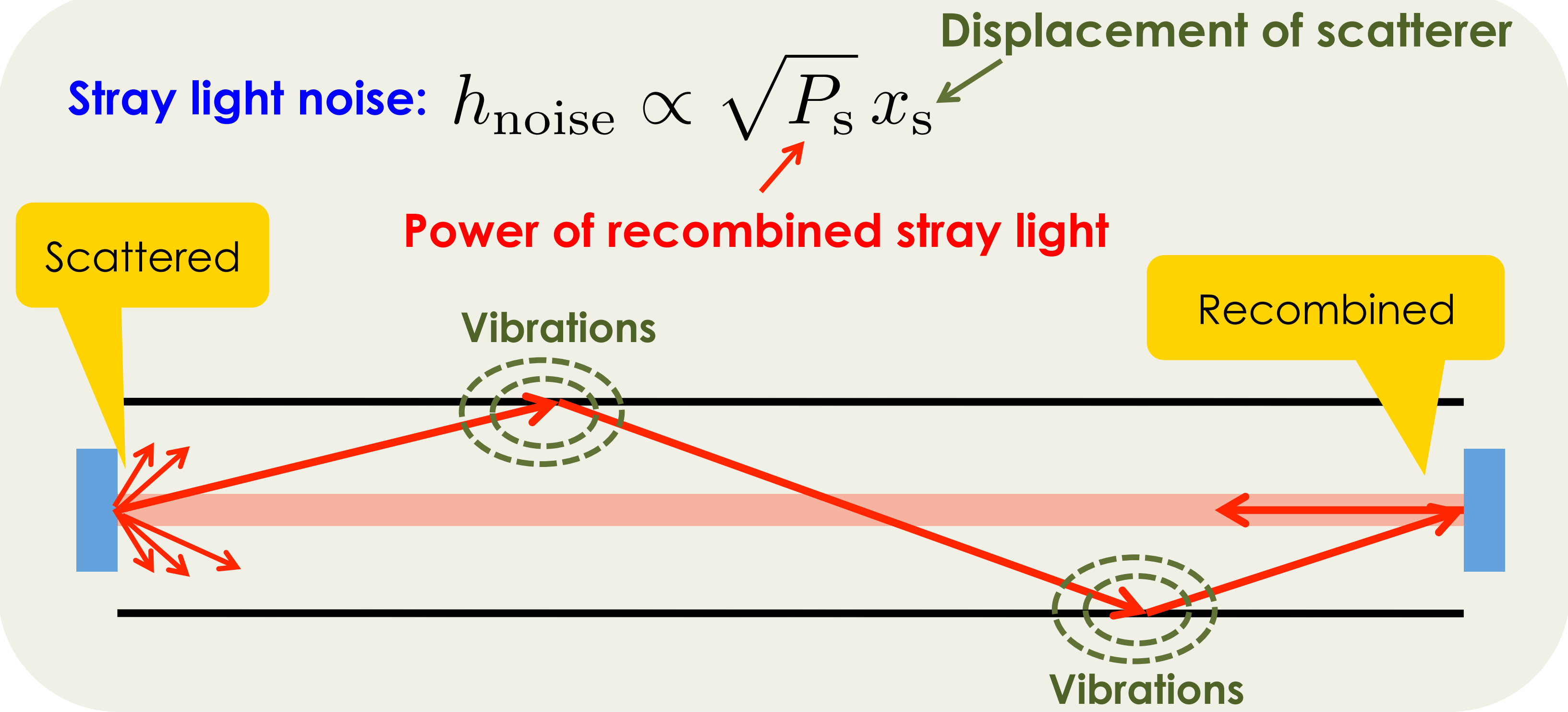
Achieved low working frequency.

Stray-light noise *A practical, stubborn show stopper*

KAGRA

(1) Consider a stray light generated by a mirror of the interferometer hits at a secondary scatterer, say, an inner surface of a vacuum chamber, that is fluctuated by a seismic motion or acoustic vibration.
(2) The stray light is again scattered there and its phase gets fluctuated, and some of it shower on the interferometer optics.
(3) In the end, a little of it would recombine into the main optical beam. The recombined stray photons can cause ***fake signals*** in the interferometer output --- stray light noise.

Stray light noise: $h_{\rm noise} \propto \sqrt{P_{\rm s}}\, x_{\rm s}$

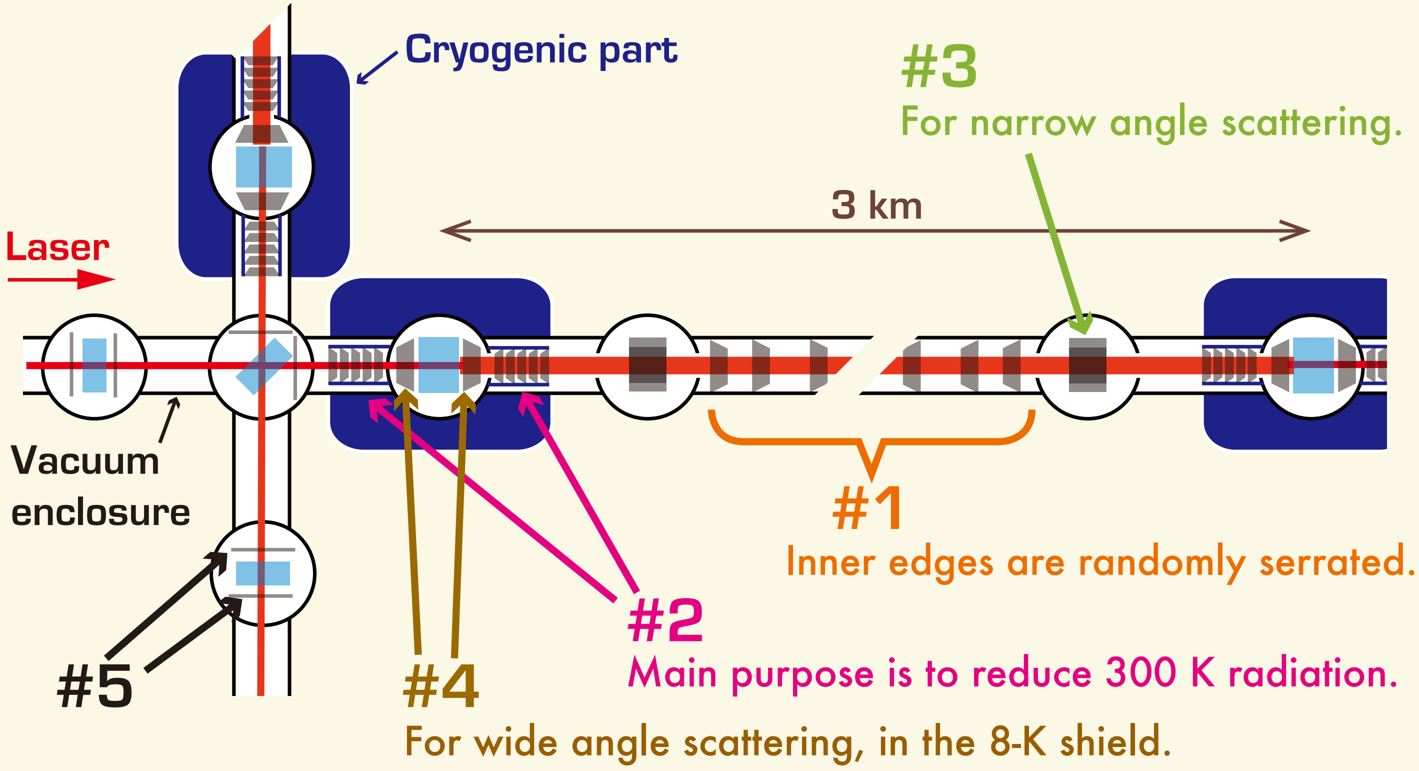


Note: when the secondary scatterer vibrates with the order of one micro-meter, i.e. a wavelength of the laser light, the noise conversion occurs in a non-linear way, and the simple linear relation no longer holds.

Baffle system for KAGRA

KAGRA

Delivered.	⇨	#1 Arm duct baffles – 125 baffles per each 3-km arm
Delivery started.	⇨	#2 Cryo-duct shield – 5 m long, cooled down to about 80 K
Prototype	⇨	#3 Narrow-angle baffles
Concept design	⇨	#4 Wide-angle baffles – cooled down to about 8 K
Prototype	⇨	#5 Others



Schematic view of the main interferometer of KAGRA and its baffles

Black coating on baffle surface

The black coating on the baffles/beam dumps is critical.

Common requirements:

- Vacuum compatibility: < 10^{-7} Pa
- As low reflectivity as possible at 1064 nm
- Industrial applicability for large areas up to φ 800 mm

For cryoduct shields (#2):

- Cryogenic compatibility: < 80 K
- As low reflectivity as possible for 300 K radiation (10 um)
- Applicability to aluminum

For wide-angle baffles (#4):

- More cryogenic compatibility: < 8 K

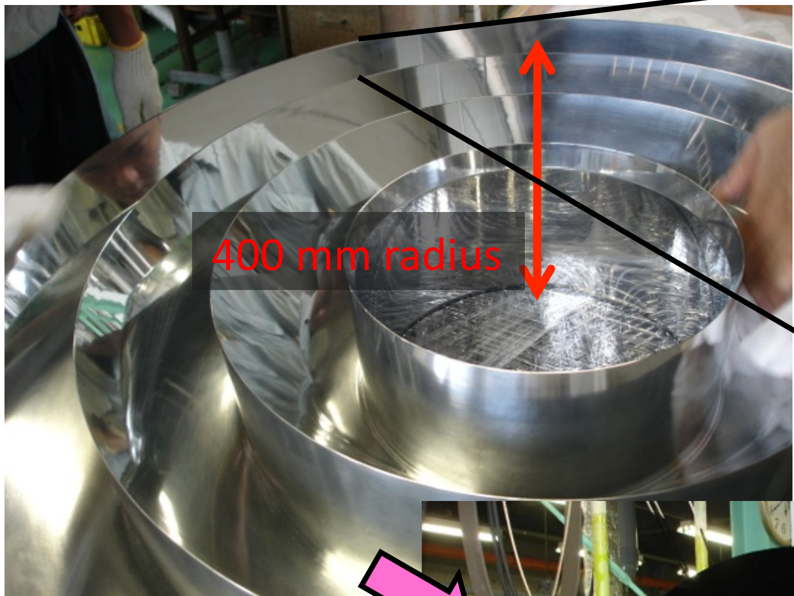
Getting stringent!

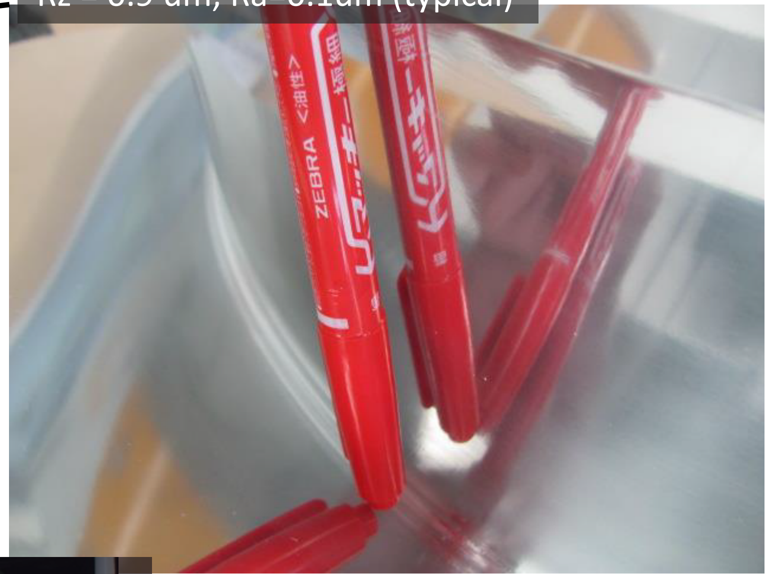
Unique to KAGRA

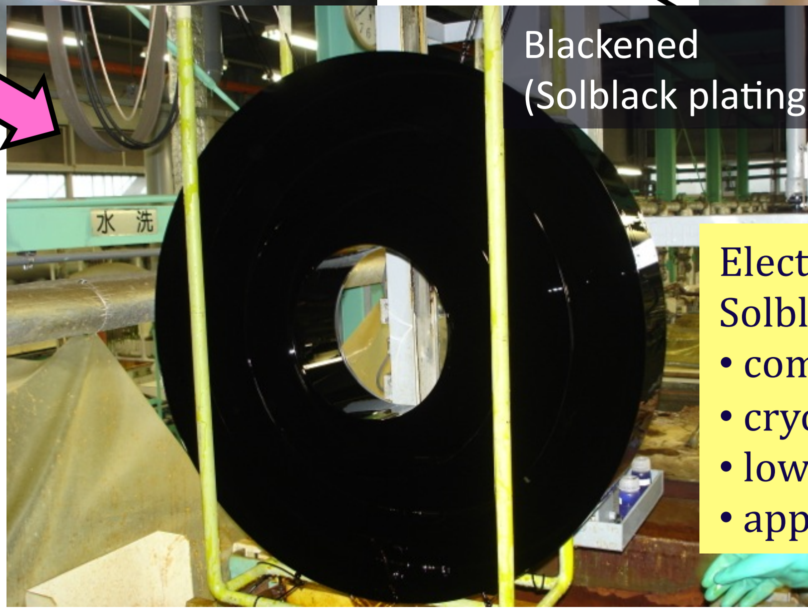
PASS

Narrow-angle baffle prototype

Substrate: Al (A5052 in JIS)





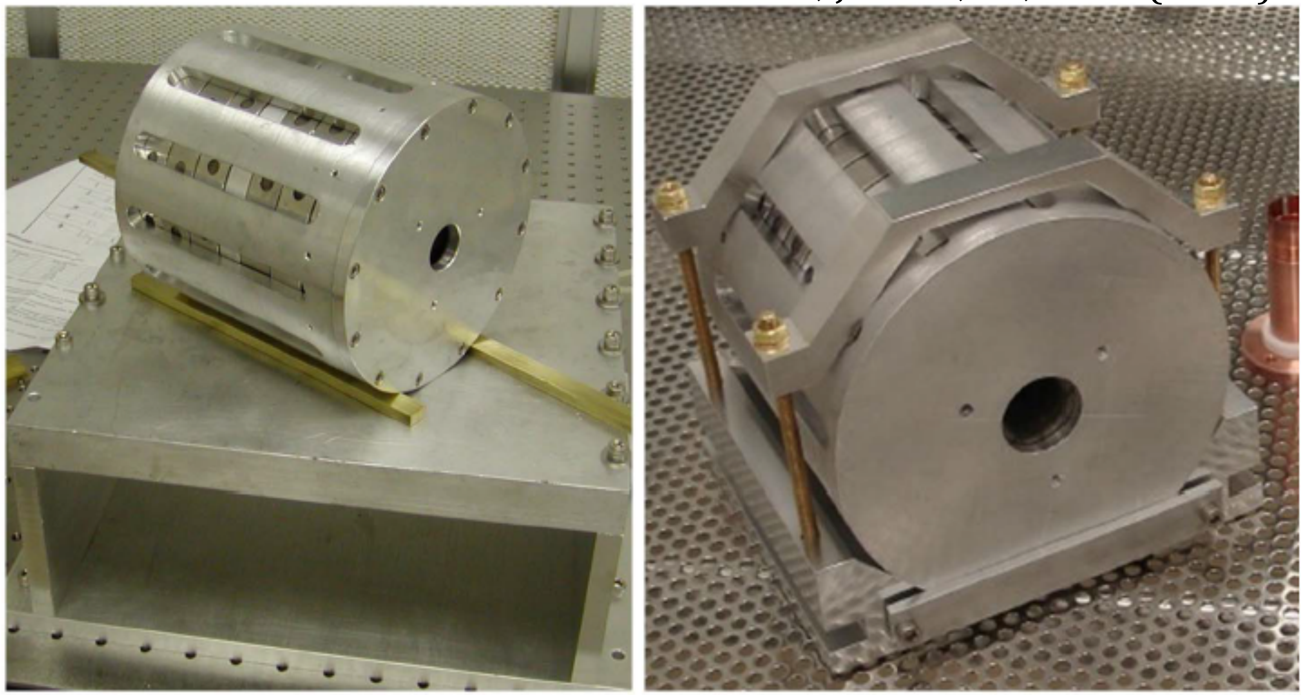


Electro-chemical buffing: less scattering.
Solblack:
- compatible with vacuum (10^{-7} Pa),
- cryogenic (<8K),
- low reflectivity (~2%@1064nm),
- applicable to large area.

Input/output optics

- Laser source, mode cleaner, Faraday isolator, mode-match telescope, periscopes...
- Installation would start in 2014 (for iKAGRA)
- Starting with a few W laser source in iKAGRA phase
- Under discussion: use of Faraday isolators for LIGO/Virgo one (from Univ. of Florida)

O. V. Palashov et al., JOSA B, 29, 1784 (2012)



(a) (b)

Fig. 1. (Color online) Faraday rotator magnet system for the (a) LIGO and (b) Virgo VPFI.

Summary

- KAGRA is promoted by ICRR, Univ. of Tokyo in collaboration with KEK and NAOJ, and many other institutes.
- Excavation of tunnels for KAGRA interferometer completed.
- Installation of vacuum systems, optics, suspensions will start in 2014.
- In 2015, initial KAGRA (iKAGRA) commissioning and "run" will be major activity.
- Upgrade to baseline KAGRA (bKAGRA) will take place progressively with the first observation run in 2017-18.