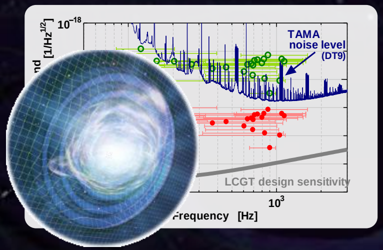
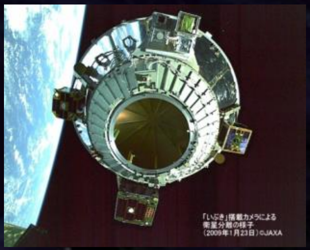
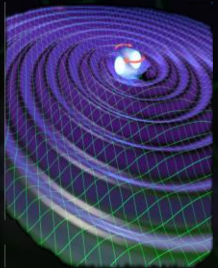


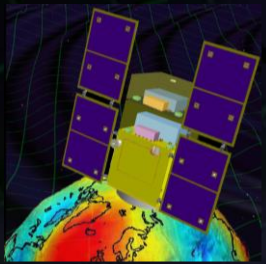


The GW research in Japan

- Current Status of KAGRA -

Masaki Ando (Univ. of Tokyo / NAOJ)
on behalf of the KAGRA collaboration





KAGRA Collaboration

KAGRA collaboration:
~250 members from
~60 Universities or
Institutes

Designed by S. Miyoki

Outline

- KAGRA Overview
- iKAGRA status
- Planning for bKAGRA

KAGRA（かぐら）

Large-scale Cryogenic Gravitational-wave Telescope

2nd generation GW detector in Japan

Large-scale Detector
- Baseline length: 3km
- High-power Interferometer

Cryogenic interferometer
- Mirror temperature: 20K

Underground site
- Kamioka mine, 1000m underground

Goal of KAGRA

- Observe more than 1 event/yr GW event with 90% probability.
- Start observation in FY2017.

⇩

- Most promising GW source would be NS binaries.

We need

(i) Observation range: ≧ 115Mpc (sky-average)

(ii) Duty factor : ≧ 80%

for 1 event/yr detection rate with 90% probability,

※ Obs range with fundamental noise shall be 128Mpc+ with a safety factor for technical noise being 10%.

Strategy of KAGRA

- Underground facility to reduce seismic noise.
  - More than 300m from ground surface.
  - Possible reduction of Newtonian noises.

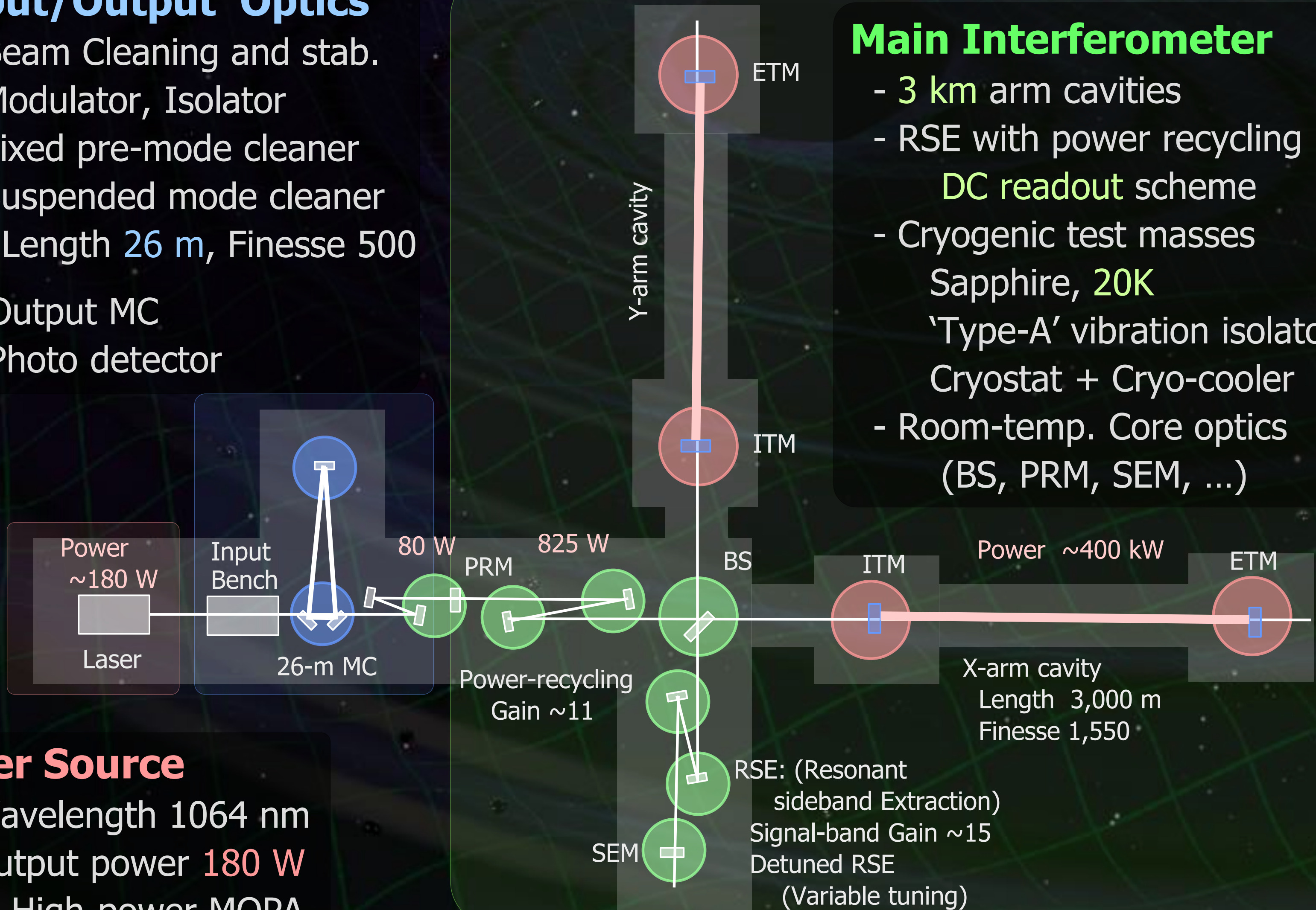
- Cryogenic operation to reduce mirror thermal noise.
  - 23kg Sapphire substrates for high quality cryo-mirrors.
  - 1.6mm Sapphire rod suspensions for heat extraction.
  - Decent input power to cool down the mirrors (55-80W).

- Quantum noise reduction
  - Slight SRC detuning to increase obs range of NS binaries.
  - Broad bandwidth for high parameter estimation accuracy.
  - DC readout with optimal readout phase.

KAGRA Configuration

Input/Output Optics
- Beam Cleaning and stab.
- Modulator, Isolator
- Fixed pre-mode cleaner
- Suspended mode cleaner
  Length 26 m, Finesse 500
- Output MC
- Photo detector

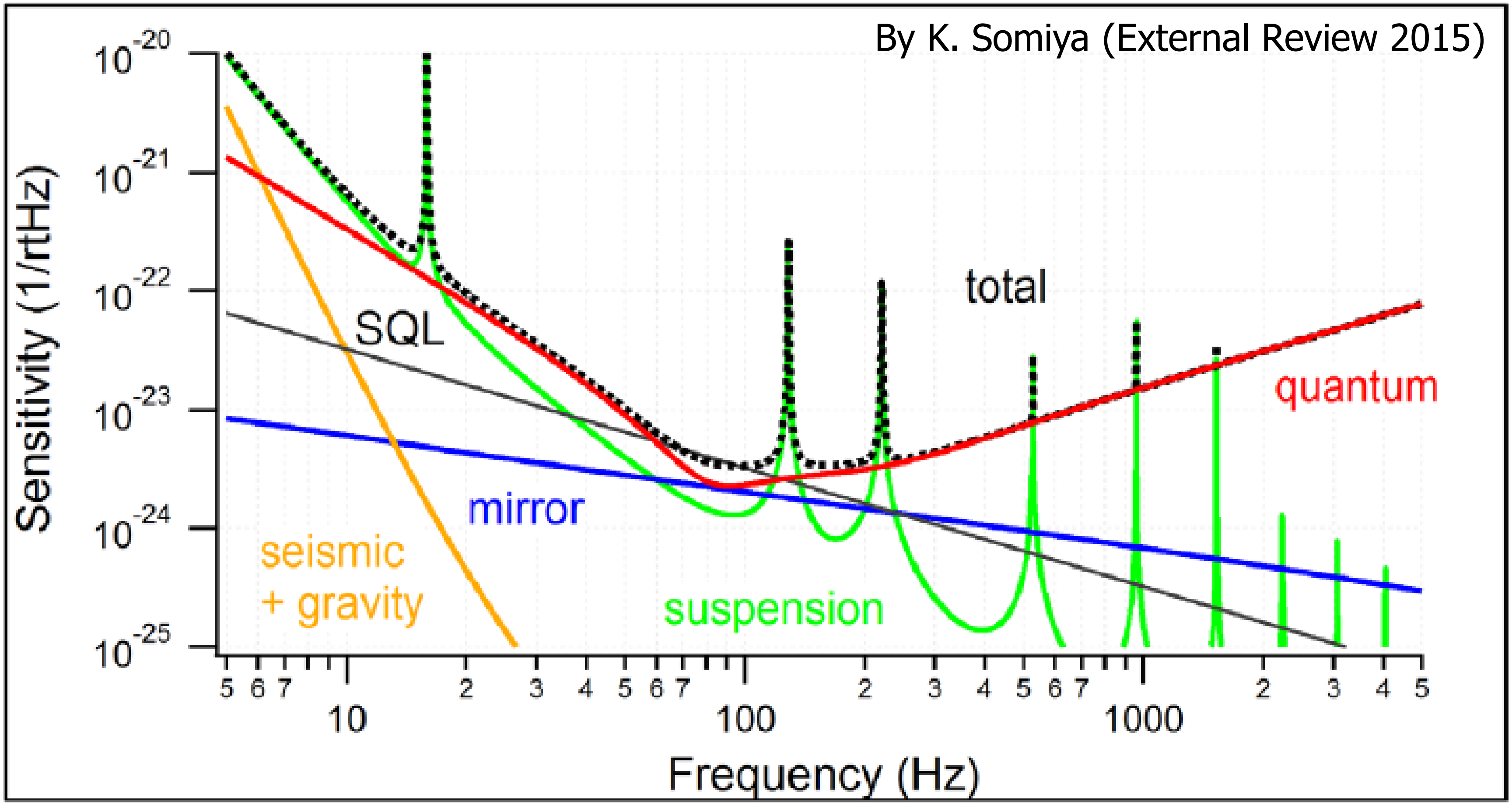
Main Interferometer
- 3 km arm cavities
- RSE with power recycling
  DC readout scheme
- Cryogenic test masses
  Sapphire, 20K
  'Type-A' vibration isolator
  Cryostat + Cryo-cooler
- Room-temp. Core optics
  (BS, PRM, SEM, ...)



Laser Source
- Wavelength 1064 nm
- Output power 180 W
  High-power MOPA

KAGRA Fundamental Sensitivity Limit

Observation range of 148Mpc for NS binary mergers.
→ Satisfies the requirement (128Mpc+)



Duty Factor Breakdown

The overall duty factor is 80% → satisfies the requirement

	Loss (days)	Repetition (1/yr)
(A) Maintenance		
long	60	0.5
medium	5	1
short (adjustment)	0.5	12
(B) Malfunctions		
laser exchange	4	0.2
digital system error	4	1
circuit malfunction	4	1
facility accident	4	1
suspension break	50	0.2
data server exchange	1	0.5
local sensor error	1	0.5
(C) Interferometer unlock	0.91 hours/day	

By K. Somiya (External Review 2015)

KAGRA Site

Underground site at Kamioka, Gifu prefecture

Facility of the Institute of Cosmic-Ray Research (ICRR), Univ. of Tokyo.

Neutrino
- Super Kamiokande, Kamland

Dark matter
- XMASS

Gravitational wave
- CLIO, KAGRA

Geophysics
- Strain meter

- 220km away from Tokyo
- 1000m underground from the top of the mountain. (Near Super Kamiokande)
- 360m altitude
- Hard rock of Hida gneiss (5 [km/sec] sound speed)

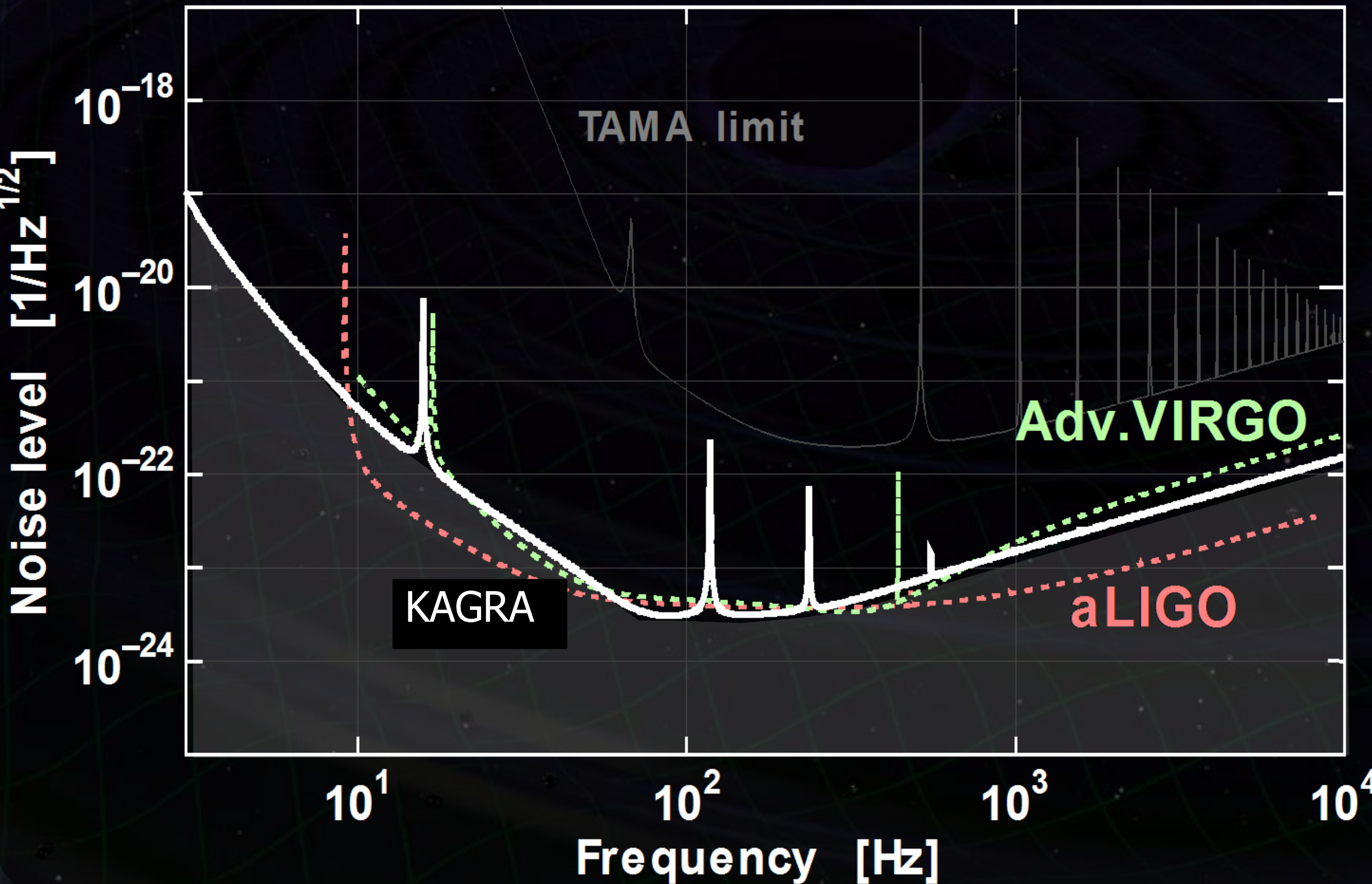
Comparison of 2nd Generation IFOs

KAGRA

	2nd-generation detectors			3rd generation
	aLIGO	**Ad. VIRGO**	**KAGRA**	**ET**
Observation	~ 2015	~ 2016	~ 2017	~ 2026
Site	Surface Hanford, Livingstone (India)	Surface Pisa	Underground Kamioka	Underground 3 IFOs
Baseline	4 km	3 km	3 km	10 km
Obs. Range(*1)	306 Mpc	243 Mpc	237 Mpc (*2)	3 Gpc
IFO config.	Broadband RSE	Detuned RSE	RSE (Variable tuning)	RSE Xylophone
TN reduction	Large beam, Low mech-loss mirror, Thermal compensation		Cryogenic	Cryogenic
1st stage VIS	Active	Passive	Passive	Passive

(*1) Obs. Range for NS-NS binary mergers, Optimal direction and polarization, SNR>8.
(*2) Number may be changed.

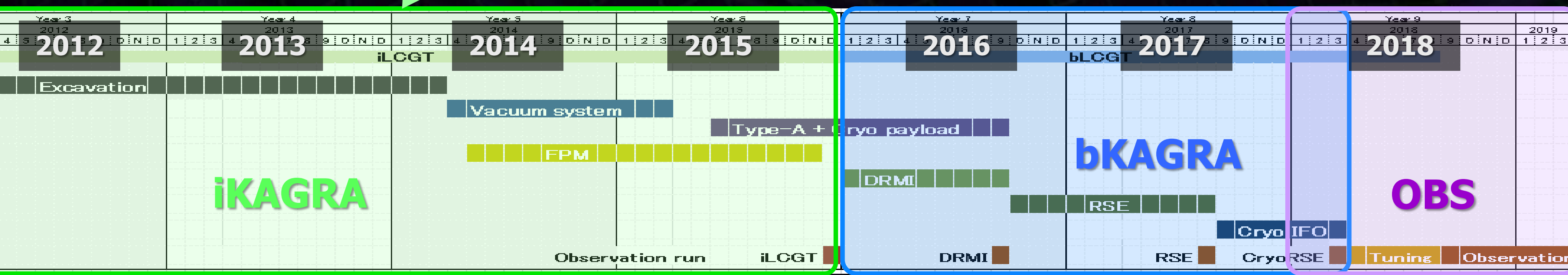
Sensitivity Comparison



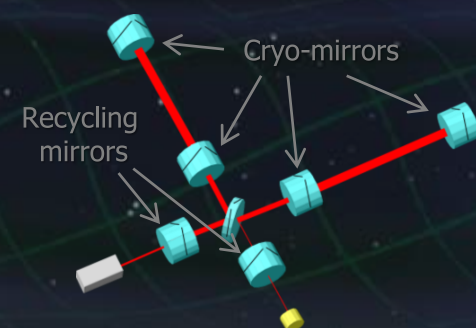
Project Status

KAGRA Overall Schedule

- **iKAGRA** (2010.10 – 2016.3)
  Michelson interferometer
  - Baseline 3km room temp.
  - Operation of total system with simplified IFO and VIS.



- **bKAGRA** (2016.4 – 2018.3)
  Operation with full config.
  - Final IFO+VIS configuration
  - Cryogenic operation.



iKAGRA (Initial KAGRA)

- Scope
  - To confirm the operational scheme of 3-km baseline interferometer, the environmental condition, and layout accuracy inside the tunnel.
  - To gain understandings and experiences necessary for the observation with the final bKAGRA interferometer.

⇩

- Targets

  (1) 1-month obs., no requirement for sensitivity

  (2) Full system test of data acquisition, transfer, and storage.

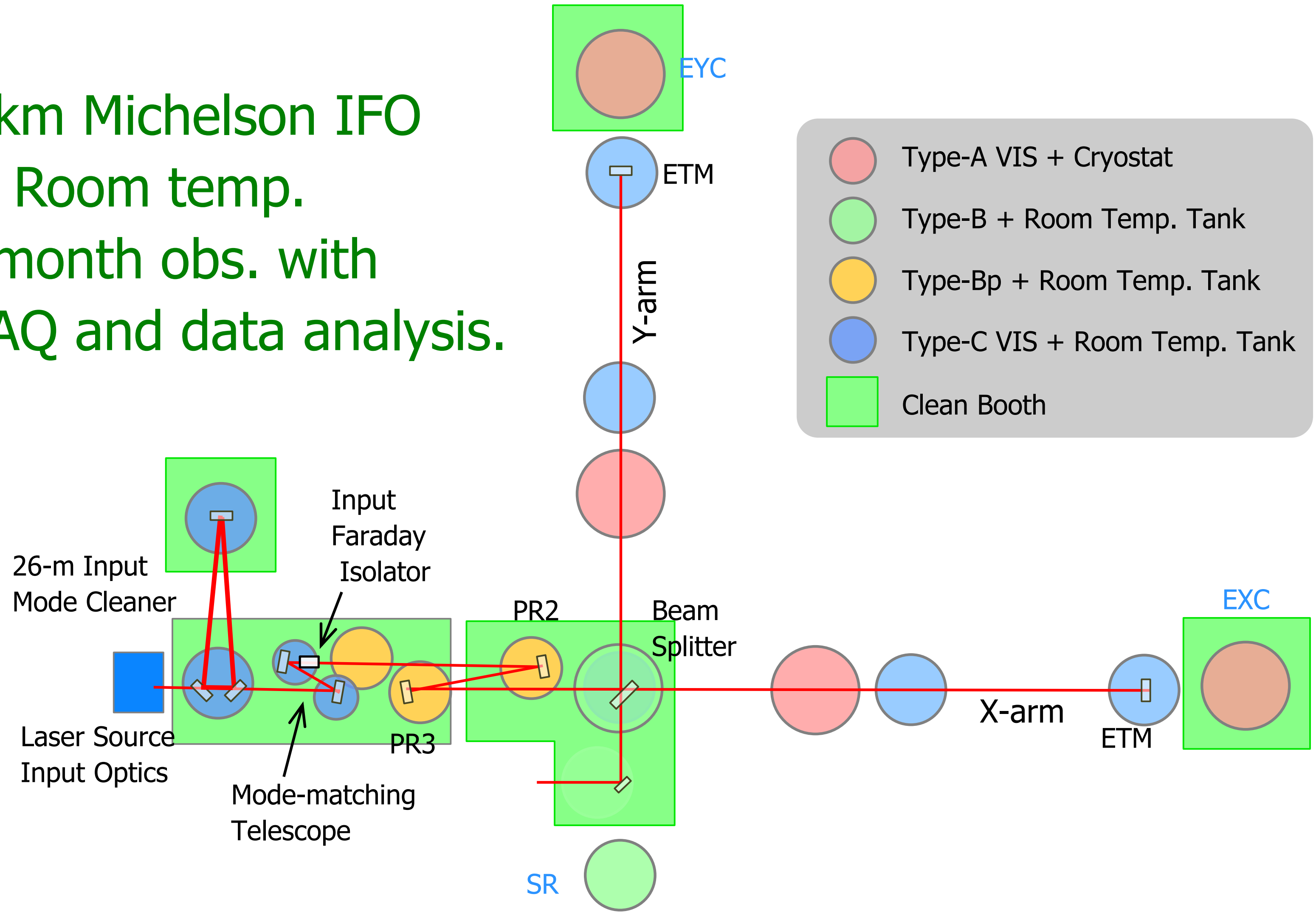
  (3) First data-analysis and test of detector characterization.

  (4) Check the environmental condition and layout accuracy.

  (5) Preparation for cryogenic and vibration-isolation systems.

iKAGRA Configuration

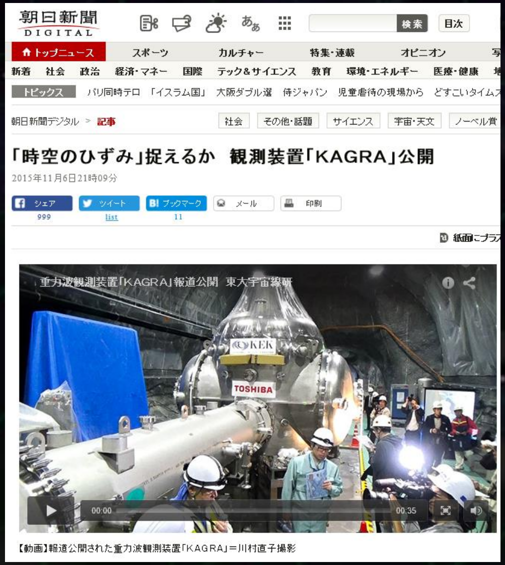
- 3-km Michelson IFO at Room temp.
- 1 month obs. with DAQ and data analysis.



Press Conference and Ceremony

- Press conference and ceremony for the 1st-phase completion of experimental facility (Nov. 6th, 2015).
  → Appear in most of major medias (TV news, Newspaper).

Photo from ICRR Web site



Asahi Newspaper Digital

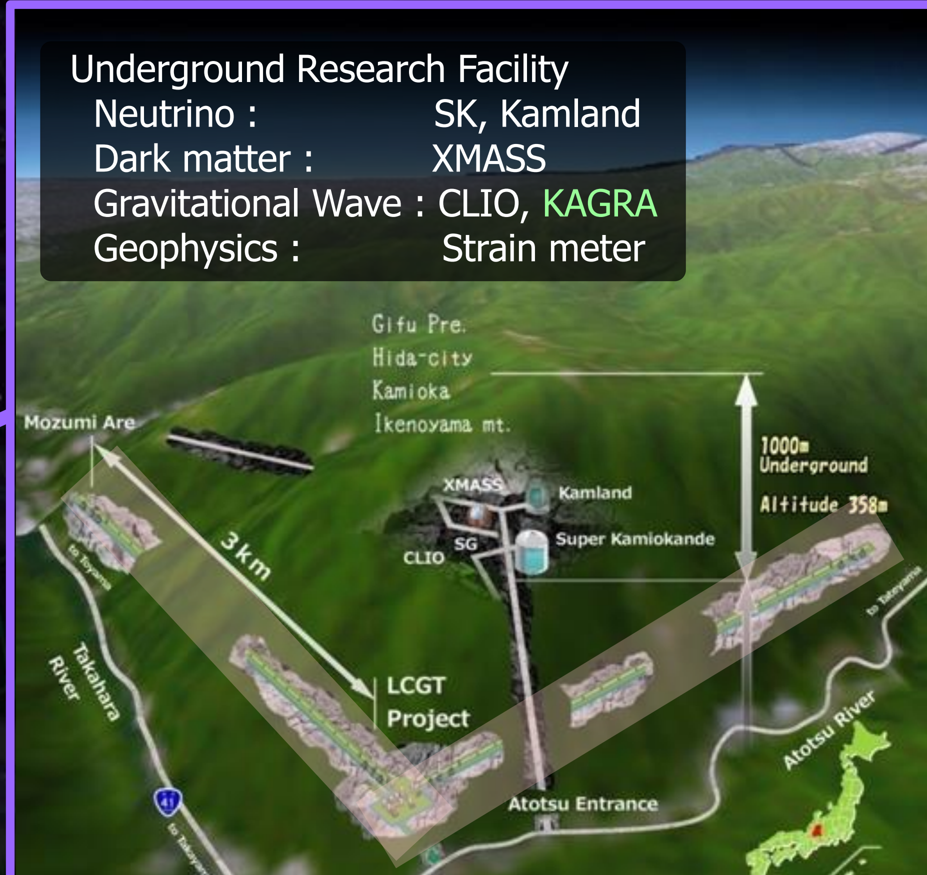
Mainichi Newspaper Web

Short Summary of iKAGRA Status

- Preparation of experimental facility (Tunnel, Facility, Vacuum and Cryogenic systems) is almost completed.
- Installation of Input Optics (Laser source, PMC, Input Mode Cleaner, Input Faraday Isolator) are being finished.
- Test hanging of Vibration Isolation system is mostly finished. Installation to the vacuum tank (PR2, PR3, BS, End Test Masses) will start soon.
- Mirrors for iKAGRA are ready. Auxilliary Optics and Analog Circuits for IFO are being ordered and assembled.
- Digital system, Data Management System are being ready.
  → Data can be monitored at the surface building.
- Data analysis tools are under development.

KAGRA Site

ICRR Kamioka underground site, Gifu prefecture



Map by Google

Tunnel and Vacuum System

- Tunnel excavation finished by March 2014.
- Connection and leak test for 3km Vacuum ducts finished.
  Most of the vacuum tanks are also installed.
- Vacuum tanks installed, except for those for SR and TR.

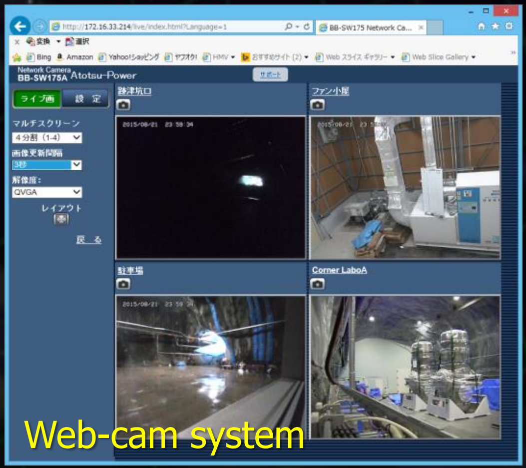
3-km Tunnel and Beam Duct (Photo by S. Miyoki)

Center Cavern (March 2015)

Facility

- Facility construction finished:
  Wall painting, separation wall, Floor, Air flow, Electricity, Crane, Network, Laser clean room, Most of clean booths, Toilet, PHS, Spiral Ladder for 2nd floor, X-end shelter, … .
- Clean booth for SR, ITM Cryostats, and 2nd floor will completed in FY2016.

Atotsu entrance shutter



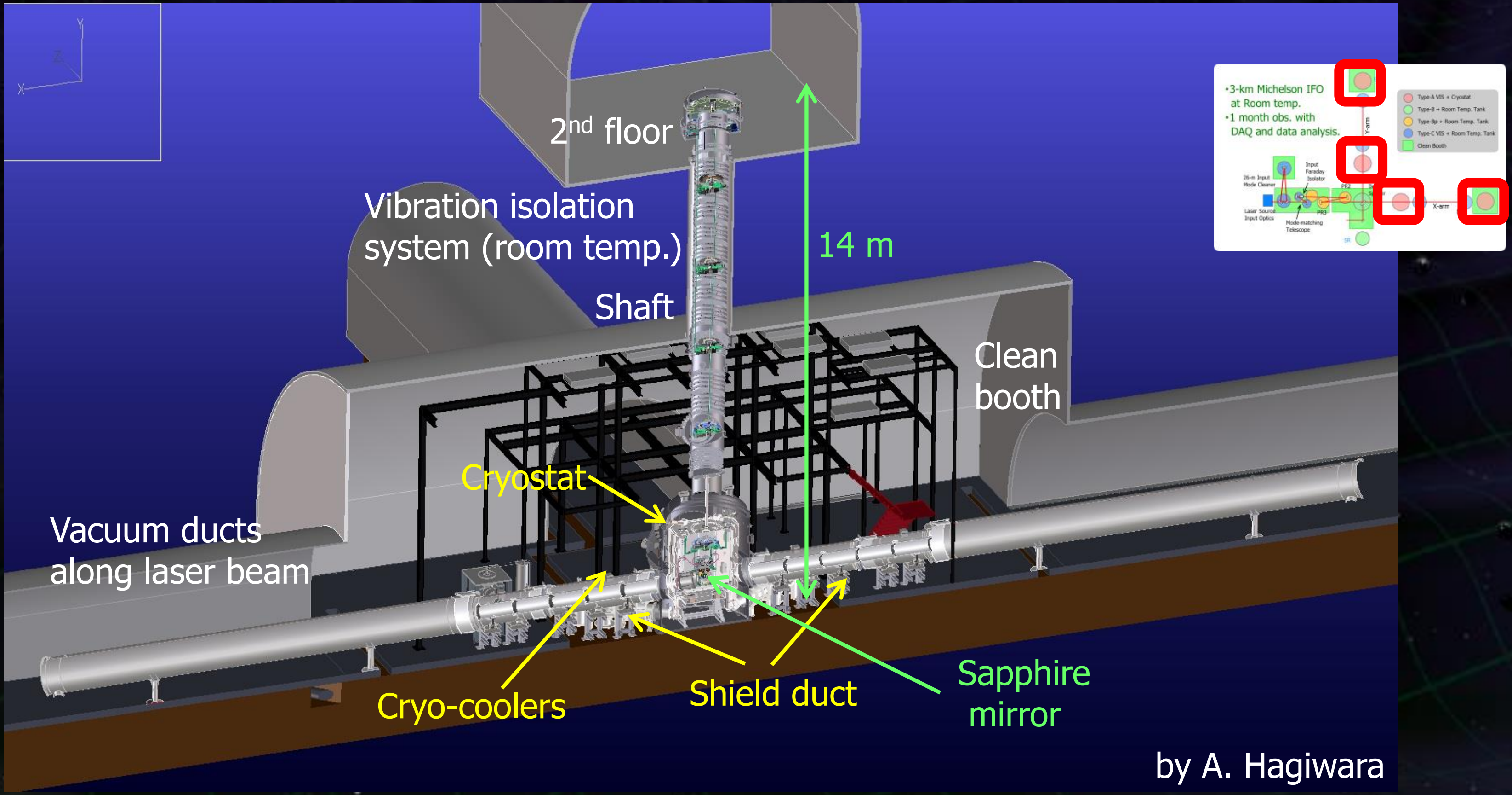
Web-cam system


BS area clean booth

Photo by S. Miyoki

Cryogenic System Design

- 4 cryogenic systems for the main test masses, cooled down to 20K.
- Each comprised of Cryostat, 4 cryo-coolers, and 2 shield ducts.



Cryogenic System

- Installation of Cryostats and cryo-coolers for them were finished. 6 of 8 shield ducts have been installed.
- Under leak test now. → used also in iKAGRA as parts of the vacuum system.
- On-site cooling test of the full system will be in FY2016.

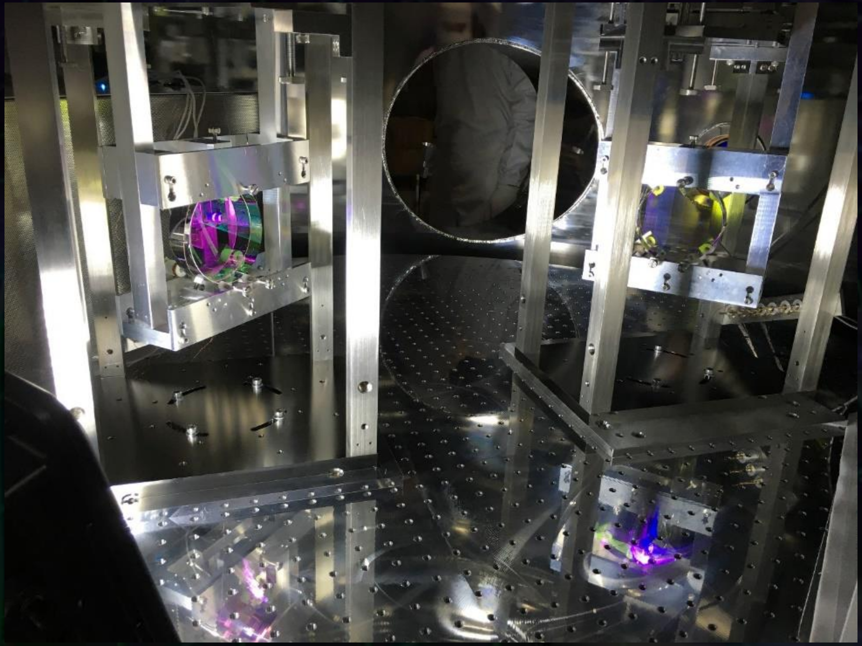
Photo by K. Yamamoto

Photo by S. Miyoki

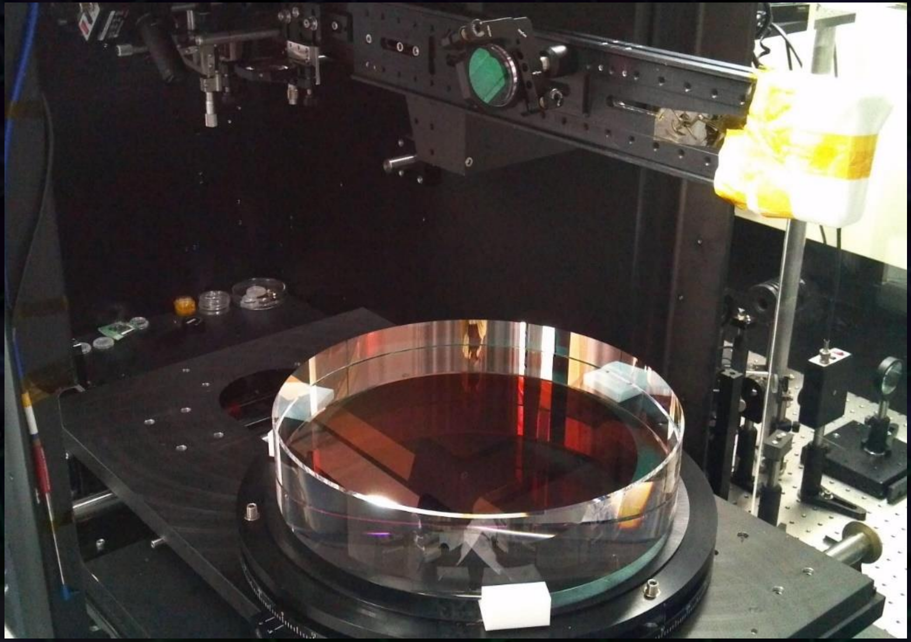
Mirrors for iKAGRA

- iKAGRA optics are completed:
  Silica TMs, BS, PR3, PR2, MC mirrors.

Photos by Hirose



MCi(right) and MCo(left) inside vacuum chamber

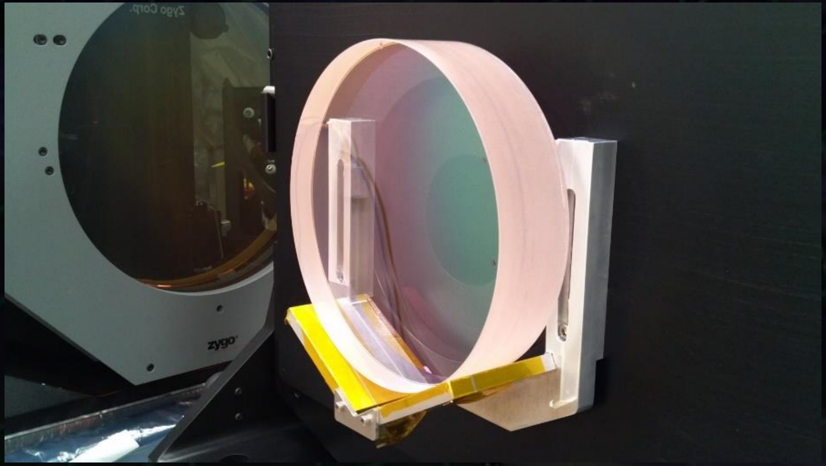


Beam splitter during coating
Characterization (370mm dia)

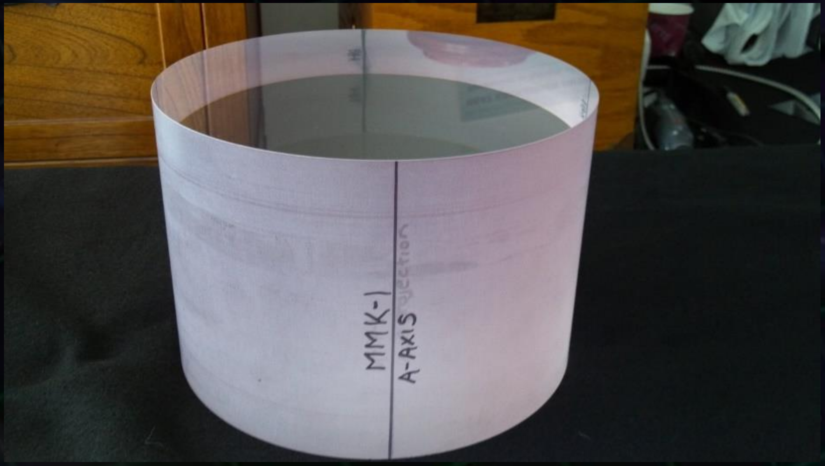
Mirrors for bKAGRA

- Sapphire TMs, PRM, SRM, MMTs are to be done
  → ETMs, PRM, SRM are being polished and all optics will be completed in the next FY.
- Sapphire R&D (test polishing/coating with a 200mm-dia crystal) was successful.

Photos by Hirose



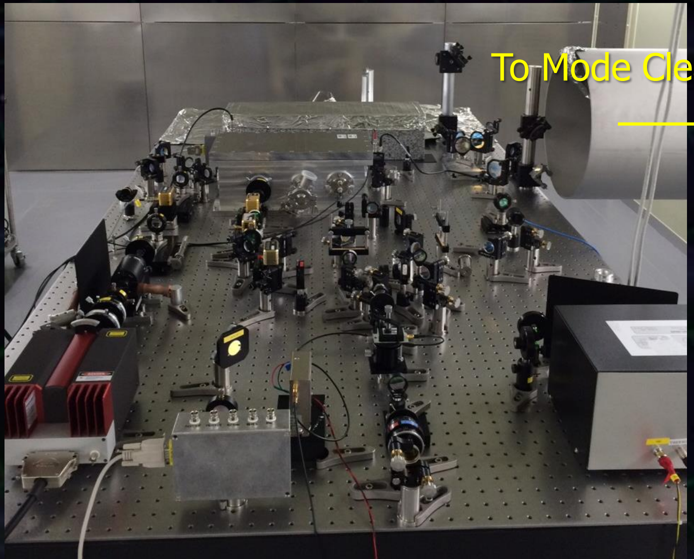
Coated sapphire mirror (test piece) during figure measurement (200mm dia)



A brand-new c-plane sapphire bulk (223mm dia)

Input Optics : Pre-Stabilized Laser

- Pre-stabilized laser
  - Commercial laser source
  - The pre-mode cleaner locked to the laser frequency, from the control room using the digital system.
  - The laser frequency was locked to a fiber ring cavity.
    → Verified that the laser frequency is actually stabilized.



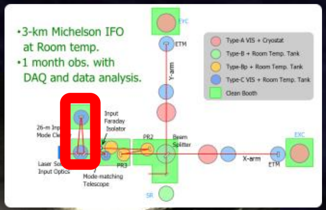
Pre-Stabilized Laser (Dec 2015)

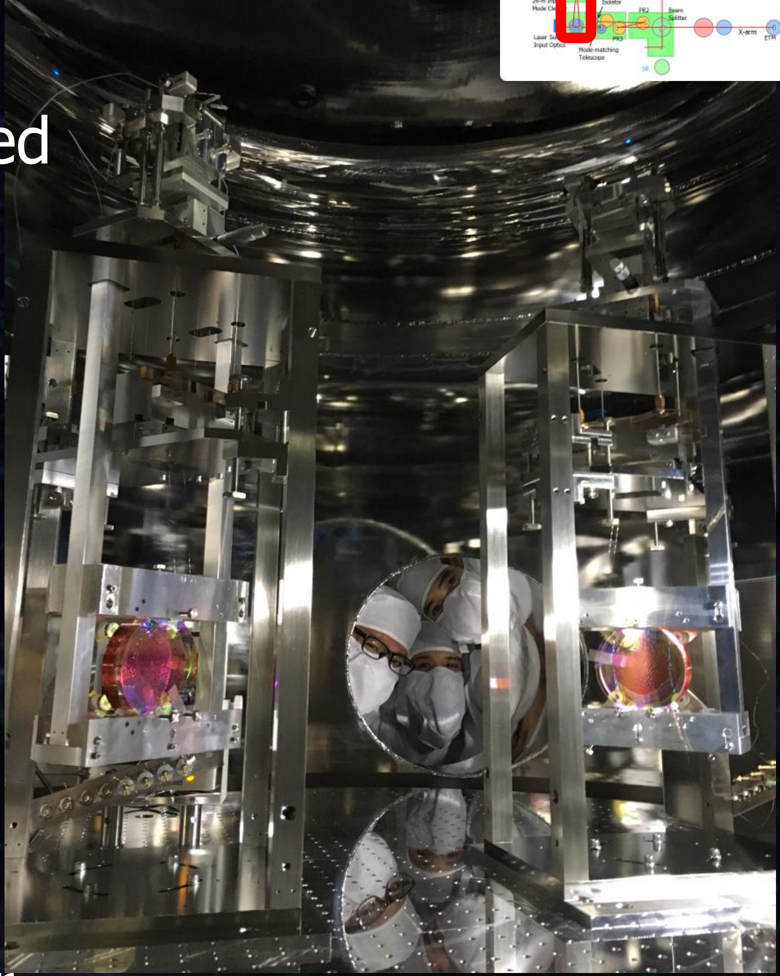
Input Optics : Mode Cleaner and IFI

KAGRA

- Input Mode Cleaner
  - All the three mode cleaner mirrors/suspensions were installed in the MCF and MCF chambers.
  - First contact for all the three MC mirrors was removed.
  - All the optical lever systems were installed.

- Input Faraday Isolator
  - The input Faraday isolator and almost all the related optics were installed in the IFI chamber.

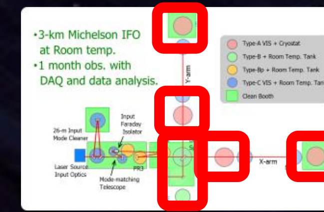




Mode Cleaner Suspension in a vacuum tank (Nov. 2015)

Vibration Isolation Design

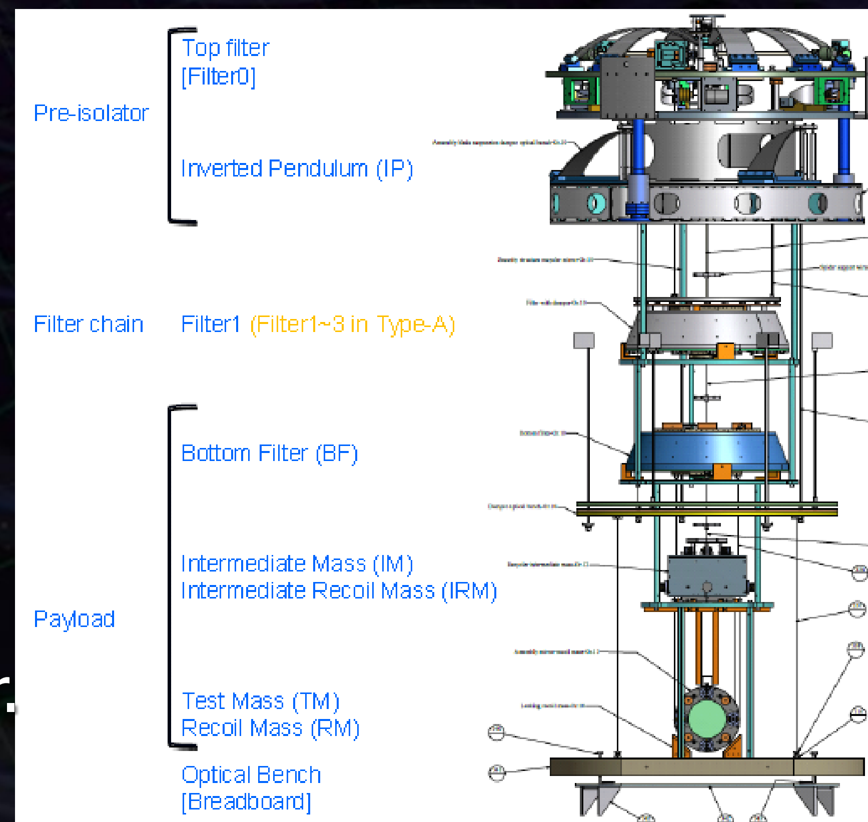
KAGRA



- Type-A (cryogenic test mass) and Type-B (BS and SR mirrors) SAS.
- Multi-stage, low-freq. isolator for silica room-temp. optics (BS, PRC, and SEC).
- Full Type-B system test at TAMA300 facility.

→ Type-Bp hanging test at Kamioka site with spare mirror.

→ Installation.



R. Takahashi (April 2012)

Vibration Isolation System

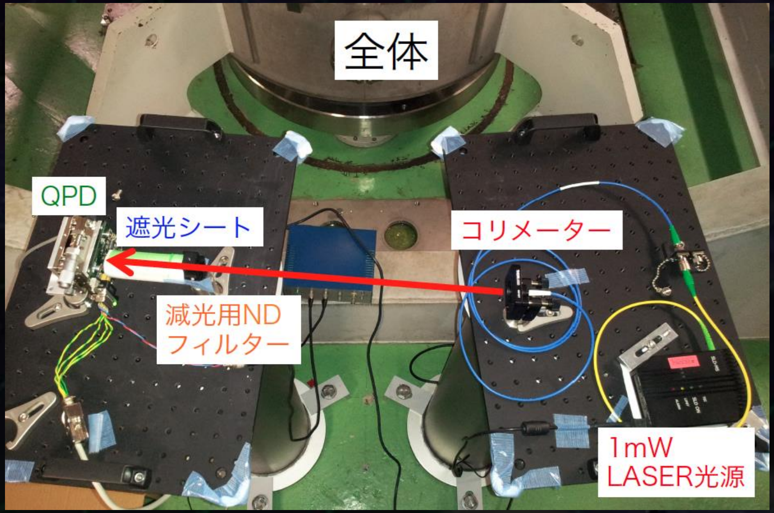
- The prototype test of the Type-B suspension at TAMA finished successfully.
- PR3 suspension with a spare mirror is being assembled. To be installed into the vacuum chamber in the next week.

Type-B prototype test at TAMA

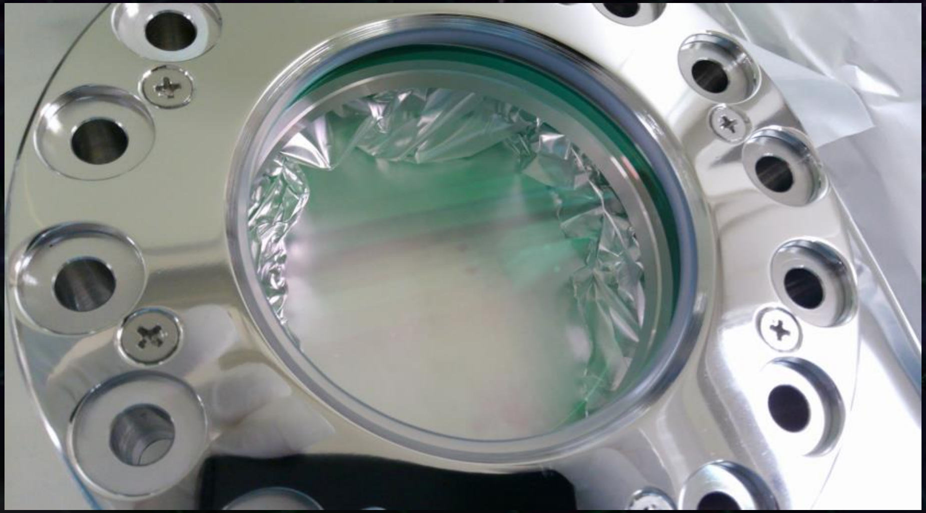
Hanging test for PR3 Type-Bp system (outside the tank) at Kamioka site.

Auxilliary Optics

- Auxilliary Optics :
  Optical baffles, Viewports, Optical lever, CCD monitors, Transmission monitor.



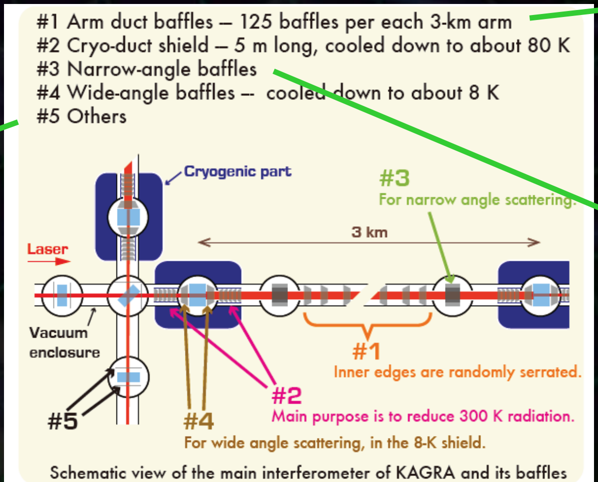
Optical level test at TAMA site



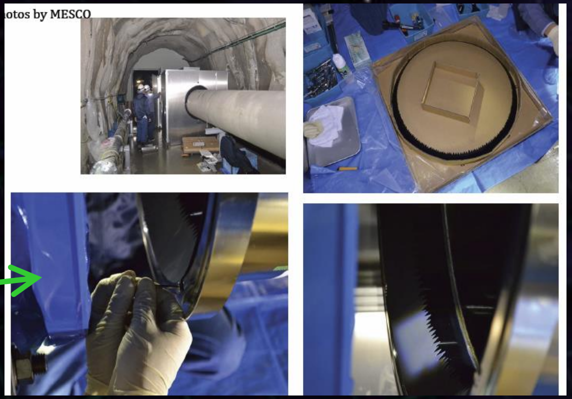
High-quality window assembled to flange
(for laser input to the vacuum)

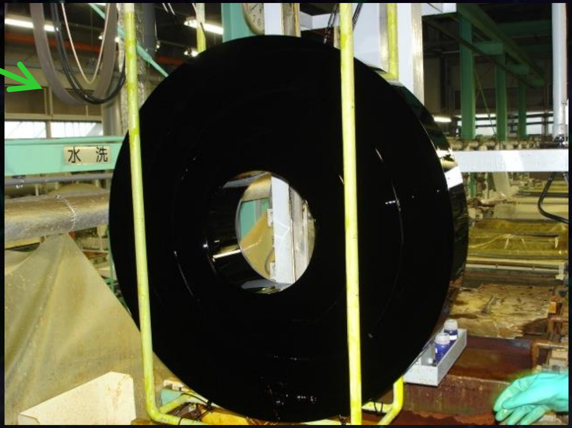
Auxilliary Optics : Baffles

- #1 Arm baffles have been installed.
- #2 Cryo-shield duct baffles have been installed.
- #3, 4 Narrow-angle and large-angle baffles are in design and prototype test.
- #5 Small baffles : first articles delivered.



Schematic view of the main interferometer of KAGRA and its baffles



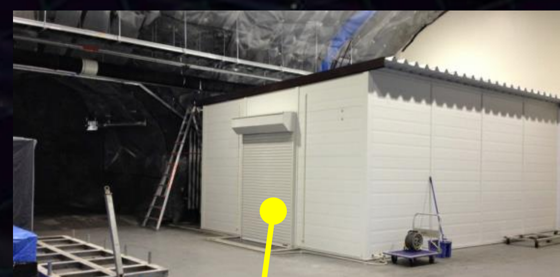


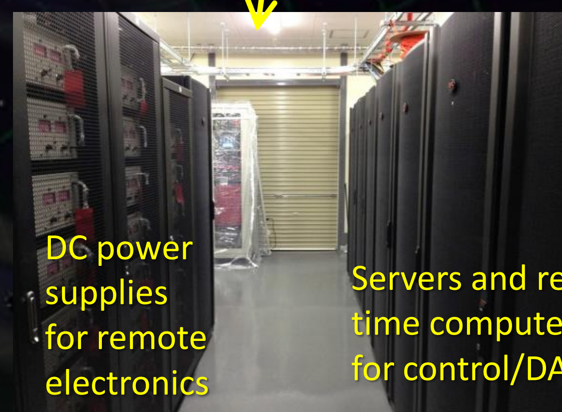
Digital System

- Installation of Digital Control system, used for interferometer control and data acquisition, was almost finished.
  → Can be monitored and controlled from the surface building.

Storage, Monitor and control at the surface building

Server room inside tunnel





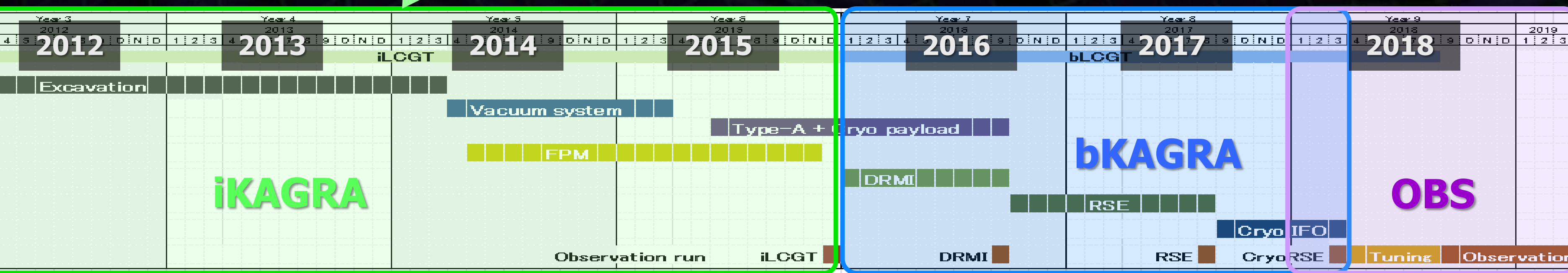
Field racks in tunnel around the interferometer

Photo by O. Miyakawa

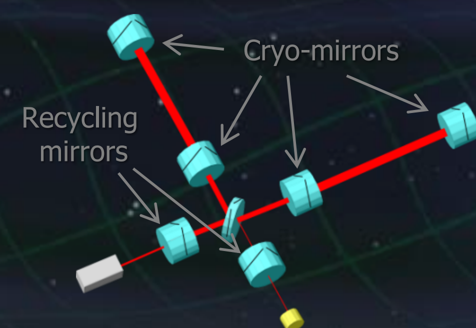
bKAGRA Plan

KAGRA Overall Schedule

- **iKAGRA** (2010.10 – 2016.3)
  Michelson interferometer
  - Baseline 3km room temp.
  - Operation of total system with simplified IFO and VIS.



- **bKAGRA** (2016.4 – 2018.3)
  Operation with full config.
  - Final IFO+VIS configuration
  - Cryogenic operation.



KAGRA Overall Schedule

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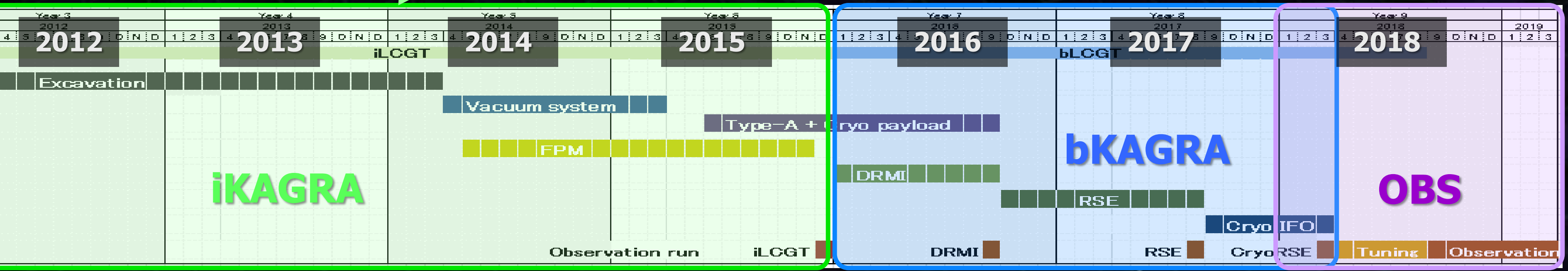

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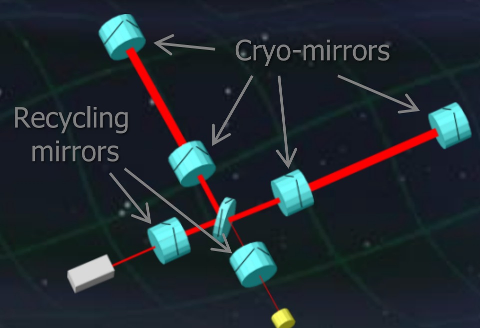
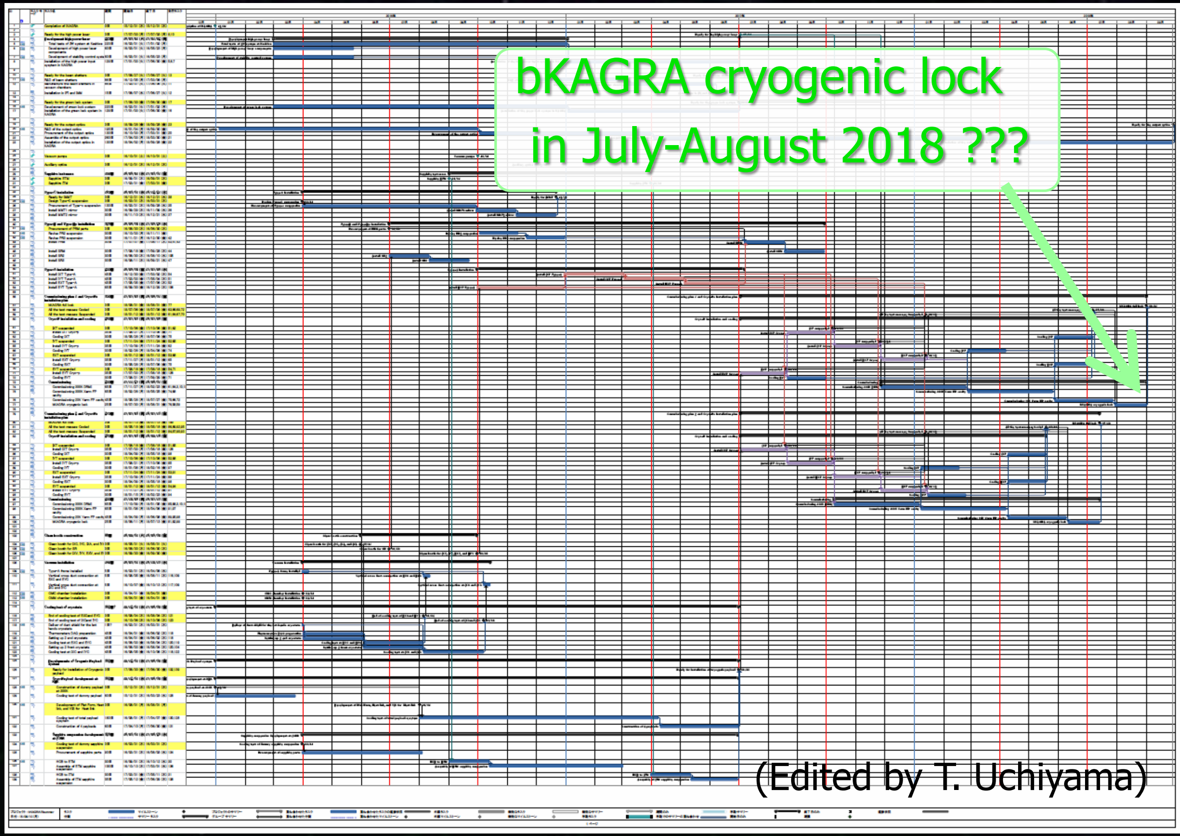


Current Overall Roadmap

- Summing-up the bottom-up schedule.
  Critical tasks : Clean booth, Cryo-payload, Vibration isolation, interferometer commissioning, …
  → will be discussed together with top-down requirement.



Summary

- The KAGRA infrastructure is almost completed.

- Installation and commissioning for iKAGRA operation are in progress rapidly.
- The schedule is still tight for observation run by the next March.
  → Ways to compress the schedule is being discussed.

- Preparations for bKAGRA are in progress in parallel.

End