

ICRR External Review
16-18 January, 2013

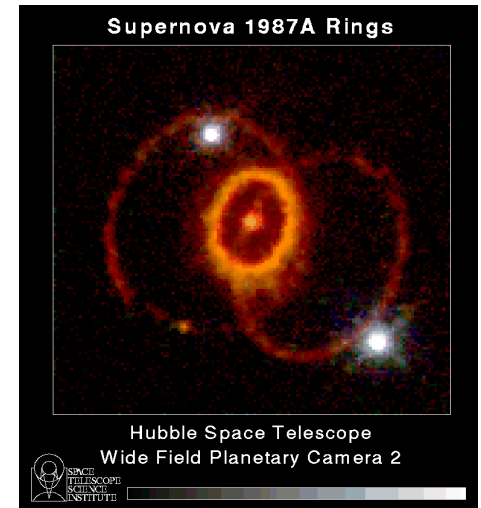
Gravitational Wave

Kazuaki Kuroda

Gravitational wave project office

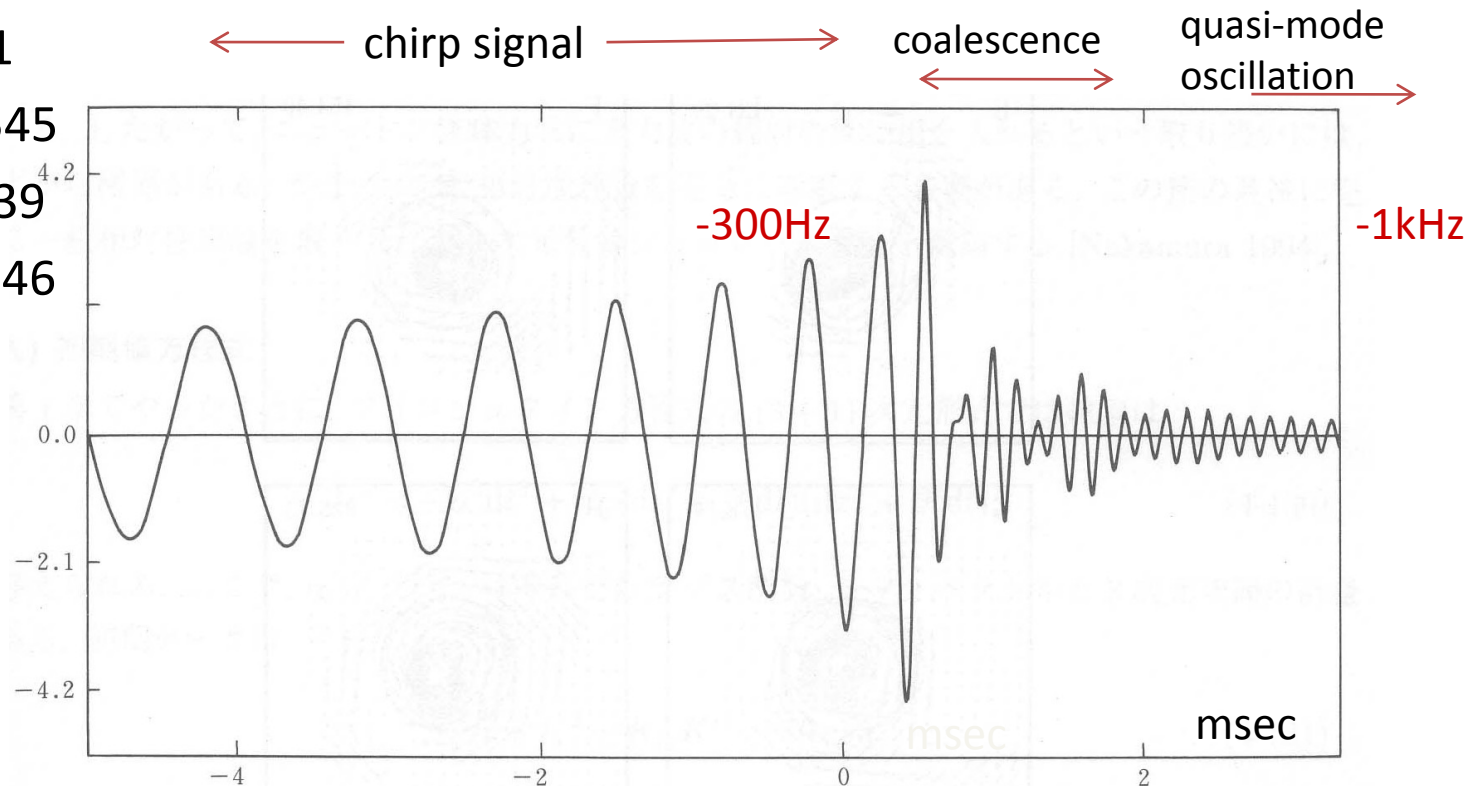
Target GW Sources of KAGRA

1. Coalescence of neutron star binaries
2. Coalescence of black hole binaries
3. Core collapse of massive stars
4.



Existing neutron star binaries in our Galaxy

- PSR B1913+16
- PSR B1534+21
- PSR J1141-6545
- PSR J0737-3039
- PSR J1906+0746



Scientific Objective of Gravity Group

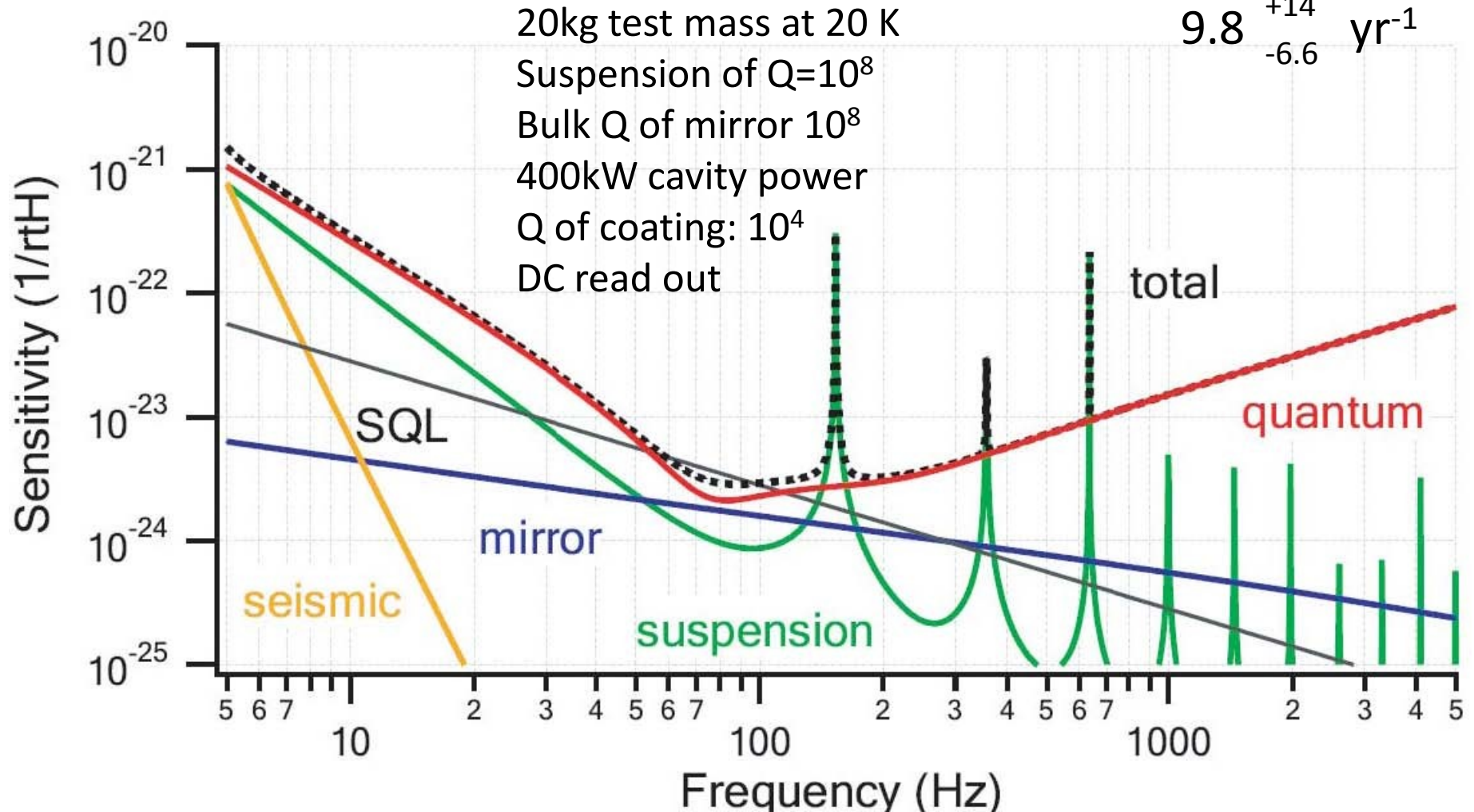
- Detection of gravitational waves
 - Test of Einstein's theory of general relativity
 - Equation of state of extremely high density object
- Astronomical observation by gravitational waves
 - Density of compact stars and their coalescence rate
 - Knowledge on star formation rate and its evolution
 - Mystery of short gamma ray burst
- Development of advanced techniques
 - Quantum noise limited interferometer
 - Increase of observational frequency band

Ultimate design sensitivity of KAGRA

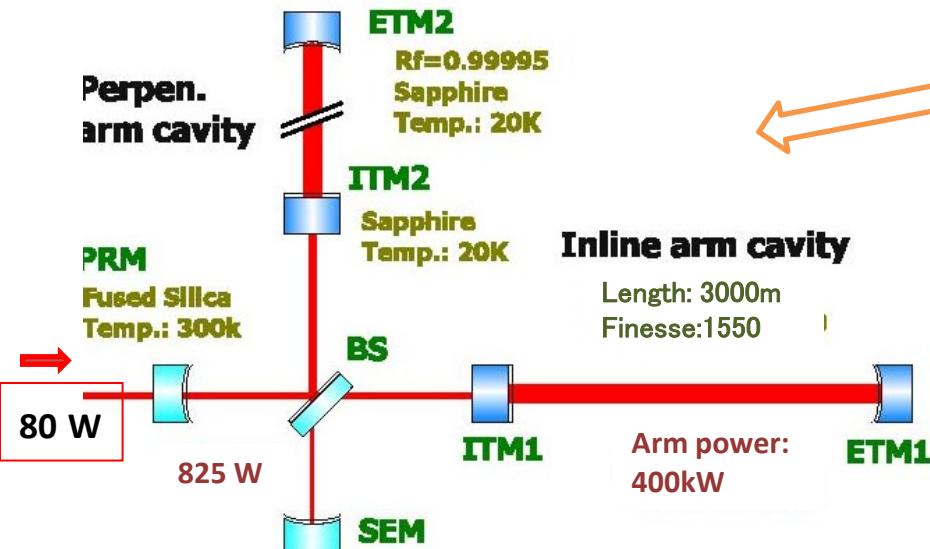
This sensitivity achieves 167 Mpc for
coalescence GW of 1.4 Ms NSB.

Duty factor: > 80%
Expected event rate

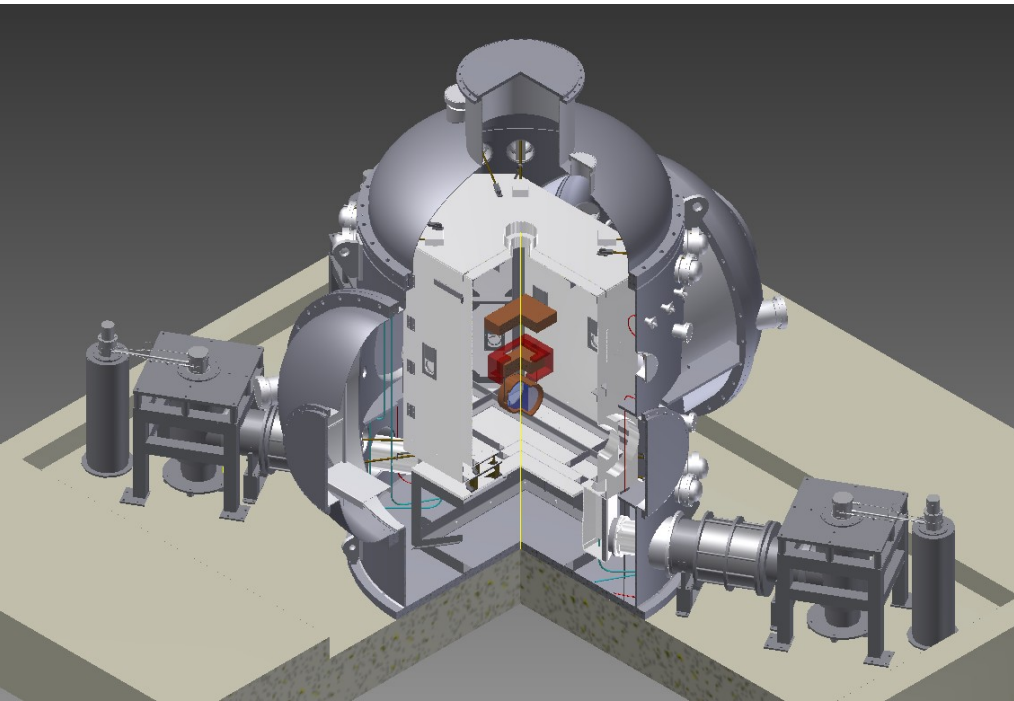
$$9.8^{+14}_{-6.6} \text{ yr}^{-1}$$



Main structure of KAGRA design

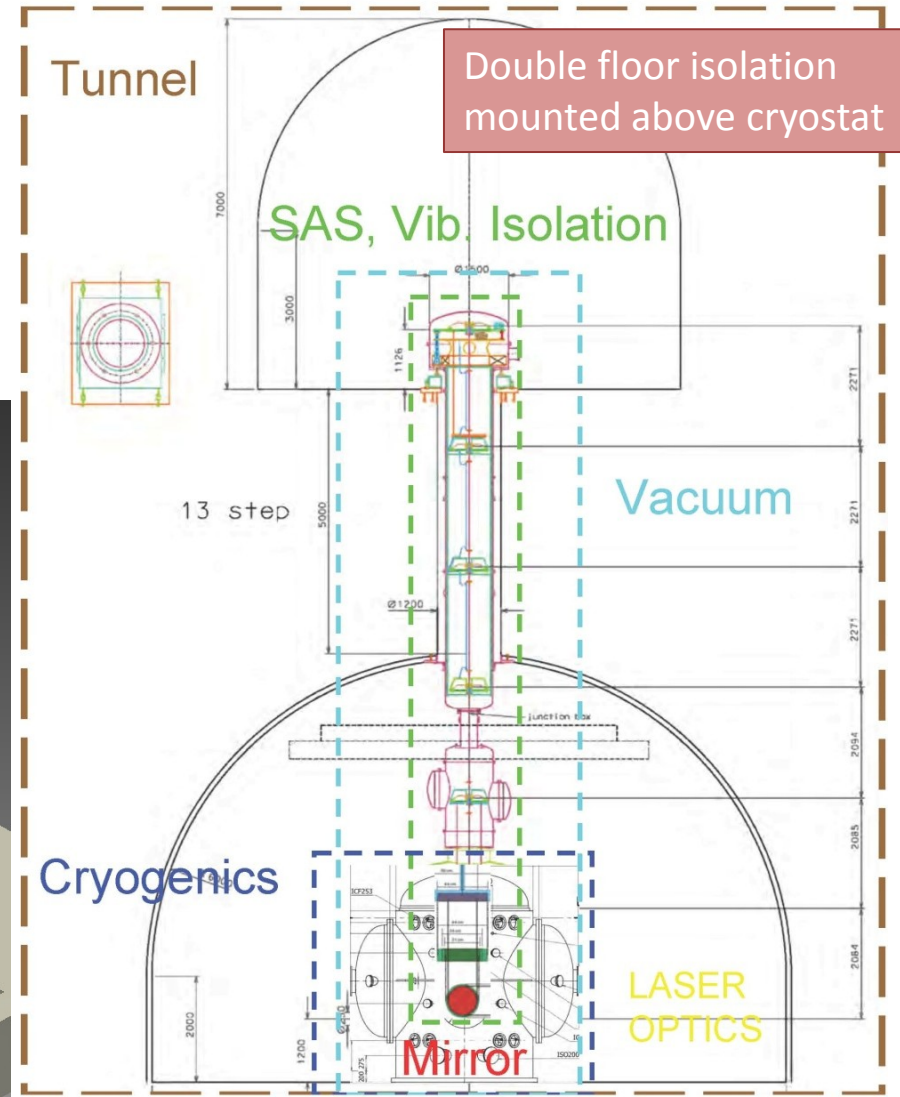


Cryostat for main mirrors



KAGRA optical design

Power recycled Fabry-Perot Michelson interferometer with Resonant-side-band extraction



R&D research: TAMA/CLIO



TAMA in Mitaka, Tokyo

CLIO is a 100 m cryogenic locked Fabry-Perot interferometer placed underground at Kamioka mine.

Thermally limited sensitivity was achieved in 2009 by cooling mirrors down to 10 K. It is a test bench for cryogenic part of KAGRA.

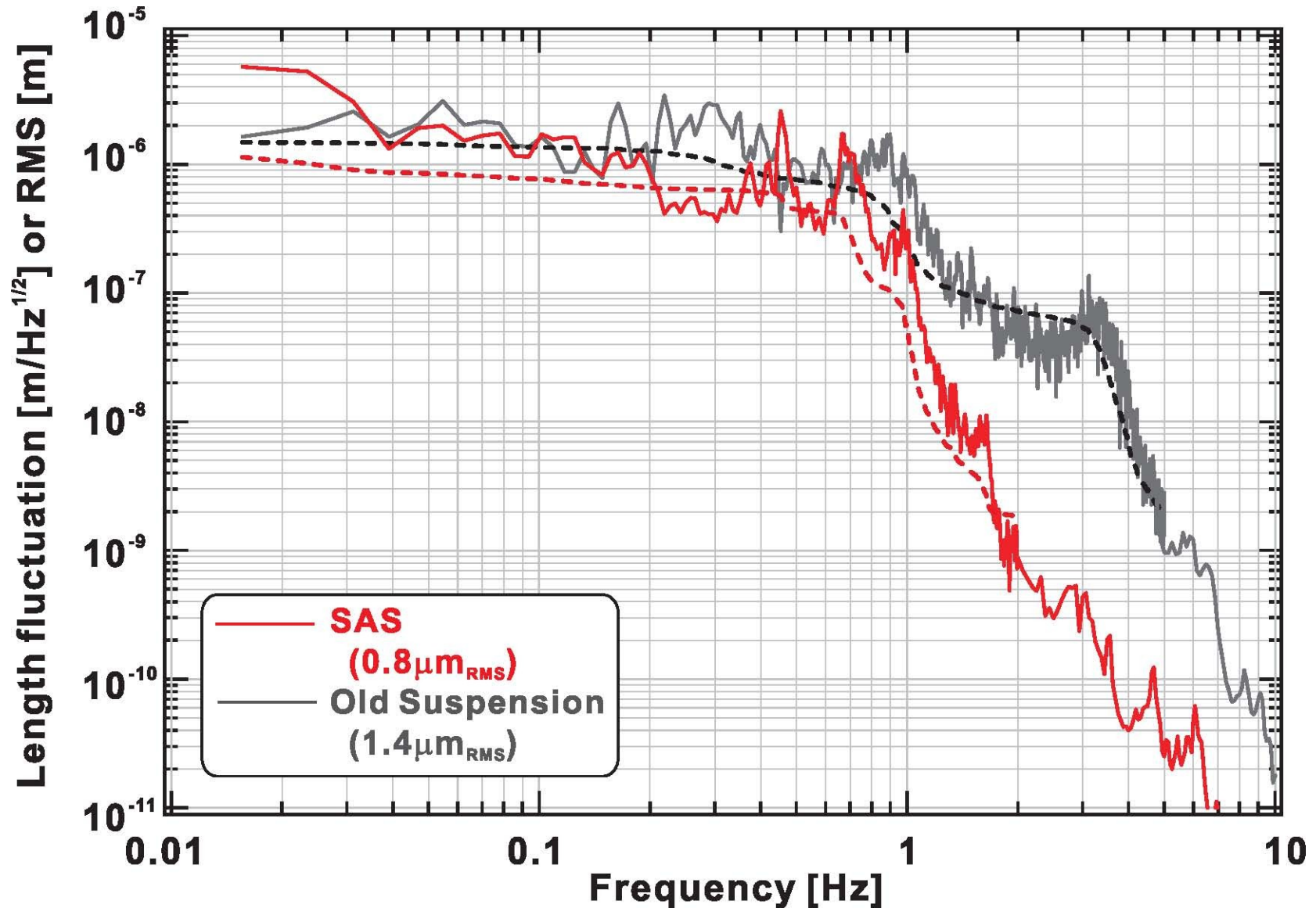
TAMA is a 300 m baseline Fabry-Perot Michelson Interferometer with power recycling and achieved the best sensitivity and long observation run earlier than any other long baseline interferometers by 2000.

R&D are being conducted for advanced interferometer techniques for KAGRA.

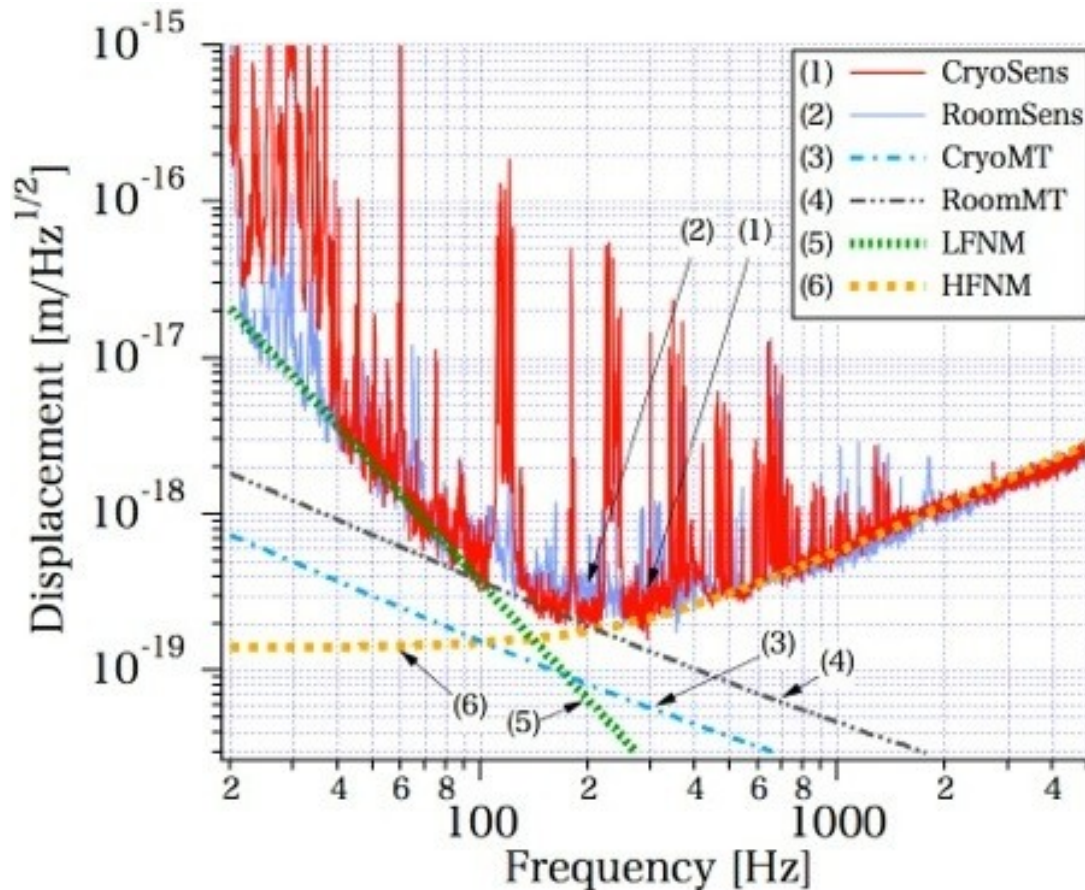


CLIO underground at Kamioka

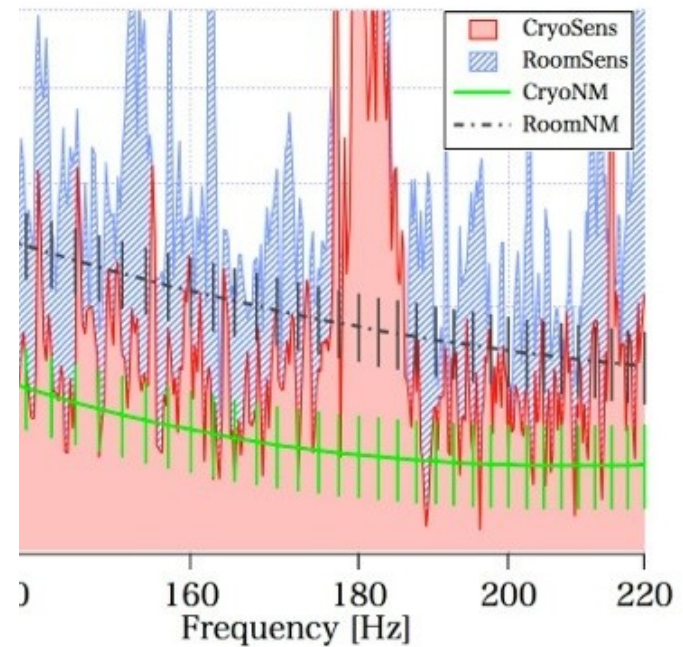
R&D: Low frequency sensitivity improvement by TAMA-SAS installed by 2008



R&D: First demonstration of reduction of thermal noise at cryogenic temperature by CLIO



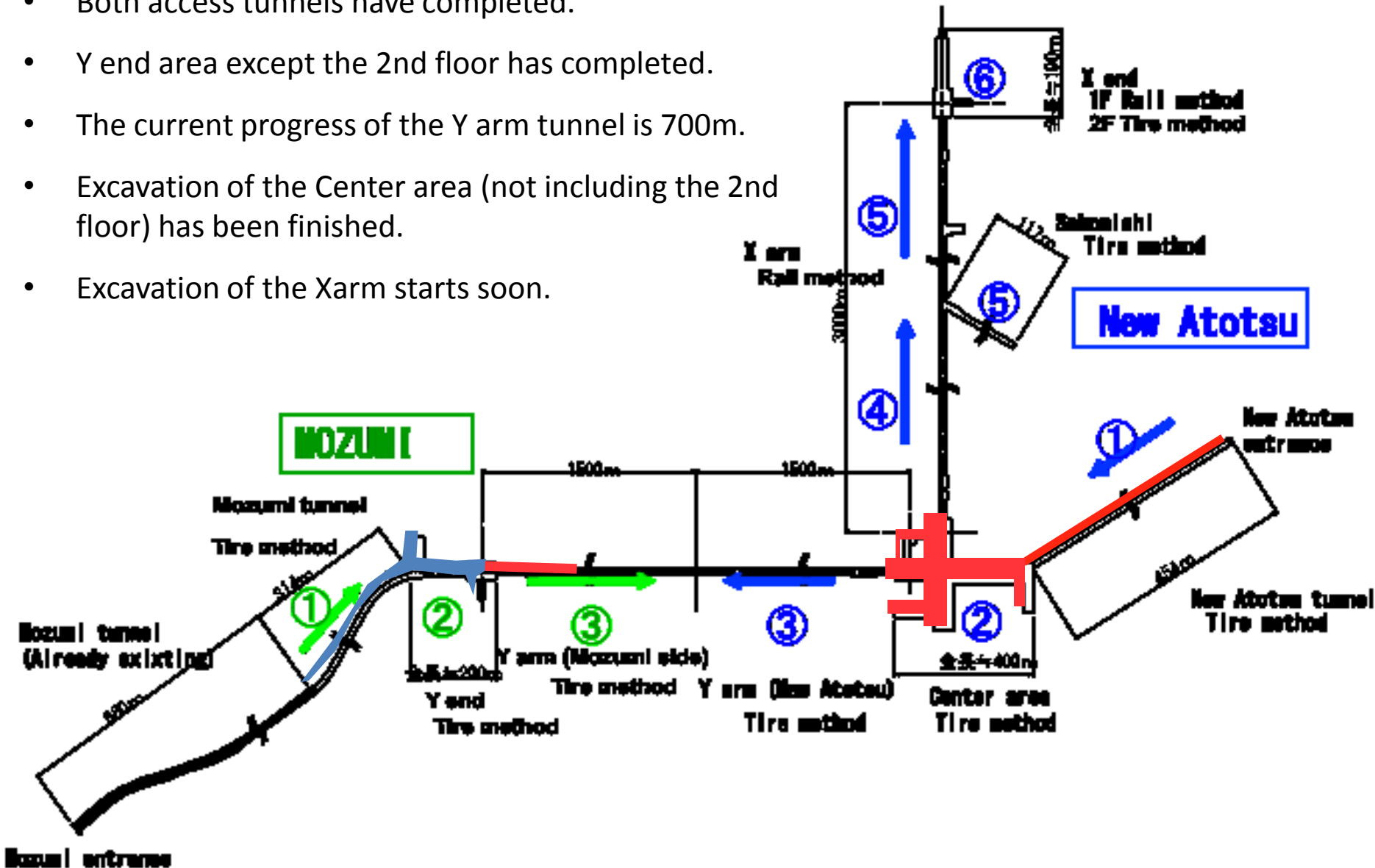
Closeup of improvement



(Cryo-Sensitivity) TM was suspended by 0.5mm aluminum wire with heat links
(Room-Sensitivity) TM was suspended by 0.1 mm Bolfur (amorphous metal) wire

Tunnel excavation: current status

- Both access tunnels have completed.
- Y end area except the 2nd floor has completed.
- The current progress of the Y arm tunnel is 700m.
- Excavation of the Center area (not including the 2nd floor) has been finished.
- Excavation of the X arm starts soon.



Vacuum: Manufacture and Installation

Process 1: “surface passivation by electro-polish followed by baking”

outgassing rate; 10^{-8} Pa m³ m⁻² s⁻¹, or lower

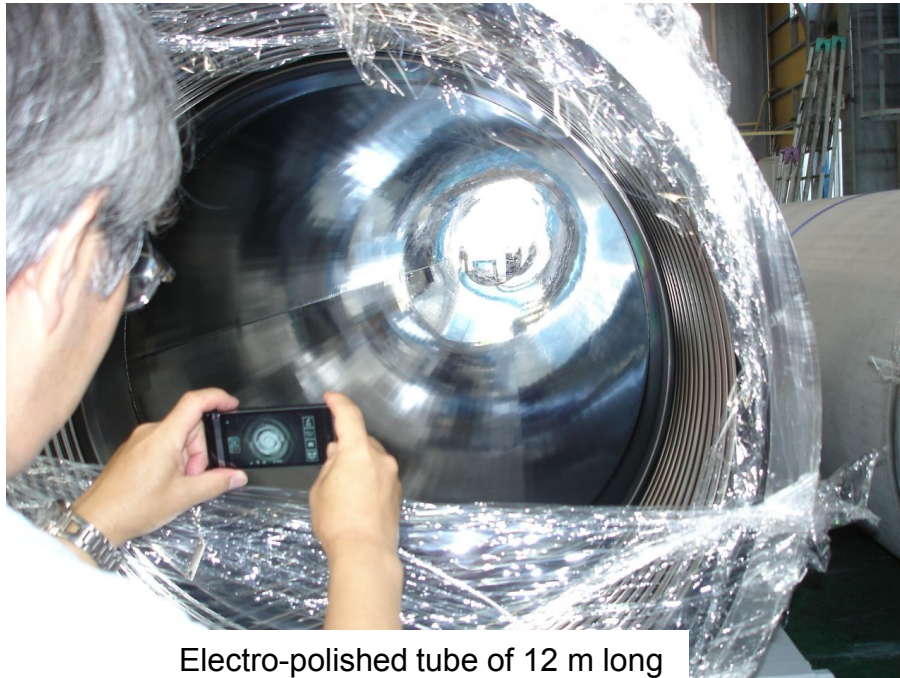
surface roughness; Rmax 3 μm, Ra 0.5 μm

Process 2: “mirror finish by Electro-Chemical Buffing (tubes in the mid 800-m region)”

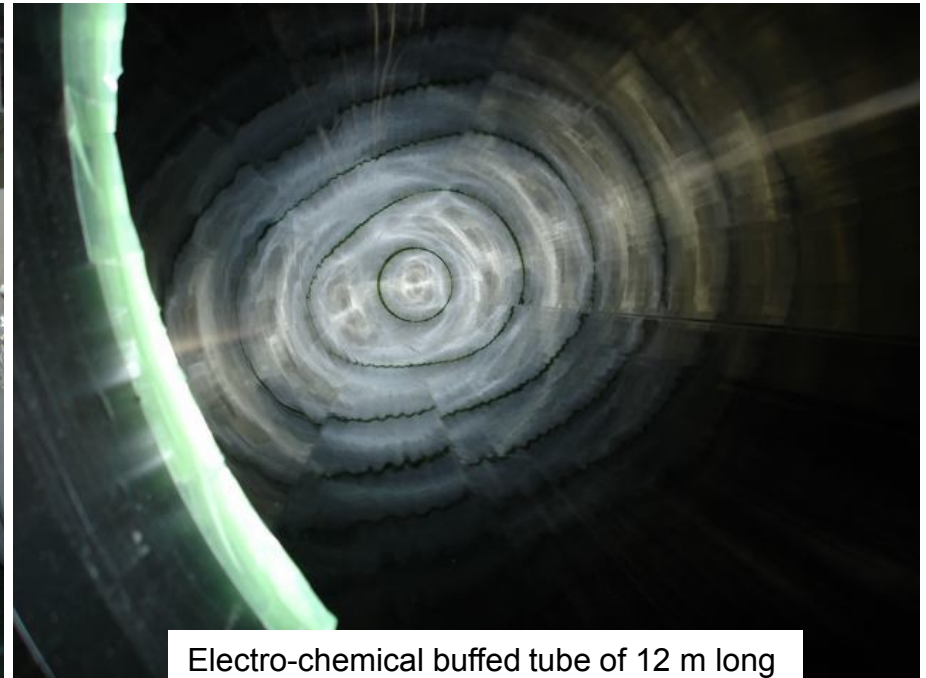
surface roughness; Rmax 0.2 μm, Ra 0.03 μm

Assembling: “flange connection with metal O-ring (silver plated)”;

erosion proof by humidity test



Electro-polished tube of 12 m long



Electro-chemical buffed tube of 12 m long

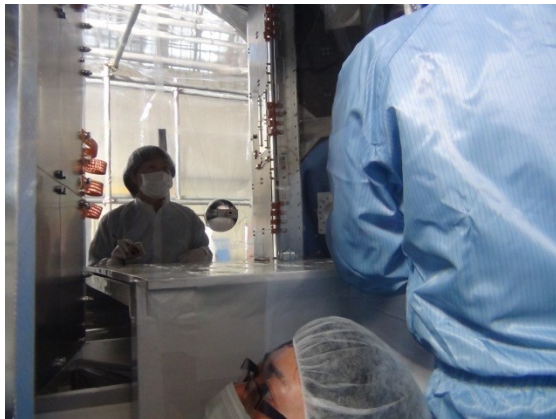
Cryogenics : Cryostat assembling and performance test



Dressing partition of
No.1 Cryostat



Ceiling part of 8K shield



Al sphere for an initial cooling
test of mirror suspension

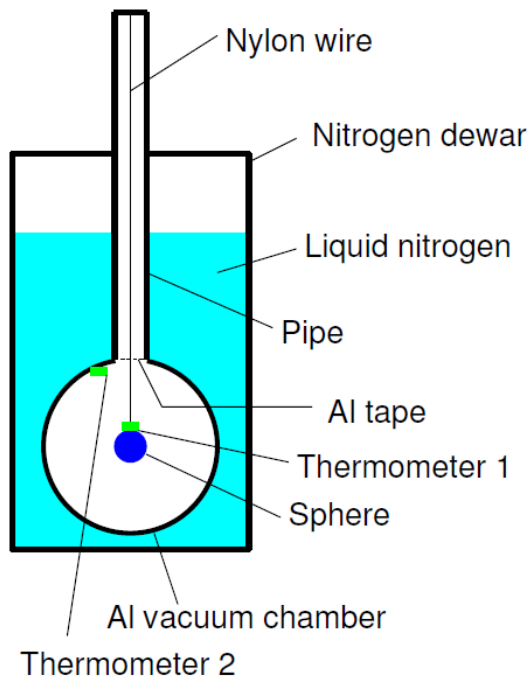
- Assembling of cryostats and preparation of performance tests are in progress in the TOSHIBA Keihin Product Operations.
- Basic test items
 - Cooling time, minimum attainable temperature under various heat loads.
- Specific test items
 - Cryostat No.1 : Cooling test of $\phi 105$ Al sphere without DLC.
 - Cryostat No.2 : Cooling test of $\phi 105$ Al sphere with DLC.
 - Cryostat No.3 : Vibration measurement of 8K shield using interferometer(ICRR) and accelerometer(Roma Univ.)
 - Cryostat No.4 : Cooling test of a scaled preliminary model of cryogenic payload.

Cryo-payload: cooling time reduction

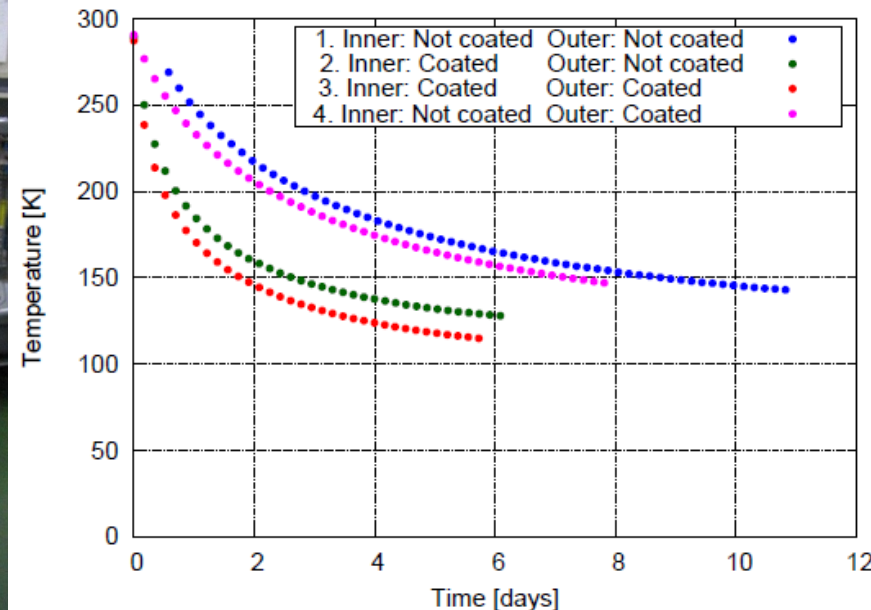
DLC coating (black coating) makes initial cooling time twice times shorter.

In ICRR, this DLC effect has been observed in experiment.

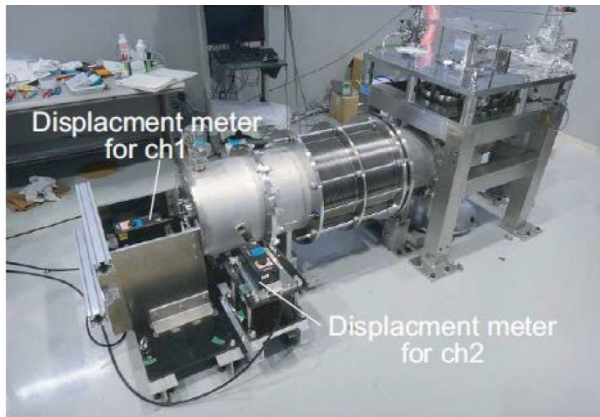
Moreover, similar experiments will be conducted in cooling test of KAGRA cryostat in Toshiba.



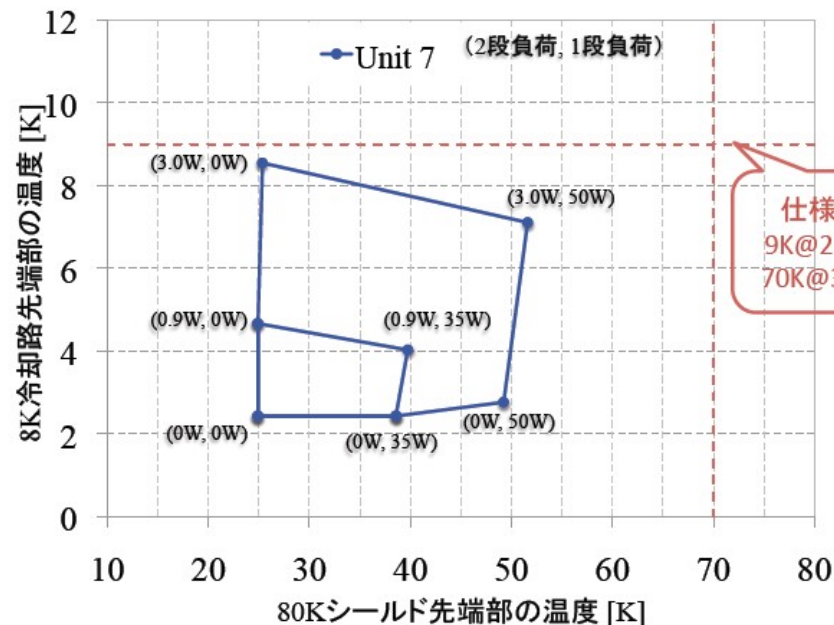
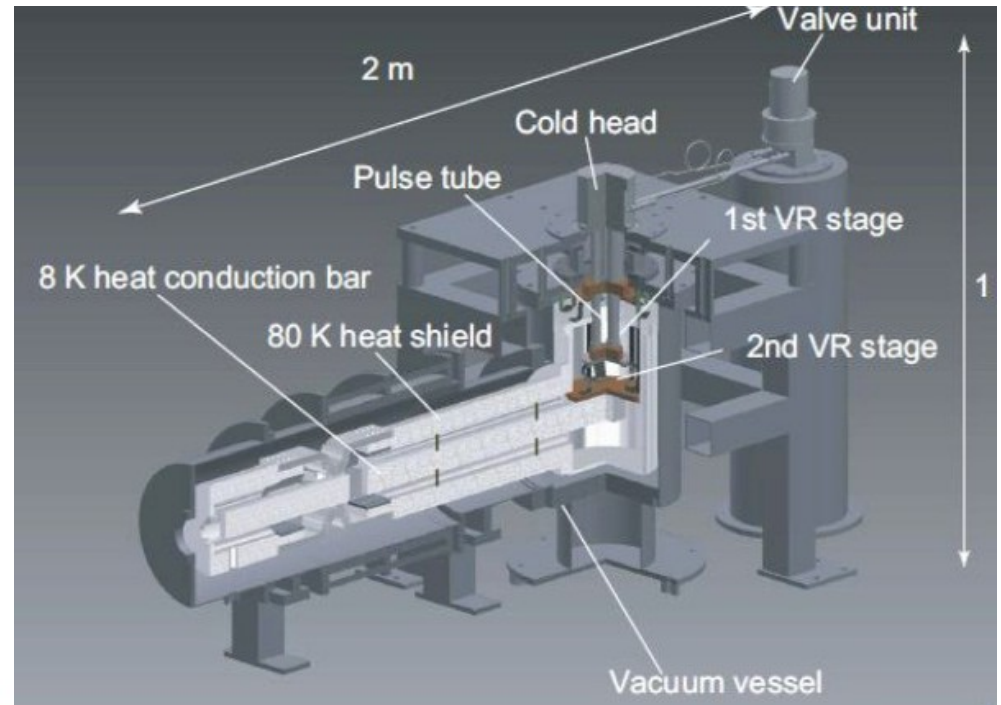
Time reduced by one-third



Cryogenics: 4K cryo-cooler unit



4K cryocooler unit and set of displacement meter.



Load map of cryocooler

- 仕様値
9K@2.5W
70K@35W
- 4K cryocooler units with vibration reduction mechanism are manufacturing.
 - 5 units in 2011FY and 9 units in 2012FY.
- Cooling power of the cryo-cooler satisfied the requirement.
- Vibration level was improved by a reinforcement of support structure.

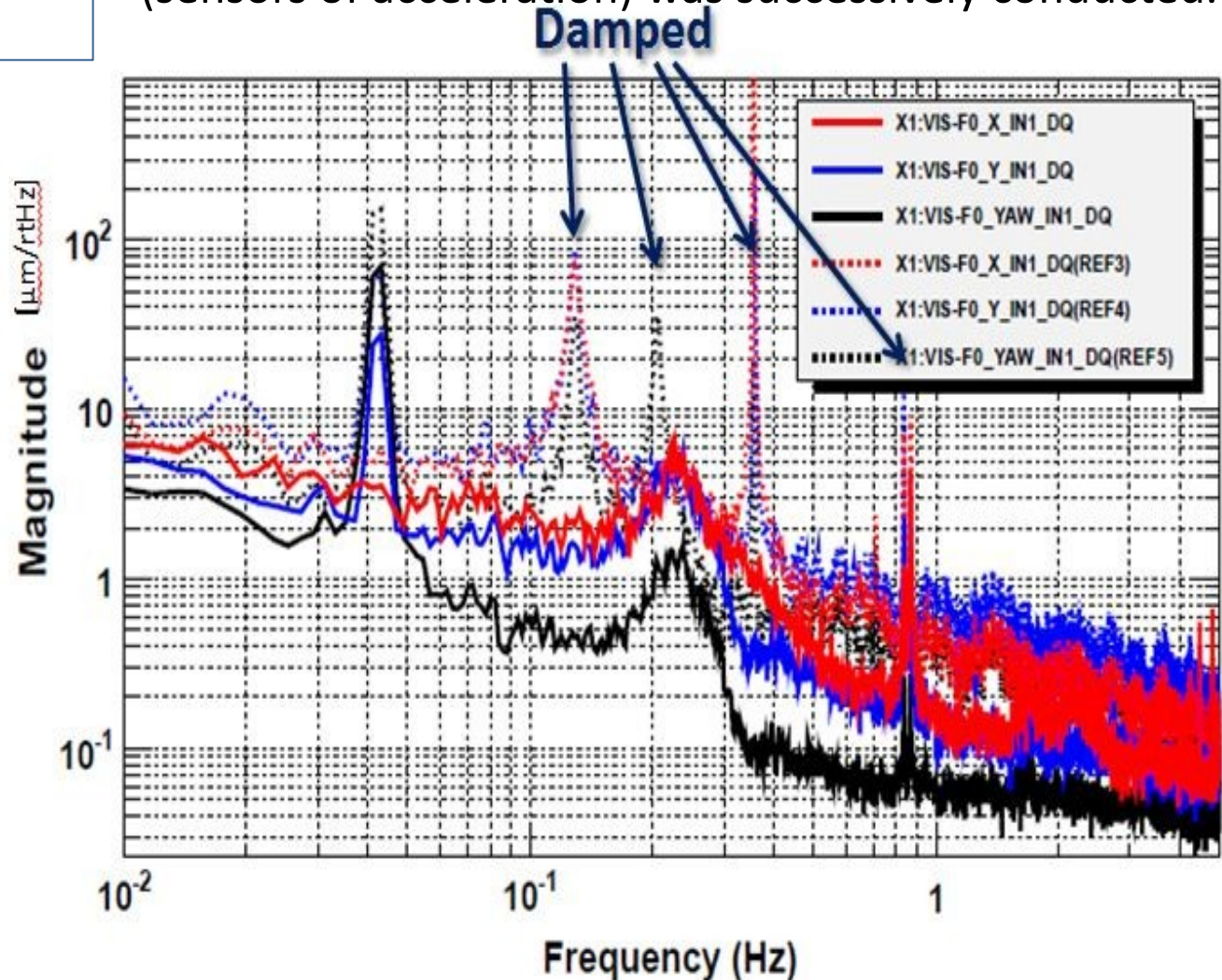
SAS for KAGRA

Digital control of Inverted Pendulum for horizontal isolation 3 degrees of freedom using LVDT&voice coil (sensors of acceleration) was successively conducted.

Pre-isolator consists of three set of Inverted pendulums and vertical filter

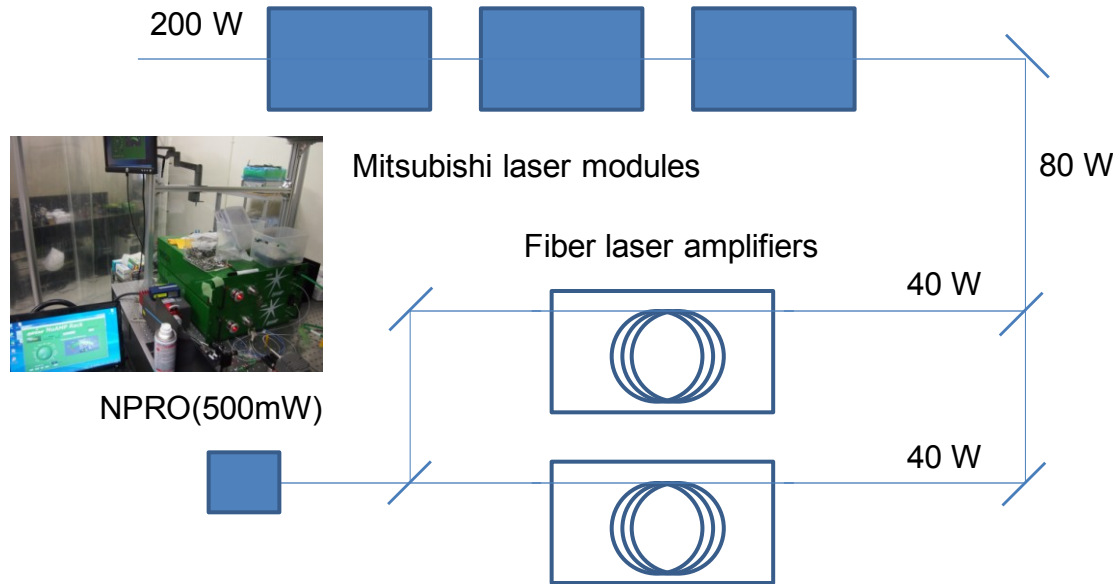


Prototype test of Pre-isolator in Kashiwa



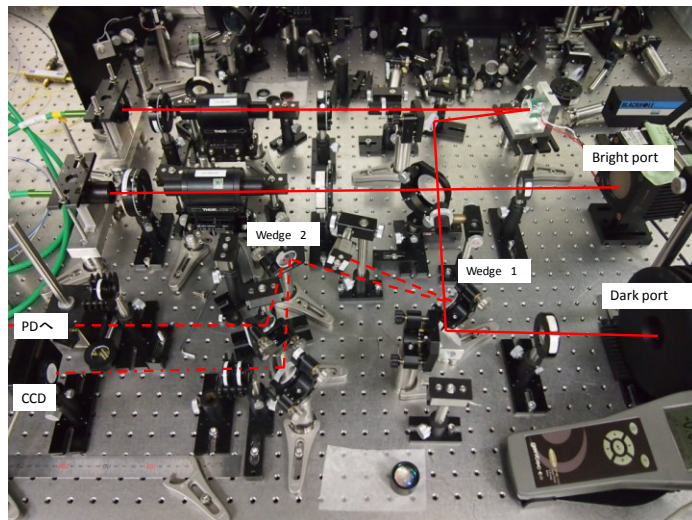
Digital control system is constructed in collaboration with aLIGO

Laser : R&D for high power



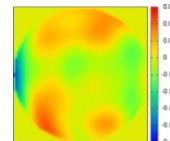
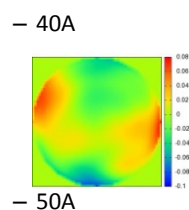
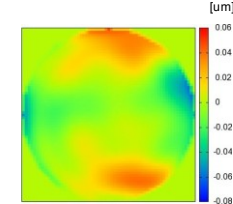
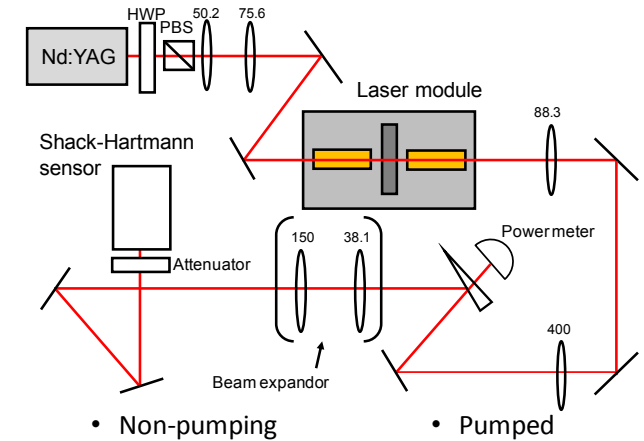
NPRO(500mW)

Coherent addition



The highest power was 64 W obtained from two 40-W outputs.

Wave-front distortion caused by a solid-state amplifier



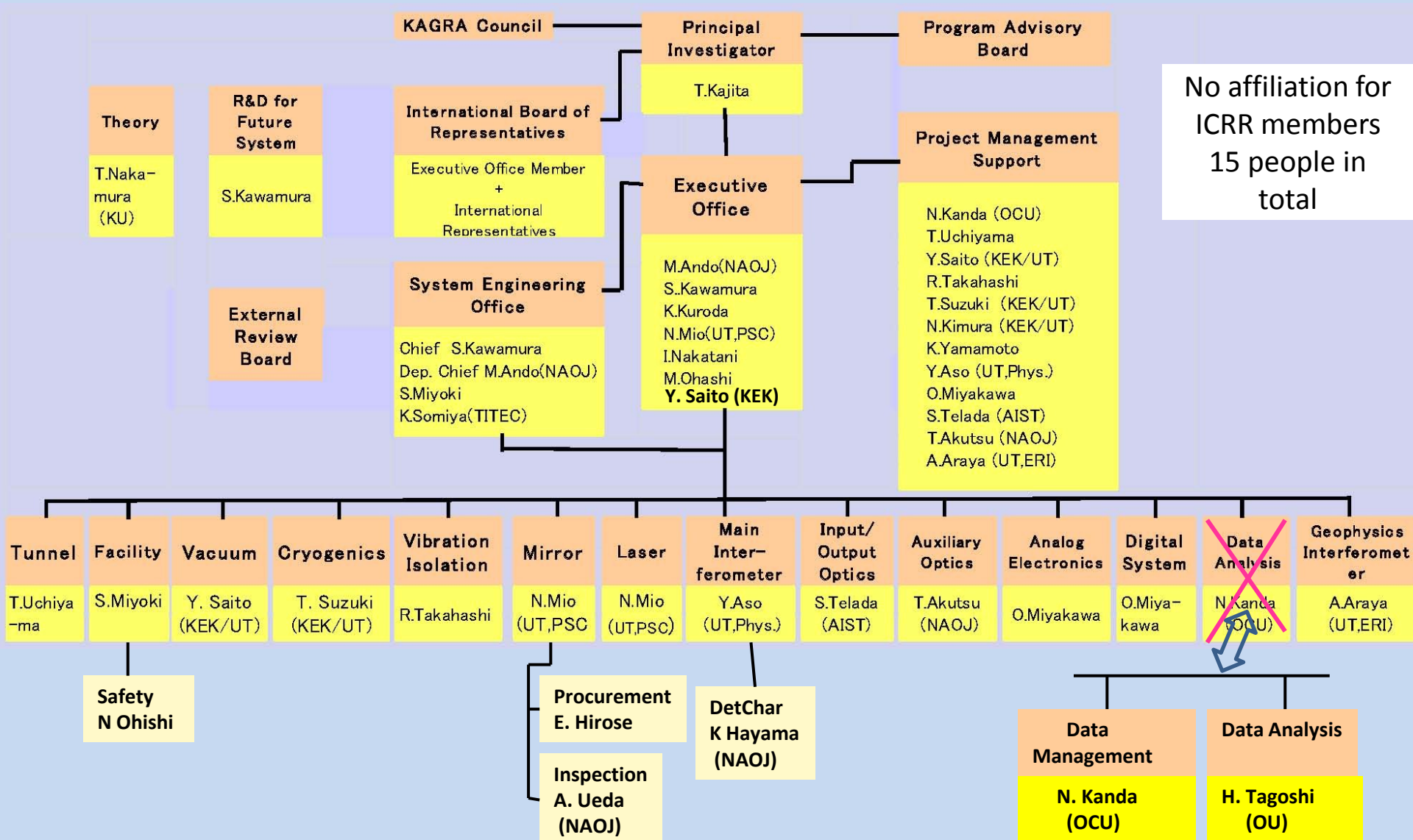
Profiles are changed but the PV value is on the same order.

- The performance of each component is being tested.
- Total system assembly will be started soon as the next step.

Collaboration with overseas people & organizations

- Collaborations under formal exchange of academic agreement or MOU with ICRR or UT
 - LIGO Lab, EGO, Glasgow, SUCA, UWA, Tsinghua U, SIC, LSU, U Sannio
 - KAGRA appreciates LIGO-lab for the support of expertise of various experts with some hard wear optics
- Agreement between collaborations
 - MOU among LSC & Virgo has been concluded
 - Attachment with LSC was signed and attachment with Virgo will be signed soon.
- Researchers' exchange with ET under ELiTES
 - <https://www.et-gw.eu/elitesmainmenu>
- Research collaborations under JSPS program
 - Korean workshop
 - Germany and Japan

Manpower organization



Manpower status

	Staff in ICRR(Kashiwa)	Staff in Kamioka	Collaboration member
R&D research by CLIO (-2008)	5	1	20
Design study for large scale cryogenic gravitational wave telescope (-2009)	5	2	~ 60
Start of KAGRA construction in (2010) Now, in 2013	(12) 15 (+3adm) (1PI, 2P, 1AP, 1PD, 2RA, 2T, 2AT, 4Gu)	(3) 4 (+3adm) (1AP, 3RA)	(160) 190

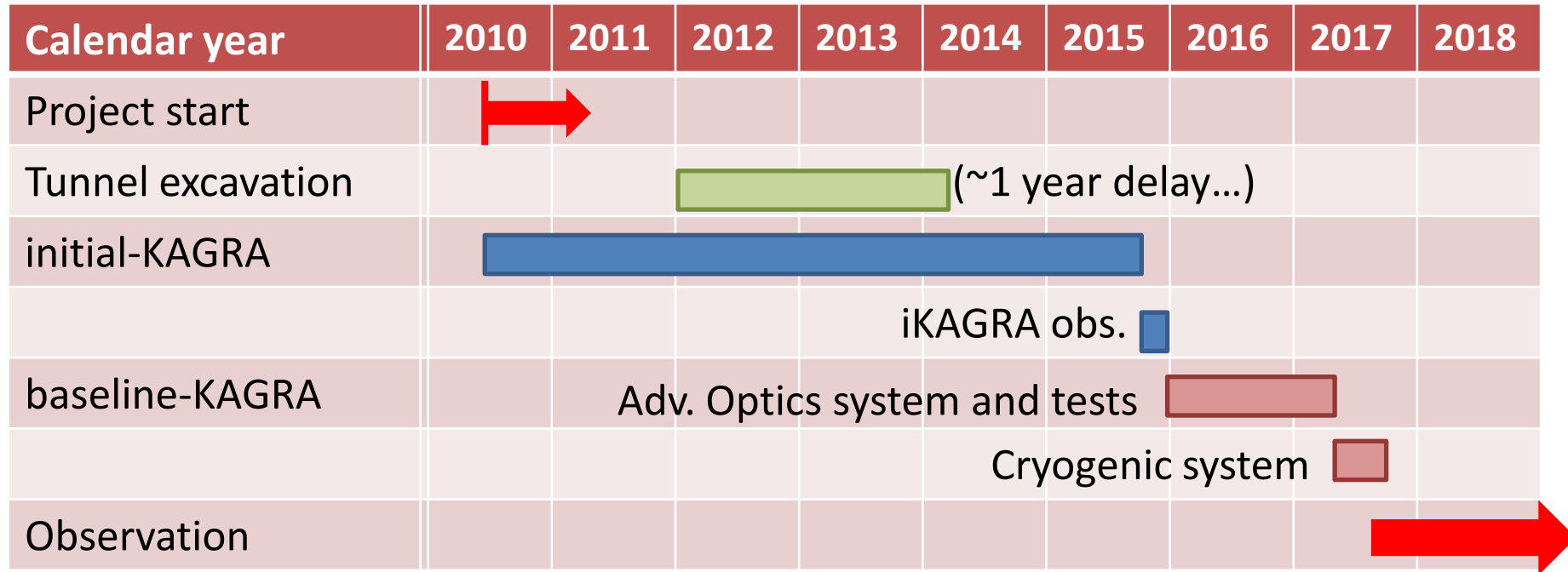


Kamioka branch of GWPO opened an office in this August for housing administration staff and researchers working for KAGRA



Hokubu-Kaikan refurbished from Kindergarten for KAGRA (140m²)

Time Line (Construction and Observation)



The construction/observation plan is in 2 stages:

- ✓ In 2015, non-cryogenic observation (iKAGRA).
- ✓ Operation with cryogenic system in 2017 (bKAGRA).
- ✓ (High sensitivity operation in 2018?)

Summary

- R&D for gravitational wave detection lead to funding of LCGT (now KAGRA) in 2010
- KAGRA construction is under way
- KAGRA is supported by many organizations that collaboration members belong to
- KAGRA has close collaborations with LIGO/LSC and EGO/Virgo
- First milestone for KAGRA is the operation in 2015
- bKAGRA operation starts in 2017
- Observation run since 2018

Appendix: KAGRA Collaborator (I)

ICRR.UT : Kajita Takaaki, Kuroda Kazuaki, Nakatani Ichiro, Ohashi Masatake, Kawamura Seiji, Miyoki Shinji, Uchiyama Takashi, Miyakawa Osamu , Takahashi Ryutaro, Yamamoto Kazuhiro, Ohishi Naoko, Friedrich Daniel, Nishida Erina, Ishizuka Hideki, Tokoku Chihiro, Hirose Eiichi, Kamiizumi Masahiro, Iwasaki Utako, Sakakibara Yusuke, Sekiguchi Takanori , Chen Dan, Nakano Masayuki, Tejima Koudai, NAOJ: Fujimoto Masa-katsu, Ando Masaki, Akitoshi Ueda, Akutsu Tomotada, Tatsumi Daisuke, Kotake Kei, Hayama Kazuhiro, Agatsuma Kazuhiro, Nakamura Koji, Ishizaki Hideharu, Torii Yasuo, Tanaka Nobuyuki, Eguchi Satoshi, Yamamoto Akira, Tomiyoshi Haruyama, Suzuki Toshikazu, Kimura Nobuhiro, Ioka Kunihiro, Saito Yoshio, Koike Shigeaki, Phys. UT: Yokoyama Jun'ichi, Taruya Atsushi , Itoh Yousuke, Tsubono Kimio, Aso Yoichi, Hiramatsu Shigenori, Kokuyama Wataru, Okada Takeshi, Kawara Takayoshi, Matsumoto Nobuyuki, Michimura Yuta, Shoda Ayaka, Shibata Kazunori, Ushiba Takafumi, GFSF.UT: Watanabe KyoHei, Oikawa Kei, Hiratani Shinya, E.UT : Moriwaki Shigenori, Mio Norikatsu, Ohmae Noriaki, S.TIT : Hosoya Akio, Kawai Nobuyuki, Somiya Kentaro, Susa Yuki, Ueda Shinichiro, S.OCU: Kanda Nobuyuki, Yamamoto Takahiro , Yuzurihara Hirotaka, Tanaka Kazuyuki, Nakao Kenichi , S.Kyoto.U: Nakamura Takashi, Seto Naoki, ILS.UEC: Ueda Kenichi, Yoneda Hitoki, Nakagawa Kenichi, Musha Mitsuru, Araya Akito, Takamori Akiteru, Hosei U: Sato Shuichi, Hayashi Syohei, Higashiura Kousuke, Sumiya Mananori , NAIST: Takatsuji Toshiyuki , Bitou Youichi, Telada Souichi, NICT : Nagano Shigeo, S.Osaka U: Tagoshi Hideyuki, Sano Yasumichi, Takamura Satoru, Baiotti Luca,

Appendix: KAGRA Collaborator (II)

YITP. Kyoto U: Sasaki Misao, Shibata Masaru, Tanaka Takahiro, Sago Norichika, Nakano Hiroyuki, Sekiguchi Yuichiro, Nishizawa Atsushi , S.Ochanomizu U: Gondo Rina, Saito Nana, ARISH.Nihon U: Shintomi Takakazu, S.Niigata U : Oohara Kenichi, H.YEU: Takahashi Hirotaka, CIT.Nihon U: Himemoto Yoshiaki, ST.Hirosaki U: Asada Hideki, S.Tohoku U: Futamase Toshifumi, Takahashi Fuminobu, S.Rikkyo U: Harada Tomohiro, Saijo Motoyuki, S.Hiroshima, Kojima Yasufumi, S.Ryukyu U: Uryu Koji, ASE.Waseda U: Yamada Shoichi, SOKENDAI: Hashizume Katsuya, Teikyo U: Ohmori Takao, JASSO: Sakata Shihori, IMS: Shikano Yutaka, MPQ.AEI: Kawazoe Fumiko, Caltech: Chen Yanbei, Kawabe Keita, Arai Kouji, Izumi Kiwamu, Miao Haixing , UWA: Michael Tobar, David Blair, Ju Li, Zhao Chunnong, Wen Linqing, LSU: Warren Johnson, Kokeyama Keiko, BNU.Astro: Zhu Zong-Hong, IUCAA: Dhurandhar Sanjeev V. , Mitra Sanjit, Moscow U: Vadim Milyukov, LATMOS/CNRS : Lucio Baggio, CUT: Yang Zhang, Peking U : Cao Junwei, CMS.ITRI.Taiwan : Pan Sheau-Shi , Chen Sheng-Jui, U Maryland: Numata Kenji, Columbia U: Szabolcs Marka, Zsuzsanna Marka, U West Scotland: Stuart Reid, Sannio U: Riccardo DeSalvo, Innocenzo Pinto, Galdi Vincenzo, Pierro Vincenzo, Castaldi Giuseppe, Croce Rocco P., Maria Principe, Roberto Conte, Fiumara Vincenzo, Matta Vincenzo, Francesco Chiadini, Fabio Postiglione, Shanghai Normal U: Zhai Xiang-hua, Ping Xi, Tsing Hua U: Ni Wei-Tou, Mei Hsien-Hao, Korea U: Yoon Tai Hyun, Inje U: Lee Hyung Won, SNU: Lee Hyung Mok, MJU: Kim Jae Wan, KAERI: Cha Yong-Hio, Hanyang U: Lee Hyun Kyu, PNU: Lee Chang-Hwan, KISTI: Kang Gungwon, Korea NIMS: Oh John J., Oh Sang Hoon, KPNU: Park Myeong-G, KNU: Kim Sang Pyo, KIAS: Maurice van Putten, SICCAS-GCL, Xu Jun, Zheng Lihe, Wang Jingya, PSU: Kashiya Kazumi, MSU: Yagi Kent