Current status of KAGRA

Kazuhiro Yamamoto
on behalf of KAGRA collaboration

Institute for Cosmic Ray Research, the University of Tokyo

31 August 2016
LIGO-Virgo Collaboration meeting
@Hilton Glasgow Grosvenor, Glasgow, Scotland, U.K.

Introduction

KAGRA : 2nd generation detector
with 3km arm at Kamioka in Japan

Two unique key features

Underground site with small seismic motion

Cryogenic techniques to reduce thermal noise

Congratulation !

KAGRA congratulates the first and second detections of Binary Black Holes mergers in 2015 !

This greatest news stimulated discussion about schedule of KAGRA to join the observation network.

Schedule of KAGRA

Internal discussions as well as the recommendation of PAB (external review) lead us to the following schedule.

Phase-1 (until March 2018)
3km cryogenic Michelson interferometer

Phase-2 (until 1st quarter of 2019 ?)
Cryogenic full configuration interferometer

Phase-3 (From 2nd quarter of 2019 ?)
Commissioning and Observation runs

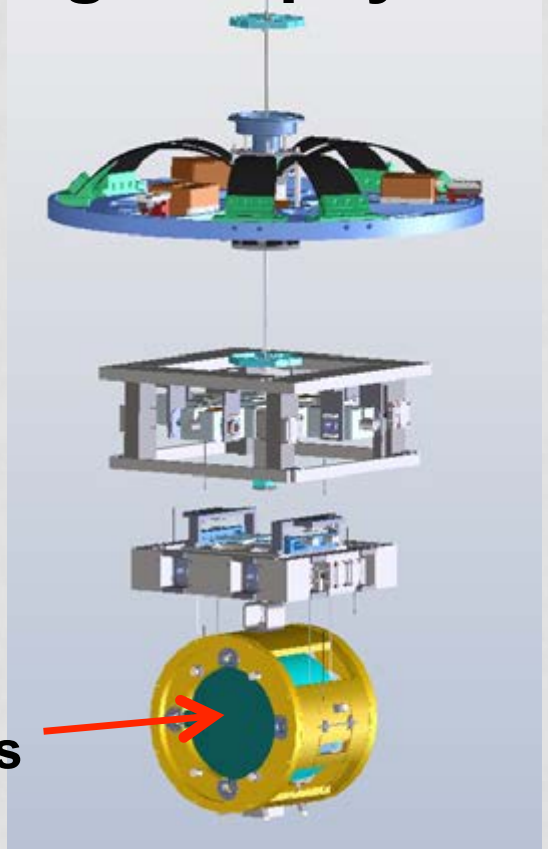
Schedule of KAGRA

Phase-1 (until March 2018)
3km cryogenic Michelson interferometer

Demonstration of critical technologies
(1)Cryogenic payload (around 20K)
(2)Vibration isolation system for cryogenic payload (14m height)

They are installed at both ends as components of simple Michelson interferometer.

Cryogenic payload

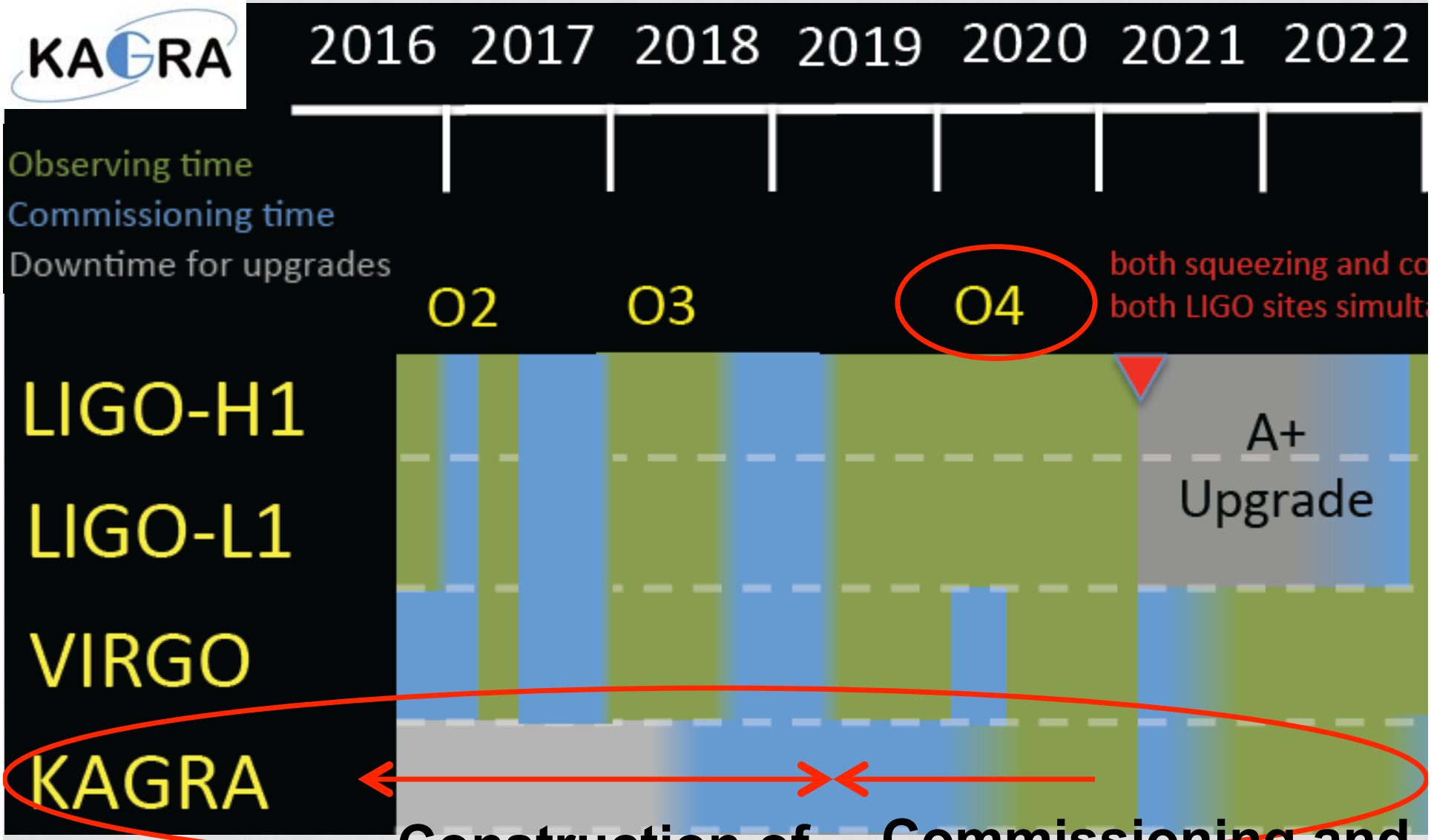


Cooled sapphire mirror suspended by sapphire fibers (Sapphire monolithic stage)

Schedule of KAGRA

Phase-2 (until 1st quarter of 2019 ?)
Cryogenic full configuration interferometer
(1)Installation of optics for FP cavity, RSE …
(2)Lock of Power recycled RSE FP Michelson interferometer
(Serious interferometer sensing/control activities)

Phase-3 (From 2nd quarter of 2019 ?)
Commissioning and Observation runs
KAGRA can join the network in this phase.
(second half of O4, 2020, in earliest case)



By Lisa Barsotti
Dawn Workshop
7 July 2016

Schedule of KAGRA

We are preparing description and FIGURES about sensitivity evolution and schedule as follow for next revision of

Living Rev. Relativity, **19**, (2016), 1
DOI 10.1007/lrr-2016-1

LIVING REVIEWS in relativity

Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO and Advanced Virgo

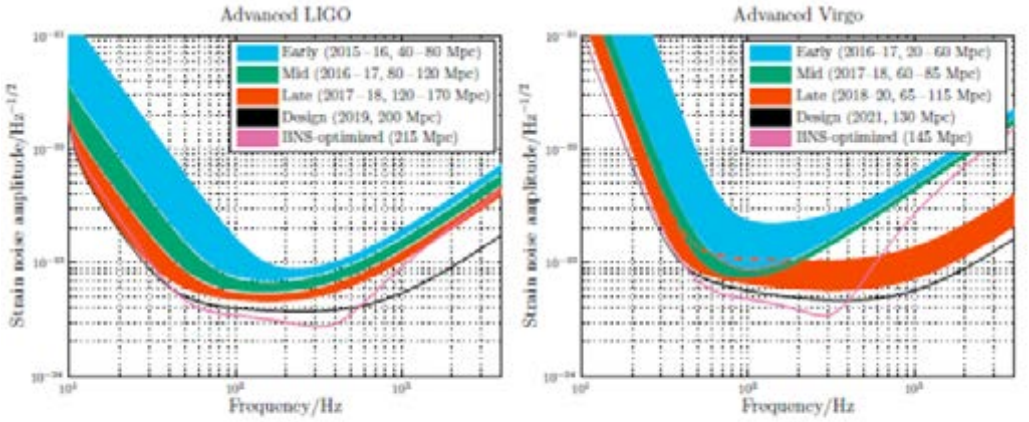


Figure 1: aLIGO (*left*) and AdV (*right*) target strain sensitivity as a function of frequency. The binary neutron-star (BNS) range, the average distance to which these signals could be detected, is given in megaparsec. Current notions of the progression of sensitivity are given for early, mid and late commissioning phases, as well as the final design sensitivity target and the BNS-optimized sensitivity. While both dates and sensitivity curves are subject to change, the overall progression represents our best current estimates.

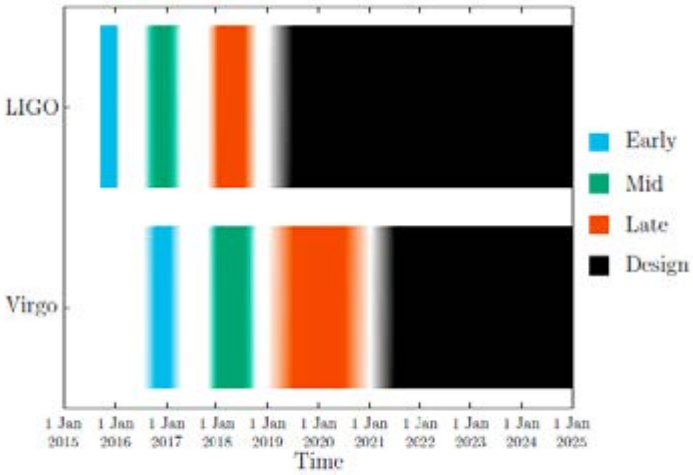


Figure 2: The planned sensitivity evolution and observing runs of the aLIGO and AdV detectors over the coming years. The colored bars show the observing runs, with the expected sensitivities given by the data in Figure 1. There is significant uncertainty in the start and end times of the observing runs, especially for those further in the future, and these could move forward or backwards by a few months relative to what is shown above. The plan is summarised in Section 2.2.

Recent news

iKAGRA (room temperature) phase finished.
Engineering run was held on March and April 2016.

Promise with Japanese government was kept !

Recent news

Performance of cryostat at KAGRA site will be checked by April 2017.
(1)Cooling test
(2)Measurement of radiation shield vibration
(Collaboration with Rome University, ELiTES)

Y. Sakakibara et al.,Classical and Quantum Gravity 31 (2014) 224003.
F. Frasconi *et al.*,Meas. Sci. Technol. 25 (2014) 015103.
D. Chen *et al.*, Classical and Quantum Gravity 31(2014) 224001.

Recent news

Cryogenic payload

The first cryogenic payload has already been delivered and assembled !

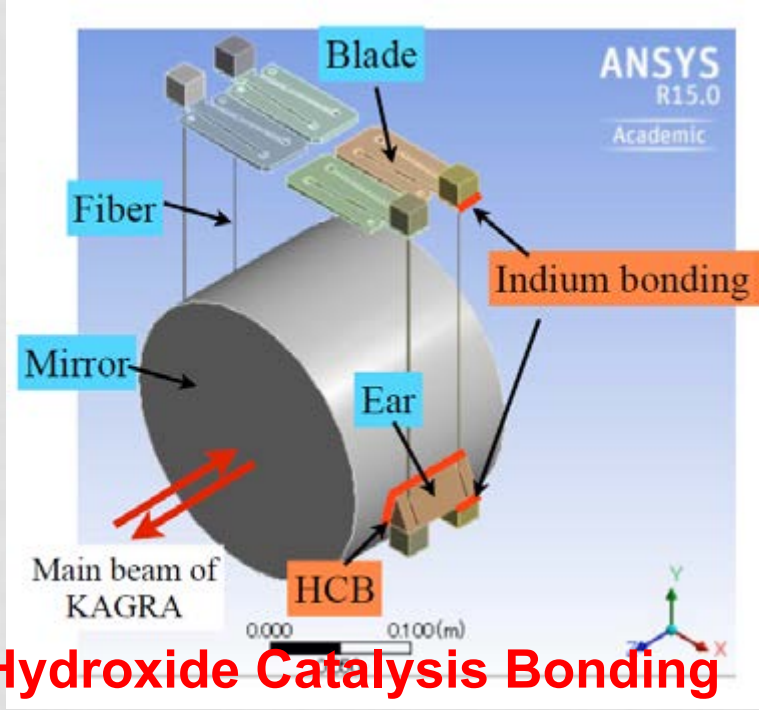
Performance test (adjustment and control system, measurement of transfer function) is in progress or being prepared.

Recent news

Sapphire monolithic stage

Prototype test
Hydroxide Catalysis Bonding (HCB) of two sapphire ears on sapphire bulk as dummy mirror (August 2016)
Next step is suspending.

European colleagues (ELiTES) supports development of sapphire suspension.
HCB : Glasgow
Jig for HCB : Perugia

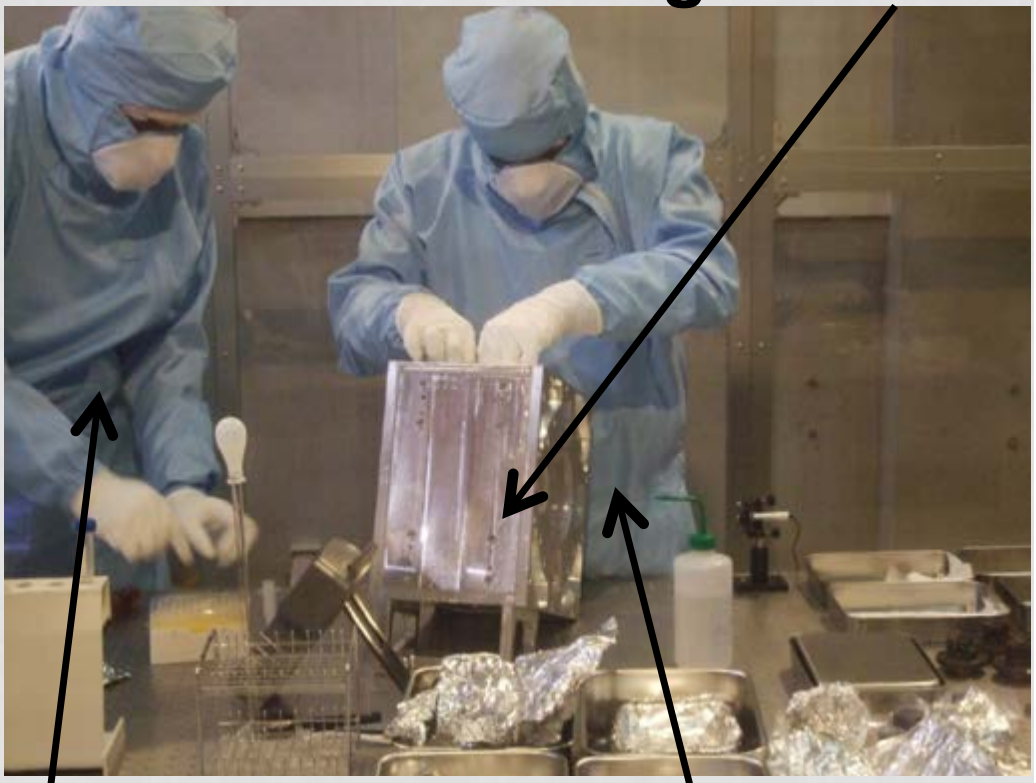


Hydroxide Catalysis Bonding


Sapphire ear


Sapphire bulk as dummy mirror

Recent news



Jig for HCB

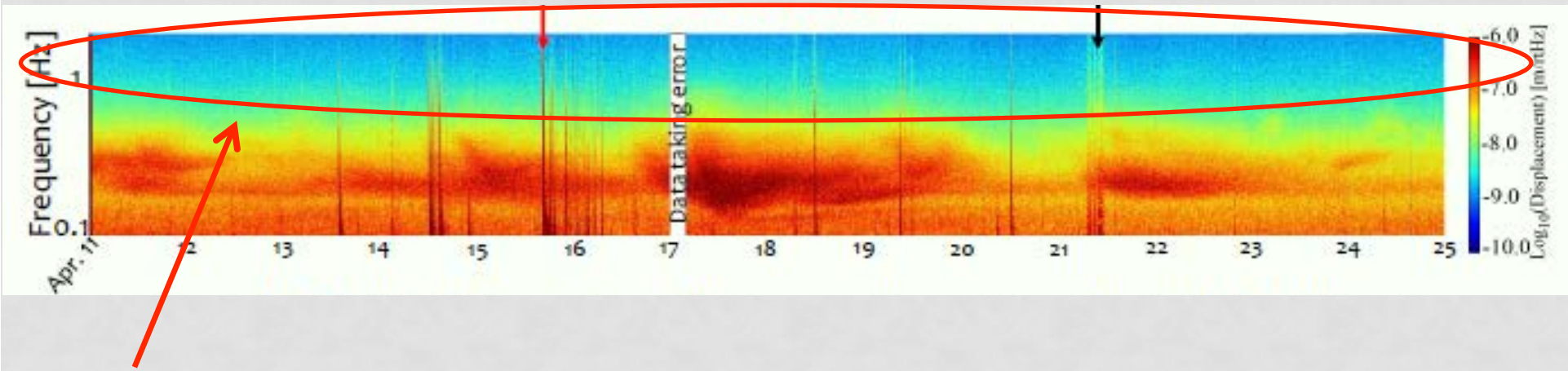
Kieran Craig (Tokyo)

Marielle van Veggel (Glasgow)

Helios Vocca (Perugia)

Recent news

Monitor of seismic motion at KAGRA site (11-25 April 2016)



Around 1Hz, seismic motion is 10^{-9}m/rtHz (100 times smaller than typical one) and almost constant. Requirement for control system should be modest.

Summary

KAGRA will join international observation network (second half of O4, 2020, in earliest case) to contribute to gravitational wave physics.

International collaboration contributes to development of KAGRA interferometer.
For example, cryogenic parts, an unique key feature and challenge, is being developed and tested under collaboration with European groups (ELiTES).

KAGRA

Thank you for your attention !

2. Schedule

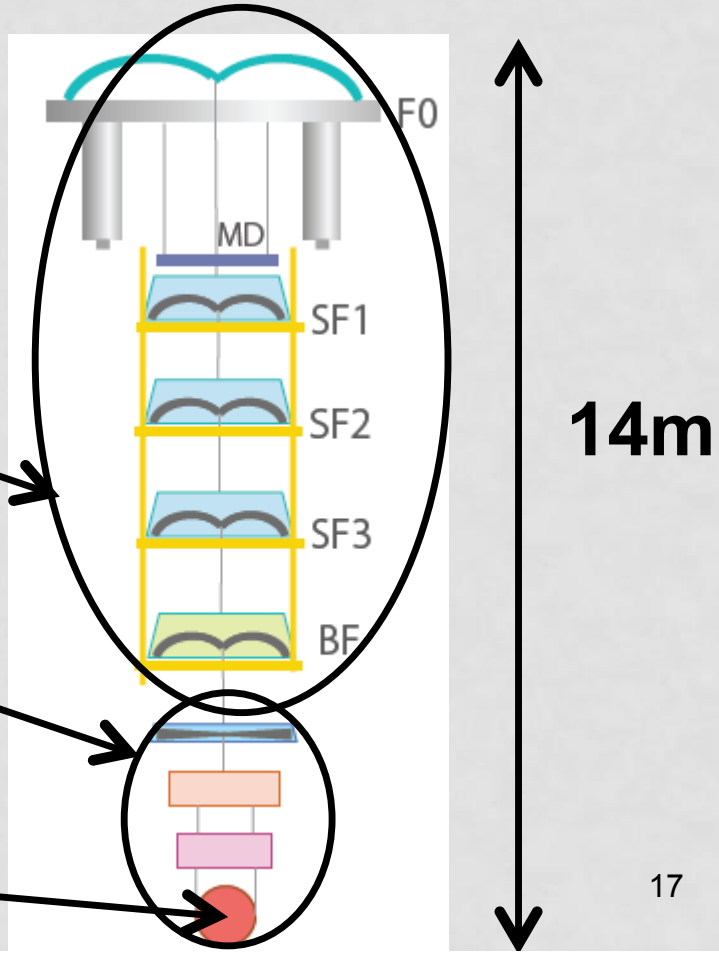
Phase-1 (until March 2018)

Operation of a 3km cryogenic Michelson interferometer

Type A vibration isolation system (room temperature)

Cryogenic payload

Cooled sapphire mirror



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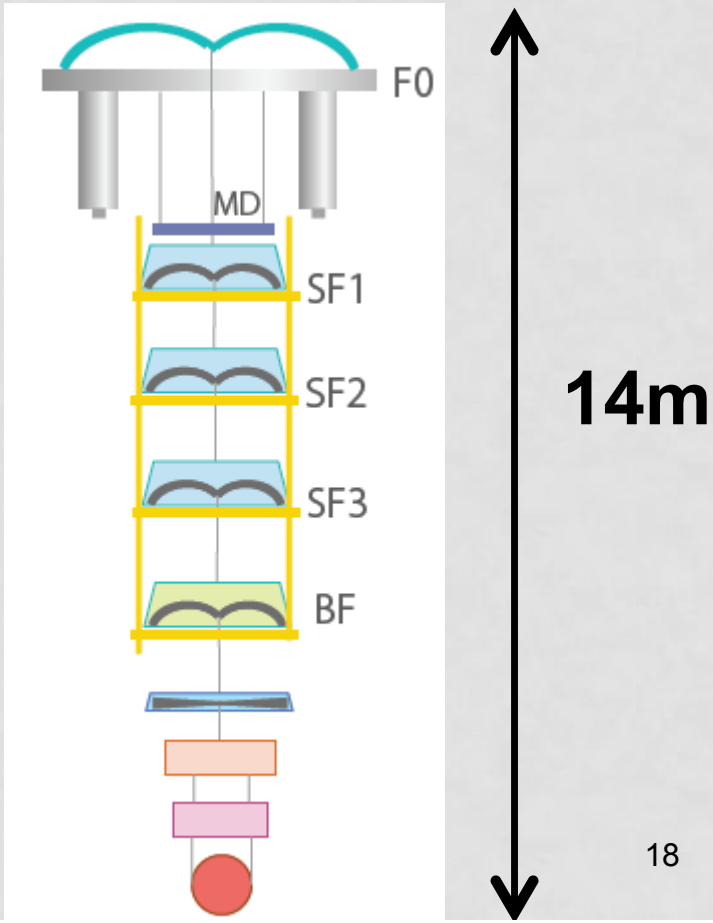
2. Schedule

Phase-1 (until March 2018)
Operation of a 3km cryogenic Michelson interferometer

They are installed and operated at both ends.

One of the largest challenges in KAGRA They must be checked in phase 1.



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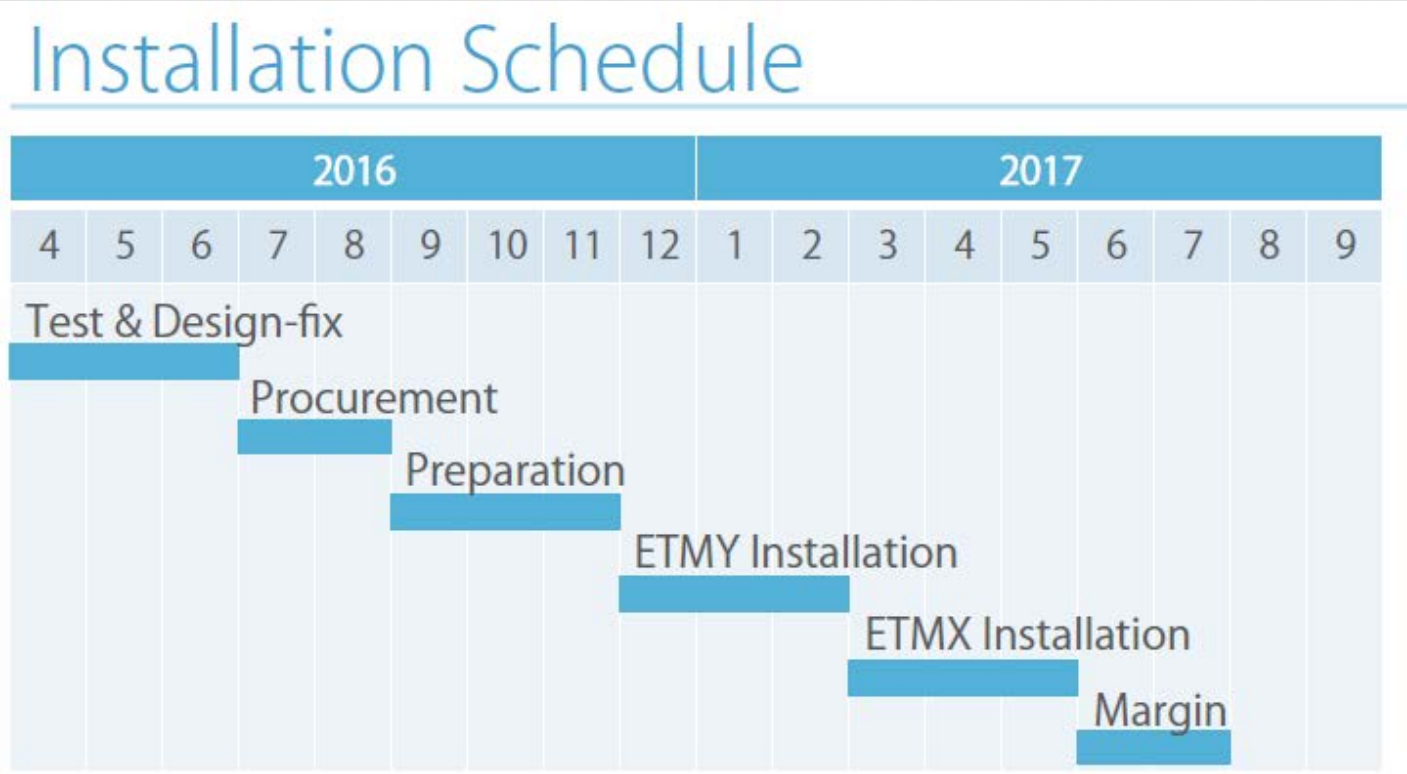
2. Schedule

Phase-1 (until March 2018)

Type A (vibration isolation for cryo payload)



After installations of Type-A room-temperature parts, Cryopayloads are integrated

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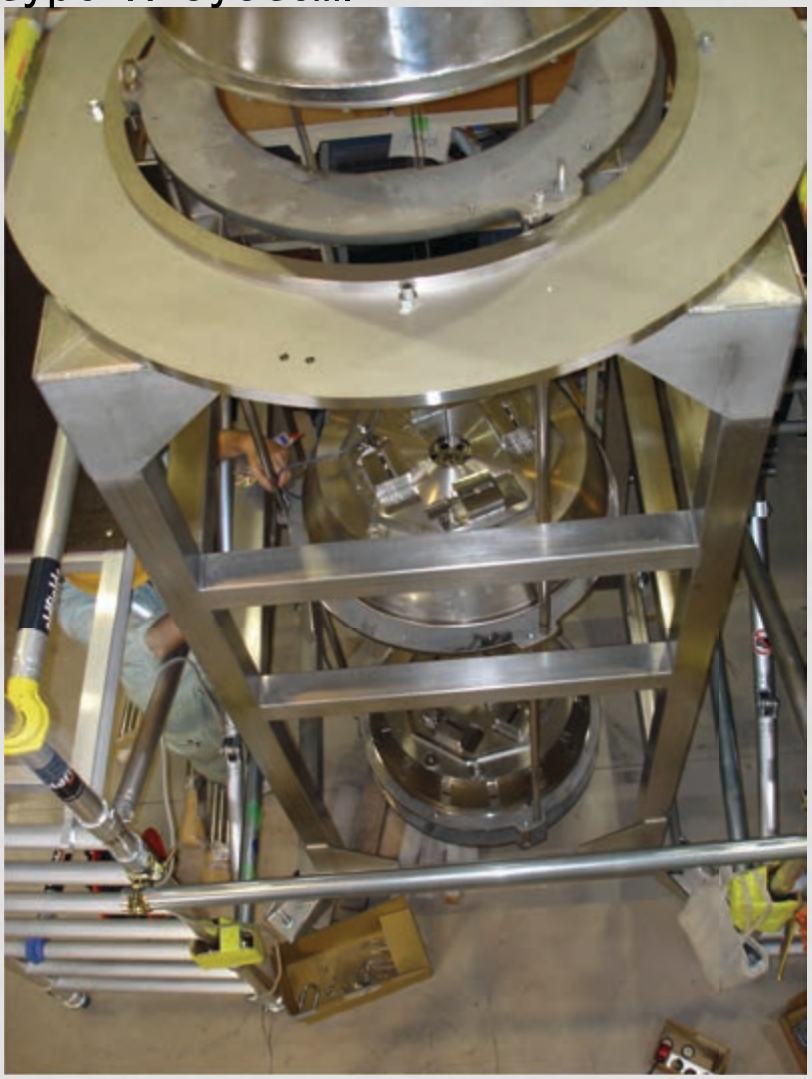
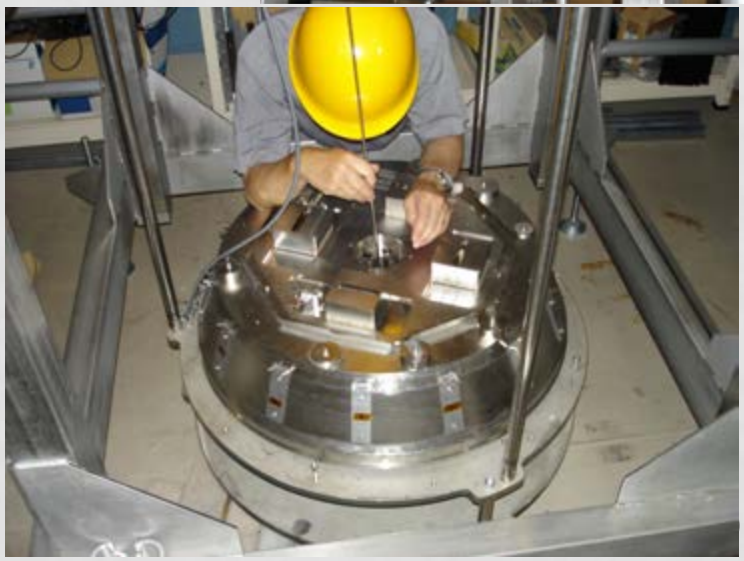
Test of earthquake stop for type-A system

Earthquake stop prototype is under testing in NAOJ to establish the installatioin procedure for type-A system.





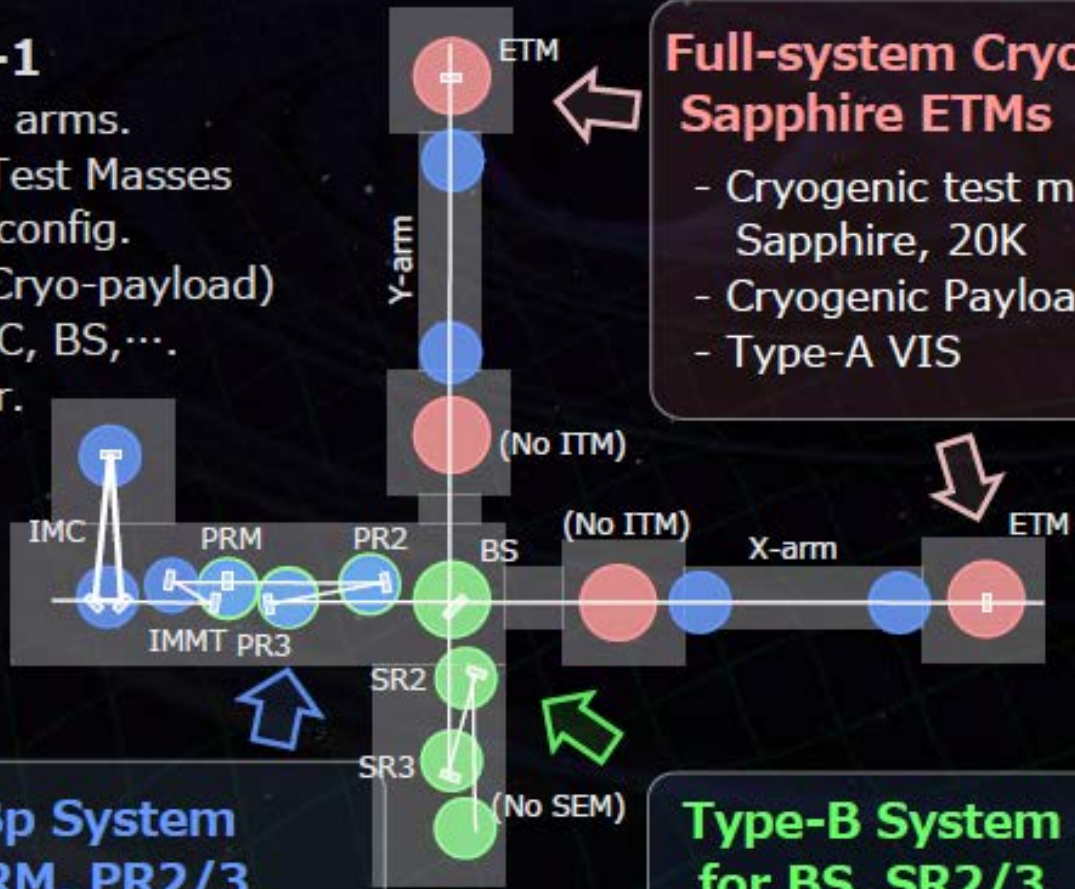
Plan for bKAGRA Phase-1

- Operate 3-km Cryogenic Michelson Interferometer.
  - * Most of the parts are the bKAGRA final ones:
    - Full configuration for ETMs.
    - Most of Upper stream parts than BS.
  - * Some simplifications from full bKAGRA:
    - No ITMs.
    - Power-recycling will be possible, but optional.
    - Low-power laser, No Green-lock system.
    - Simplified output optics:
      No SRM??, No OMC, Fixed BRT.

bKAGRA Phase-1 (- 2018.3)

bKAGRA Phase-1

- PRMI with 3 km arms.
- Cryogenic End Test Masses suspended full config. (Type-A VIS +Cryo-payload)
- Final VIS for PRC, BS,….
- Low laser power.



Full-system Cryogenic Sapphire ETMs

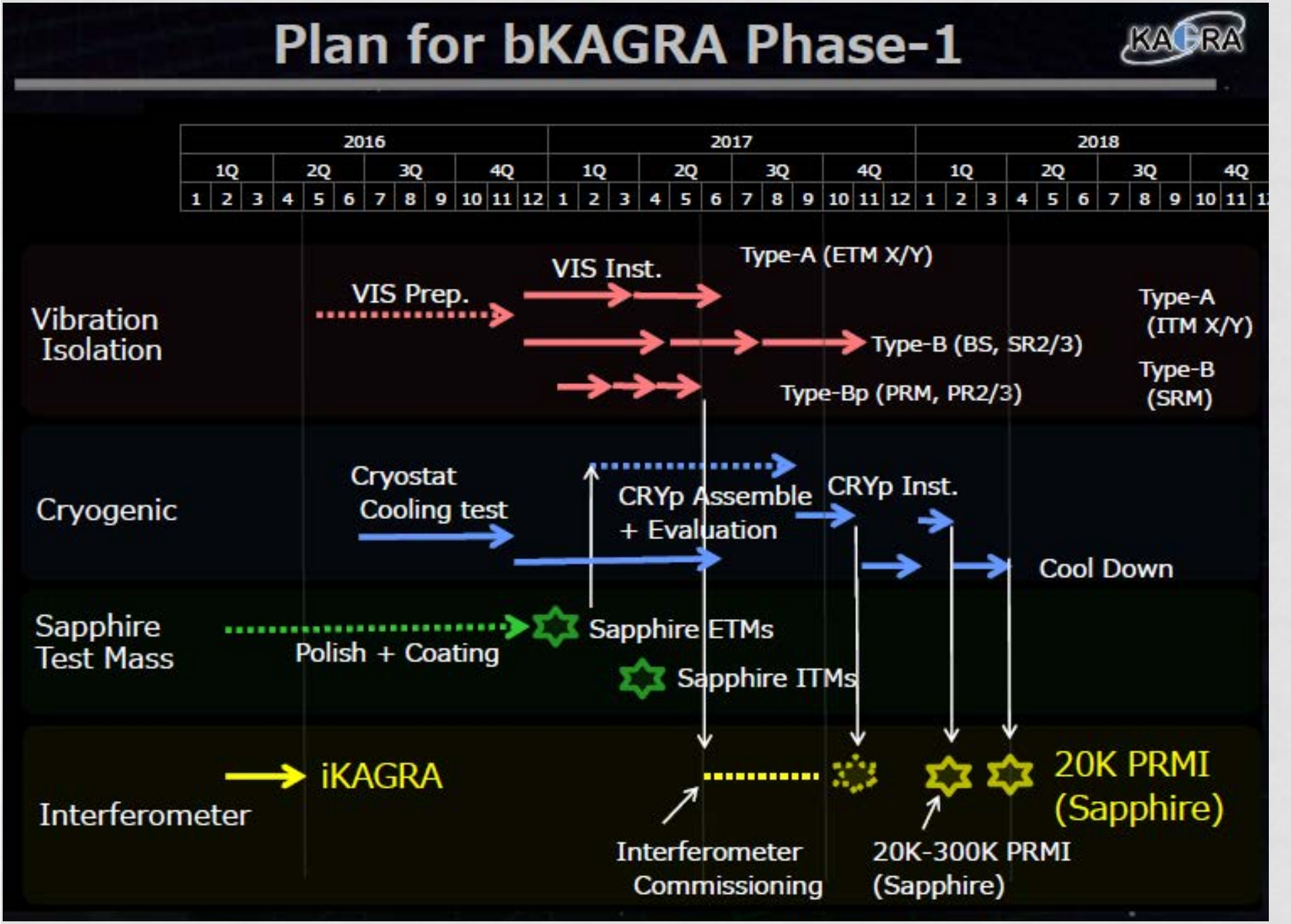
- Cryogenic test masses Sapphire, 20K
- Cryogenic Payload
- Type-A VIS

Type-Bp System for PRM, PR2/3

- Final Config.
- Room temp., 300K
- Power Recycling implementation is TBD

Type-B System for BS, SR2/3

- Final config.
- Room temp., 300K
- No SRM


Plan for bKAGRA Phase-1
KAGRA
2016
2017
2018
1Q 2Q 3Q 4Q
1 2 3 4 5 6 7 8 9 10 11 12
Vibration Isolation
VIS Prep.
VIS Inst.
Type-A (ETM X/Y)
Type-B (BS, SR2/3)
Type-Bp (PRM, PR2/3)
Type-A (ITM X/Y)
Type-B (SRM)
Cryogenic
Cryostat Cooling test
CRYp Assemble + Evaluation
CRYp Inst.
Cool Down
Sapphire Test Mass
Polish + Coating
Sapphire ETMs
Sapphire ITMs
Interferometer
iKAGRA
Interferometer Commissioning
20K-300K PRMI (Sapphire)
20K PRMI (Sapphire)

2. Schedule

Phase-2 (until 1st quarter of 2019 ?)
Operation with full configuration cryogenic RSE
Fabry-Perot Michelson interferometer

*** Full lock of the RSE interferometer will be a main issue. We cannot seriously discuss about the sensitivity in this phase.**
*** A few new items :**
-2 cryogenic ITM (Type-A + Cryogenic payload)
-SRM can be installed in Phase-1
-Green-lock system,...
*** There will be an upgrade of cryogenic payload.**

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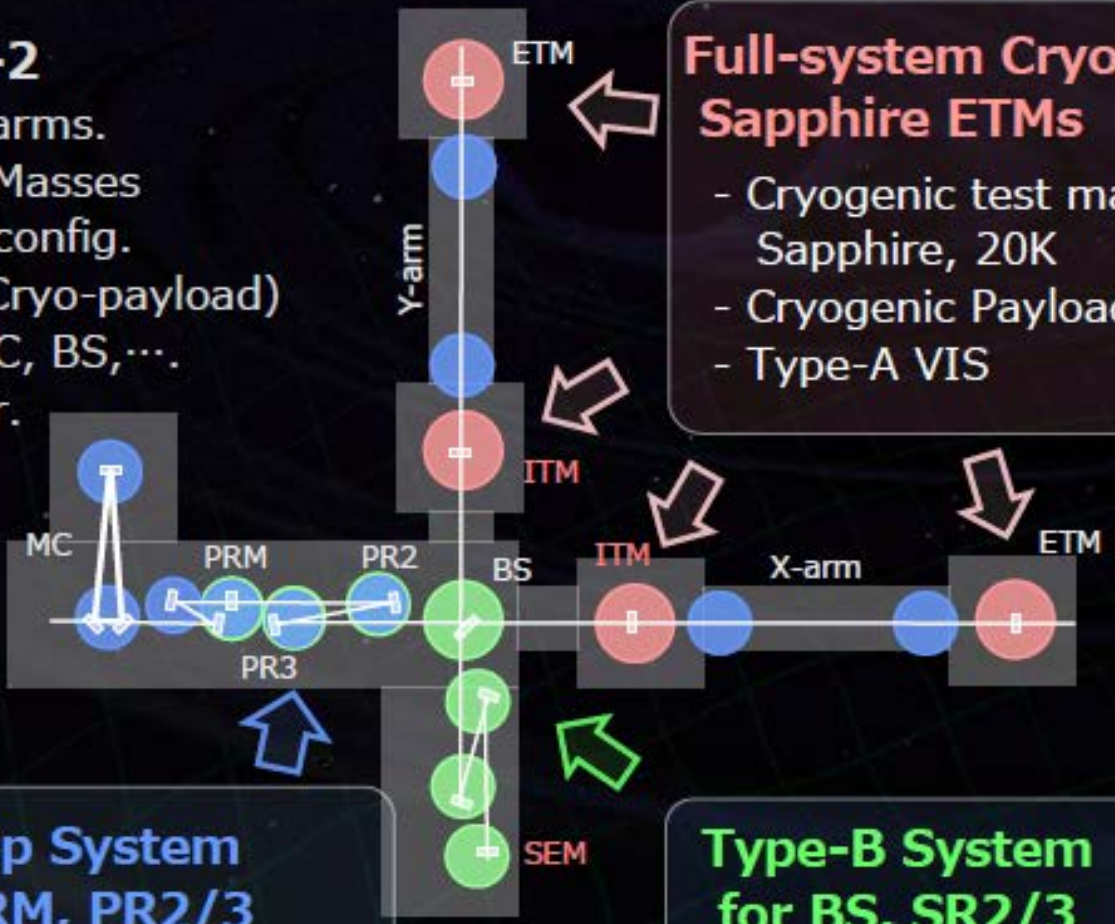
bKAGRA Phase-2 (- 2019.3)

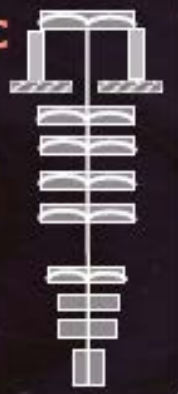
bKAGRA Phase-2

- RSE with 3 km arms.
- Cryogenic Test Masses suspended full config. (Type-A VIS +Cryo-payload)
- Final VIS for PRC, BS,….
- Low laser power.



Full-system Cryogenic Sapphire ETMs

- Cryogenic test masses Sapphire, 20K
- Cryogenic Payload
- Type-A VIS



Type-Bp System for PRM, PR2/3

- Final Config.
- Room temp., 300K
- Power Recycling implementation is TBD

Type-B System for BS, SR2/3

- Final config.
- Room temp., 300K
- No SRM

2. Schedule

Phase-2 (until 1st quarter of 2019 ?)
Operation with full configuration cryogenic RSE
Fabry-Perot Michelson interferometer

Preliminary schedule for Phase-2(maybe too tight)
-2018.4-Preparation of CRYp update,
IFO operation continued.
-2018.8-10 CRYp ITM x2 Installation.
-2018.11 300K Full interferometer operation.
-2018.12-2019.1 Cool down.
-2019.2-3 Operation of a full RSE interferometer
at cryogenic temperature.
Commissioning and Observation run.

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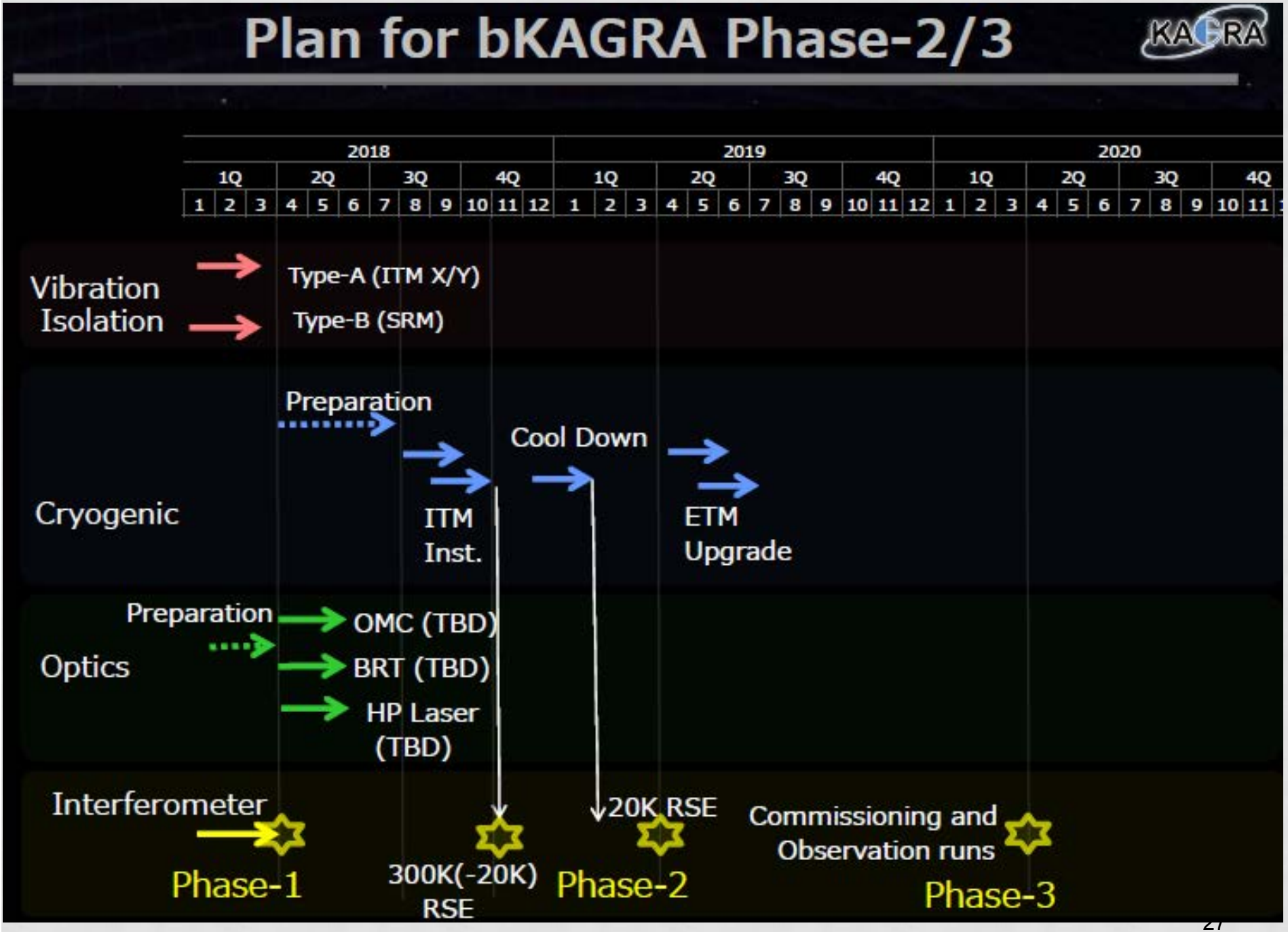
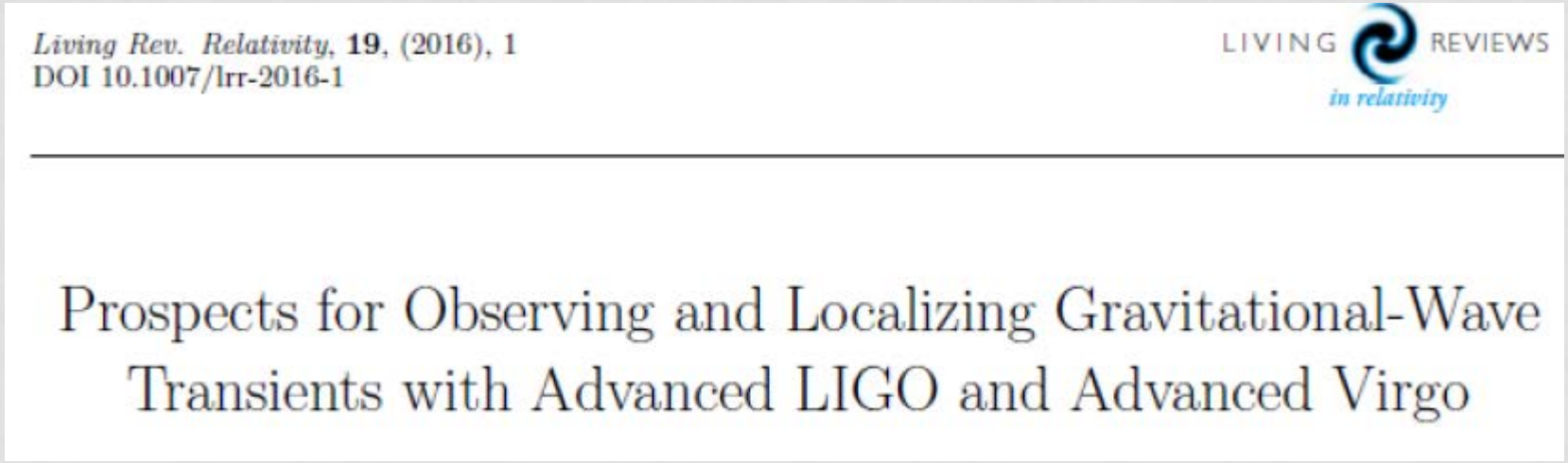

Plan for bKAGRA Phase-2/3
KAGRA
2018
2019
2020
1Q 2Q 3Q 4Q
1 2 3 4 5 6 7 8 9 10 11 12
Vibration Isolation
Type-A (ITM X/Y)
Type-B (SRM)
Cryogenic
Preparation
Cool Down
ITM Inst.
ETM Upgrade
Optics
Preparation
OMC (TBD)
BRT (TBD)
HP Laser (TBD)
Interferometer
20K RSE
Commissioning and Observation runs
Phase-1
300K(-20K) RSE
Phase-2
Phase-3

2. Schedule

Phase-3 (From 2nd quarter of 2019 ?)

Commissioning and Observation run


Living Rev. Relativity, **19**, (2016), 1
DOI 10.1007/lrr-2016-1

LIVING REVIEWS in relativity

Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO and Advanced Virgo

This review shows prospect of observation scenario, but NOTHING of details of KAGRA.
It will be revised before O2.

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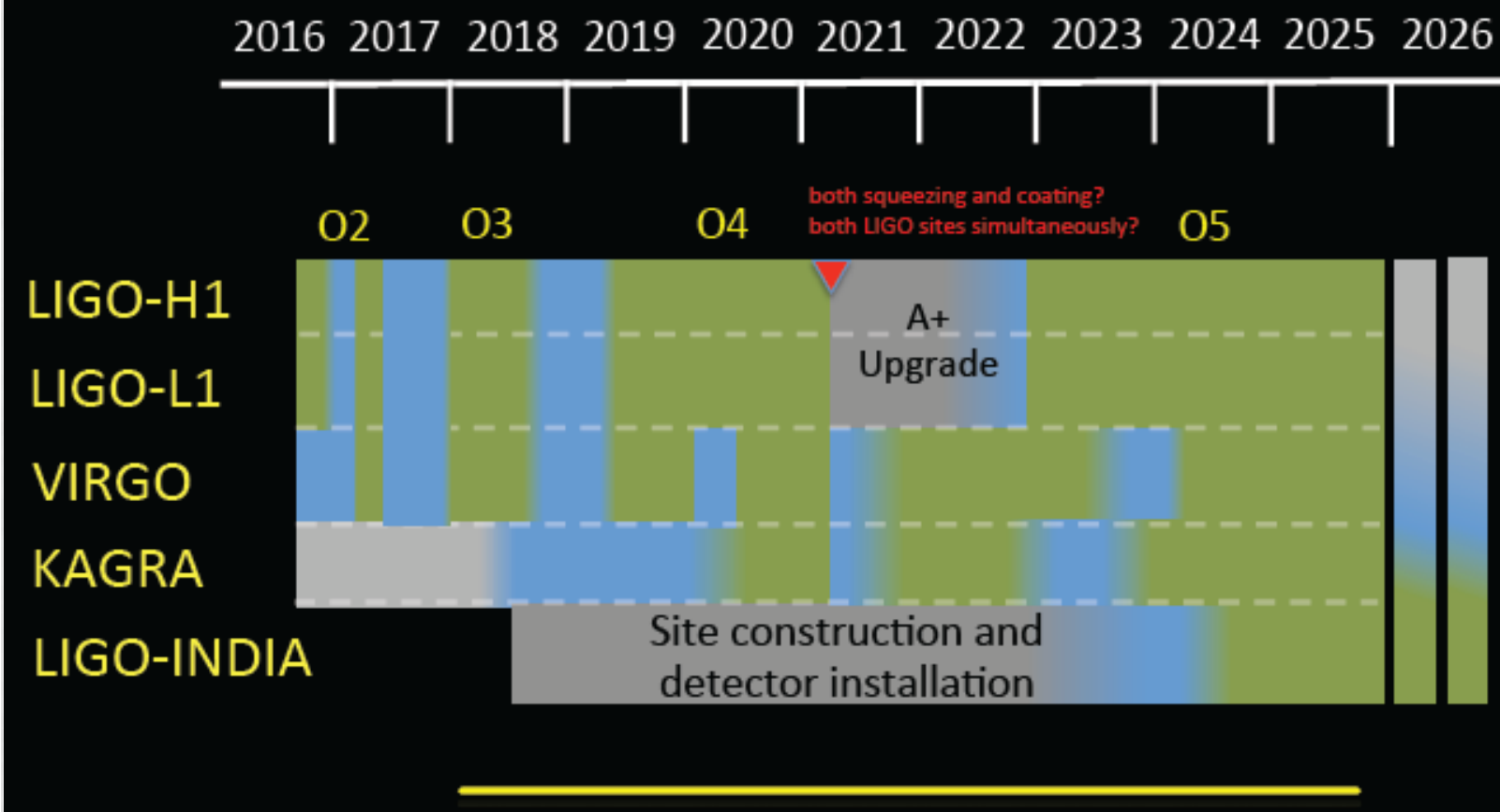
By Lisa Barsotti

Plausible world-wide observing scenario for the next decade

Observing time
Commissioning time
Downtime for upgrades



GOOD FINDINGS

- The beam went back and forth the 3-km X/Y arms
- Acquired tidal and environmental sensors data
- Type-Bp' was stable enough for 3-km Michelson
- Controlled the ETMs via 3-km RFM network
- Observation shift worked well without big trouble
- Data management also worked very well

- Many people enjoyed the integration, commissioning, and operation of the large scale interferometer (with some struggle)

2. Recent topics

(1)Cryogenics : Sapphire suspension

Finally, Hydroxide Catalysis Bonding (HCB) was applied between sapphire bulk (as dummy mirror) and sapphire ears (August 2016). We wait until middle of September for curing.

European colleagues (ELiTES) supports development of sapphire suspension.

HCB(with sodium silicate solution) : Glasgow
Jig for HCB : Perugia

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2. Recent topics

(1)Cryogenics : Sapphire suspension

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HCB(with sodium silicate solution) : Glasgow
Jig for HCB : Perugia

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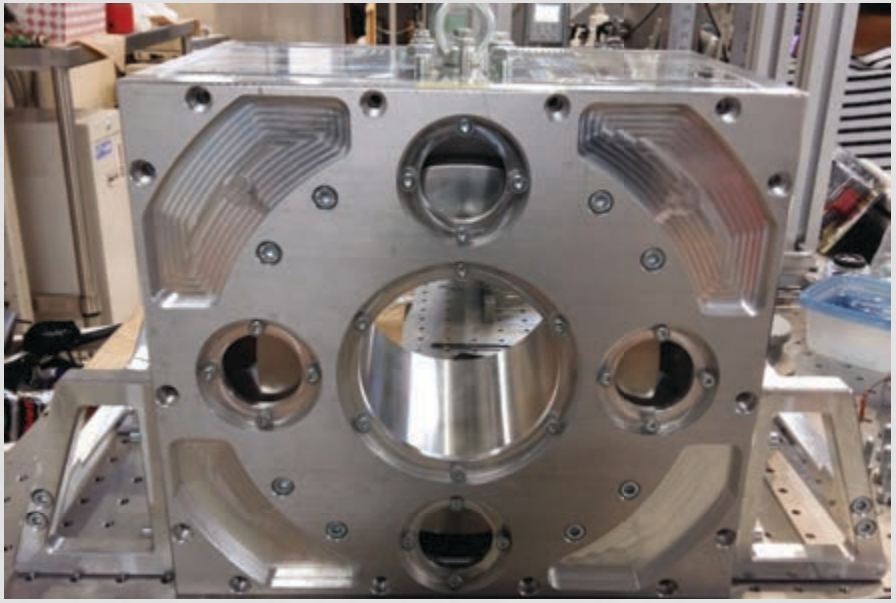
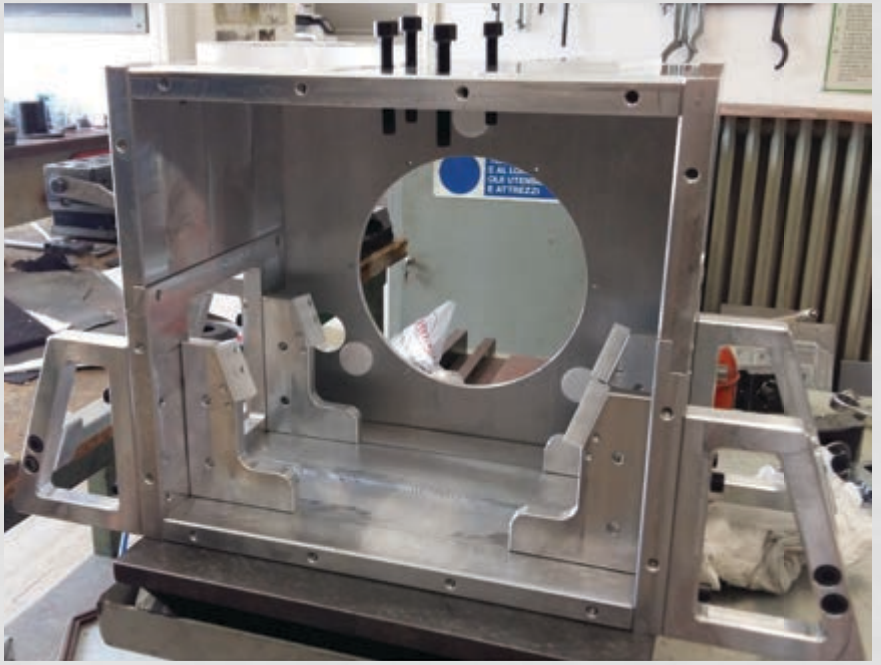
BONDING JIGS FOR KAGRA MIRRORS

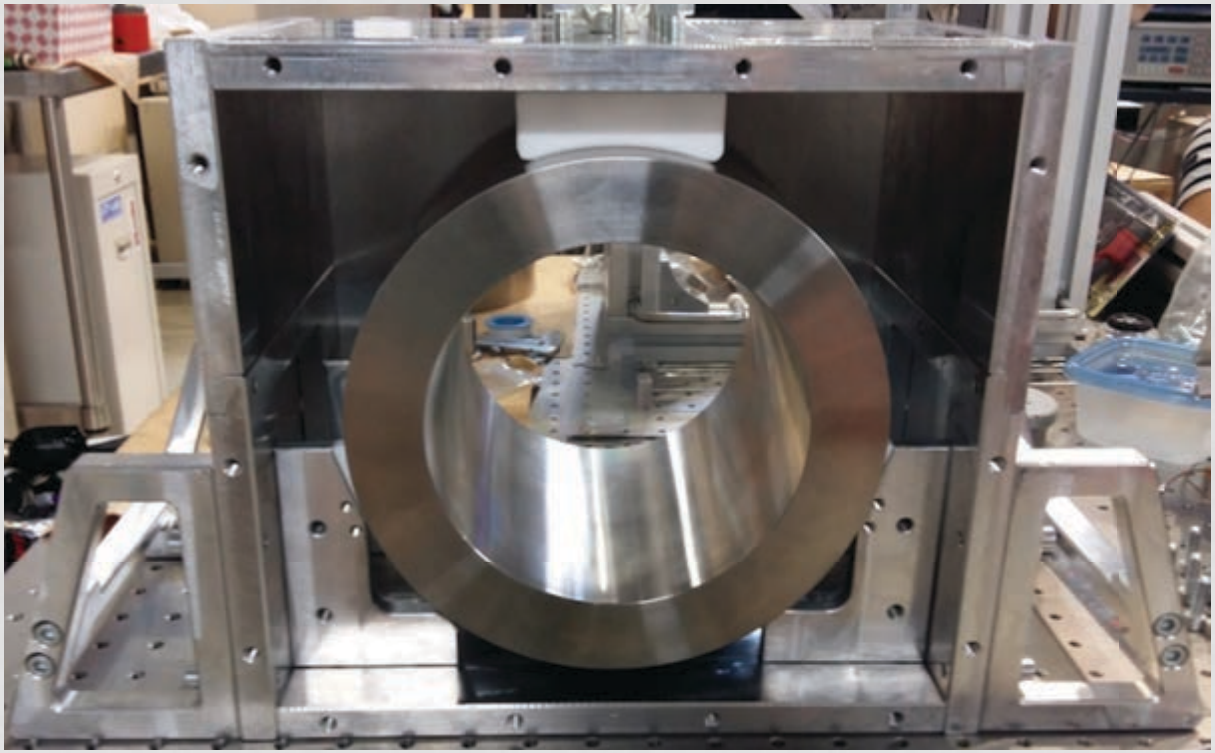
- Ear position very important for suspensions
- KAGRA will use similar jig to Adv. Virgo
- KAGRA bonding jigs developed in collaboration with U. Perugia





BONDING JIGS FOR KAGRA MIRRORS

- Mirror is pressed on all sides by teflon
- The box is rotated to rest on the handles during bonding
- Handles parallel to mirror flats
- Ear fixed in all degrees of freedom during bonding



2. Recent topics

(2)Underground site
Seismic motion, water problem, water seismic motion, water GGN, magnetic field, geophysics interferometer

F. Frasconi *et al*.,
Meas. Sci. Technol. 25 (2014) 015103.

D. Chen *et al*.,
Classical and Quantum Gravity 31(2014) 224001.

2. Recent topics

Drain of spring water in KAGRA tunnel

Basic concept

No water flow around Test-Mass Mirrors

Distance between water flow and mirror is 100m.
(According to CLIO experience, it is enough)

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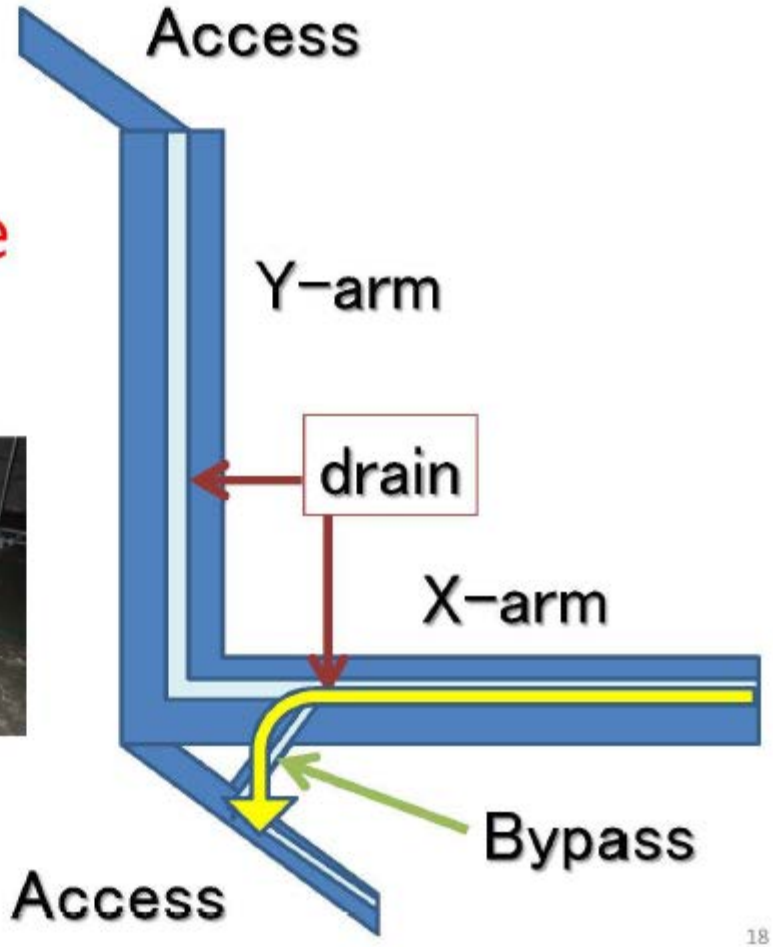
Drain of spring water in KAGRA tunnel

Water discharge for X-arm



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Drain of spring water in KAGRA tunnel

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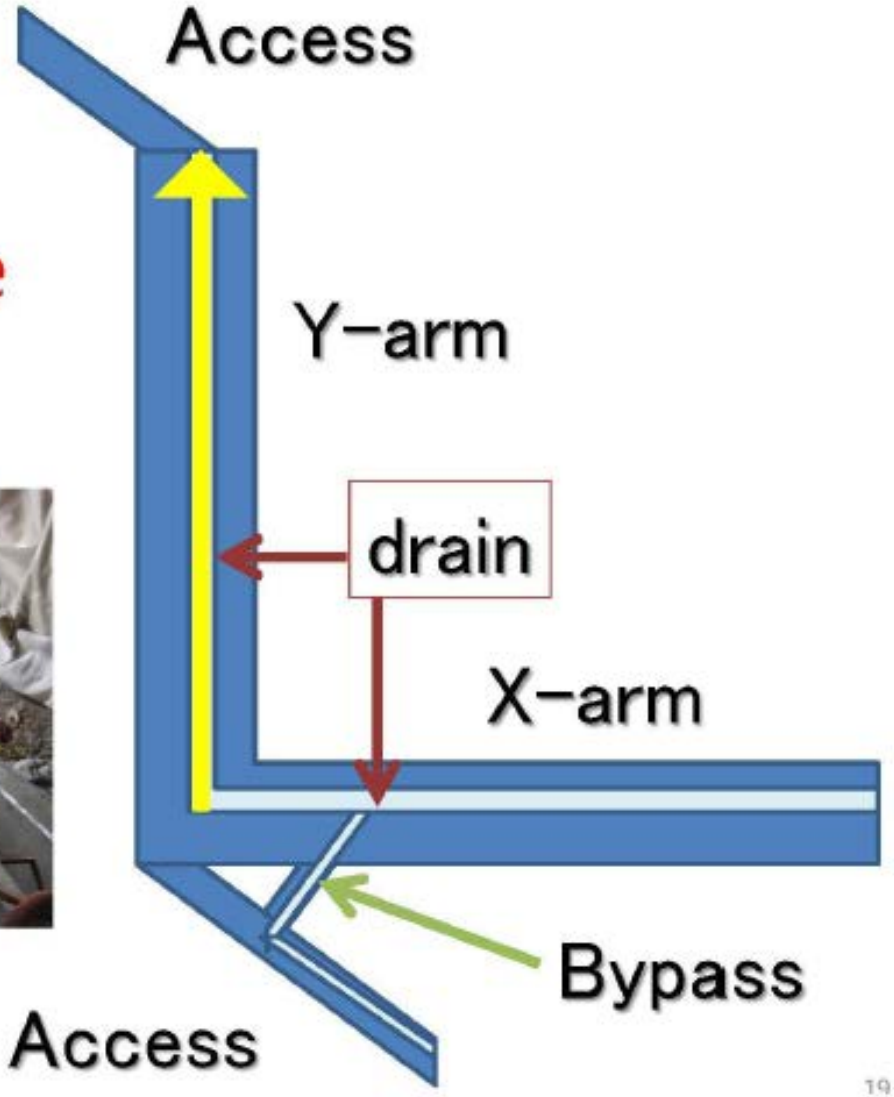
Drain of spring water in KAGRA tunnel

Water discharge for Y-arm 1



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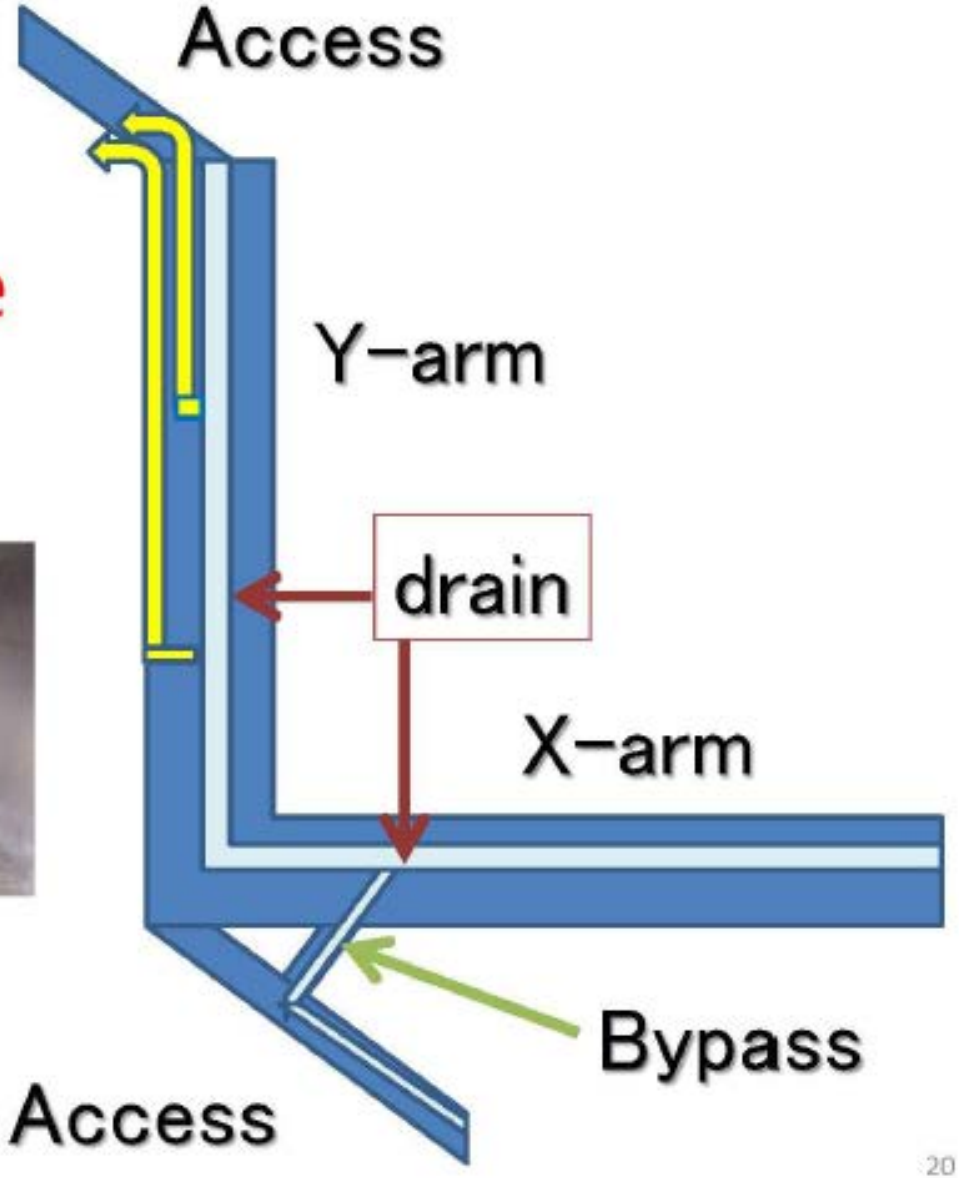
Drain of spring water in KAGRA tunnel

Water discharge for Y-arm 2



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Drain of spring water in KAGRA tunnel

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Drain of spring water in KAGRA tunnel

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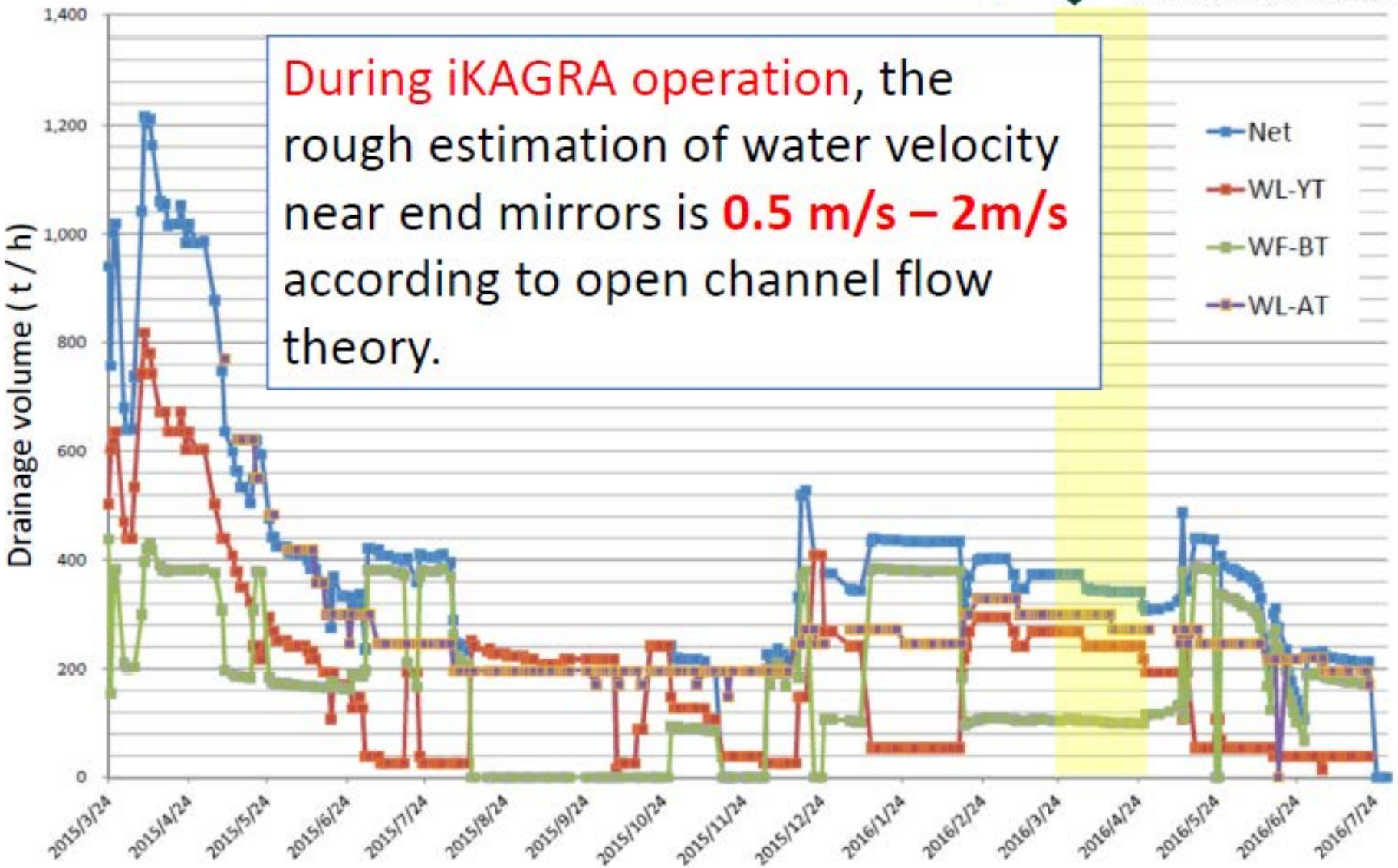
Drain of spring water in KAGRA tunnel

By 神岡鉱業株式会社 KAMIOKA MINING AND SMELTING CO.,LTD

During iKAGRA operation, the rough estimation of water velocity near end mirrors is **0.5 m/s – 2m/s** according to open channel flow theory.



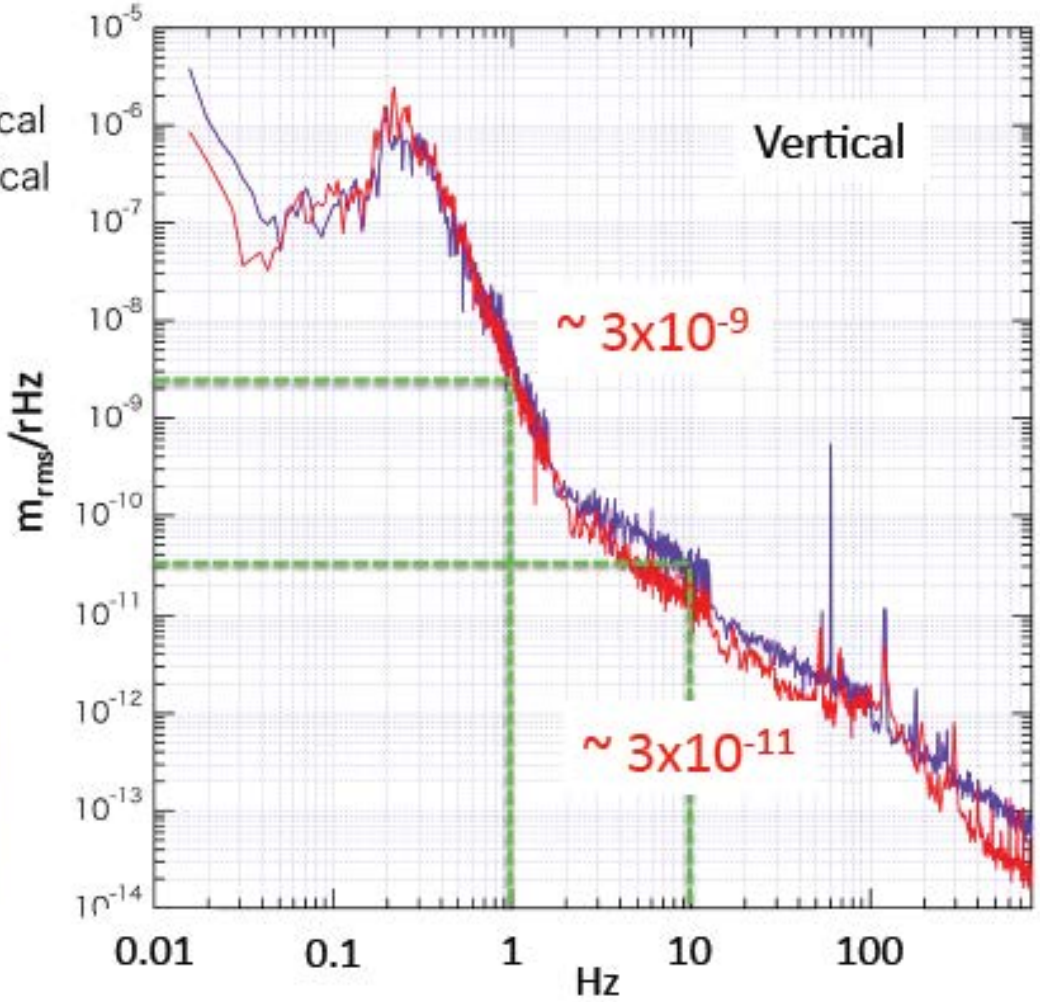
2. Recent topics

Result of Seismic Vibration Measurement at Y-end (1)

- X-end vs. Y-end -

Concrete Floor at Y-End, Vertical
Concrete Floor at X-End, Vertical

Measured by Seismometer

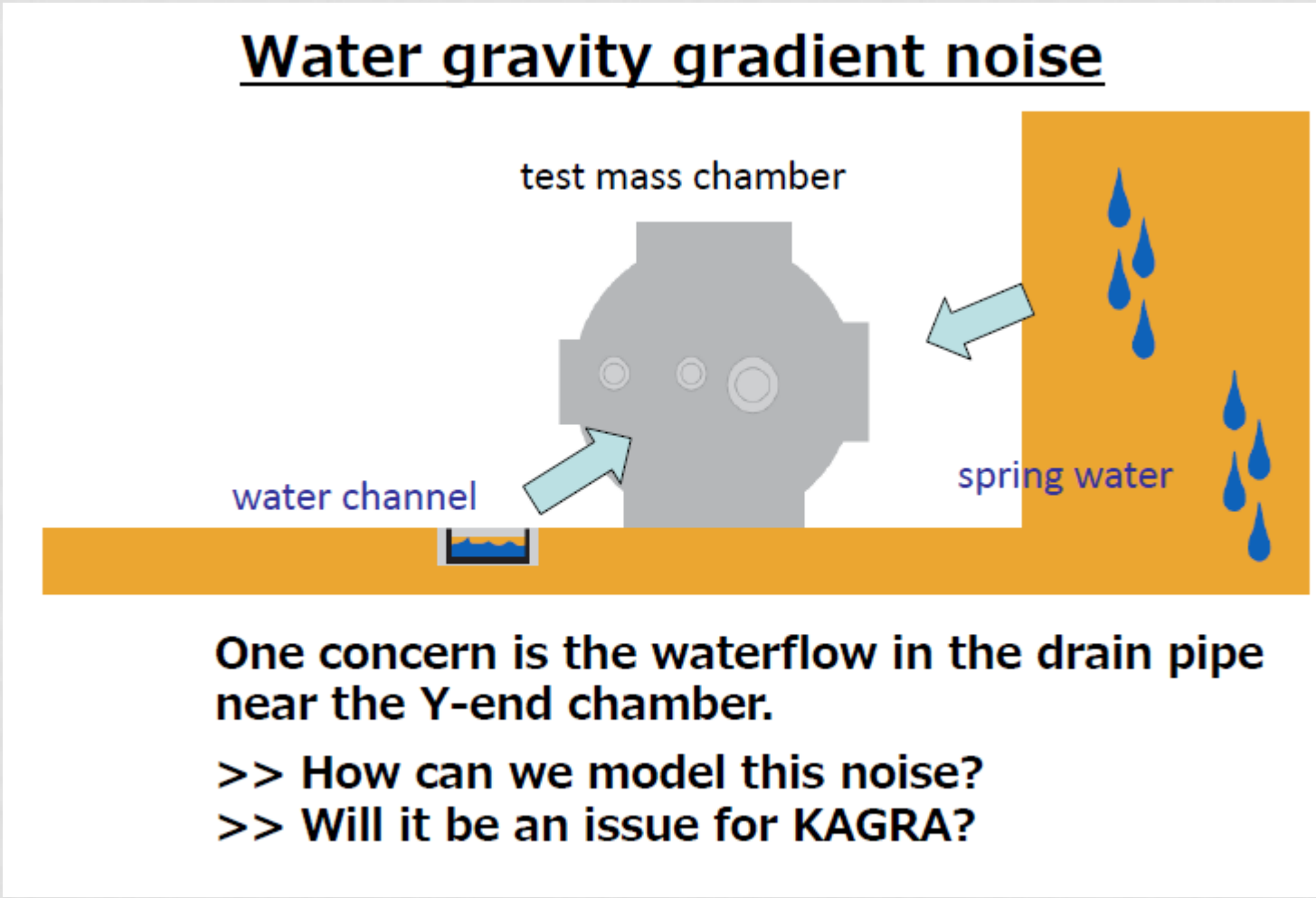


Measured spectrum is comparable with our expectation.

Seismic vibration at Y-end was little bit larger than that at X-end over 1Hz.

2. Recent topics

Water gradient gravity noise by water



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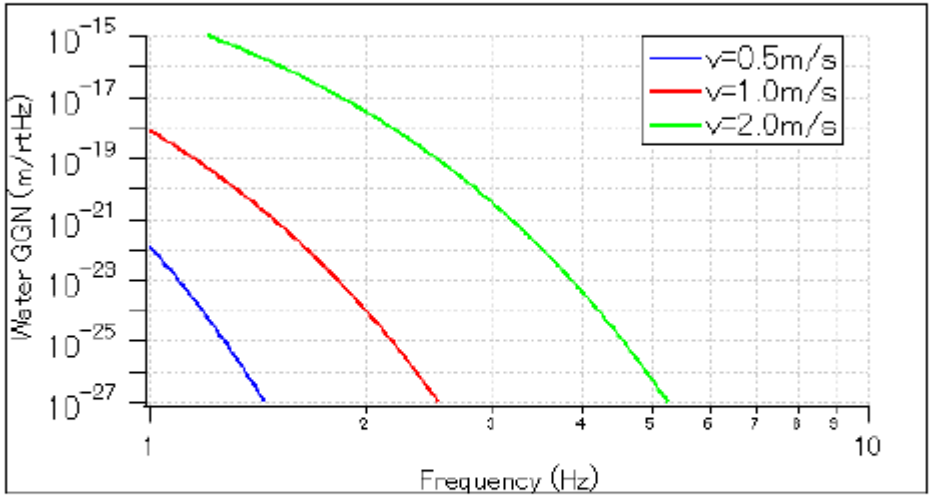
2. Recent topics

Water gradient gravity noise by water

Displacement noise spectrum

We assume w=50cm, H=2m, a=1cm, b=5mm.



With this model, the water GGN limits the KAGRA sensitivity only if v exceeds ~10m/s.

Or if the water surface moves as fast, GGN will also appear in the observation band.

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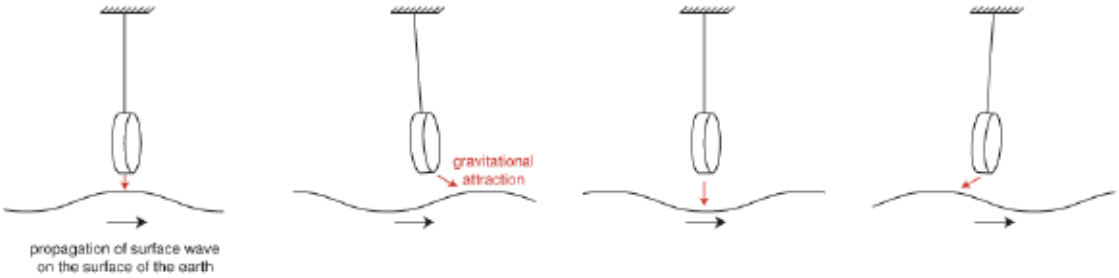
2. Recent topics

Water gradient gravity noise by water

Schedule and Strategy

- Current
  - One-day sampling total water measurement by Kamioka mine co.
  - 5-min sampling water-pond measurement at several points
- - Dec. 2016
  - Real-time imaging water-pond measurement system
    - Budget: Shikano group at IMS, NINS
- - Aug. 2017
  - Upper-bound estimation of water GGN at X and Y end mirrors
    - Rough estimation of water velocity, turbulence, and surface according to open channel flow theory including phenomenological modelling.



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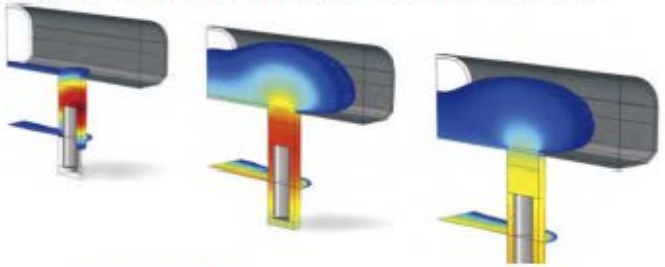
2. Recent topics

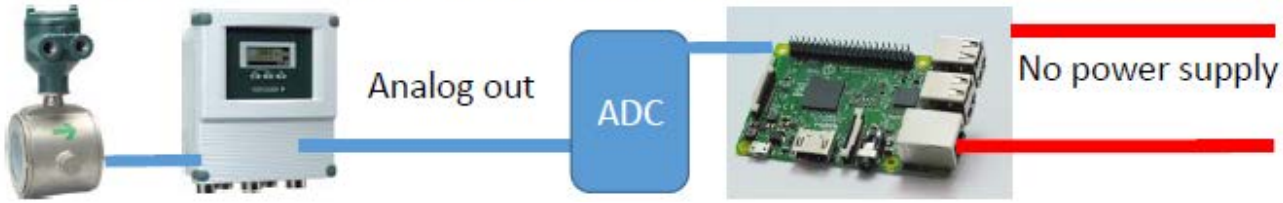
Water gradient gravity noise by water

Schedule and Strategy

- Aug. 2017 –
  - If the water GGN is serious for KAGRA sensitivity,
    - Real-time monitoring system should be planned.
    - Detailed modeling of water GGN
      - Finite-element method modeling by Comsol Subsurface Flow Module



- Missing issue:
  - No real-time monitoring system at WF-BT
    - Additional electronical supply construction at Mozumi entrance
    - No network system at Mozumi entrance -> Cheap SIM? 10,000 JPY / year



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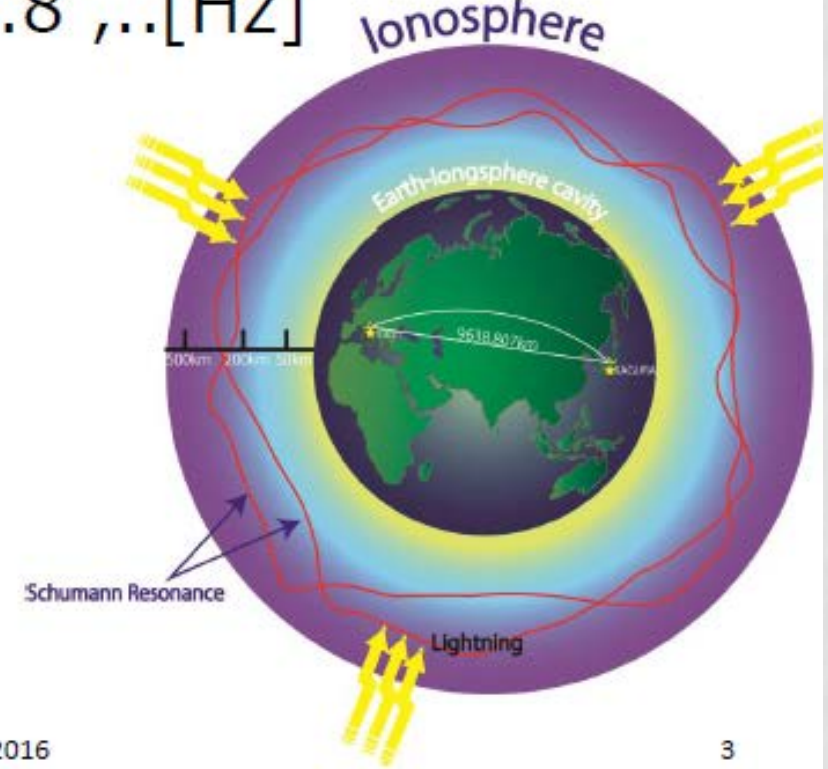
2. Recent topics

(2)Magnetic field (Schumann resonance)

- Global electromagnetic resonance
  - Earth's surface – Ionosphere cavity
  - Freq: 7.8 , 14.3 , 20.8 ,..[Hz]
  - Amp: ~1 [pT]
- Excited by lightning
  - 100 events / sec
- High coherence



F2F meeting 2016 3

2. Recent topics

(2)Magnetic field (Schumann resonance)

Schumann resonance will be an issue in stochastic analysis.
Collaboration between KAGRA and Virgo is investigating.

KAGRA site

Villa Cristina ~ 10km from VIRGO

2. Recent topics

(2)Magnetic field

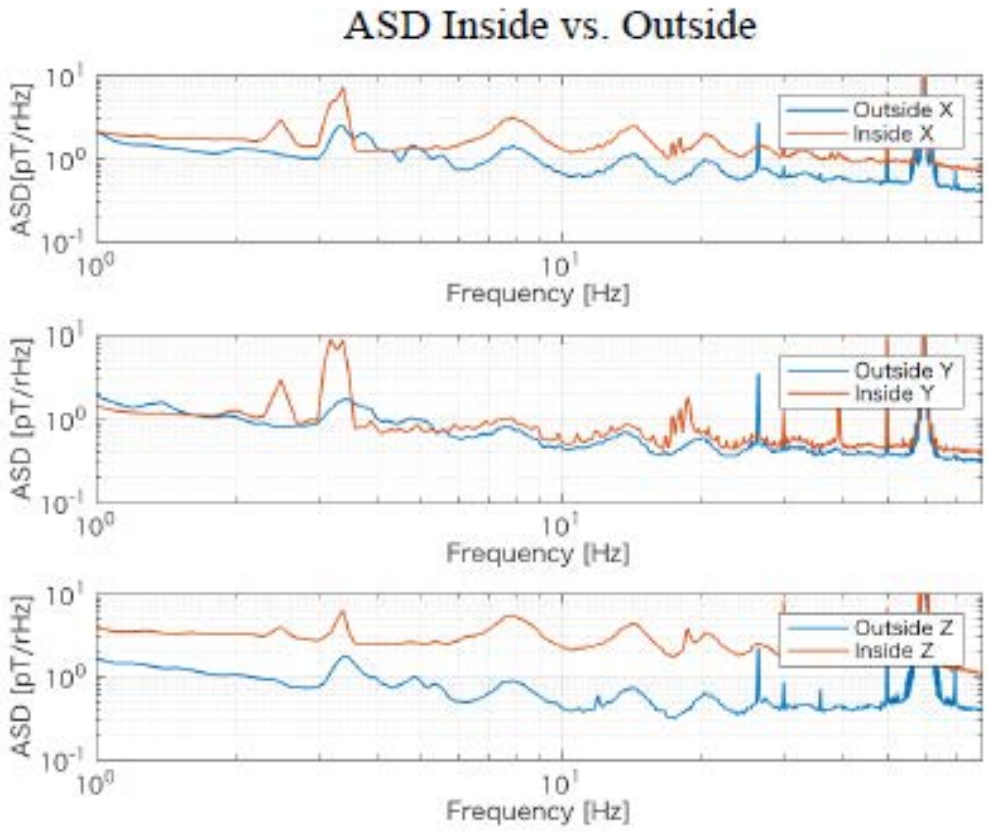
■ Result

Magnetic field inside the tunnel

is larger than outside

■ Reason

?????????



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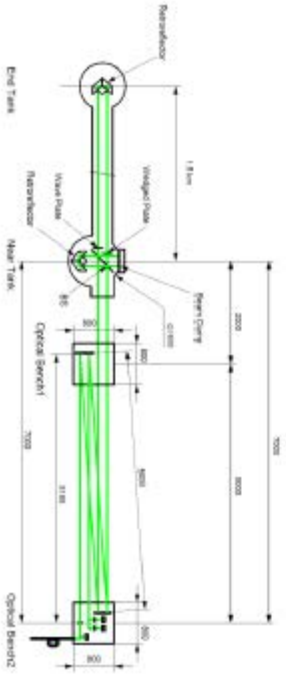
2. Recent topics

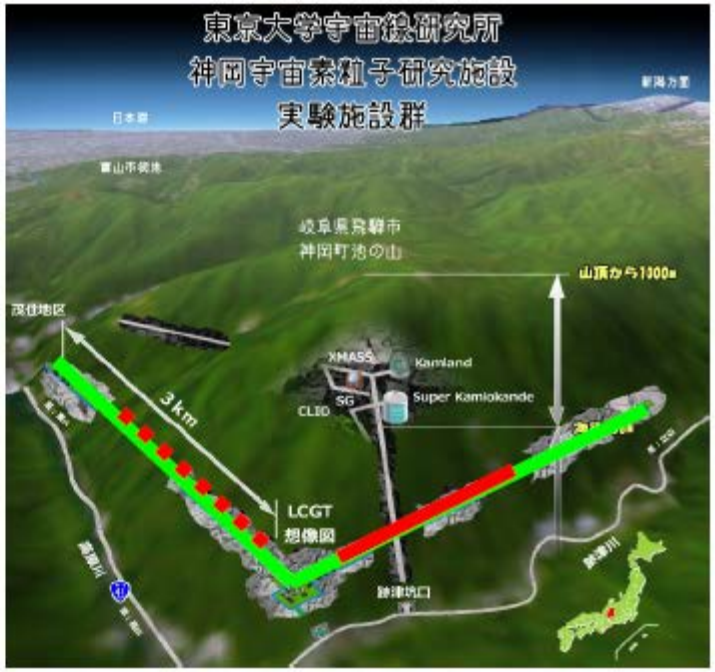
Geophysics interferometer

Geophysics interferometer

Strain sensitivity	3×10^{-13}
Baseline length	1500m
Vacuum pressure	1×10^{-4}Pa
The number of GIF	2 (X and Y, vacuum), 1 (X, interferometer)



Geophysics Interferometers along KAGRA



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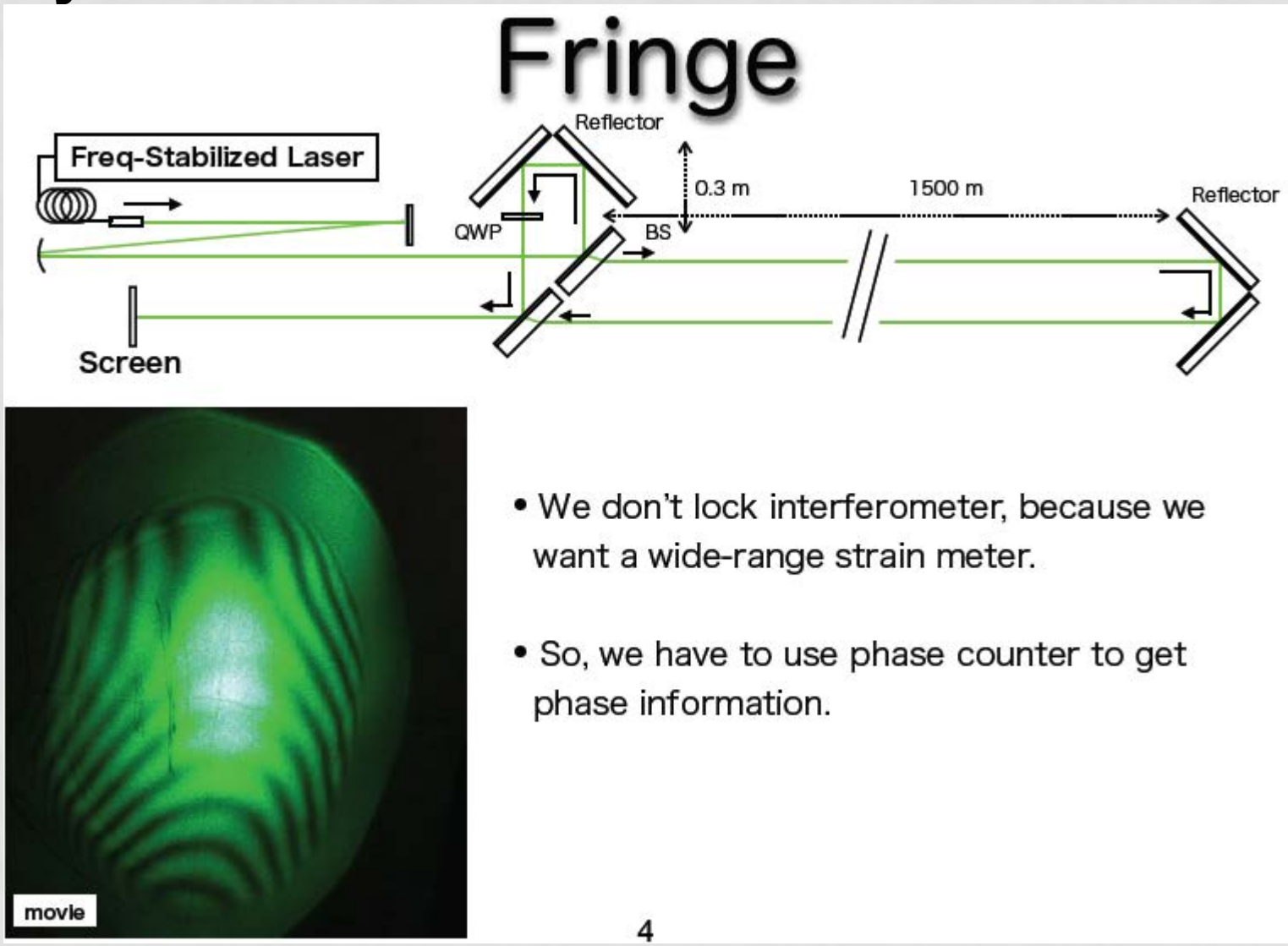
2. Recent topics

Geophysics interferometer



- We don't lock interferometer, because we want a wide-range strain meter.
- So, we have to use phase counter to get phase information.

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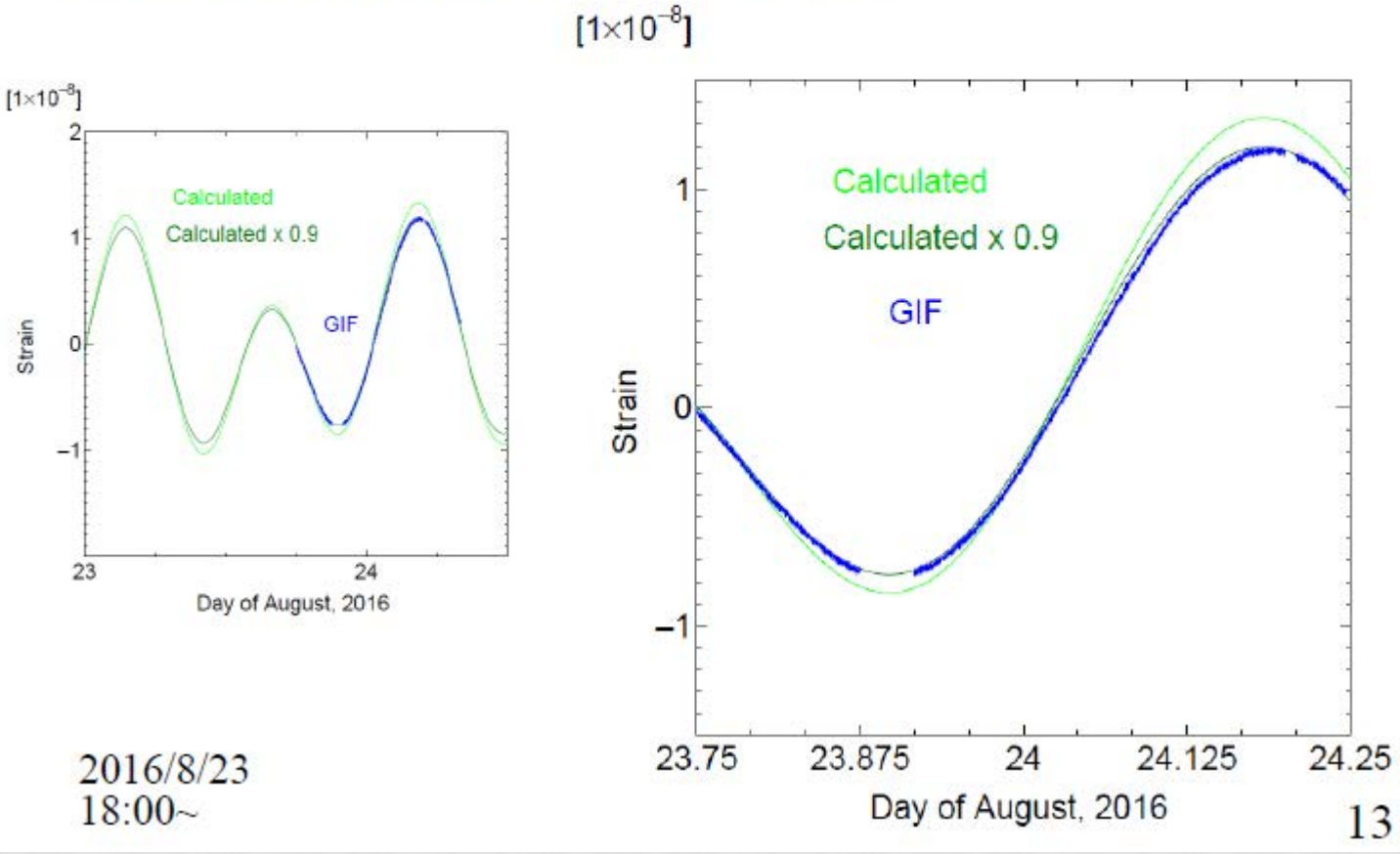
2. Recent topics

Geophysics interferometer

By averaging the phase, long-term strain signal can be obtained. Observed tides had slightly different amplitudes from the calculation, however factor 0.9 (probably topographic effect) of the calculation agreed well with the observation.



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