KAGRA+

GWADW
May 2018

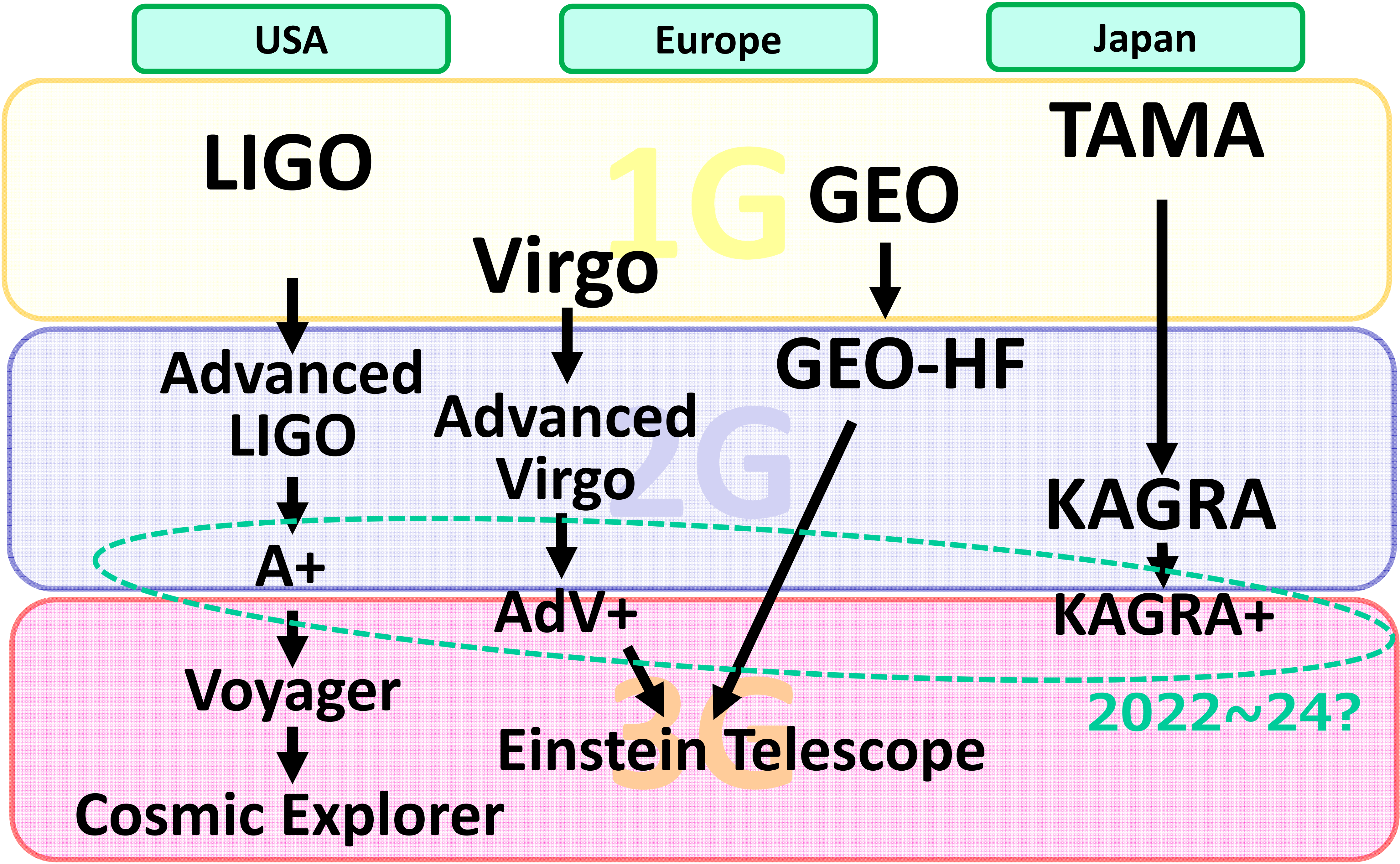
Tokyo Institute of Technology

Kentaro Somiya
on behalf of the KAGRA collaboration

(note: KAGRA+ is not yet officially approved in the collaboration)

K.Somiya

GW detectors



Possible KAGRA+ schedule

2019~20:
KAGRA's first detection

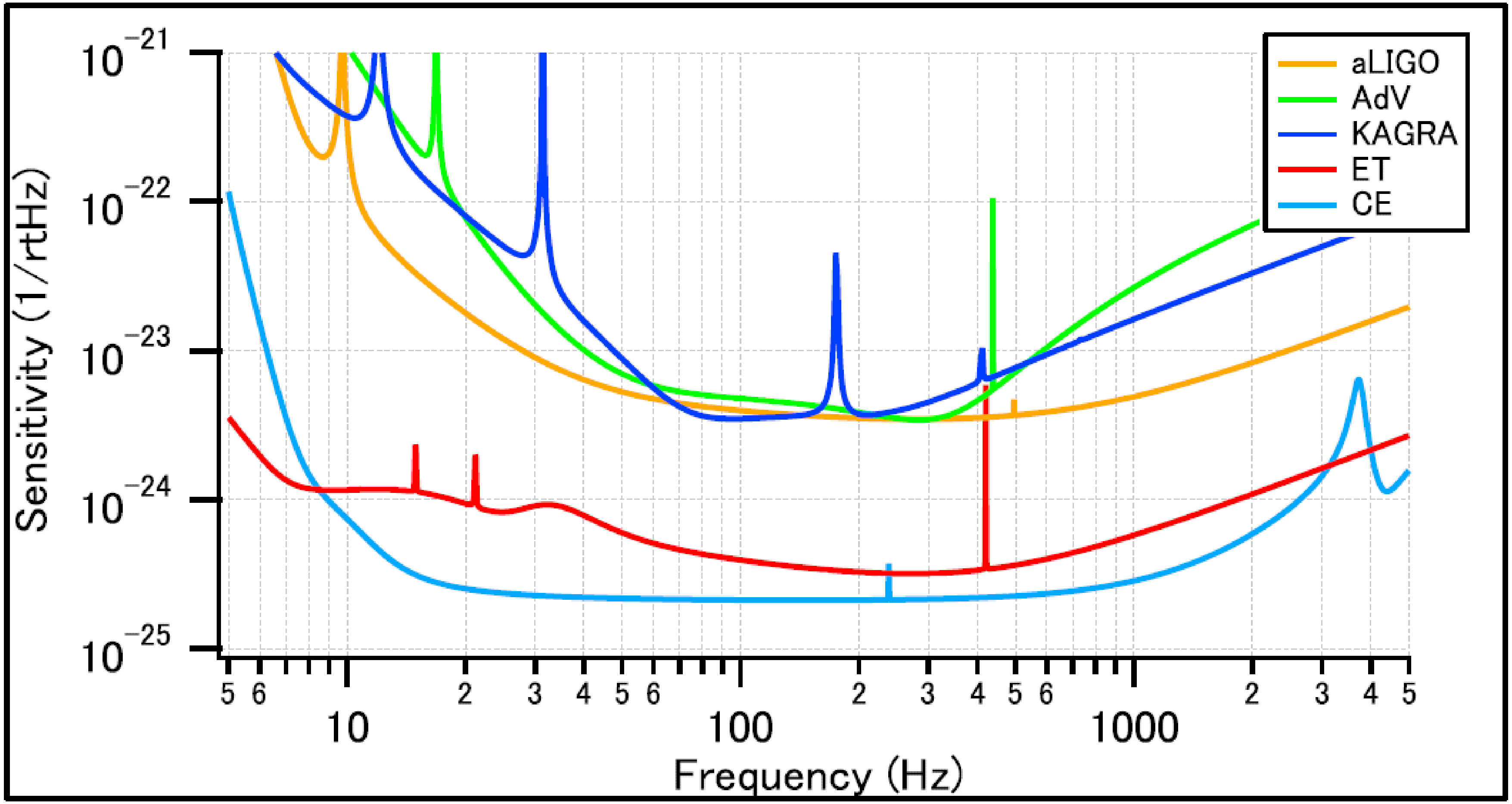
Design study of KAGRA+

2019 or 2020:
Application to a grant ($5M?)

2020~22: Implementation of new items

2022~24 KAGRA+

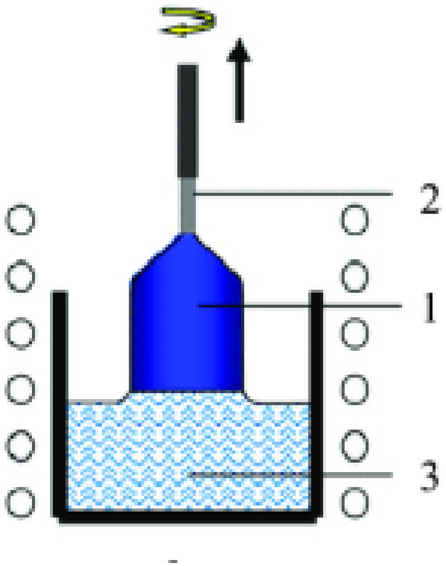
Sensitivity comparison



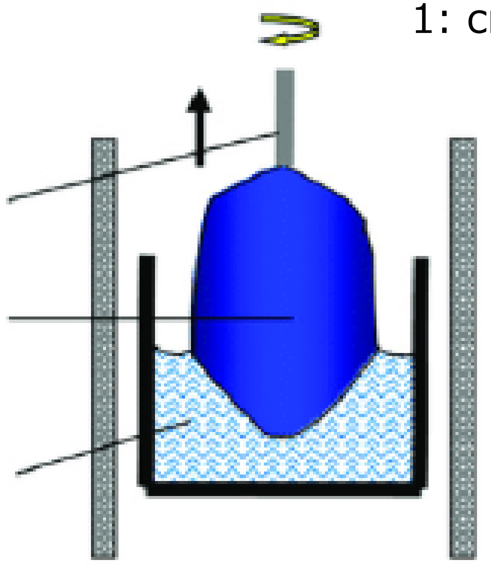
	aLIGO	AdV	KAGRA	ET-LF	CE
High power	☺	☺	☺		☺
Cryogenic			☺	☺	☺
Underground			☺	☺	

Heavier Sapphire for KAGRA+?

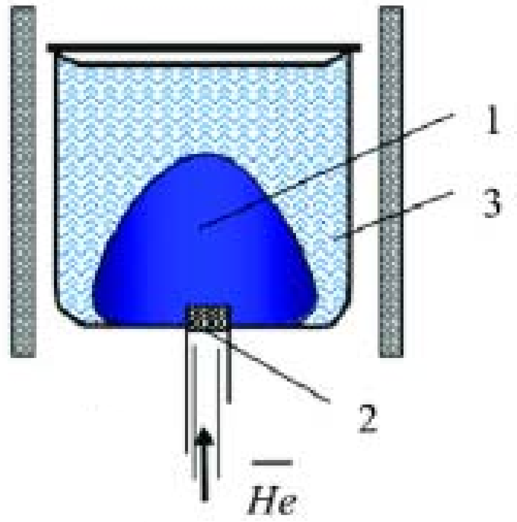
1: crystal, 2: seed, 3: melt



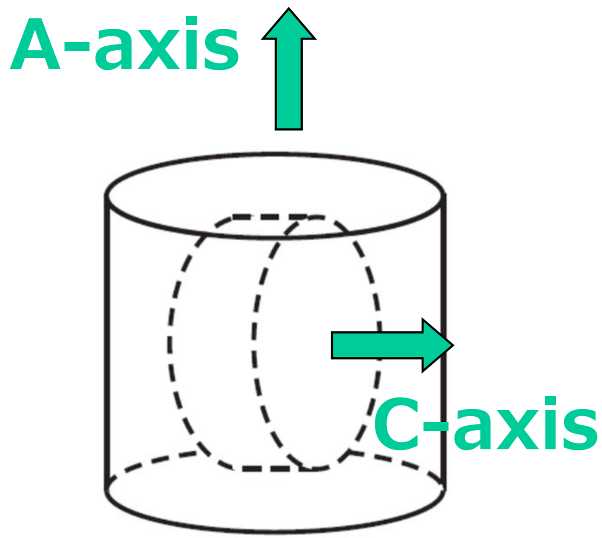
Czochralski



Kyropoulous

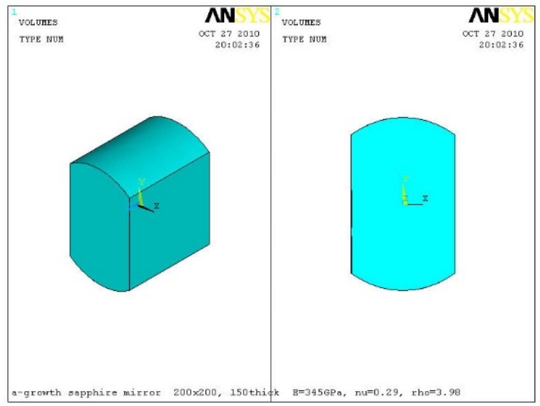


HEM



	crystal size	crystal axis	quality
Czochralski	medium	can be c-axis	bad
Kyropoulous	big	usually a-axis	good
HEM	very big	usually a-axis	bubbles

Reference: Kawaminami et al., J. of the Cer. Soc. of Japan 122, 695 (2014)



Kamaboko mirror
(40kg)

Heavier Sapphire for KAGRA+?

[Kawaminami et al., J. of the Cer. Soc. of Japan 122, 695 (2014)]

- A Japanese company has developed TSMG (Top Seeded Melt Growth) method which can produce big, c-axis, good sapphire crystals.
- KAGRA's ITMs were produced with this TSMG method.
- Eiichi is to establish a new collaborative project to produce high quality larger crystals with this company, aiming at 100kg crystal(ϕ400mm x t200mm).

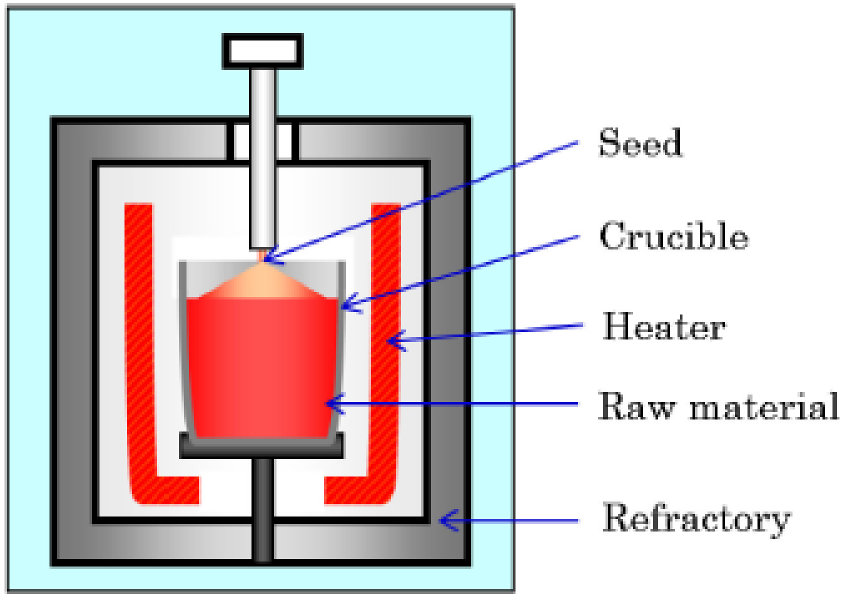
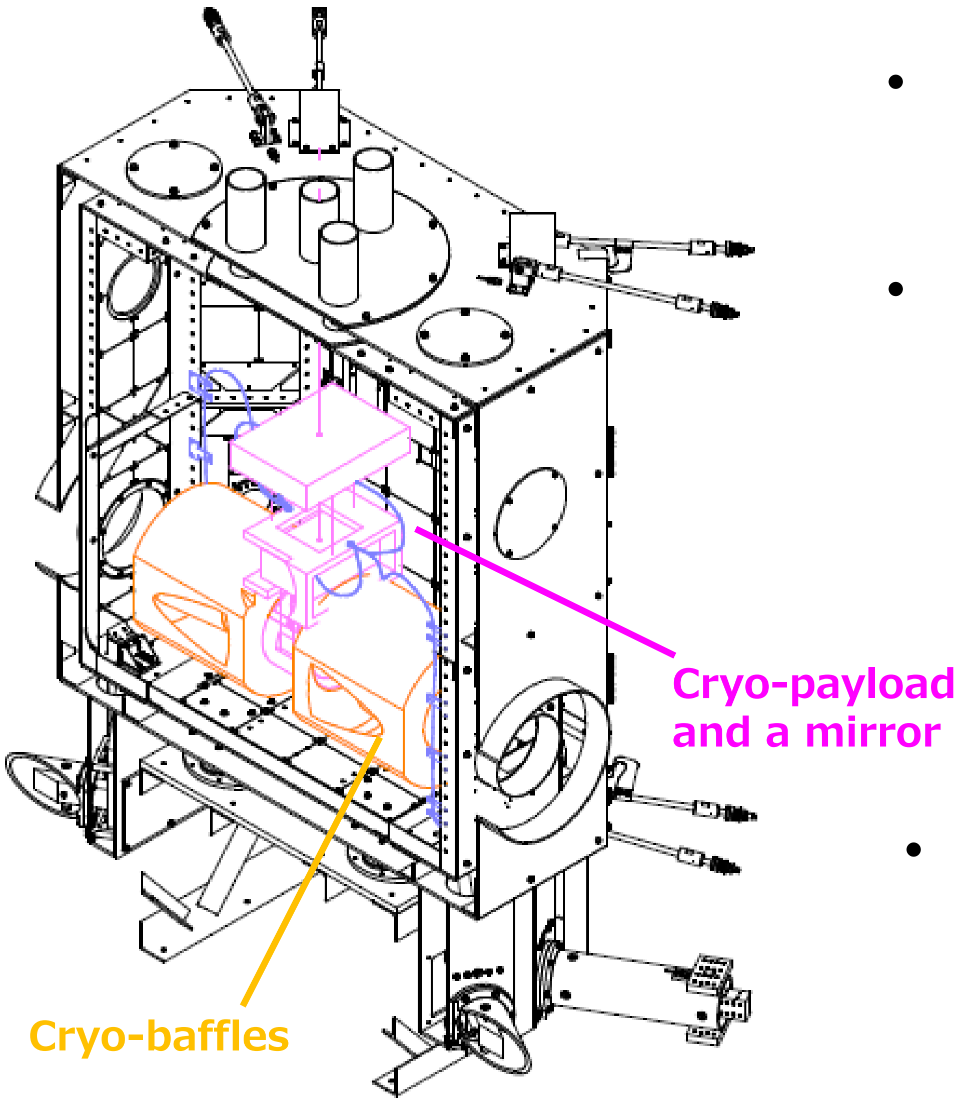


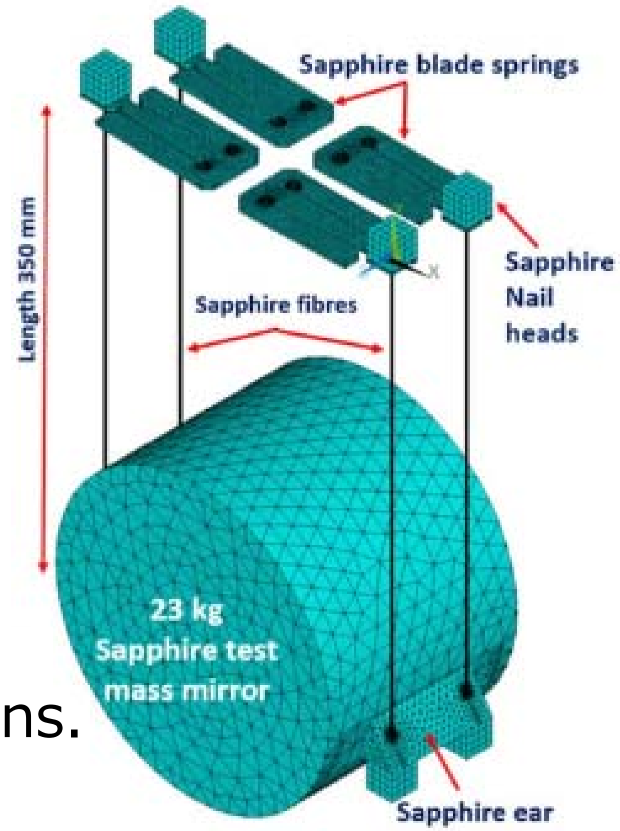
Fig. 1. Schematic illustration of the TSMG method.

- **Having both advantages of CZ and KY**
- **Small rotation over short pulling distance**
- **Arbitrarty direction of growth**
- **Oxygen vacancies (UV absorption)**

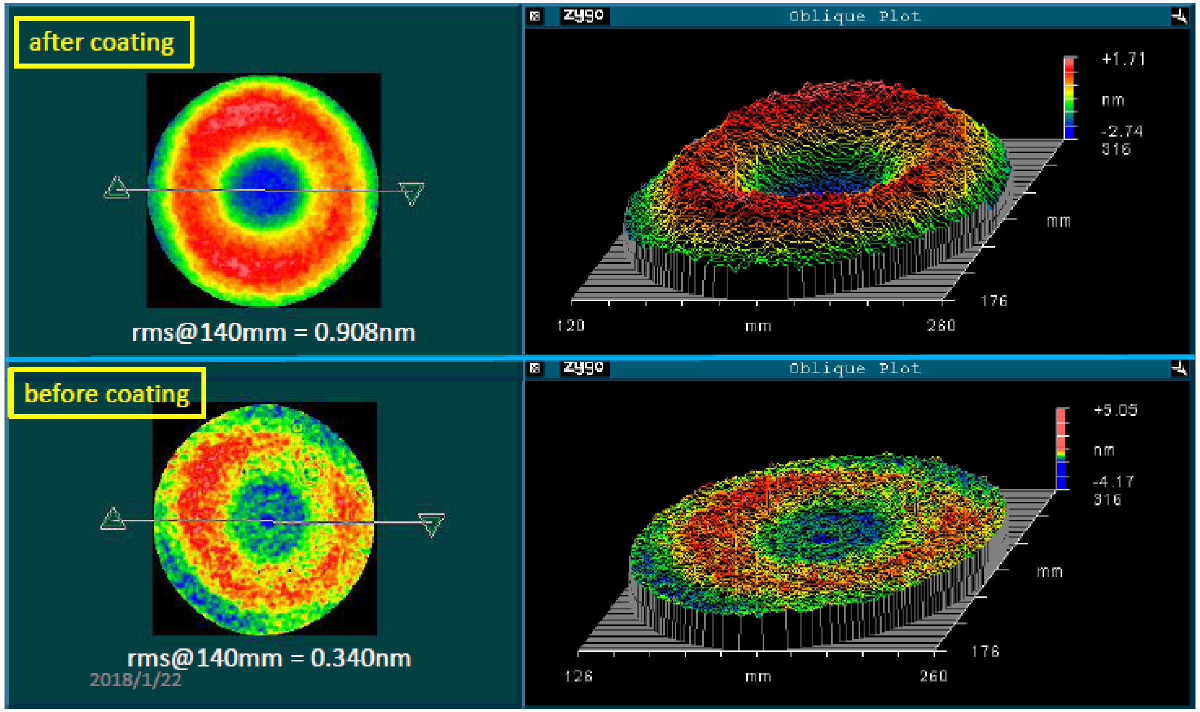
Additional issues to be solved

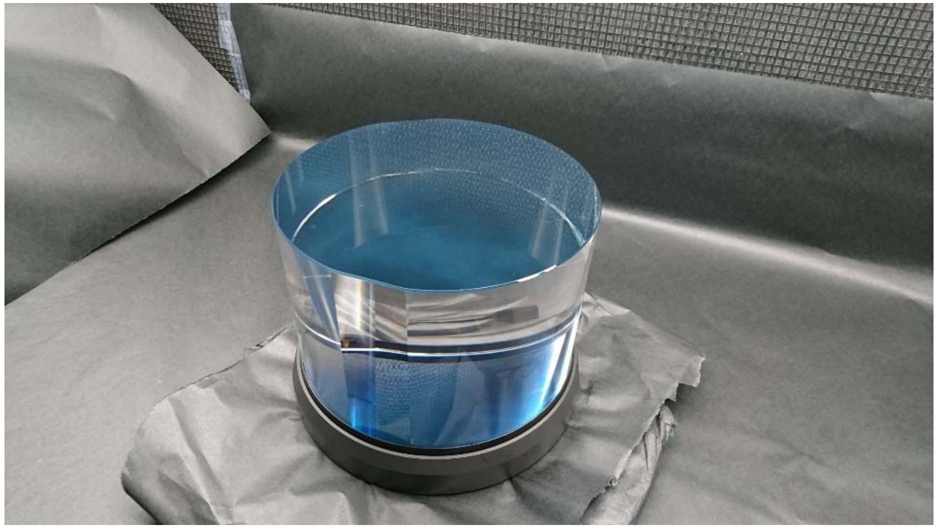


- A cryostat is quite full with the current ϕ220 x t150 crystal and cryo-baffles.
- Kazuhiro Yamamoto says x1.2 may be ok but x1.5 larger mass would be hard. (23kg x 1.2^3 = 40kg)
- Load capacity of the blade and bondings are also an issue.
- Type-A suspension may need modifications.



Cost of sapphire mirrors

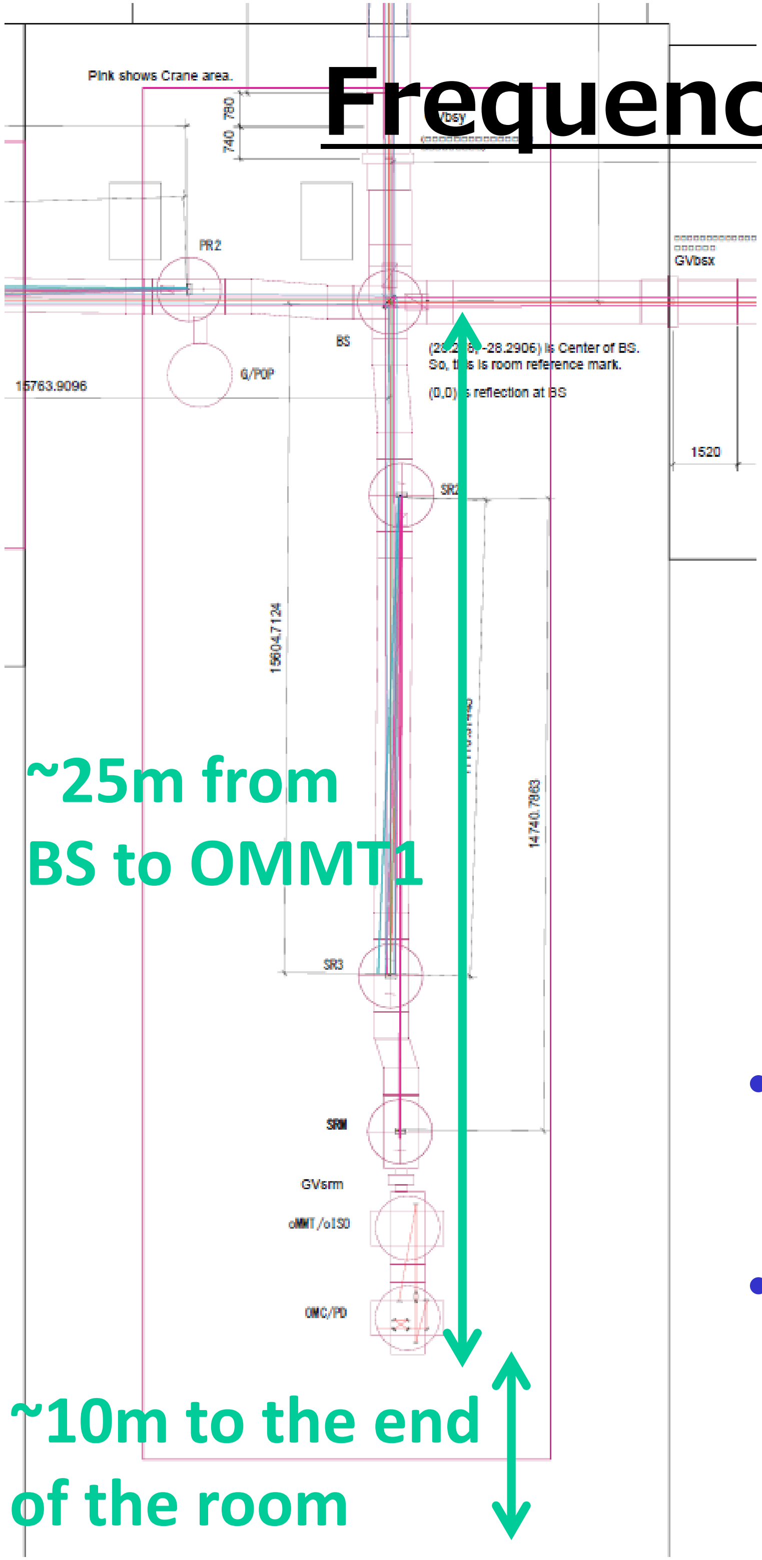


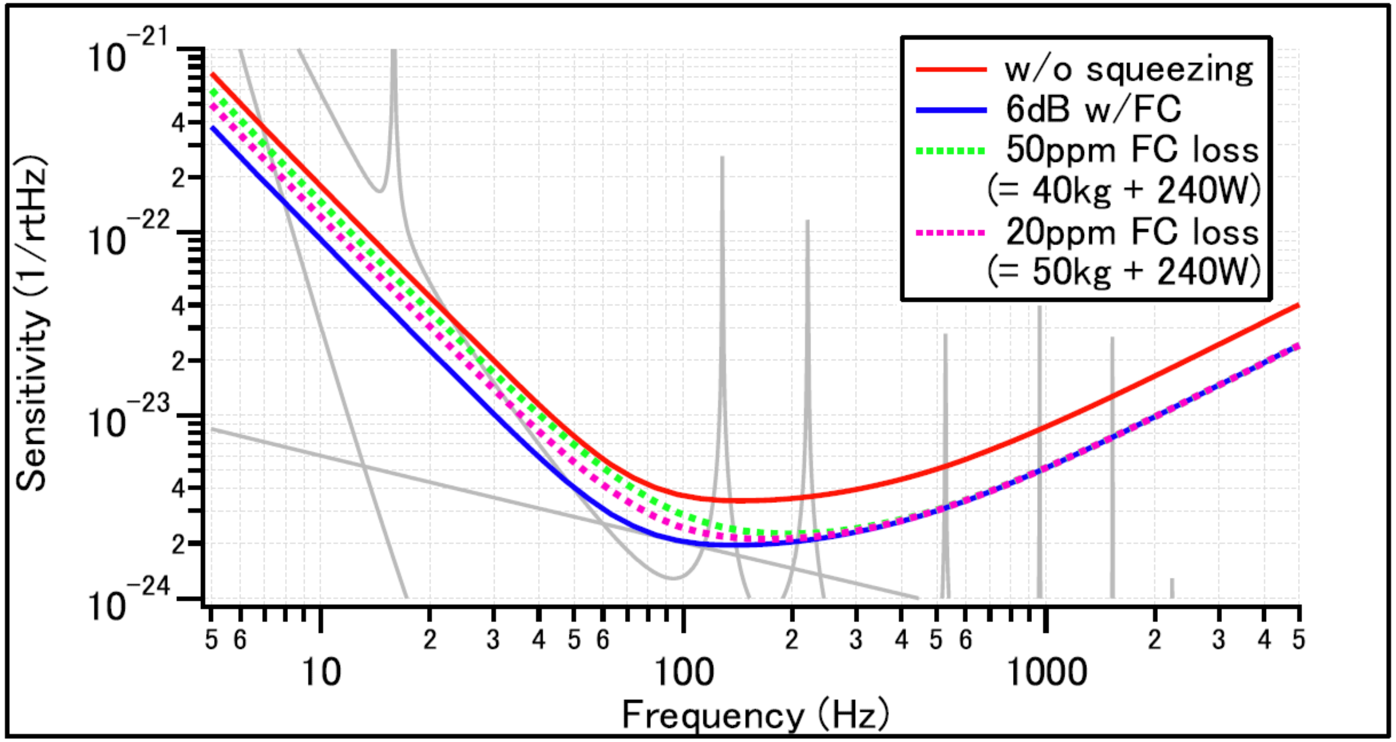


- crystal: ~$100k per piece
- polish: ~$400k per piece
- coating: ~$100k per piece

Most of the budget for the upgrade would be spent for the mirrors.

Frequency-dependent squeezing

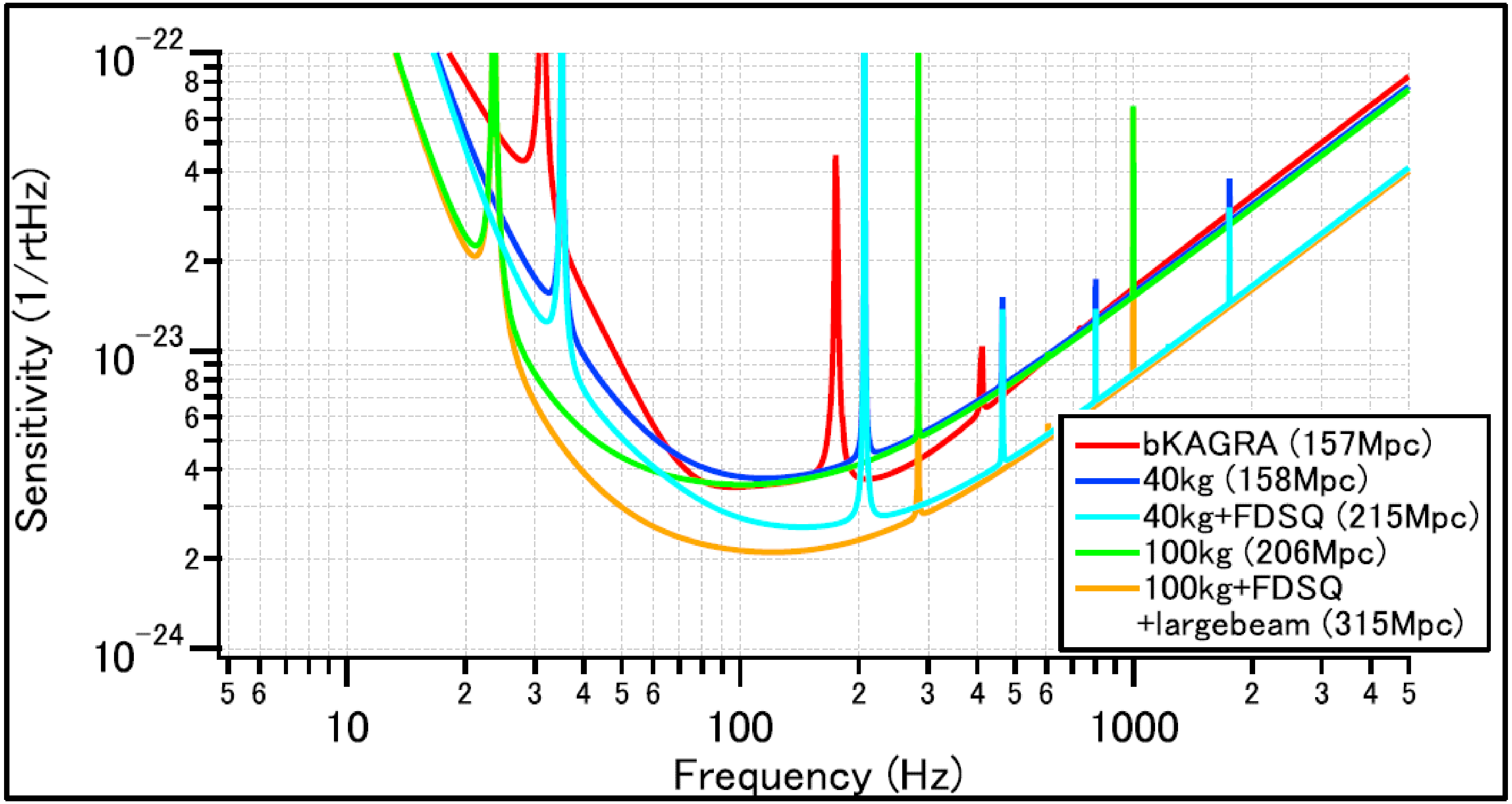




- A use of FD SQ is equivallent to a use of larger test masses (for QN).
- R&D with a 300m FC has been performed in TAMA.

[see Eleonora's talk on Wed]

Sensitivity curves with heavier masses



Required items

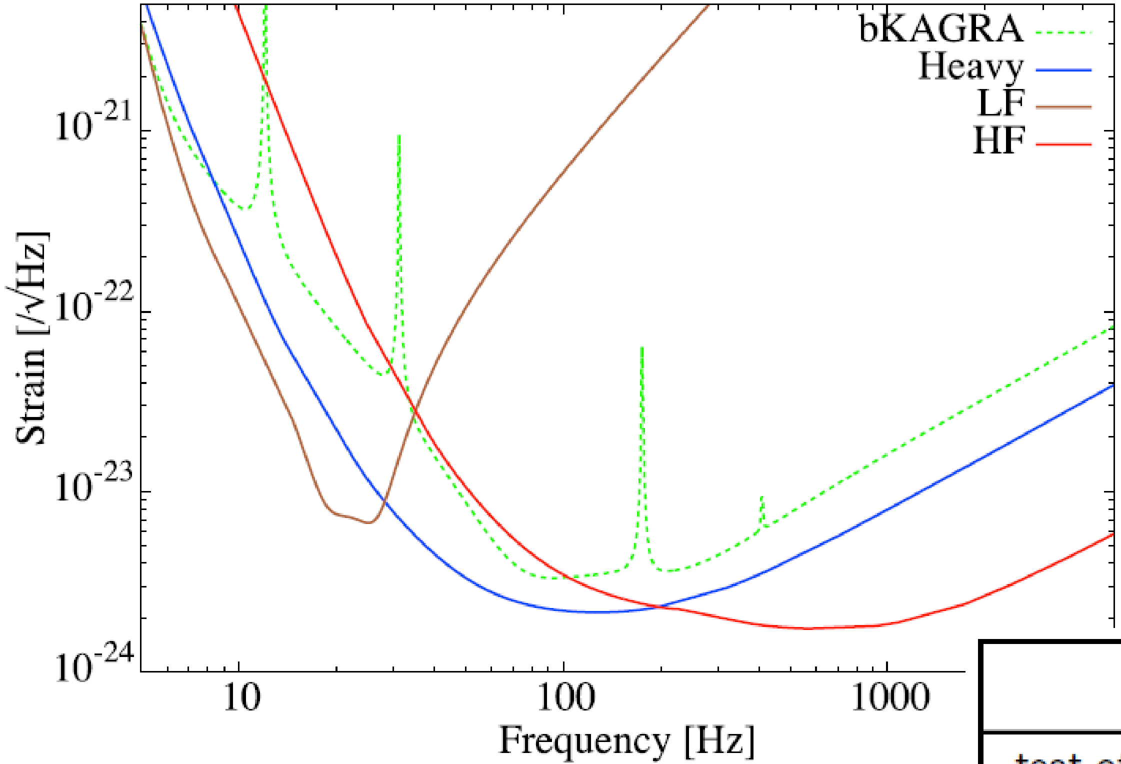
158Mpc: Mirror — $3M

215Mpc: Mirror + FDSQ — $6M

206Mpc: Mirror + Cryostat/payload + Type-A — $8M

315Mpc: Mirror + Cryostat/payload + Type-A + FDSQ + RMs — $12M

Other options



LF: low power + longer suspension
HF: high power + thicker suspension

Theory people in Japan compared the science cases to find that HF is as promising as Heavy.

[Nishizawa]

	bKAGRA	LF	Heavy	HF
test of GR with BH ringdown	×	×	△	○
existence of IMBH from hierarchical growth	△	△	○	△
existence of stellar-mass BBH from popIII	×	×	×	×
sky localization for BBH (identifying host galaxy)	△	×	○	○
pulsar ellipticity	×	×	△	○
NS equation of state	×	×	△	○

Heat extraction with thick fibers

Removable heat is given as

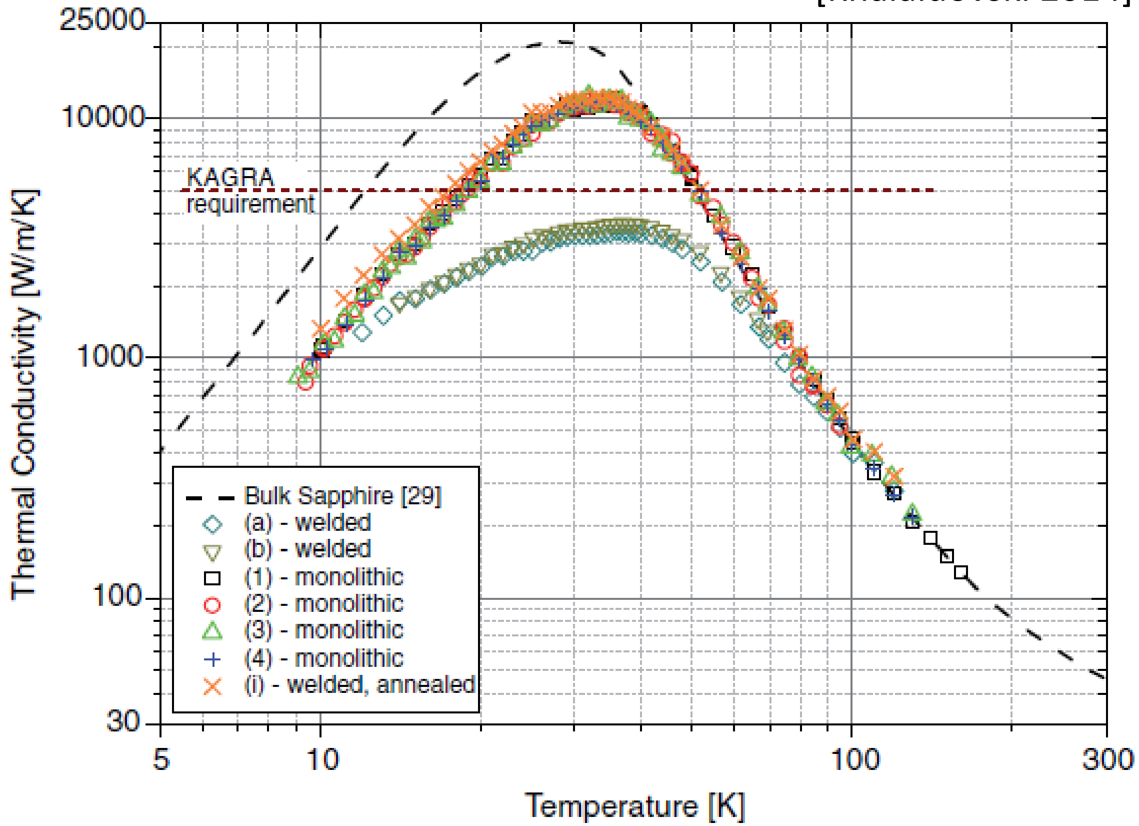
$$K_{abs} = \int_{T_1}^{T_2} \frac{\pi d^2 \kappa(T)}{l_{sus}} dT$$

where T_1 (IM) is 16K.

Sapphire thermal conductivity is approximated to be

$$\kappa = 5270\ d \times T^{2.24}\ \text{(W/m/K)}$$

[Khalaidovski 2014]



T=22K	d=1.6mm	d=2.4mm
l=35cm	0.86W	2.9W
l=20cm	1.5W	5.1W

T=24K	d=1.6mm	d=2.4mm
l=35cm	1.3W	4.4W
l=20cm	2.3W	7.7W

T=25.9K	d=2.6mm
l=35cm	7.7W

T=38.5K	d=1.6mm
l=35cm	7.7W

x10 power is capable.

High-power laser and PRG

Currently we have two 40W fiber lasers. Our solid-state amp turns out to be not easy to handle.

+

20W -> 100W

x4

arm loss	contrast	PRM	PRG
45ppm	99.9%	90%	10
30ppm	99.9%	93%	15
25ppm	99.9%	94%	17

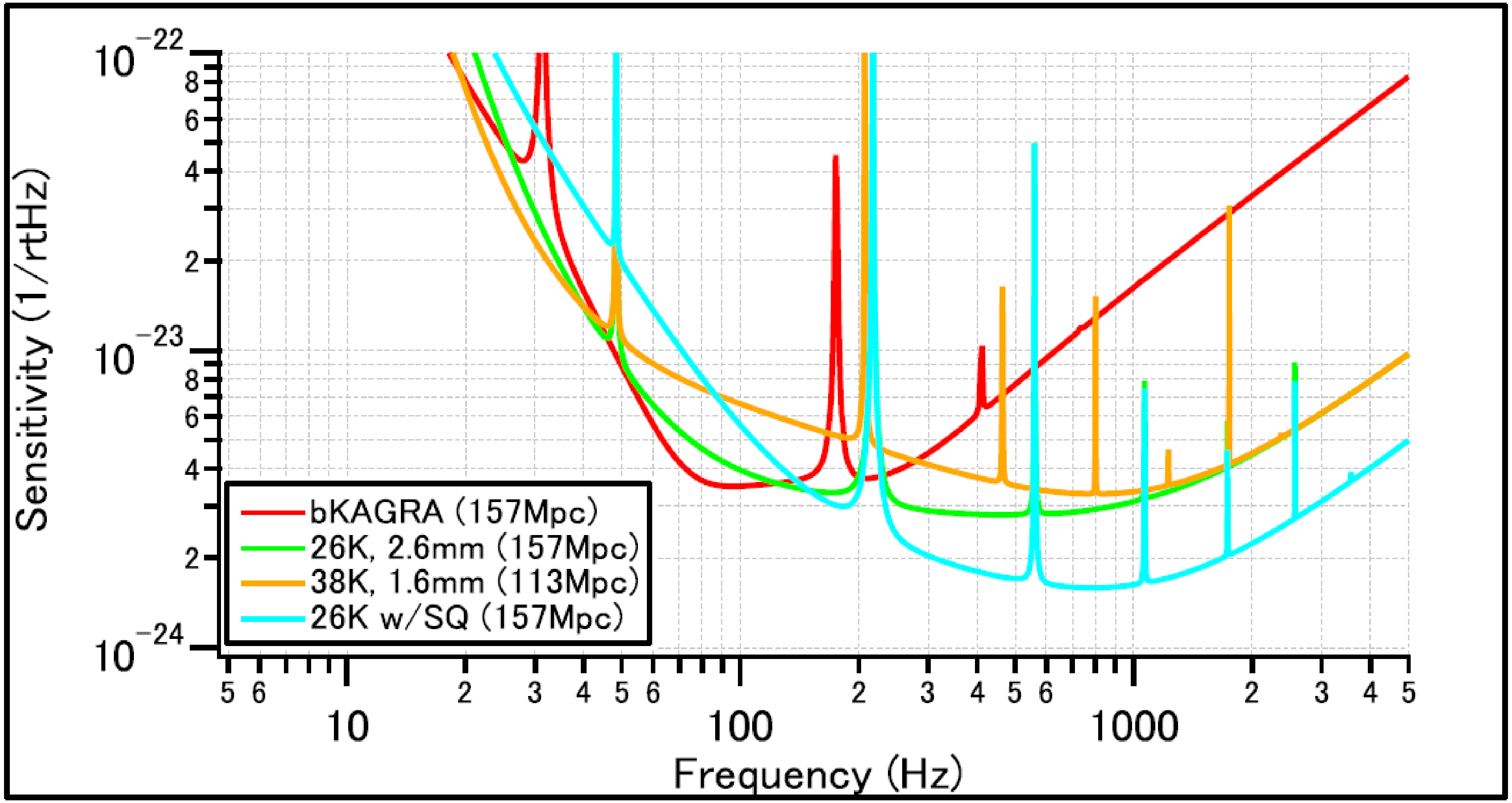
PRG could be as high as 17 if the arm loss turns out to be small.

400W LASER → 300W after MC → 5kW at BS

Other issues of high power

1. Thermal lensing in BS
2. Input Optics chain (IFI, EOM, IMC, etc.)
3. Output Optics (BD, shutter, PD, etc.)
4. PI

Sensitivity curves with high power



Required items

38K: 400W laser + IO (+ TCS) **$3M**

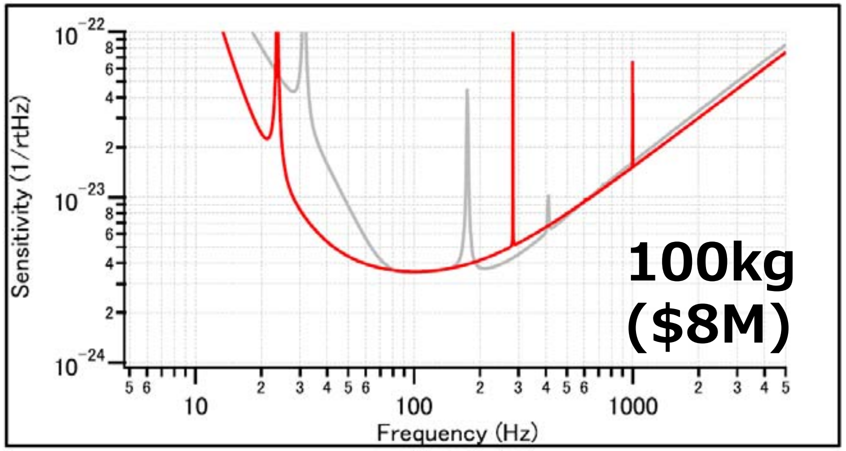
26K: 400W laser + IO + Fiber (+ TCS) **$4M**

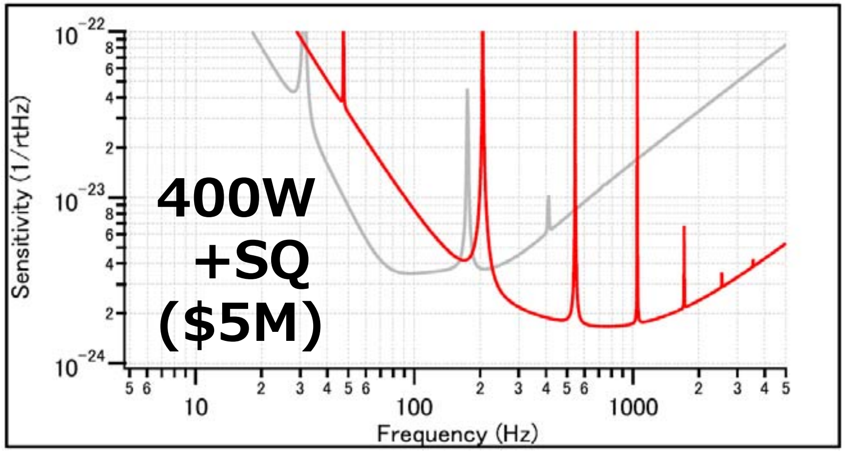
26K+SQ: 400W laser + IO + Fiber + SQ (+ TCS) **$5M**

KAGRA+ possible chart

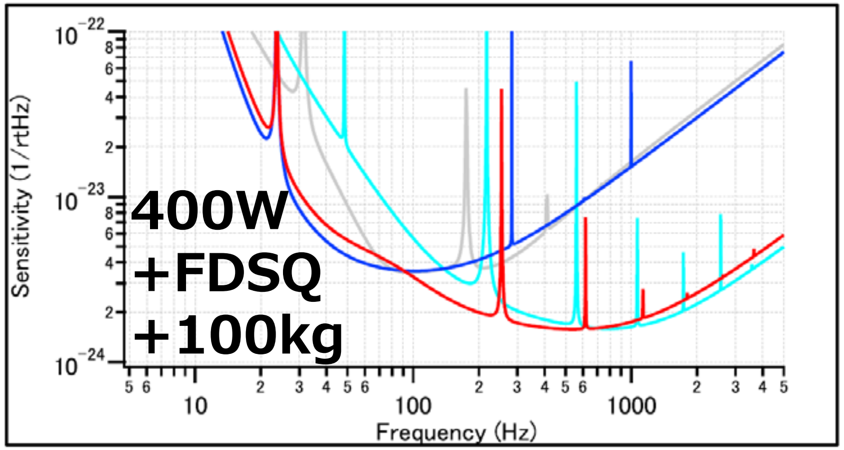
bKAGRA commissioning done

either or in 2022~24 (158Mpc)





combine them in ~2028? (293Mpc)



KAGRA++?

Summary

1. Some people in KAGRA have started working on near-future upgrade plans ("KAGRA+").

2. Possible upgrades would be (i) high-power or (ii) larger mass. An alternative may be low-f.

3. If we are aiming at an observation in 2022~24, the schedule is quite tight.

4. I would suggest that we choose one of (i)(ii) for KAGRA+ and keep the other for the further future.

5. For a detailed optimization, Yuta will explain a cool method in the next talk.