Status of KAGRA

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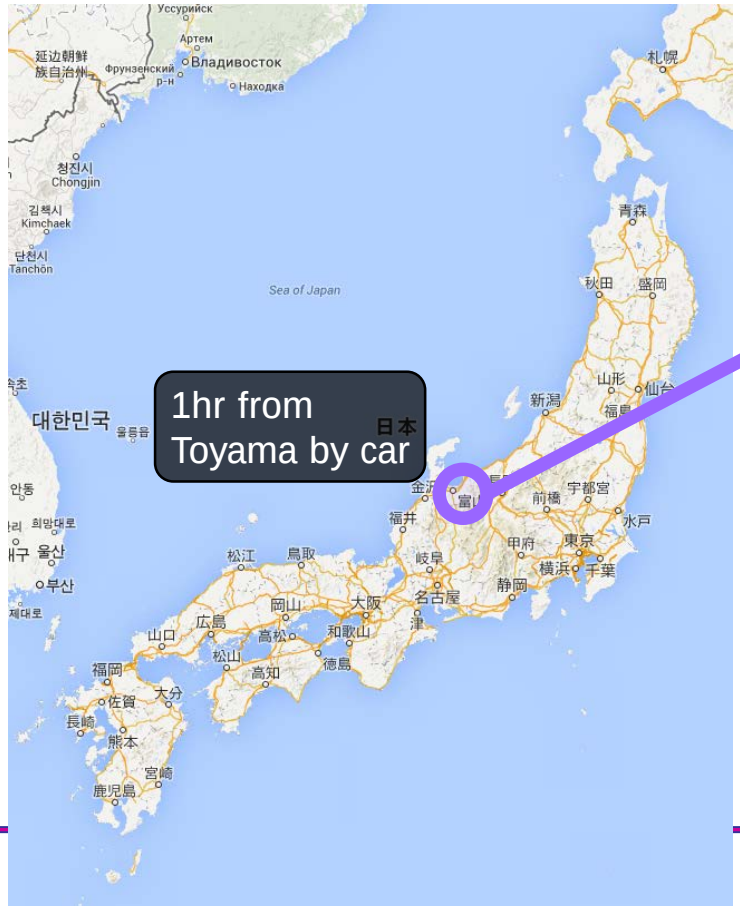
for the KAGRA Collaboration

I. Brief introduction to the KAGRA project
II. Design and status of KAGRA
III. Summary

I. Brief introduction to the KAGRA project

The KAGRA project

- Gravitational wave detector (3 km long laser interferometer)
- Currently under construction near Kamioka, Gifu
- Financed by MEXT (~ 156 M$, additional 8M$ asked)



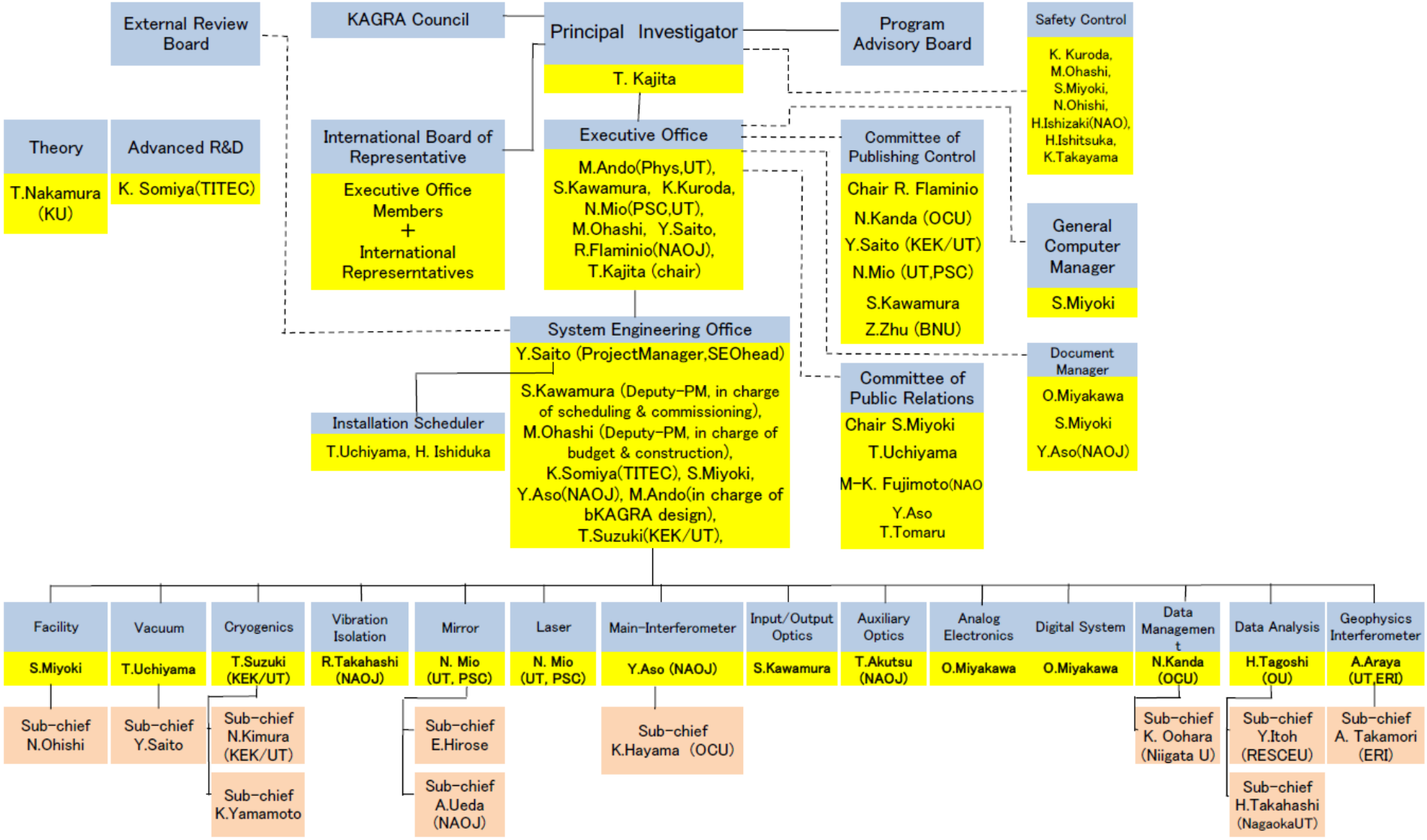
The KAGRA collaboration

- Host: ICRR
- Co-Hosts: KEK, NAOJ
- ~230 collaborators from more than 60 universities and institutes in Japan and abroad

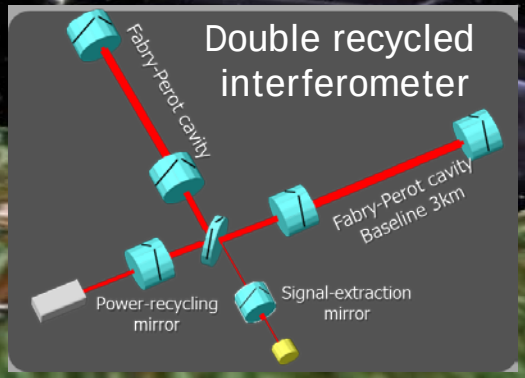


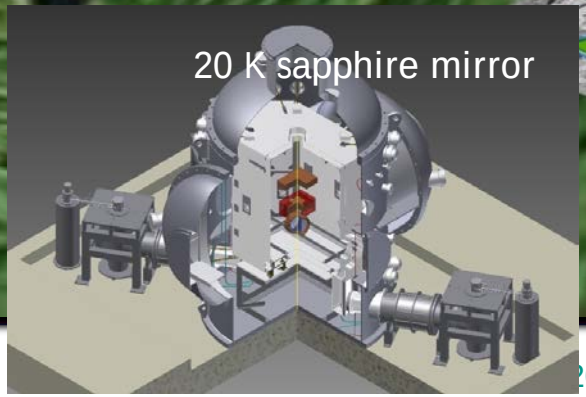



The KAGRA organization chart



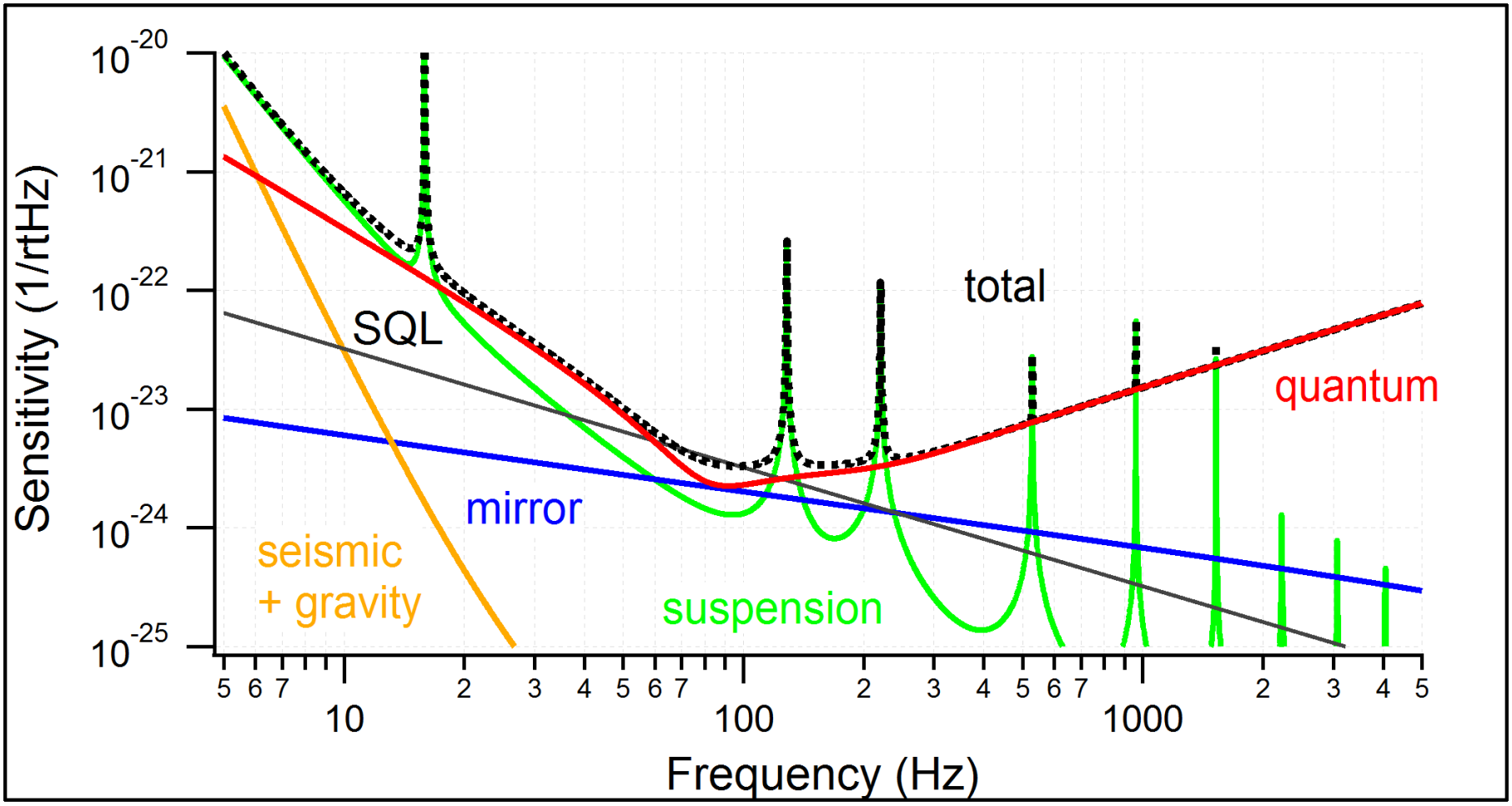
Main features of KAGRA





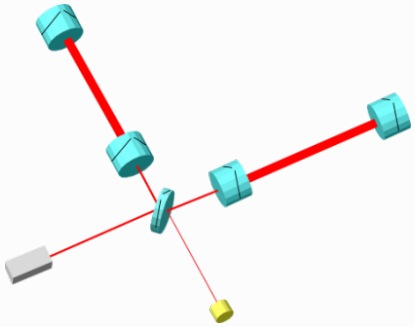
The KAGRA design sensitivity

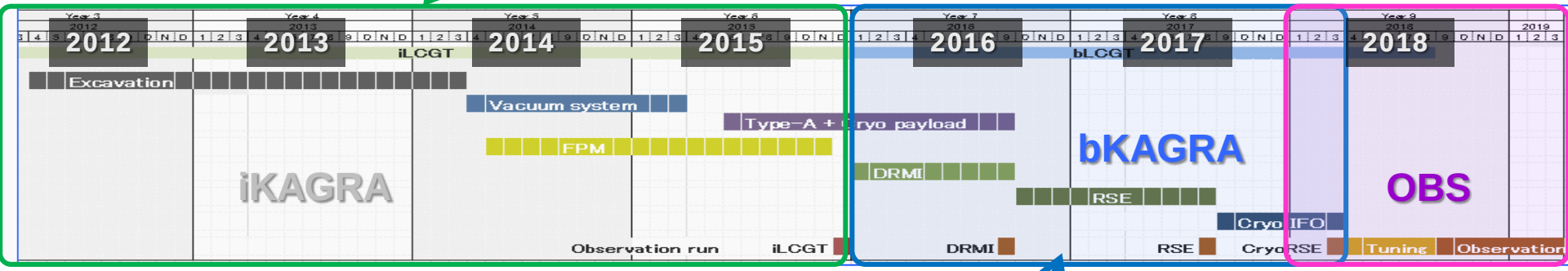
- Approaching a strain sensitivity of 10^{-24} at 100 Hz



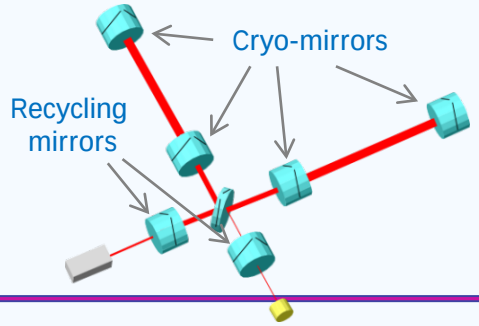
KAGRA overall plan

- **iKAGRA** (2010.10 – 2015.12)
  3-km FPM interferometer
  - Baseline 3km room temp.
  - Operation of total system with simplified IFO and VIS.



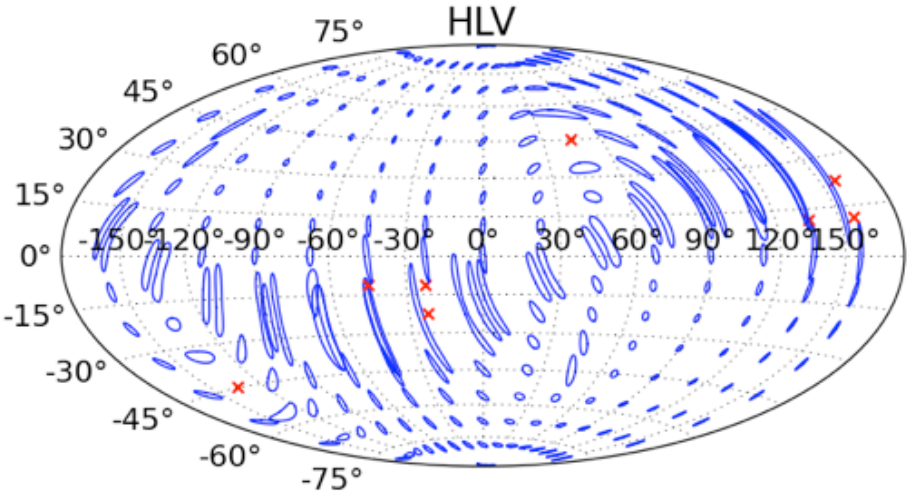


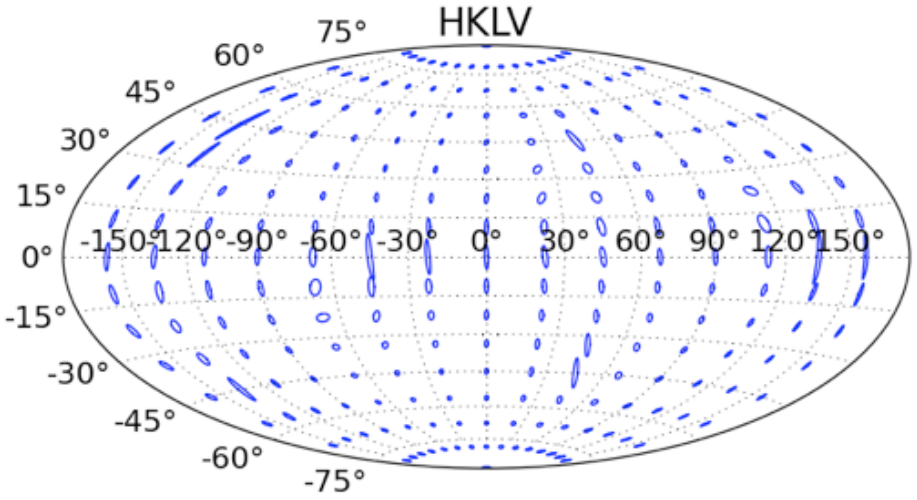
- **bKAGRA** (2016.1 – 2018.3)
  Operation with full config.
  - Final IFO+VIS configuration
  - Cryogenic operation.



Impact on the network performances

- Agreements with LIGO and Virgo have been signed
- KAGRA will join the worldwide network in 2018 increasing considerably the overall network capabilities
- Future improvements are possible with underground site and cryogenic infrastructure

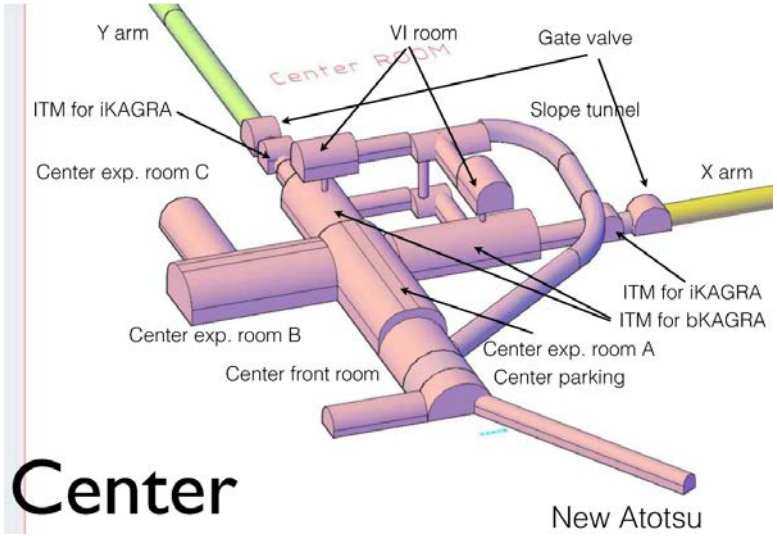




Credit: S. Fairhurst

II. Design and status of KAGRA

Tunnel

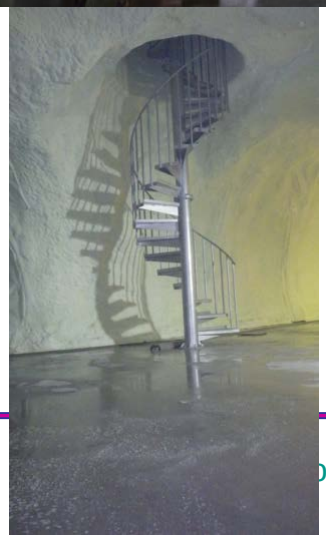

Y arm
VI room
Gate valve
Center ROOM
ITM for iKAGRA
Slope tunnel
Center exp. room C
X arm
ITM for iKAGRA
ITM for bKAGRA
Center exp. room B
Center exp. room A
Center front room
Center parking
Center
New Atotsu

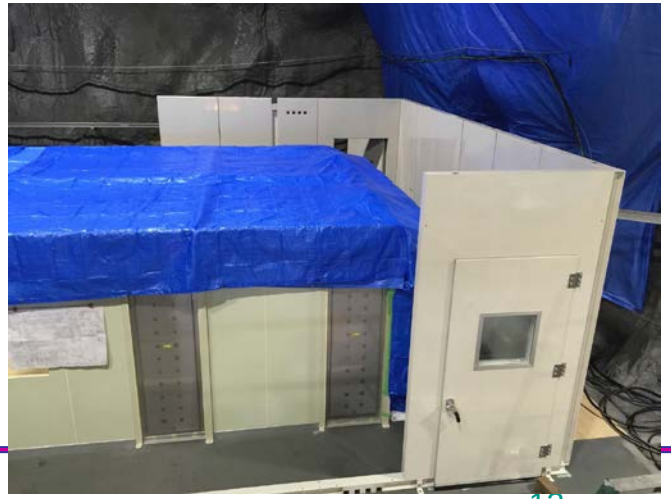
⑥
全長≒190m
X end
1F Rail method
2F Tire method
⑤
X arm
Rail method
3000m
117m
Sakonishi
Tire method
⑤
New Atotsu
④
MOZUMI
New Atotsu
entrance
①
1500m
1500m
Mozumi tunnel
Tire method
314m
①
②
③
③
②
454m
New Atotsu tunnel
Tire method
Mozumi tunnel
(Already exixting)
680m
全長≒200m
Y arm (Mozumi side)
Tire method
Y arm (New Atotsu)
Tire method
全長≒400m
Center area
Tire method
Y end
Tire method
Mozumi entrance

Tunnel

Infrastructure

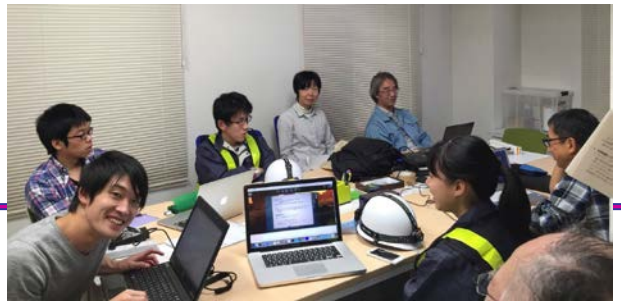
- Infrastructure completion ongoing
  - Electricity, network, safety systems, walls and floor finishing, clean rooms, …



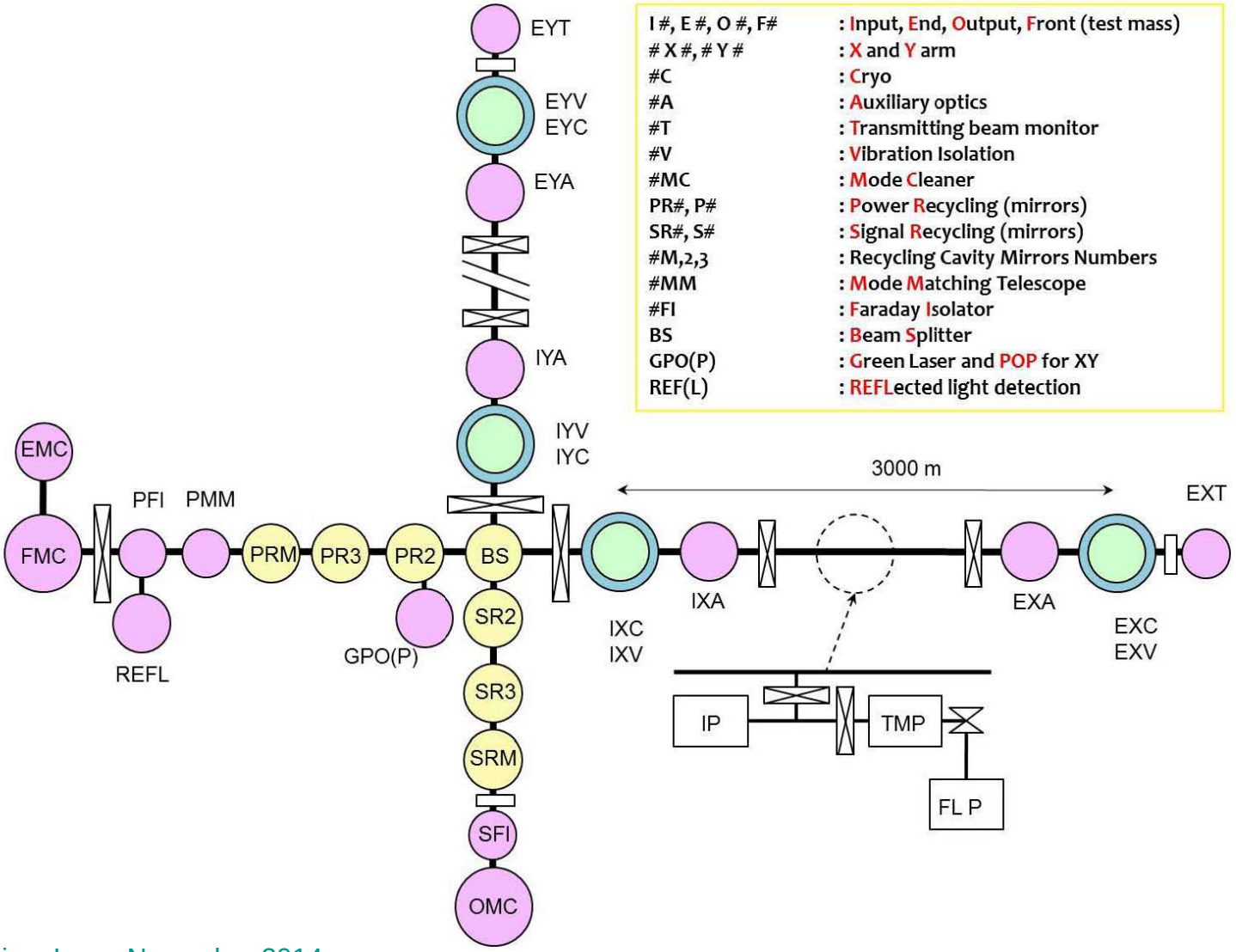


Infrastructure

- External facilities
  - Office space available in refurbished kindergarten
  - New building for data storage and computing now available



Vacuum system



Vacuum system

- Beam tube:
  - 478 sections of 12 m
  - All sections delivered and stored
  - Installation of tubes in the tunnel started
  - Should be completed by March 2015

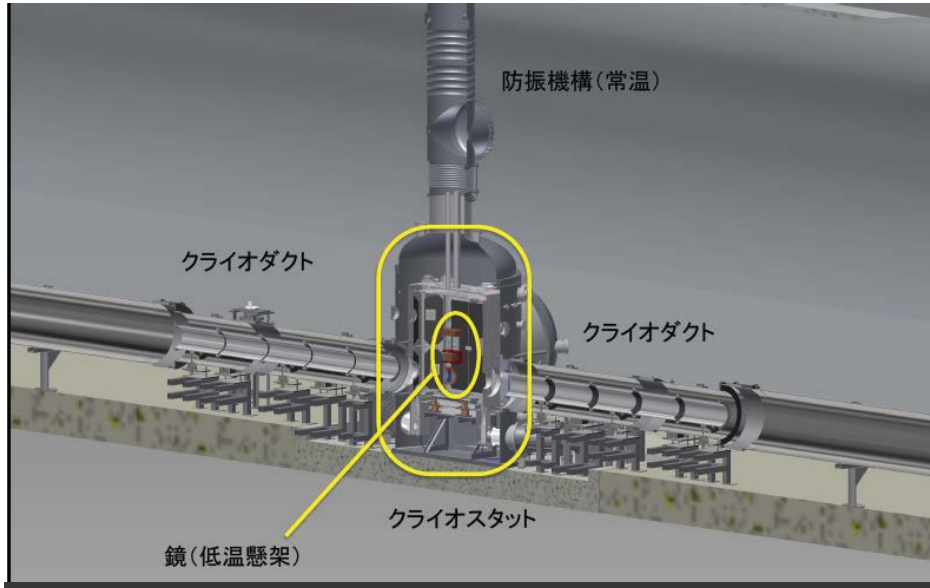
Vacuum system

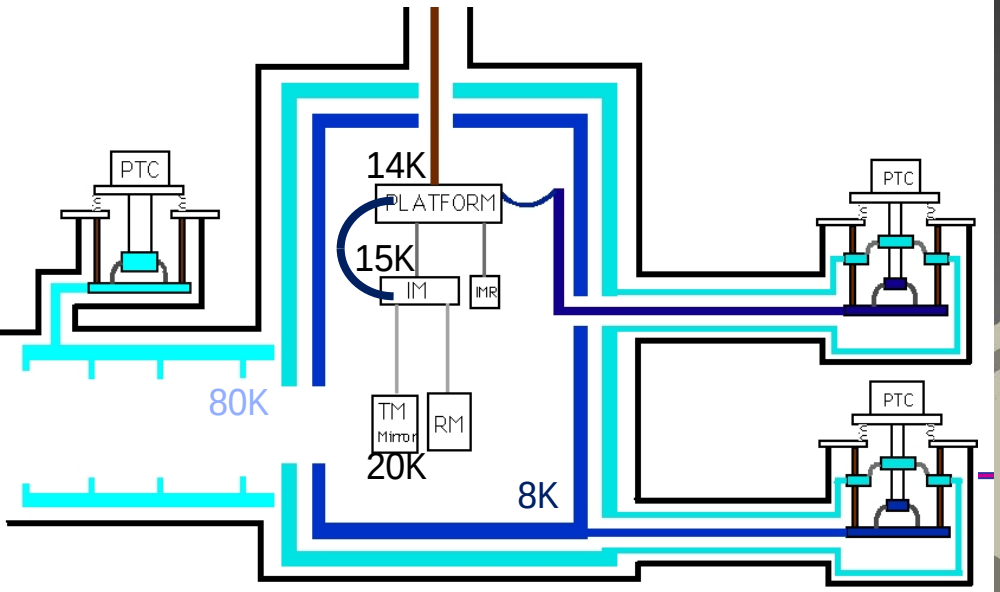
- Vacuum chambers
  - Under construction
  - Installation started
- Vacuum pumps
  - Procurement in progress
- Installation of vacuum system
  - To be completed in FY2014

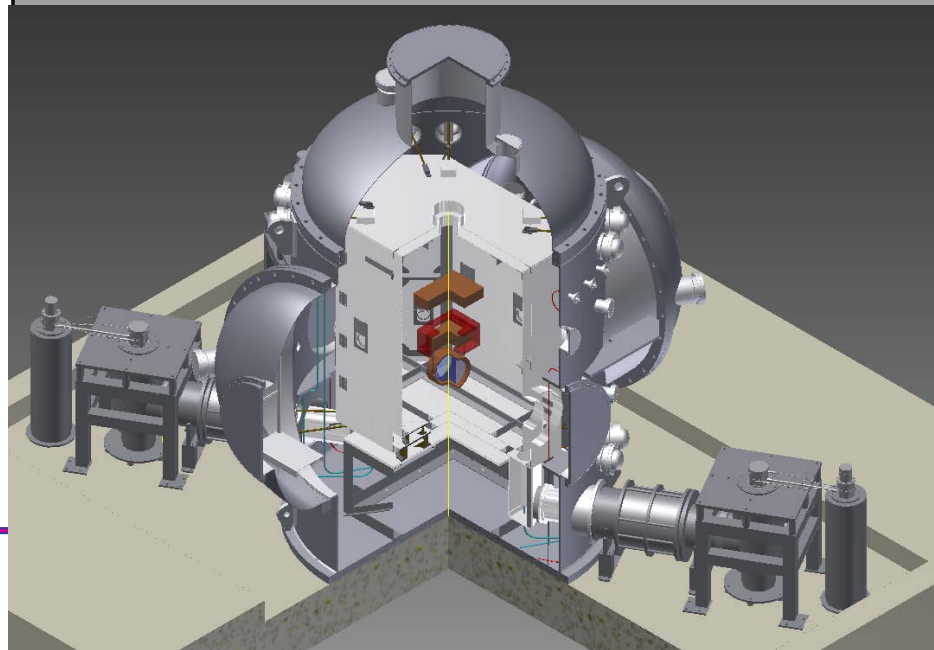
	2013		2014				2015			
	III	IV	I	II	III	IV	I	II	III	IV
electricity	tunnel excavation			wiring						
ventilation				duct						
drainage				tubing						
crane				girder						
hanging anchor				drilling						
dust prevention coating					laser room	c-room				
clean booth					laser room	c-room, e-room				
network and PHS										
arm tube										
laying a chalk line										
carrying and anchoring										
flange fastening/leak test										
chamber										
marking										
anchoring				cryo		other chambers				
mirror suspension						Type-C, Type-Bp, BS Install / tune in chambers				
input/output optics						laser setup	PMC to MC			
optical baffle (arm)					during flange fastening/arm					
target monitor (arm)					during flange fastening/arm					
vac pumping					bidding	during flange fastening/arm				
Geophysics interferometer						inst.	test/operation			
Environment monitor						preparation for install				

Cryostats

- Vacuum chamber
  - 2.6 m diameter, 3.6 high, 10 ton
- Two shields
  - 8K and 80 K
- Four cryo-coolers
  - 2 for payload and 2 for inner shield
- Cryo-ducts
  - 5 m long with baffles
  - allows reducing heat input by 10^3

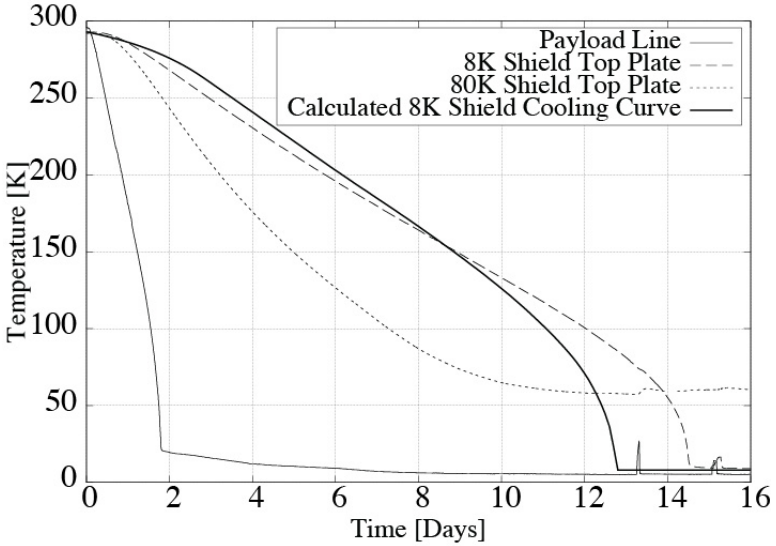






Cryostats

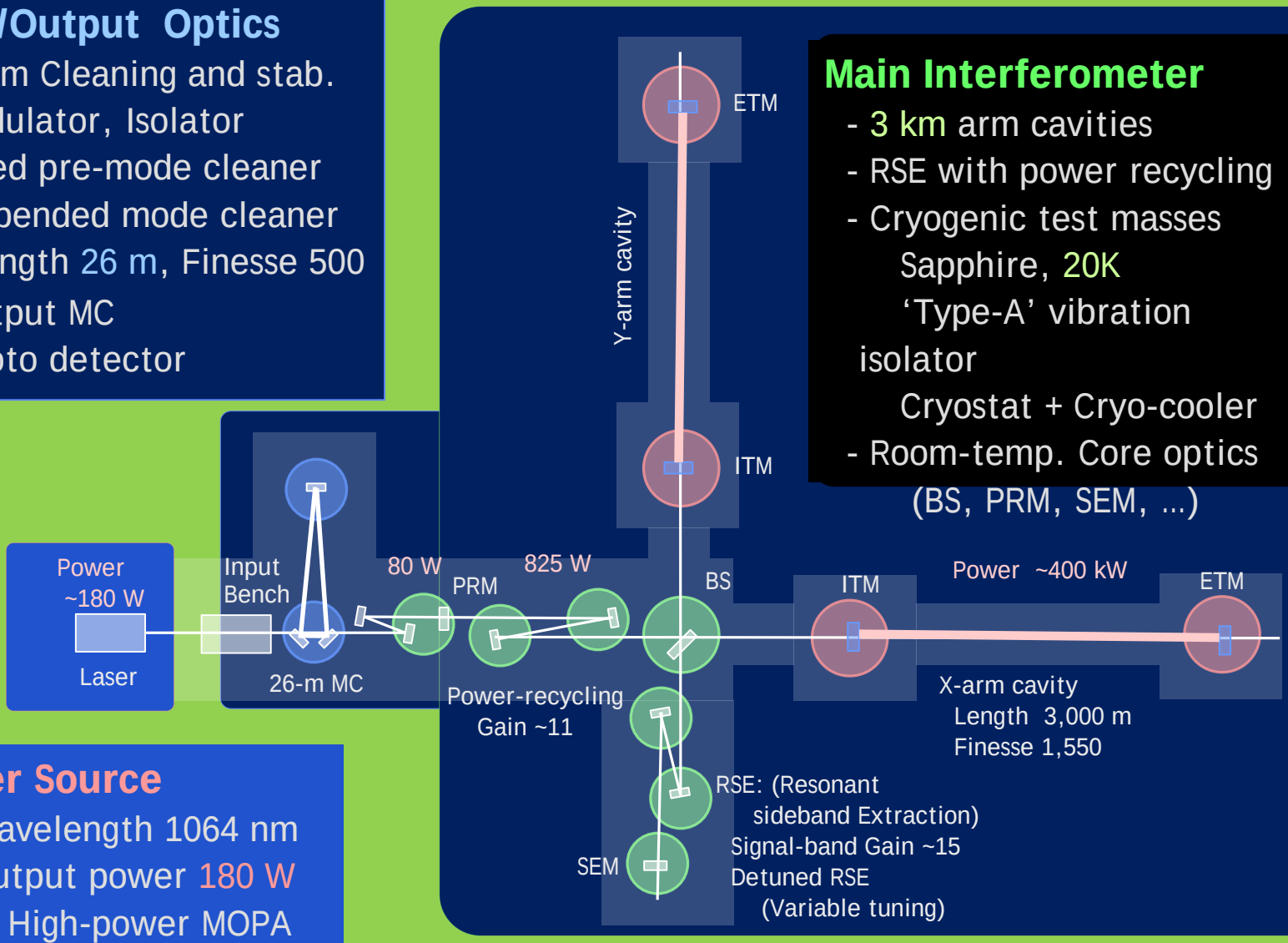
- All cryostats built and delivered
- Cooling test successful
- First two cryostats installed in the in the end caverns



Interferometer 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
- Cryogenic test masses
  Sapphire, 20K
  'Type-A' vibration isolator
  Cryostat + Cryo-cooler
- Room-temp. Core optics
  (BS, PRM, SEM, ...)

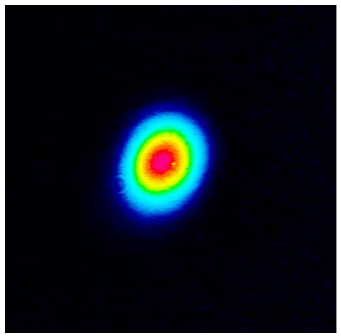


Laser Source
- Wavelength 1064 nm
- Output power 180 W
  High-power MOPA

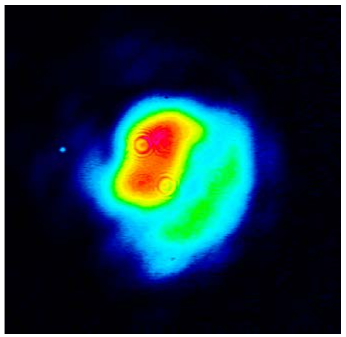
Laser

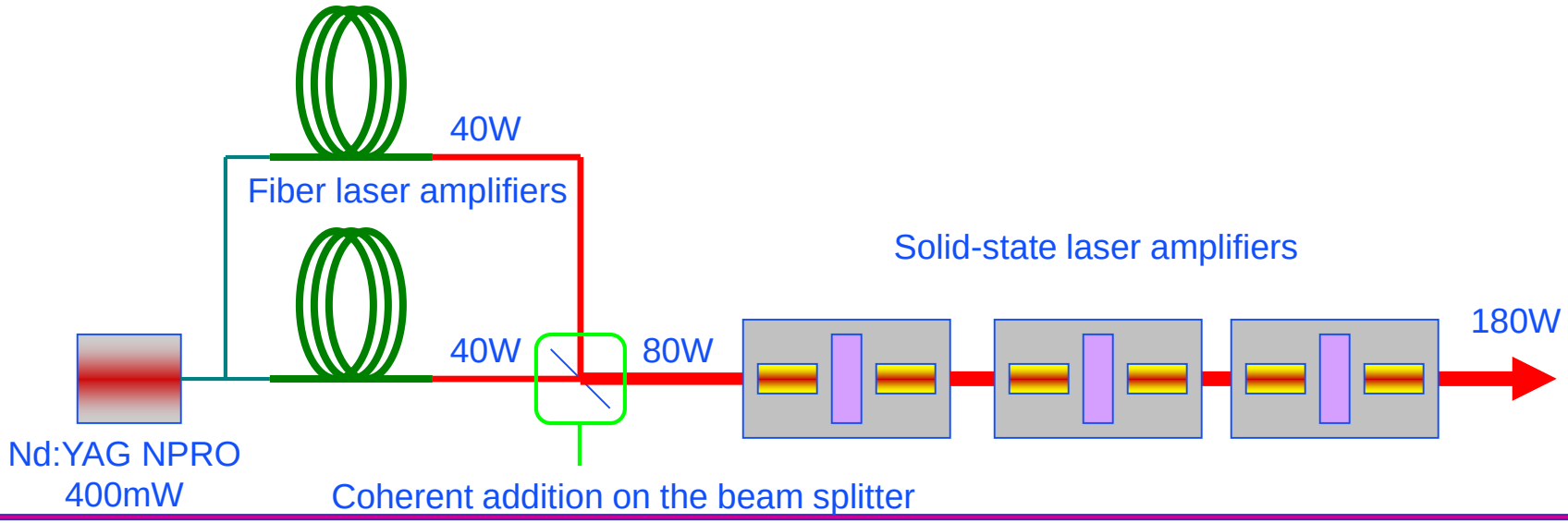
- Coherent addition of two lasers
  - 2 x 41 W = 78 W (95% efficiency)
  - New version with fibers tested
- Amplification with three solid state amplifiers to achieve 180 W
  - Work in progress
- NB: iKAGRA will use 2W NPRO

Bright port 78W



Dark port 4W

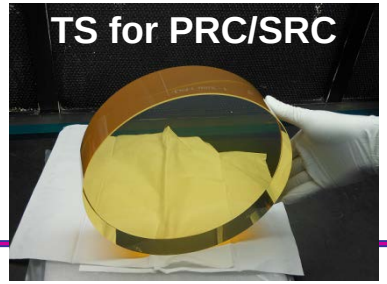


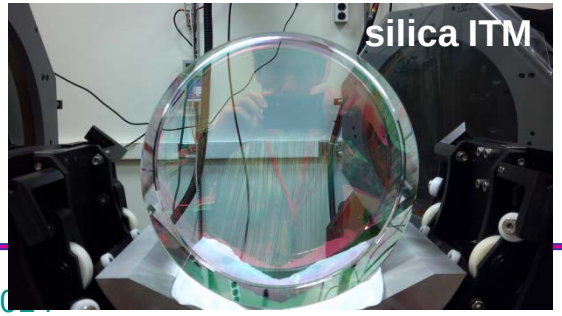


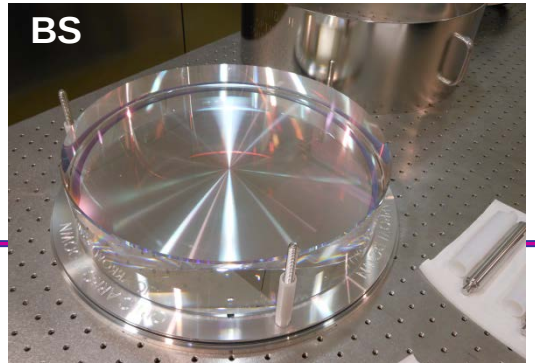
Mirrors

- Recycling cavity mirrors and iKAGRA TM: made of silica

Optics	Status	Polish	Coating
Sapphire TM	next year	TBD	TBD
Silica TM	**completed**	Coastline Optics	Coastline Optics
BS	**completed**	CSIRO	CSIRO
TS for PRC/SRC	**completed**	Zygo EPO	N/A
PR3/PR2/SR3/SR2	In progress	Zygo EPO	LMA
PRM/SRM	next year	Zygo EPO	TBD
MC	**completed**	SIgmaKK	LMA
MMTs	next year	TBD	TBD



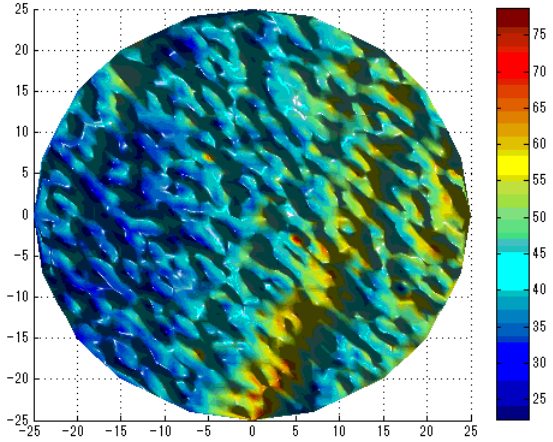


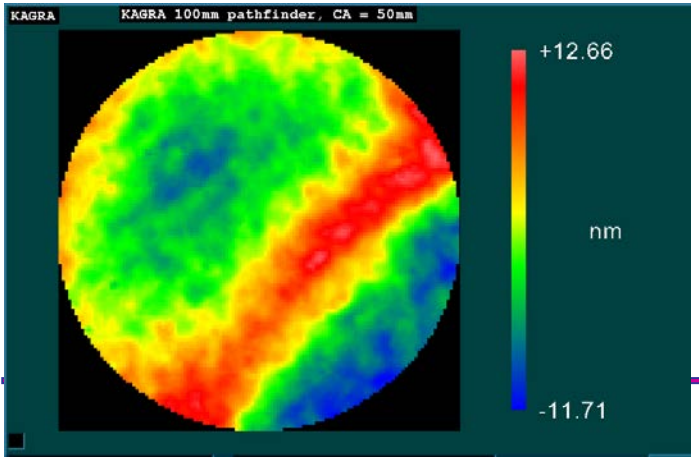


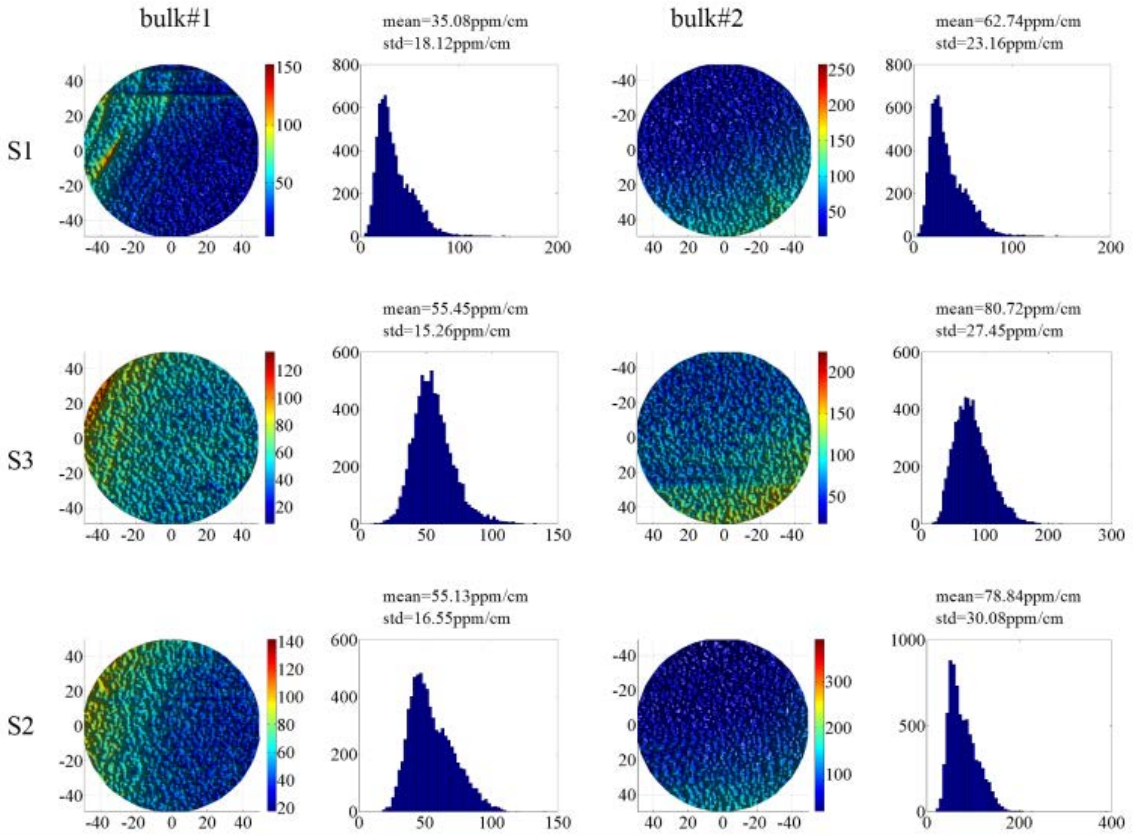
Mirrors

- Test masses: made in sapphire (3 substrates delivered out of 6)
  - Absorption in sapphire is a limitation: work ongoing to have best the quality

Study of absorption



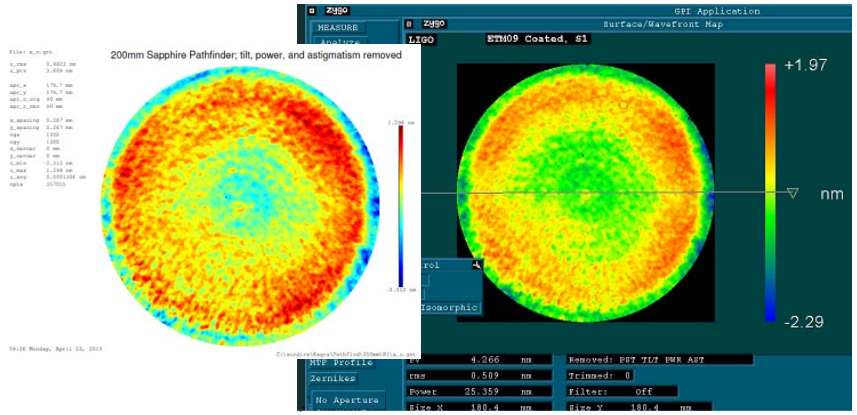




Mirrors

- Test masses: made in sapphire (3 substrates delivered out of 6)
  - Absorption in sapphire is a limitation: work ongoing to have best the quality
  - Polishing of sapphire: test successful
    - » Is compensation of substrate inhomogeneity necessary/useful?

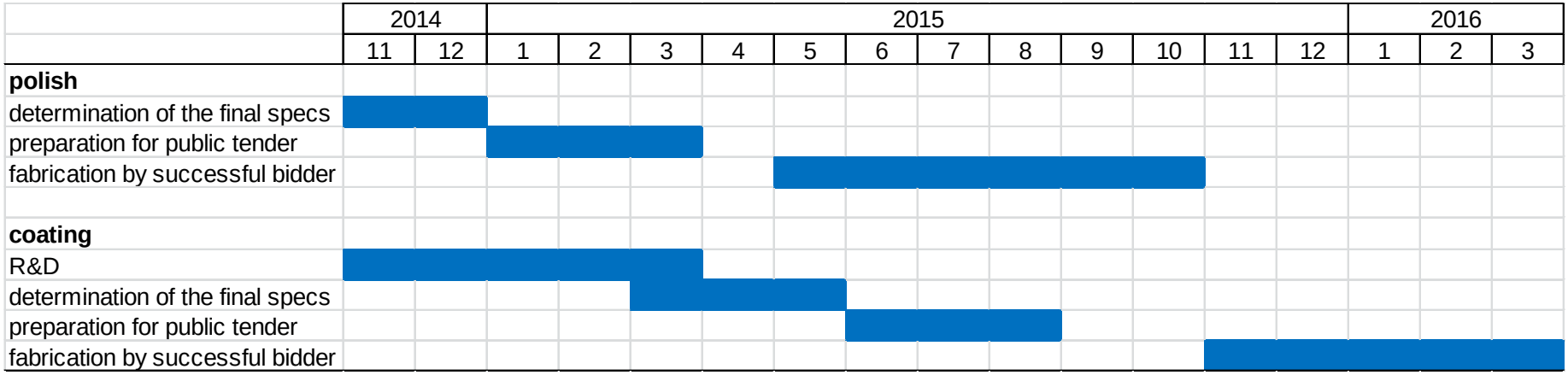
Polishing test



	ZYGO		CALTECH	
Unit: [nm]	**180mm**	**140mm**	**180mm**	**140mm**
RMS (-6 terms)	0.48	0.24	0.45	0.21
Z2,2	-0.68	-0.41	-0.30	-0.13
Z2,-2	0.45	0.26	0.29	0.27

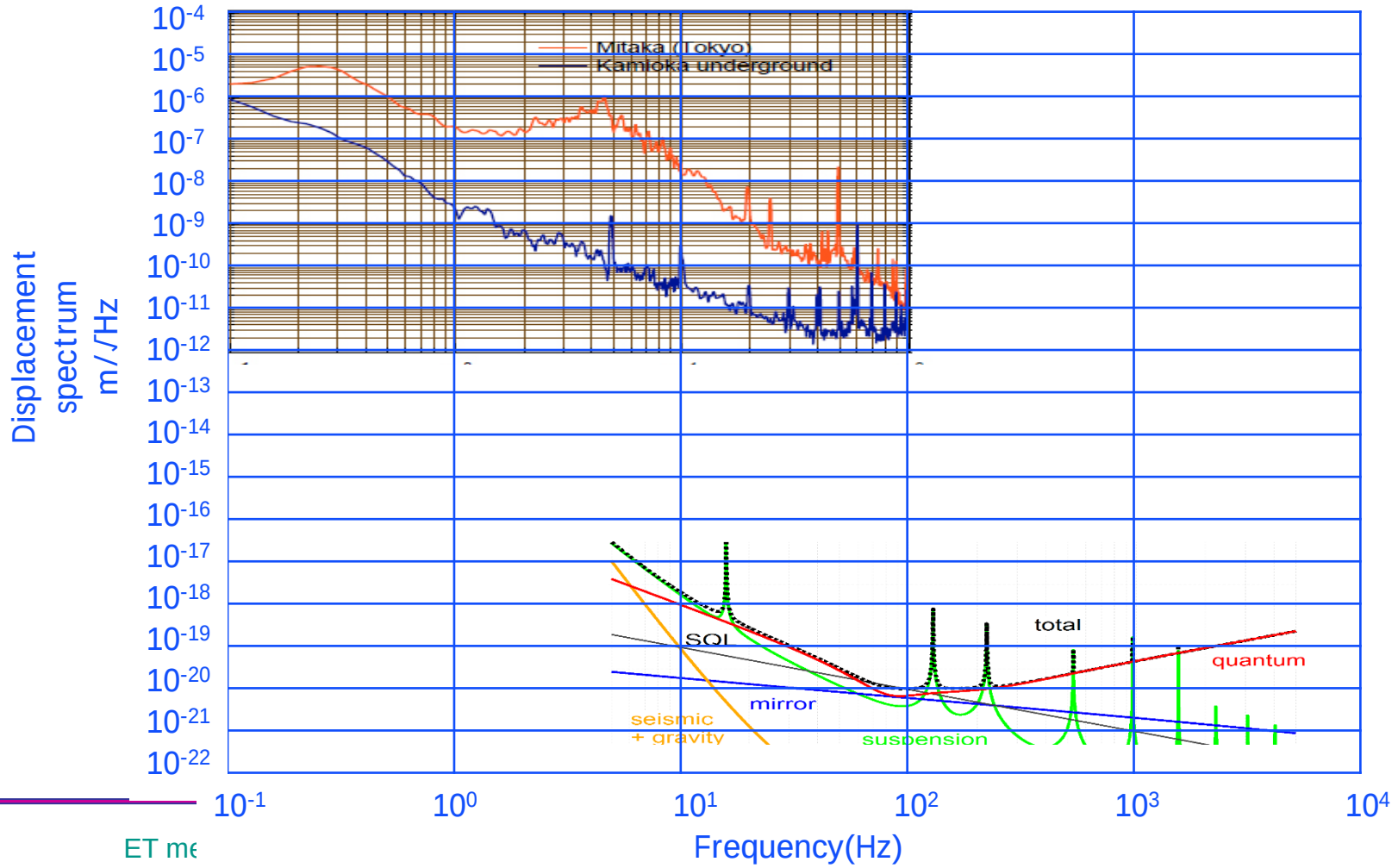
Mirrors

- Test masses: made in sapphire (3 substrates delivered out of 6)
  - Absorption in sapphire is a limitation: R&D undergoing to improve the quality
  - Polishing of sapphire: test successful
    - » Is compensation of substrate inhomogeneity necessary/useful?
  - Schedule: delivery of substrates becoming critical



Vibration Isolation

- The importance of vibration isolation
  - Even underground



Vibration isolation

- KAGRA vibration isolations based on chain of pendulums and maraging steel cantilevers (as in Virgo and TAMA)
- Different optical components need different level of vibration isolation
  - Test masses: Type A
  - Recycling mirrors: Type B (BS, SR) and Type Bp (PR and iKAGRA TM)
  - Input/Output optics: Type C

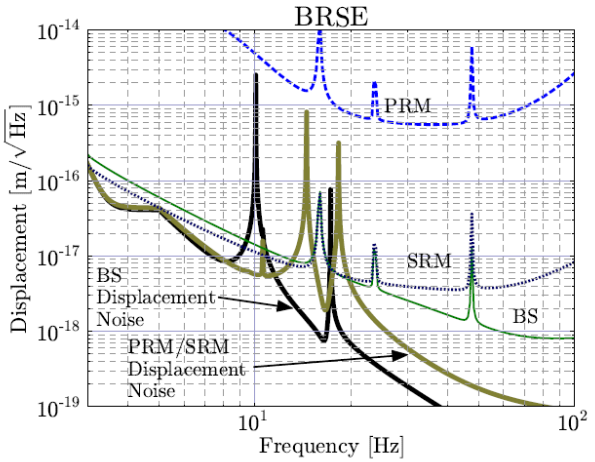
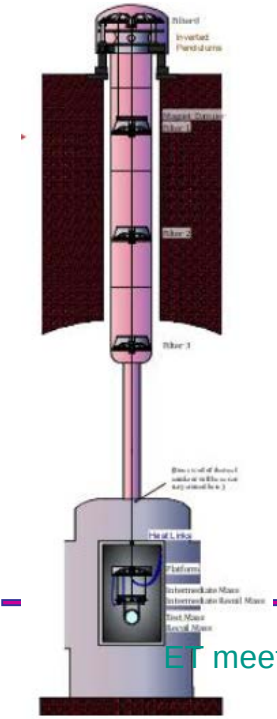
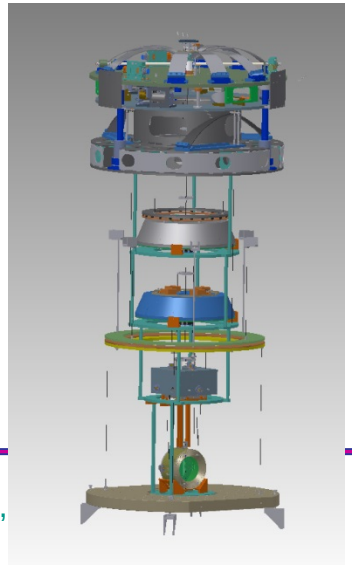


Figure 4.1: Displacement noise requirements for auxiliary mirrors: BRSE

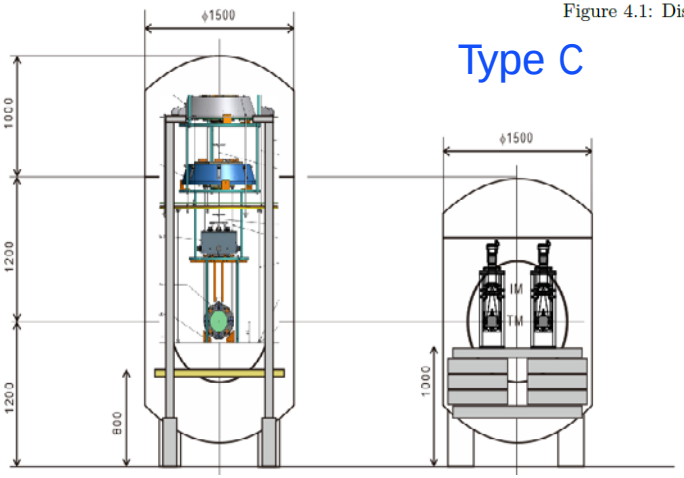
Type A



Type B



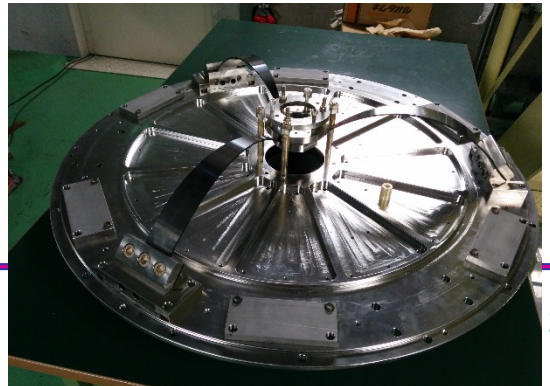
Type Bp

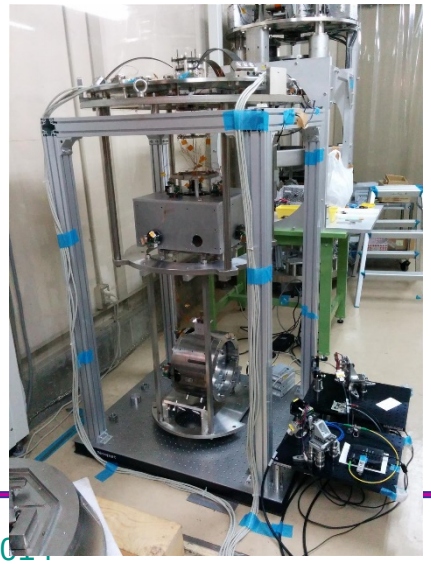


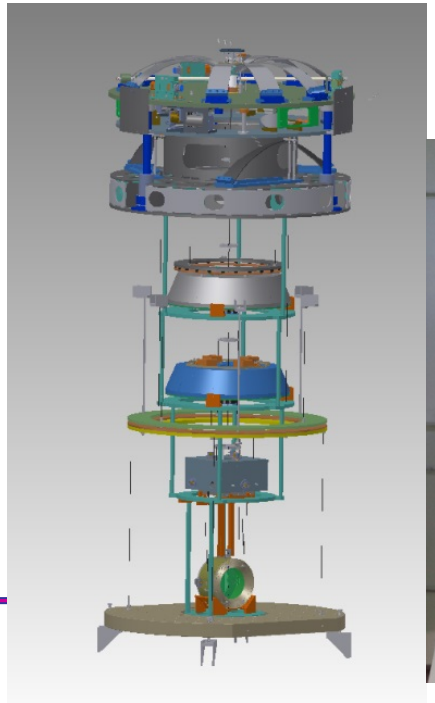
Type C

Vibration isolation

- Status of Vibration Isolation
  - All standard filters available
  - All top filters available
  - Production of bottom filters started
  - Prototype of IP assembled and controlled. New IP's in production at Nikhef
  - Prototype of payload under test at NAOJ
  - Prototype of Type B suspension under test at TAMA end building







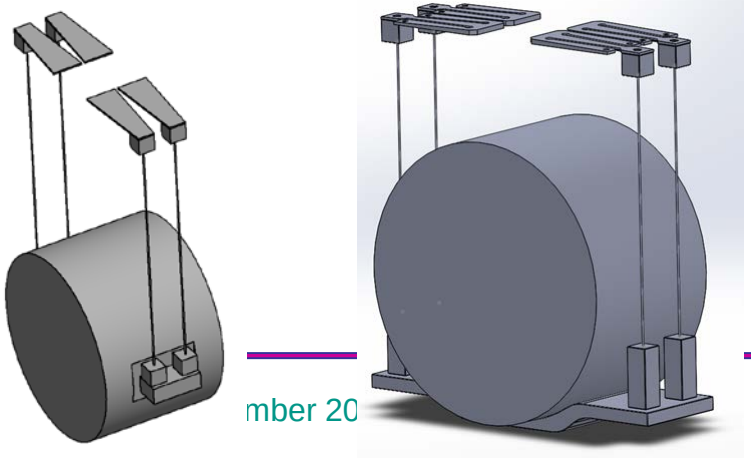
Vibration isolation

- Installation of Vibration Isolation
  - Installation of vibration isolation for input optics started
    - » Some issues with cleanliness to be assessed
  - Installation of vibration isolation for the iKAGRA mirrors in the first half of 2015
    - » Very tight schedule

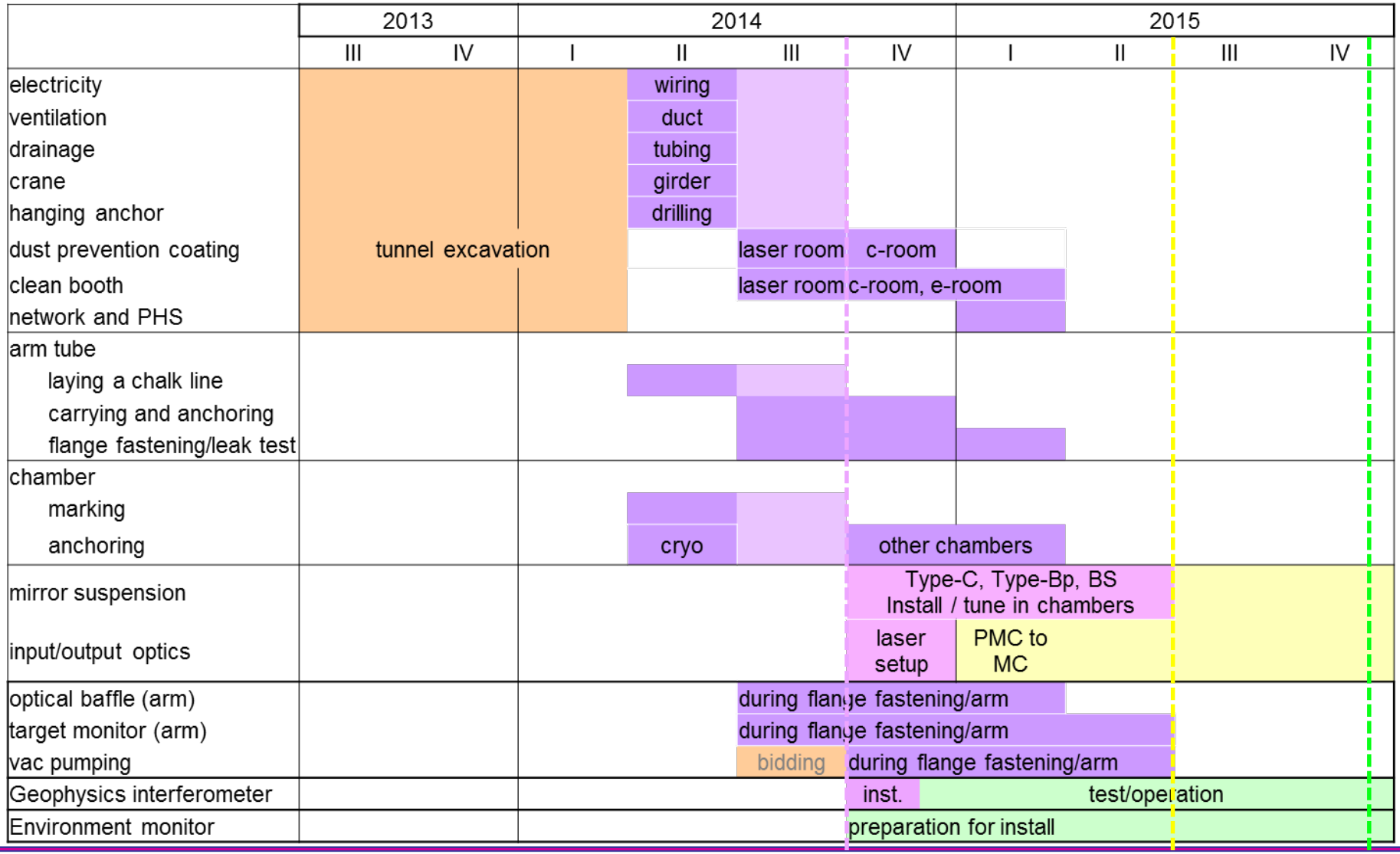
Cryogenic suspension

- Monolithic sapphire suspensions
  - Recognized as one of the main risk in the project
  - Issue: how to de-bond if sapphire fibers break?
  - Lot of activity ongoing (nice collaboration with ET teams through the ELITES program)

- Some recent results:
  - Initial cooling time decreased by 2 with DLC coating
  - Al heat links tested successfully
  - Sapphire fibers with good conductivity and quality factor identified
  - Studies of sapphire bonding strenght
  - **See K. Yamamoto talk**



iKAGRA schedule

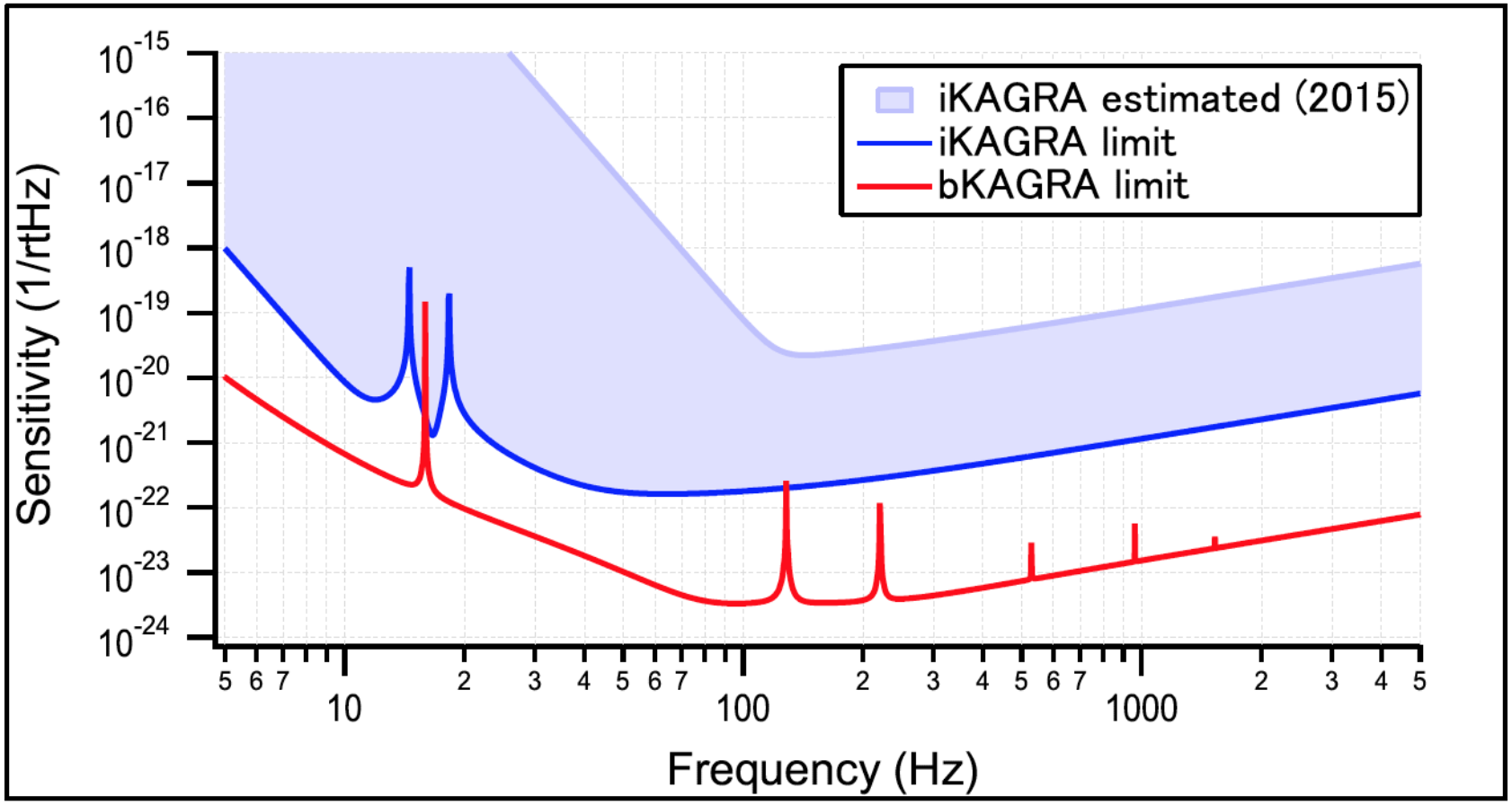


Oct 2014
input-optics installation

Jul 2015
commissioning

Dec 2015
operation

iKAGRA sensitivity



Summary

- KAGRA is promoted by ICRR/UTokyo in collaboration with KEK and NAOJ
- The preparation of the infrastructure and of the large systems is progressing well
  - **Tunnel excavation is completed !**
  - The completion of the infrastructure and the installation of the vacuum system is in progress and should be completed by March 2015
  - A lot of activity is ongoing on to prepare the interferometer subsystems
- iKAGRA installation, commissioning and observation will be major activity in 2015
- Upgrade to bKAGRA will take place progressively with the first observation run in 2018
- Agreements with LSC/LIGO and Virgo/EGO are in place for technical collaboration and to prepare the joint observations