KAGRA

Toyama International Workshop on
"Higgs as a Probe of New Physics 2015"
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Gravitational Wave Astronomy by KAGRA

Seiji Kawamura (ICRR, UTokyo)
on behalf of the KAGRA collaboration

JGW-G1503308-v2

Outline:

- Gravitational wave and its detection
- Review of KAGRA
- Current status of KAGRA
- Summary

Gravitational wave

- **Einstein Equation**

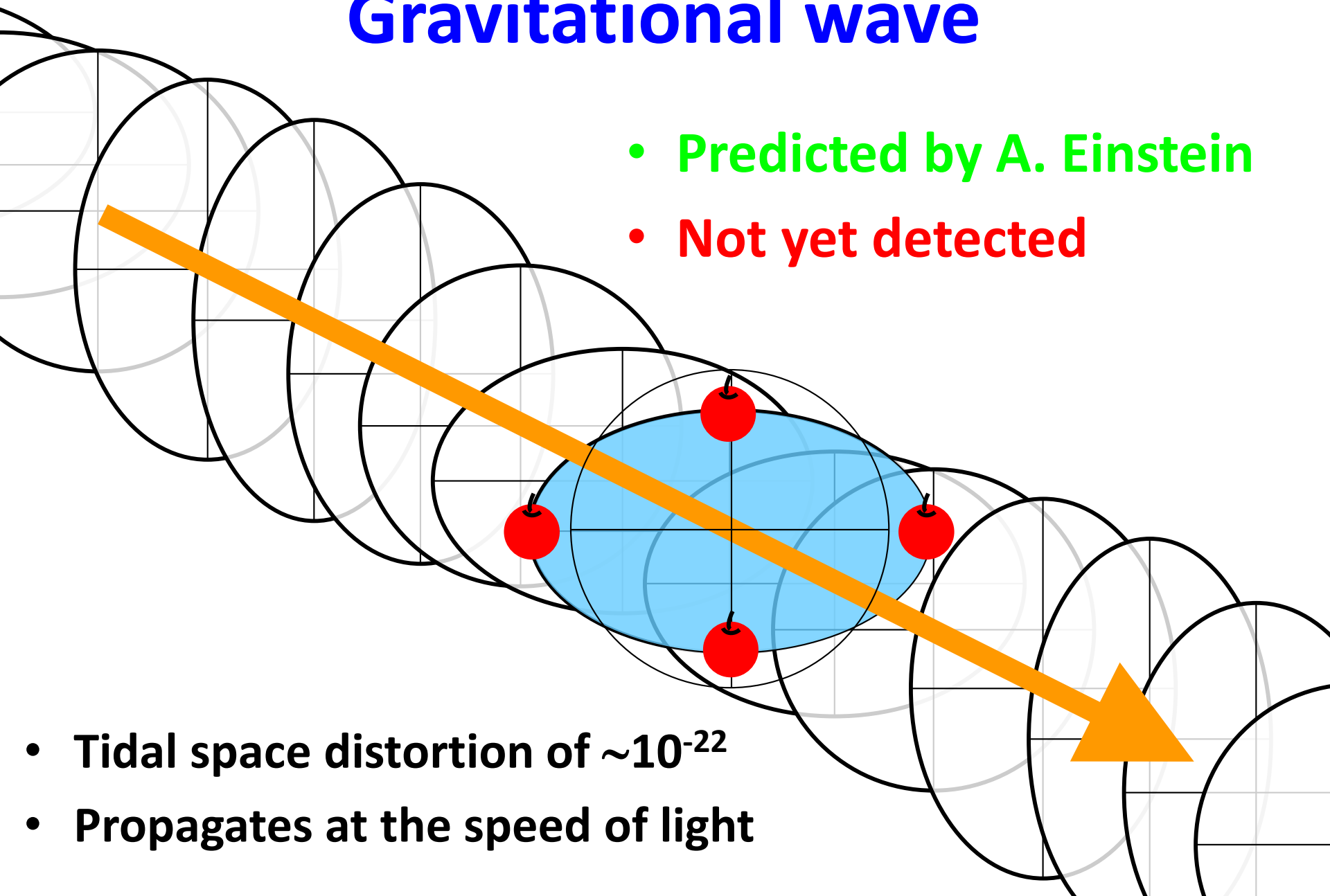
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\kappa T_{\mu\nu}$$

- **For a small perturbation 'h', a wave equation is derived**

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$\left(\nabla^2 - \frac{1}{c^2} \frac{\partial^2}{\partial t^2} \right) h_{\mu\nu} = 0$$

Gravitational wave



- Predicted by A. Einstein
- Not yet detected

- Tidal space distortion of ~10^{-22}
- Propagates at the speed of light

GW exists!

- PSR1913+16 found by Hulse and Taylor
- Period of rotation decreases by GW
- Nobel prize in 1993

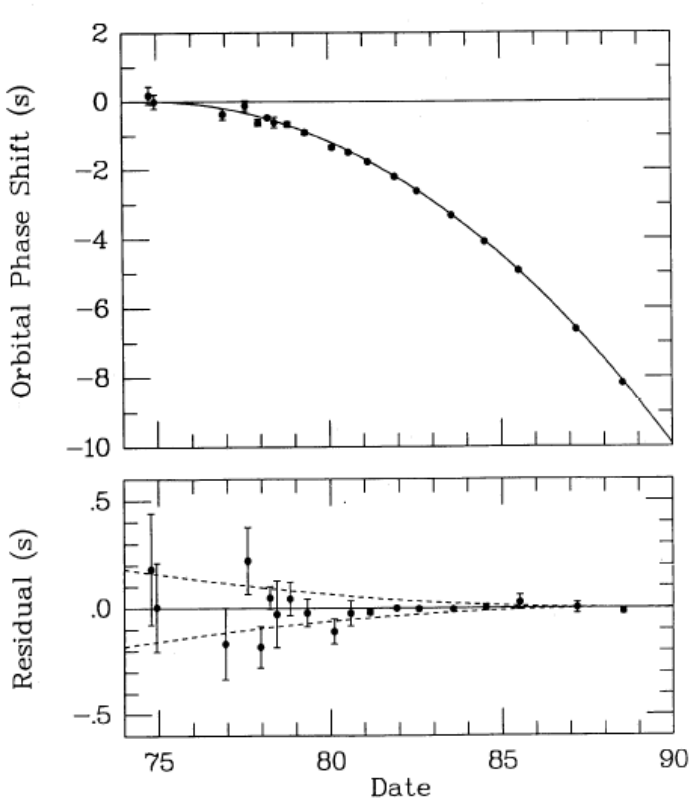
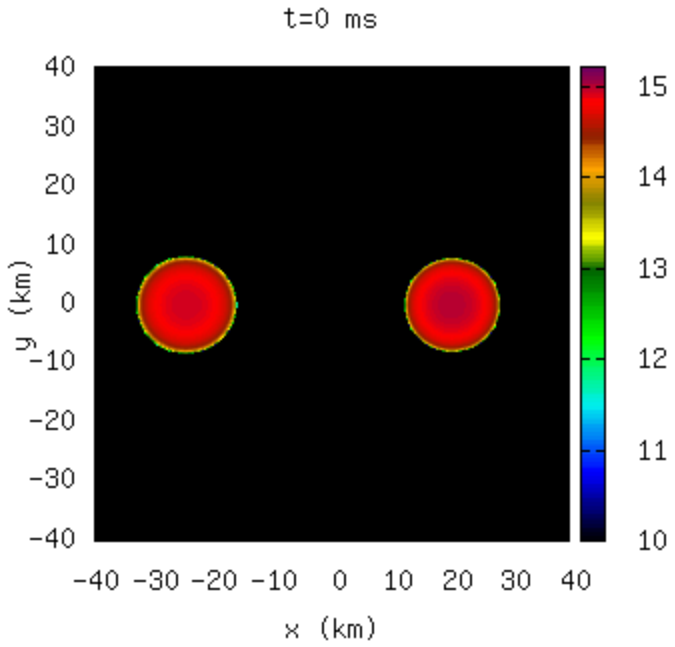
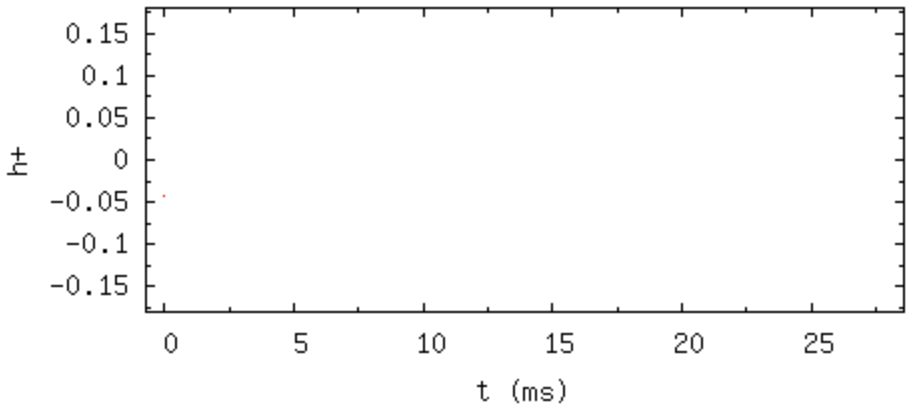


FIG. 5.—*Top:* Cumulative shift of the times of periastron passage relative to a nondissipative model in which the orbital period remains fixed at its 1974.78 value. *Bottom:* Differences between the locally measured periastron times and those expected according to the DD(1) parameter set. Dashed curves illustrate differential trends that would be expected (relative to epoch 1988.54) if the rate of orbital decay $\dot{P}_b$ were 2% larger or 2% smaller.

Taylor et al., ApJ.345(1989) p435

Simulation of neutron star binary coalescence (1)

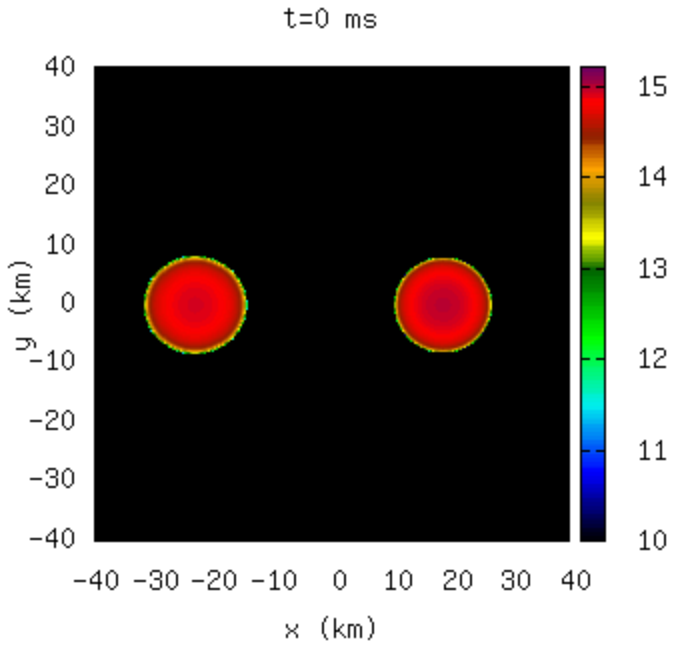


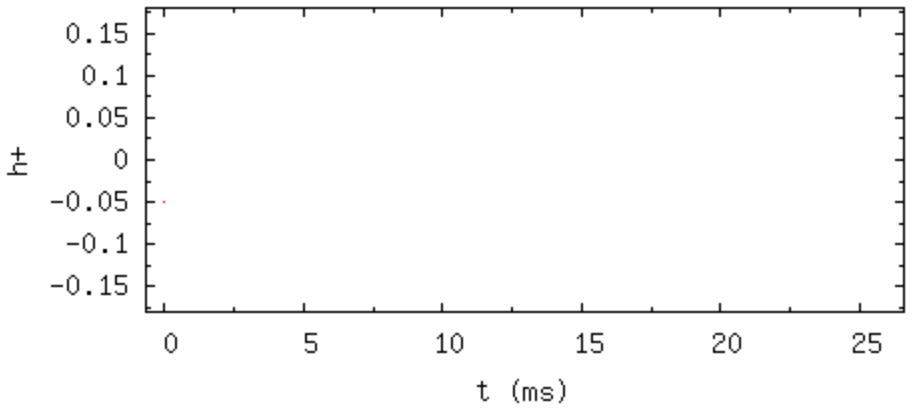


1.3 Ms – 1.6 Ms (Equation of state: APR4)

Hotokezaka, et al. (Kyoto Univ, and others)

Simulation of neutron star binary coalescence (2)

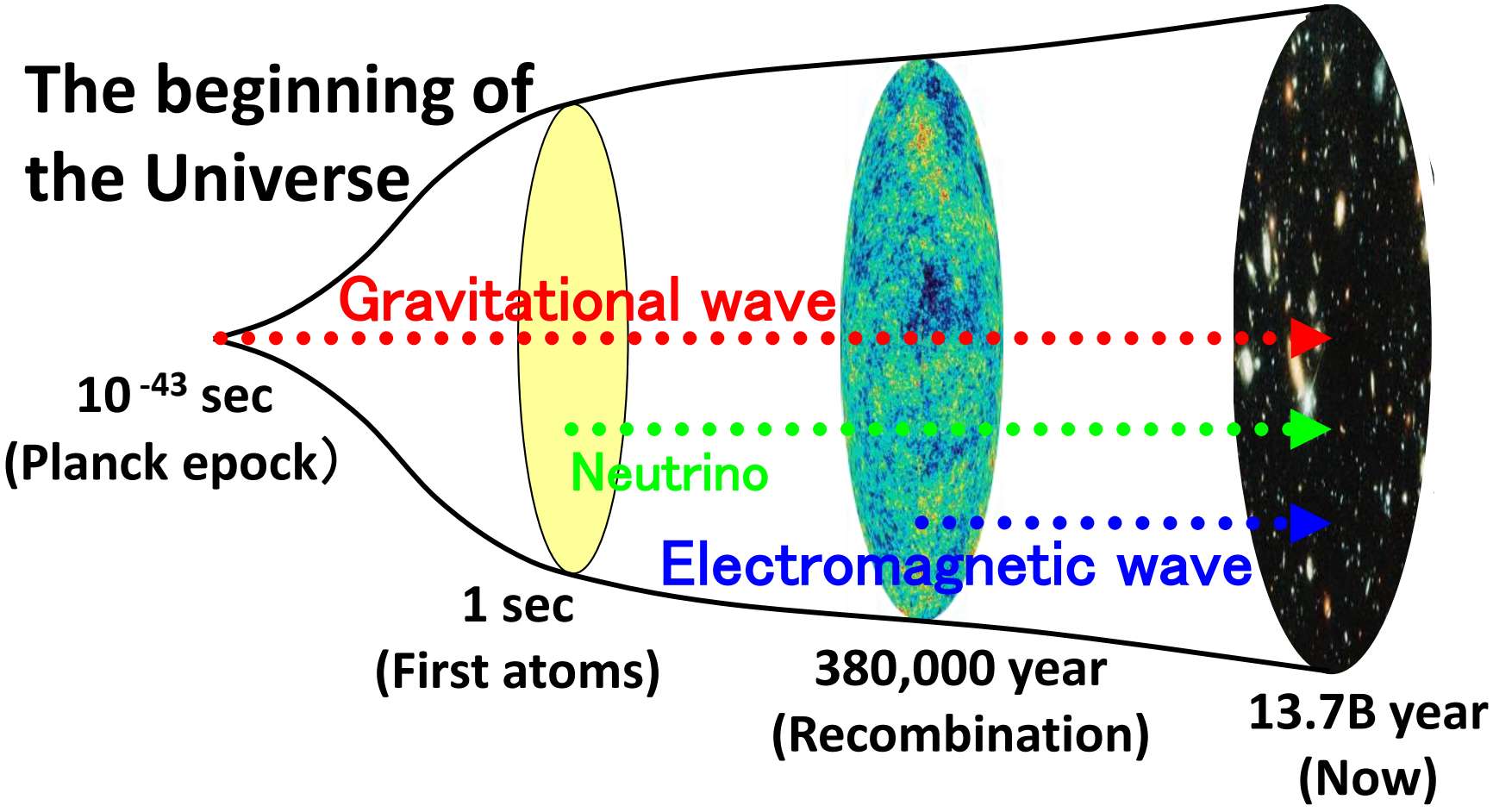




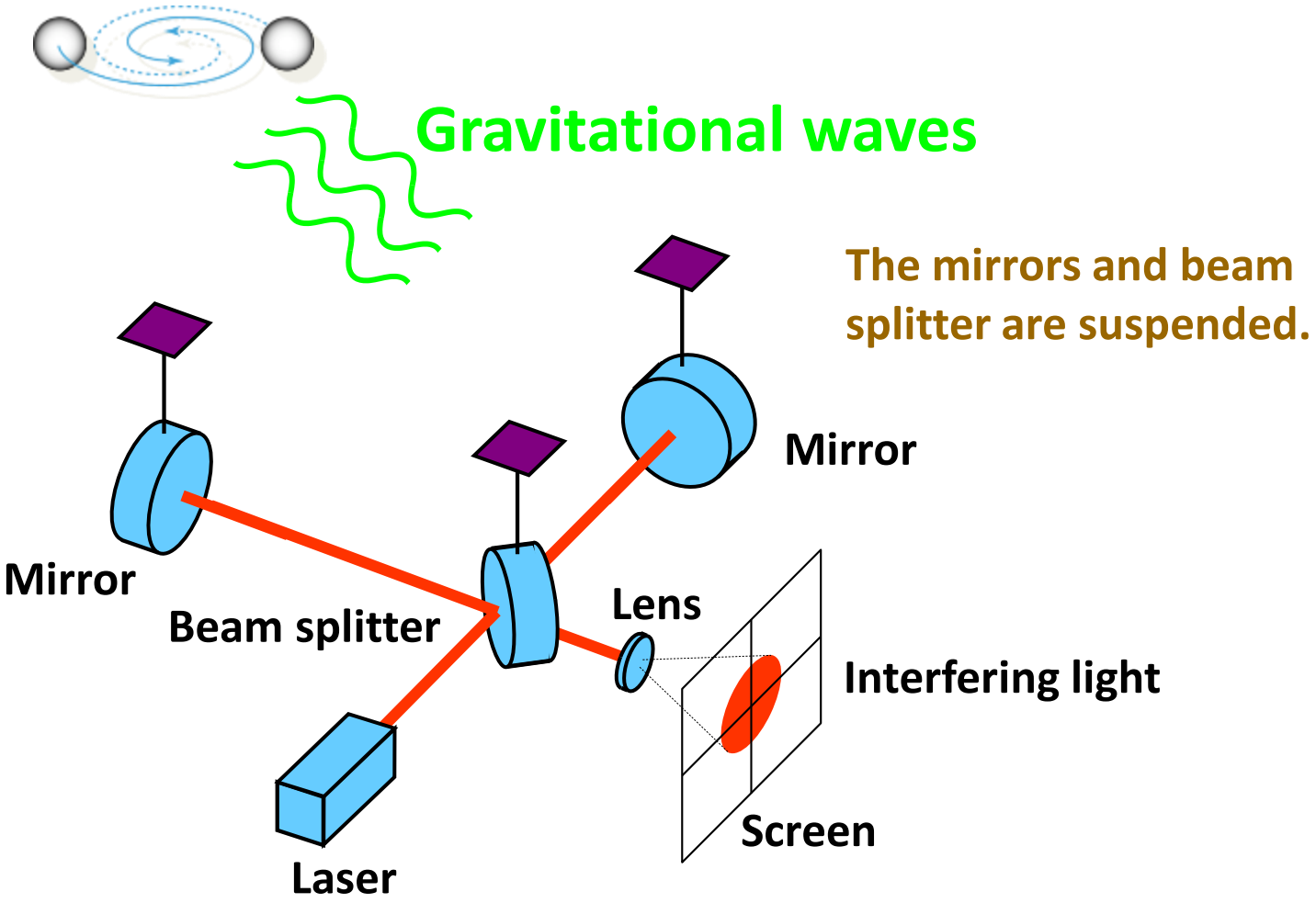
1.2 Ms – 1.5 Ms (Equation of state: APR4)

Hotokezaka, et al. (Kyoto Univ, and others)

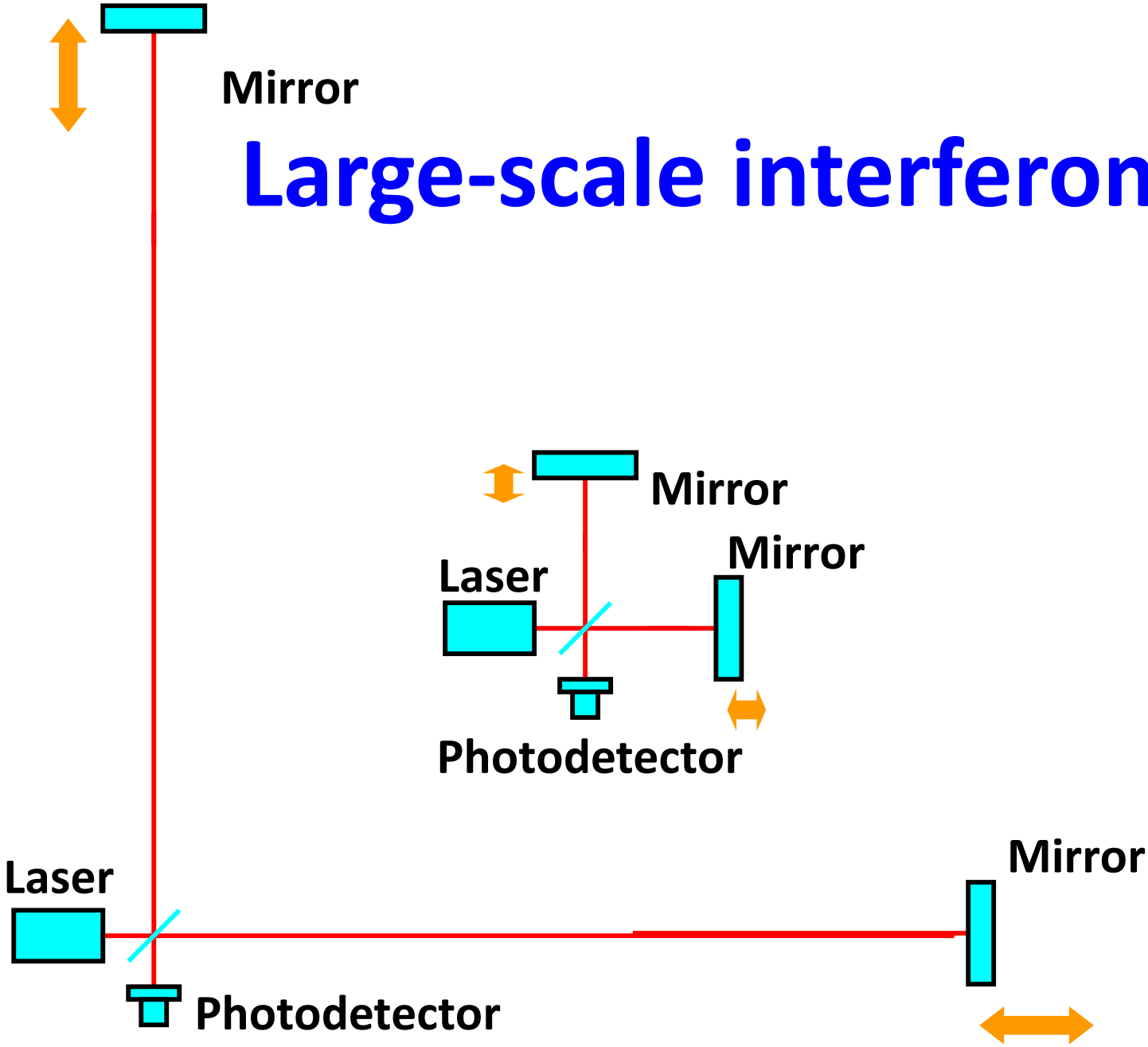
Observation of the beginning of the Universe



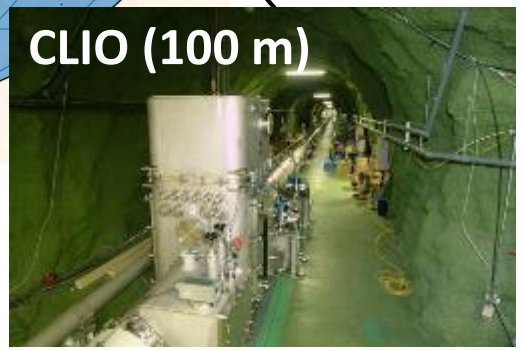
Gravitational wave detector



Large-scale interferometer

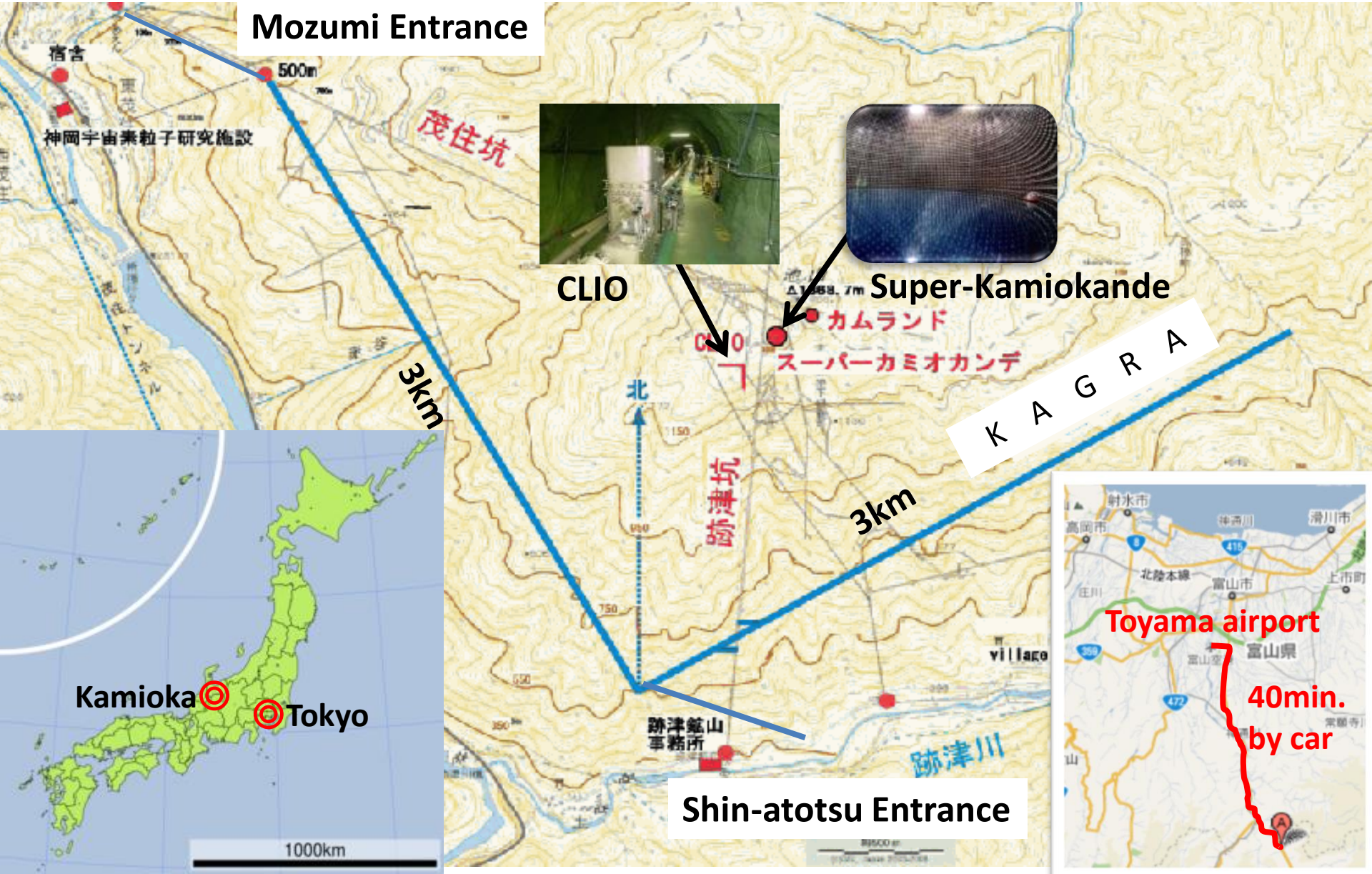


Large-scale interferometers in the world



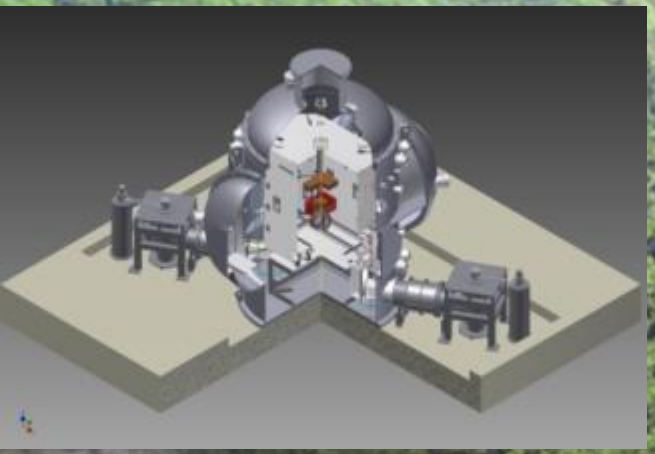

KAGRA

Location (Kamioka)



Key features of KAGRA

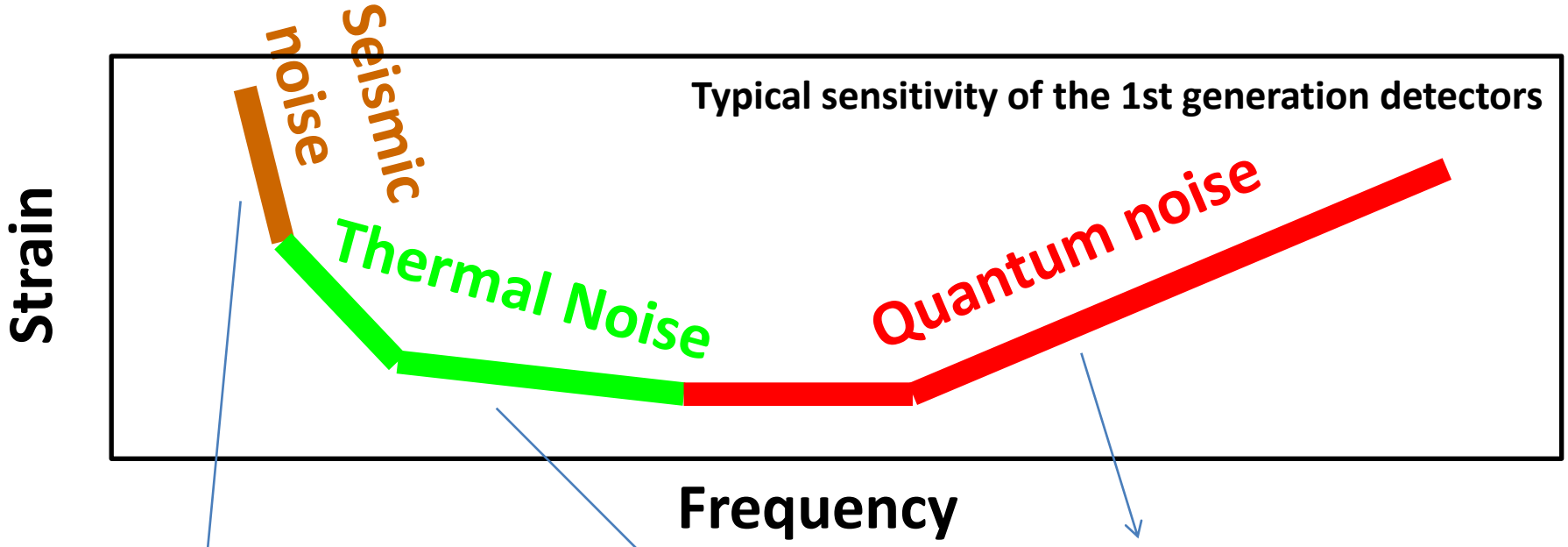
Cryogenic Mirror



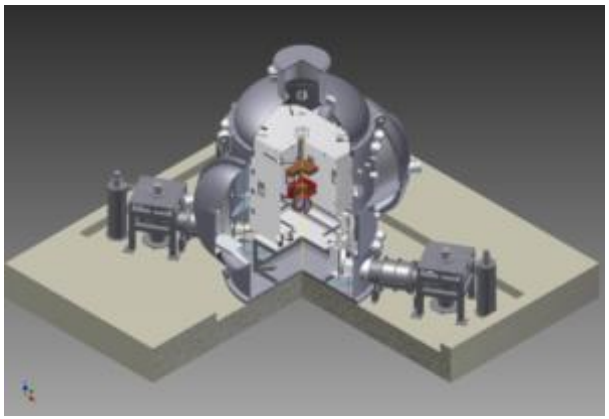
Underground

Technologies crucial for the 3rd-generation detectors; KAGRA can be regarded as a 2.5-generation detector.

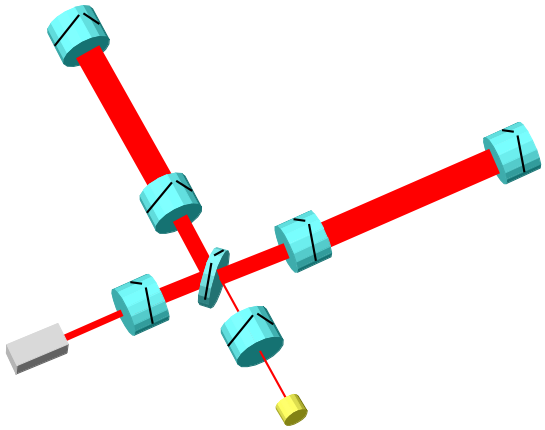
Two technologies + one



Underground

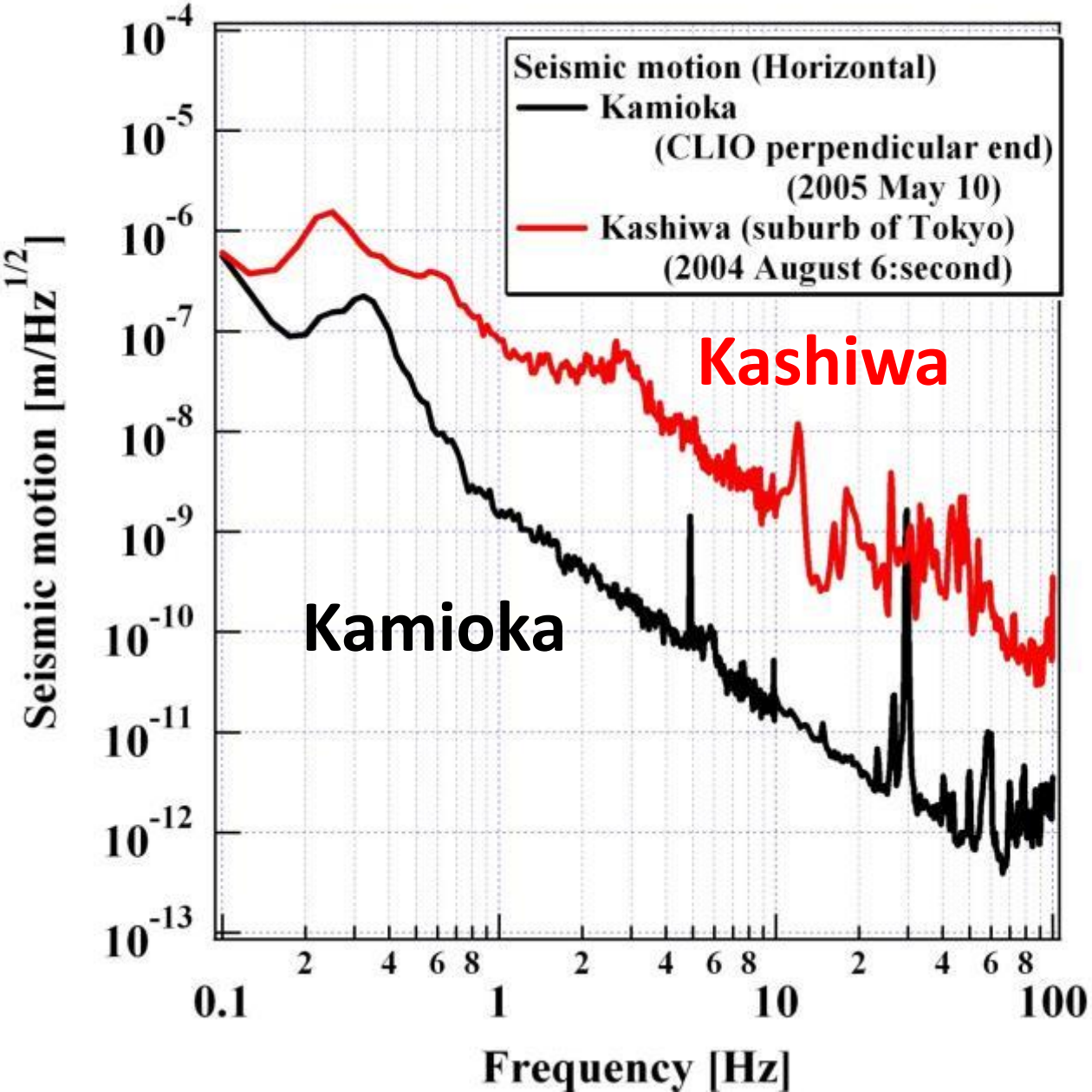


Cryogenic Mirror



Resonant Sideband Extraction

Ground motion in Kamioka mine



Further seismic isolation is still necessary

Vibration of mirrors:

10^{-11} mHz$^{-1/2}$

Should be improved
by 7 orders of magnitude

10^{-18} mHz$^{-1/2}$
@10 Hz

Vibration isolation system

2nd floor

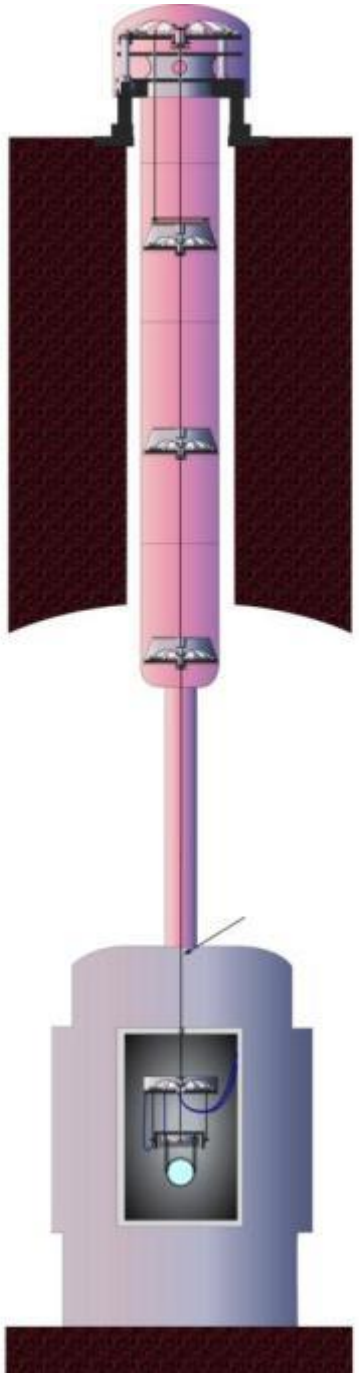
Inverted pendulum
Geometrical antispring (GAS) filter

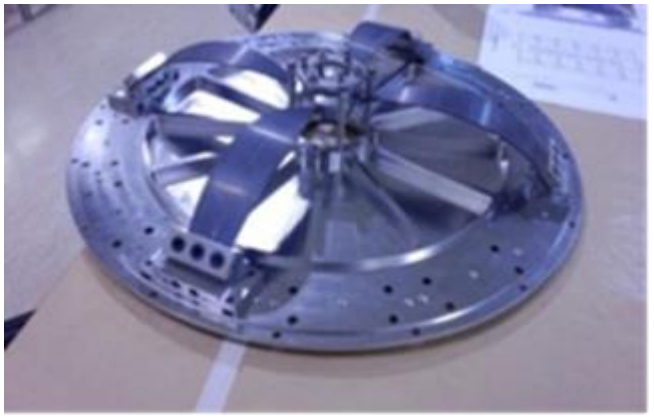
Multi-stage pendulum (with GAS filter)

1st floor

Another pendulum (with GAS filter)

Mirror suspension

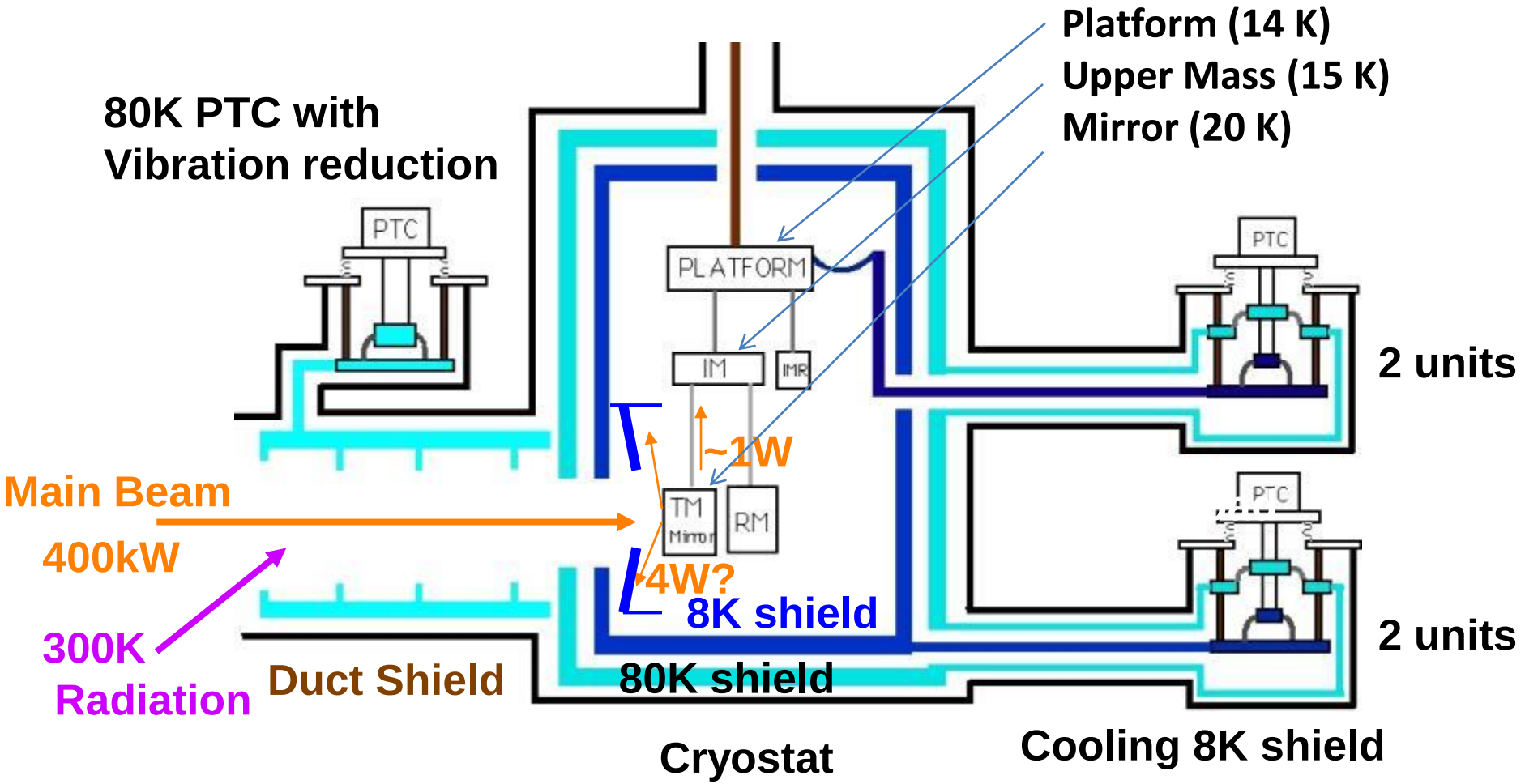




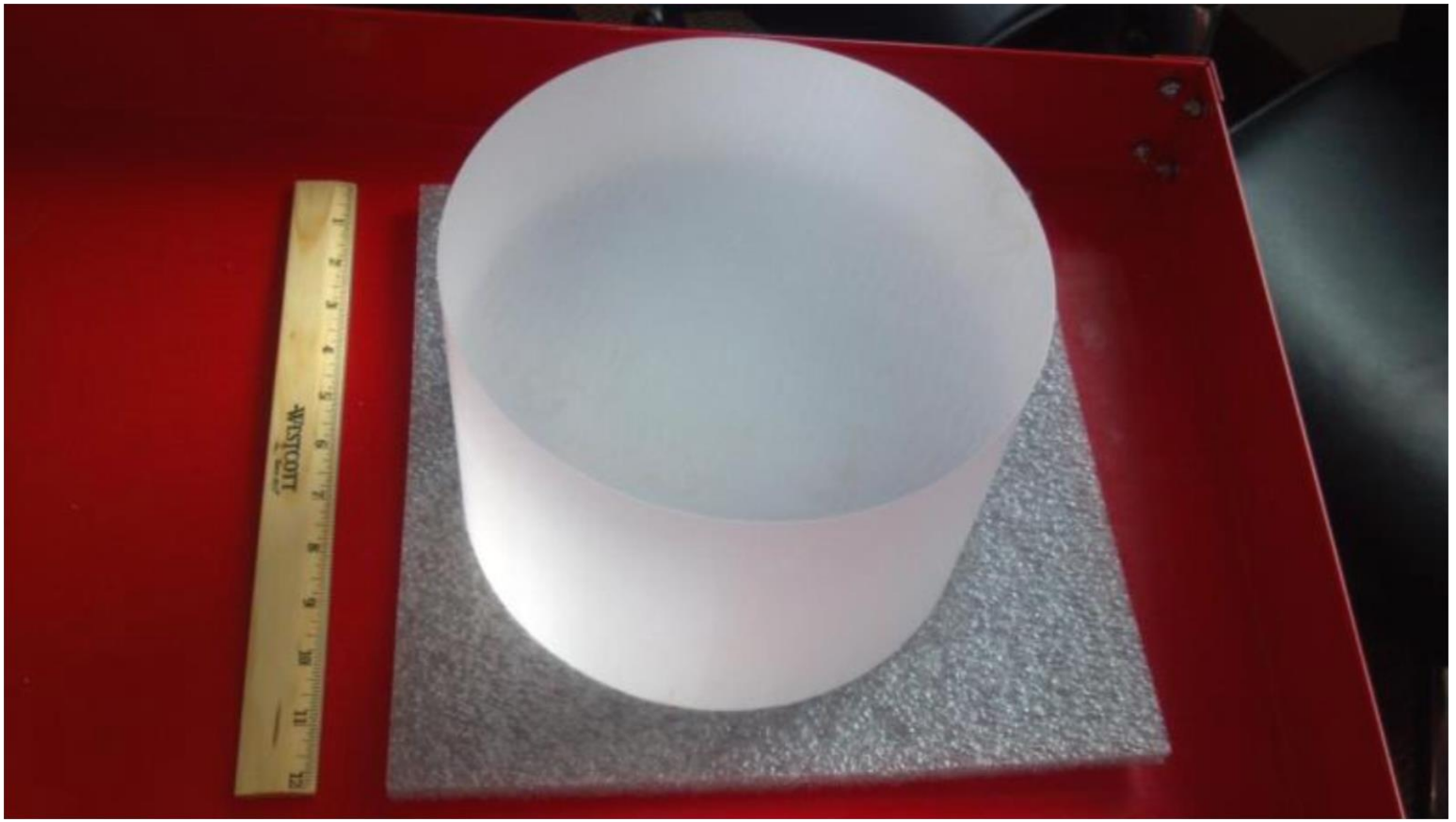
GAS filter

Two-layer structure to avoid the resonances of the tall structure.

Cryogenics System

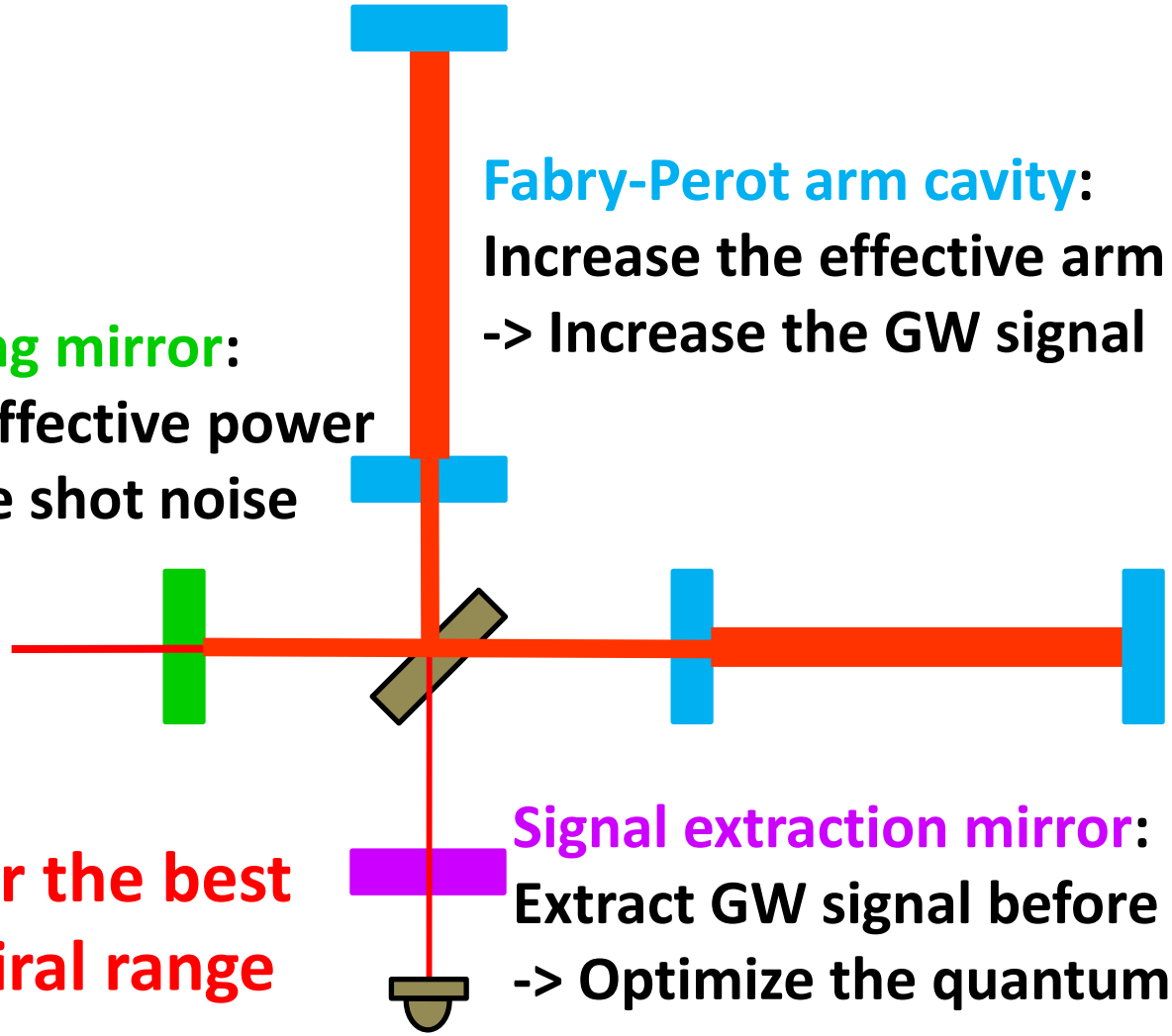


Sapphire Mirror



Two Sapphire substrates have been delivered.
(Φ220mm, t 150mm, c-axis)

Resonant Sideband Extraction interferometer



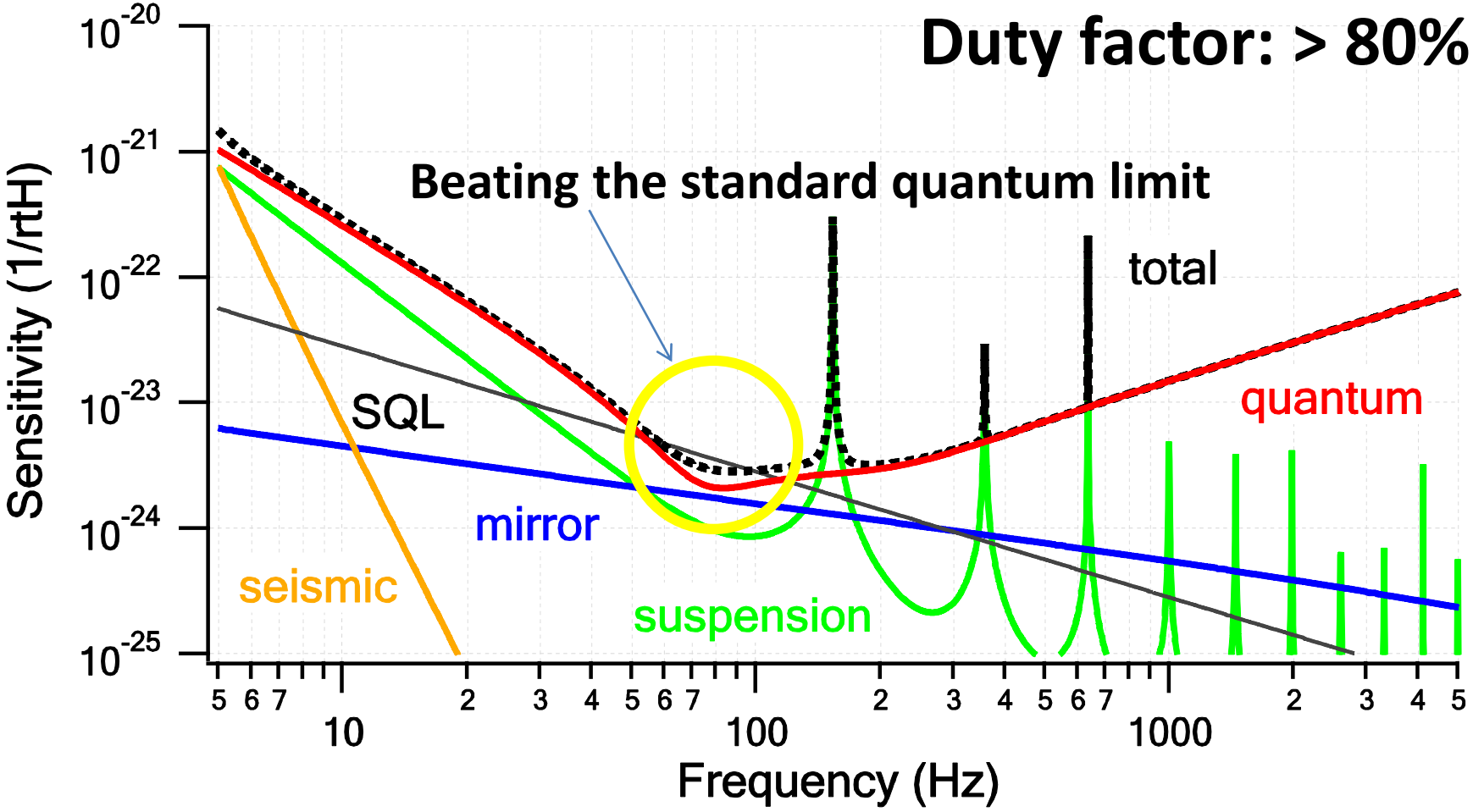
Fabry-Perot arm cavity:
Increase the effective arm length
-> Increase the GW signal

Power recycling mirror:
Increase the effective power
-> Improve the shot noise

Signal extraction mirror:
Extract GW signal before cancellation
-> Optimize the quantum noise

Detuned for the best NS-NS inspiral range

Ultimate Sensitivity Limit of KAGRA



Expected event rate for NS-NS coalescence

Inspiral range: 176 Mpc
(the same definition as LIGO/Virgo)

Assuming Inspiral rate per galaxy: ~100 Myr^{-1}

Expected event rate: ~10 yr^{-1}

We could reveal the mechanism of Short GRB with γ-ray observation group.

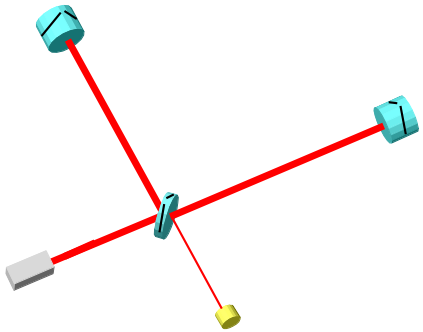
Other GW sources

- **BH-BH coalescence: e.g. 20 $M_\odot$ at 2 Gpc, 0.4~1000 events per year**
- **Quasi-normal mode of BH: e.g. 100~300 $M_\odot$ at 3 Gpc**
- **Supernova: Hopefully ~1 Mpc, ~1 event per 30 years**
- **Pulsar: Crab and Vela, possibly other invisible pulsars**
- **Beginning of the Universe: non-standard model**
- **Unknown: Nature likes to surprise us.**

Schedule of KAGRA

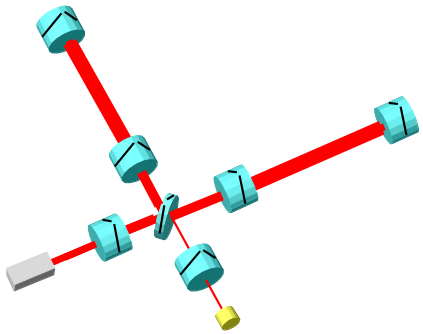
Calendar year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Project start									
Tunnel excavation									
initial-KAGRA									
iKAGRA obs.									
baseline-KAGRA									
Adv. Optics system and tests									
Cryogenic system									
Observation									

iKAGRA



- Michelson interferometer
- Room temperature
- Simple seismic isolation system

bKAGRA

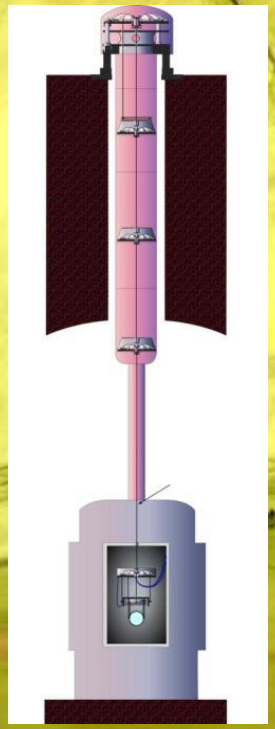


- Resonant sideband extraction
- Cryogenic temperature
- Advanced seismic isolation system

Shin-Atotsu entrance (2014.9.26)

片岡優氏撮影

1st floor of central area （2014.7.4）

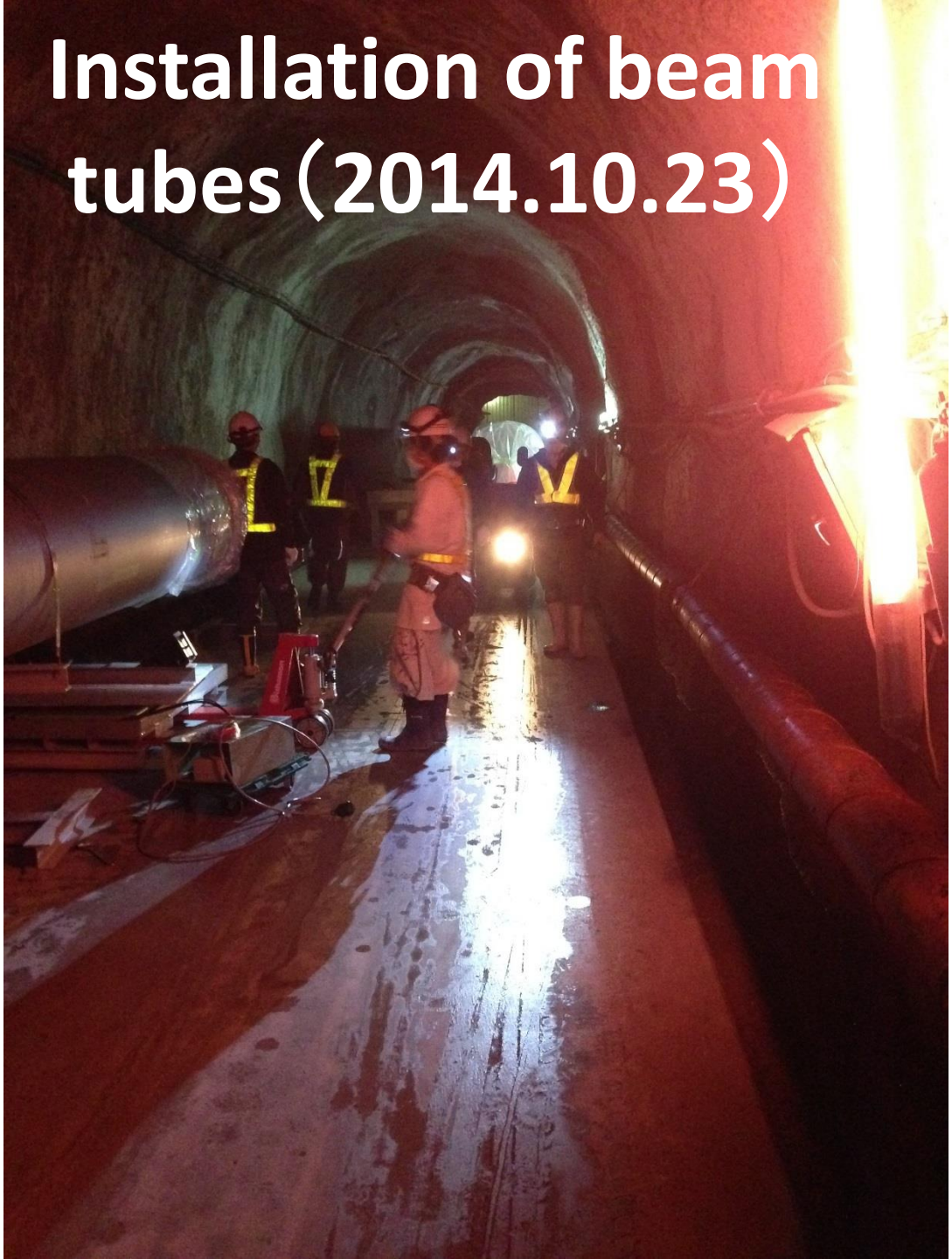


東京大学宇宙線研究所広報室

2nd floor（2014.7.4）

東京大学宇宙線研究所広報室

Installation of beam tubes（2014.10.23）



片岡優氏撮影

Clean booth and sound-proof room （2014.10.31）

麻生洋一氏撮影

Summary

- **KAGRA has cryogenic and underground GW detector (2.5-generation).**
- **We plan to build KAGRA in two steps: iKAGRA and bKAGRA.**
- **We are installing iKAGRA now.**
- **We plan to have an observation with iKAGRA at the end of 2015.**
- **We plan to start observation run with bKAGRA at the end of 2017.**