Status of Geophysics Interferometer

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Introduction

KAGRA has a long baseline strain meter named "GIF"

- GIF is …
  - used for geophysical observation
  - used to provide baseline monitor for KAGRA
  - two 1500 m antisymmetric Michelson Interferometer using a fixed mirror
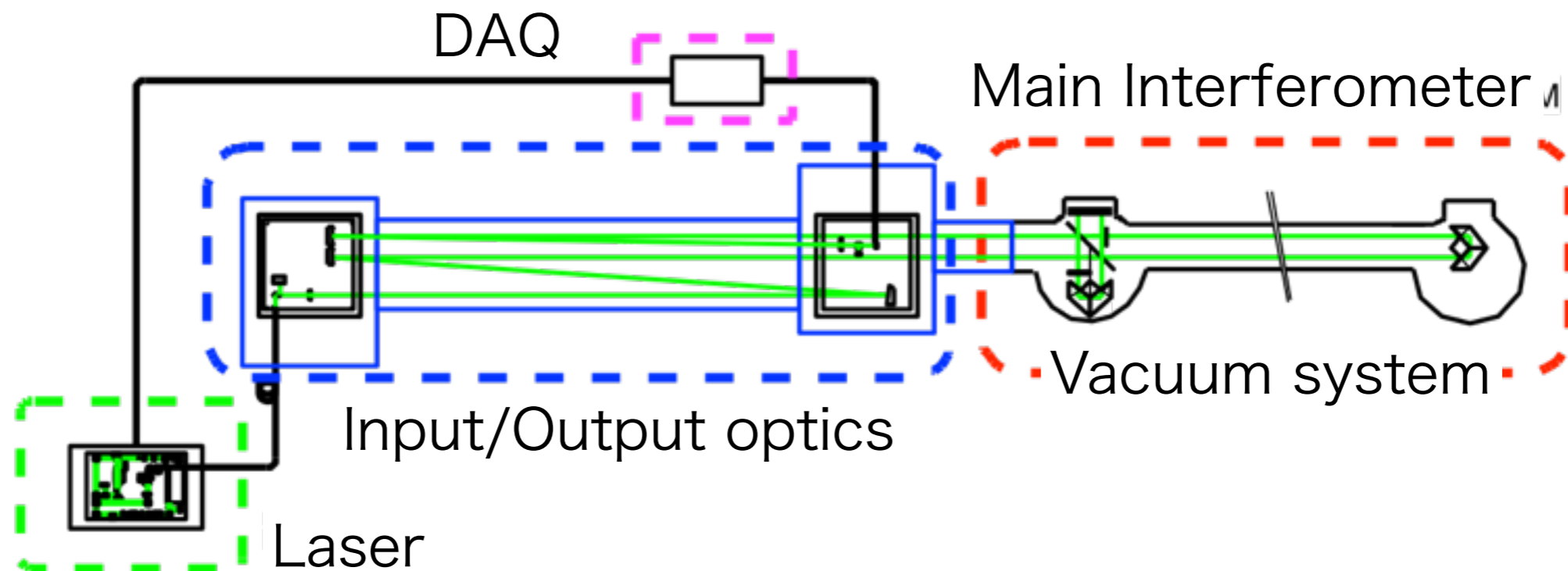 - Installed X arm only

3000 m

Y arm

X arm

500 m   1500 m   1000 m
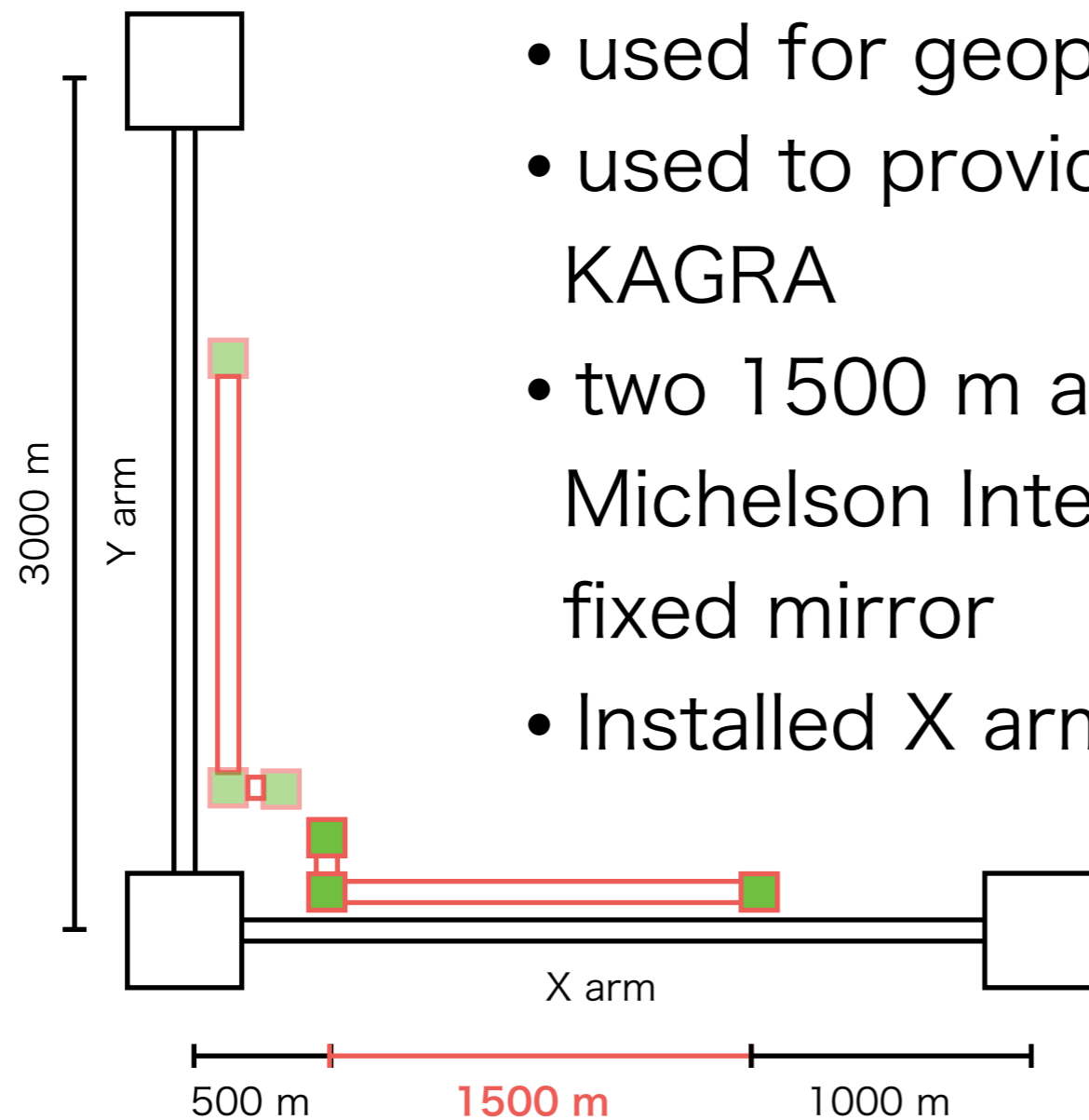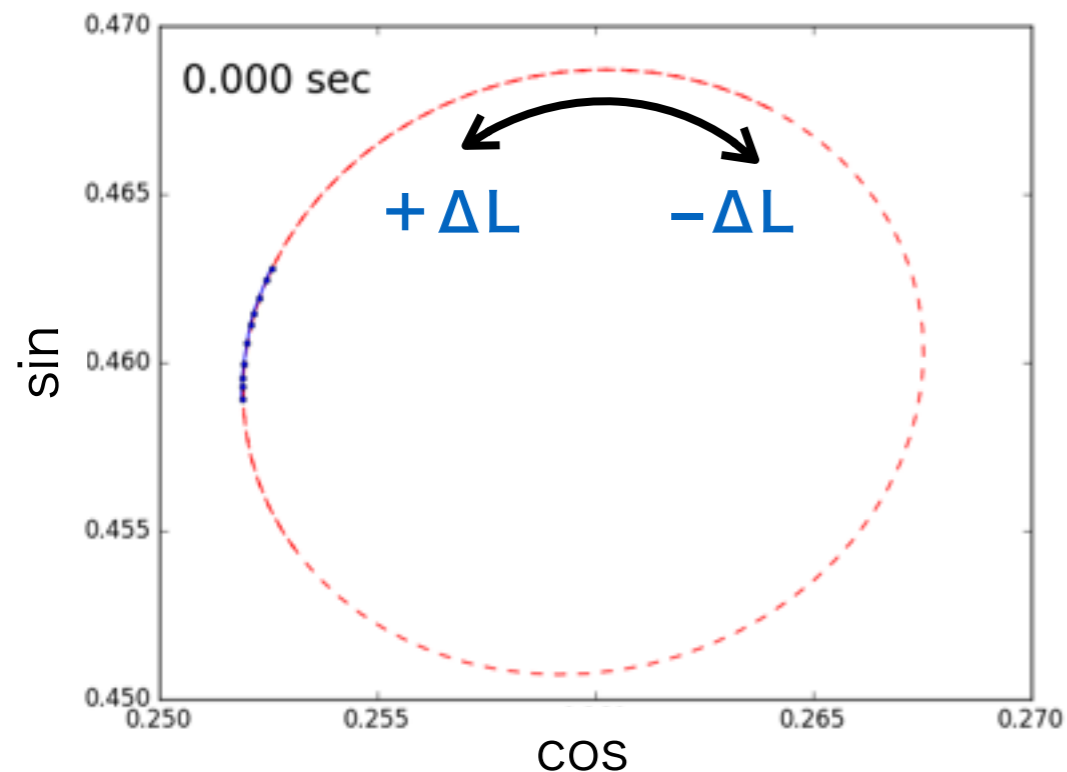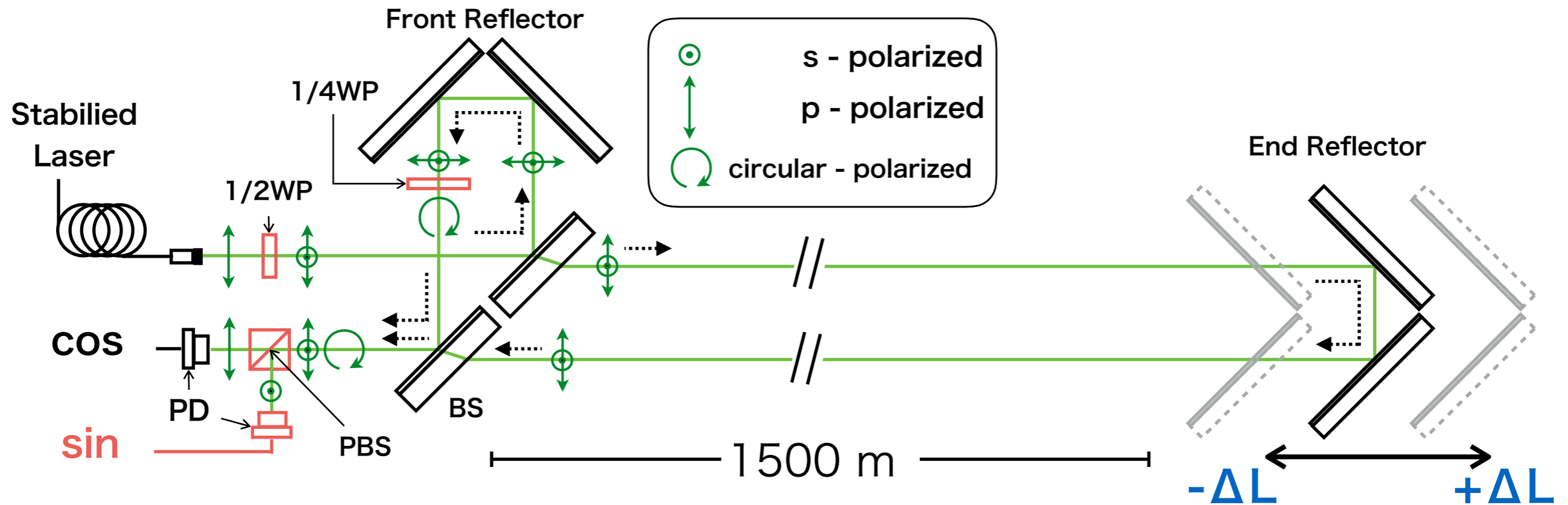
We can observe the crustal motion very precisely.

Subsystem/

- **Subsystem**
  - Main Interferometer
  - Input & Output optics
  - Laser
  - Vacuum system
  - DAQ system

DAQ

Main Interferometer

Input/Output optics

Vacuum system

Laser

GIF/ Main Interferometer

$$\Delta \text{strain} = 2\pi \frac{\Delta L}{\lambda/2} \frac{1}{1500}$$

- Strain signal is displayed as a rotation in left figure

GIF/ Input & Output optics

❑ **Mode matching telescope**

■ **Reflecting telescope (10 m, folded)**

◆ **Flat and concave mirrors (RC 10 m) and a lens**

◆ **Installed in air (out of vacuum)**

➢ Fully covered to eliminate air disturbances

■ **Mode matching**

◆ **Waist diameter at end reflector ~ 35 mm**

◆ **Designed to minimize beam diameter at BS (~ 40 mm)**

Detection port   Concave mirrors

To main IFO

Flat mirror

Lens

Fiber collimator
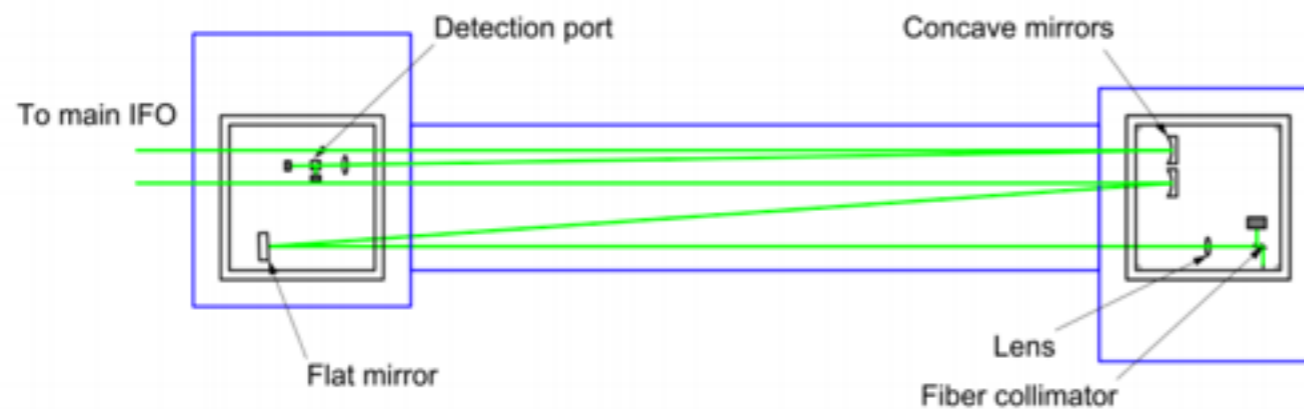
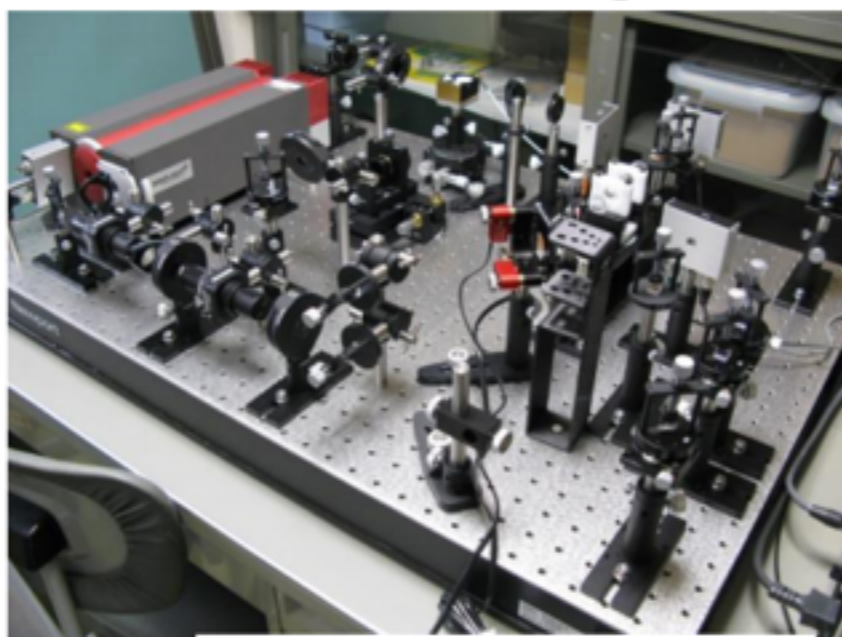Beam cover

GIF/ Laser

□ **Iodine stabilized laser**

■ **Frequency doubled Nd:YAG laser (532 nm)**

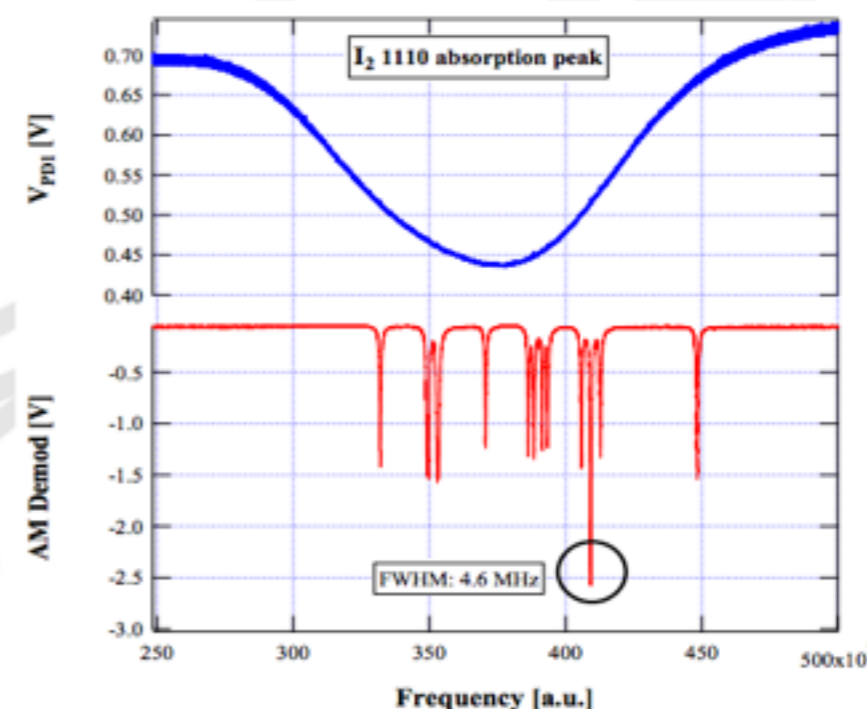◆ **Locked to I_2 absorption line**

➢ Extremely stable quantum standard

➢ Modulation transfer technique

■ **Expected stability (strain resolution): 10^{-13}**

■ **Delivered via optical fiber**

Laser optical system

I_2 absorption line

GIF/ Vacuum System

☐ **Contains main interferometer**

- **Vacuum tanks for main optics at both ends**
  - ◆ **Granite platforms directly attached to bedrock**
  - ◆ **Double-balanced bellows to eliminate stress**
- **1500 m vacuum tube**
- **Target vacuum pressure: 10^{-4} Pa**
  - ◆ **Maintained by TMPs**

optics (inside vacuum) vacuum tank flexible bellows vacuum tube flexible bellows rigid support rigid support laser beam concrete layer bedrock granite platform

Vacuum tank

GIF/ Convert to Strain

① Fitting ellipse

② Obtain rotate angle using arctan function
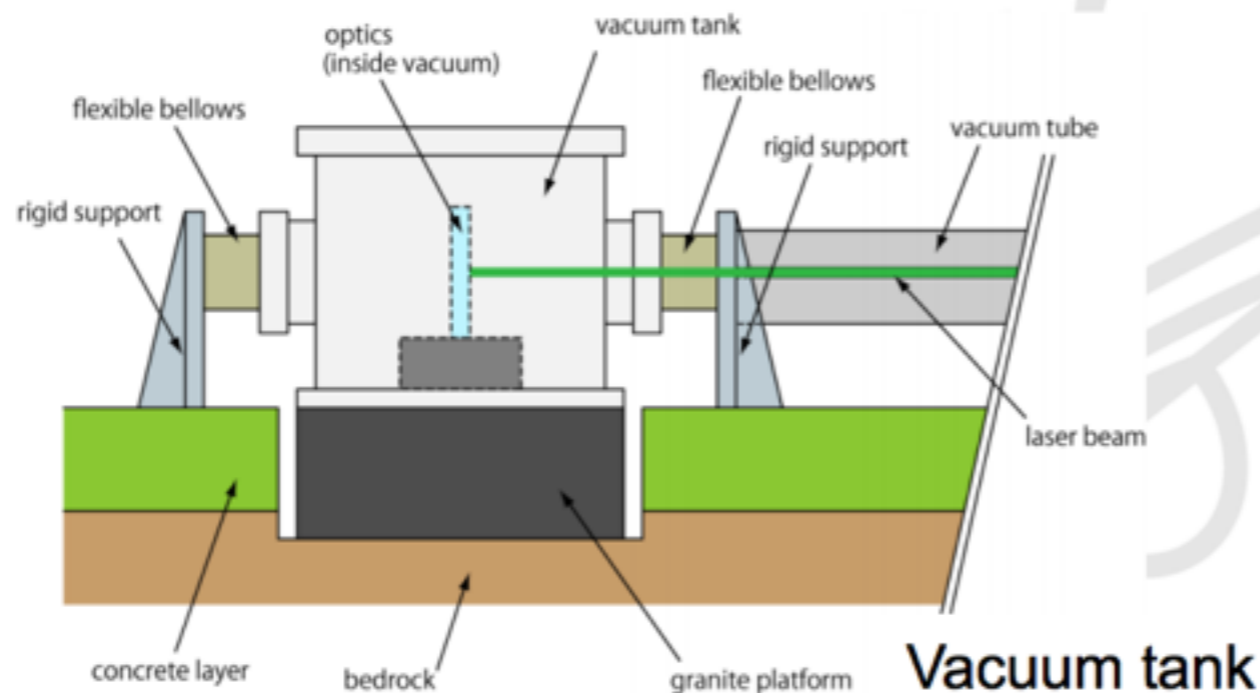
③ Obtain continuous strain data using unwrap function
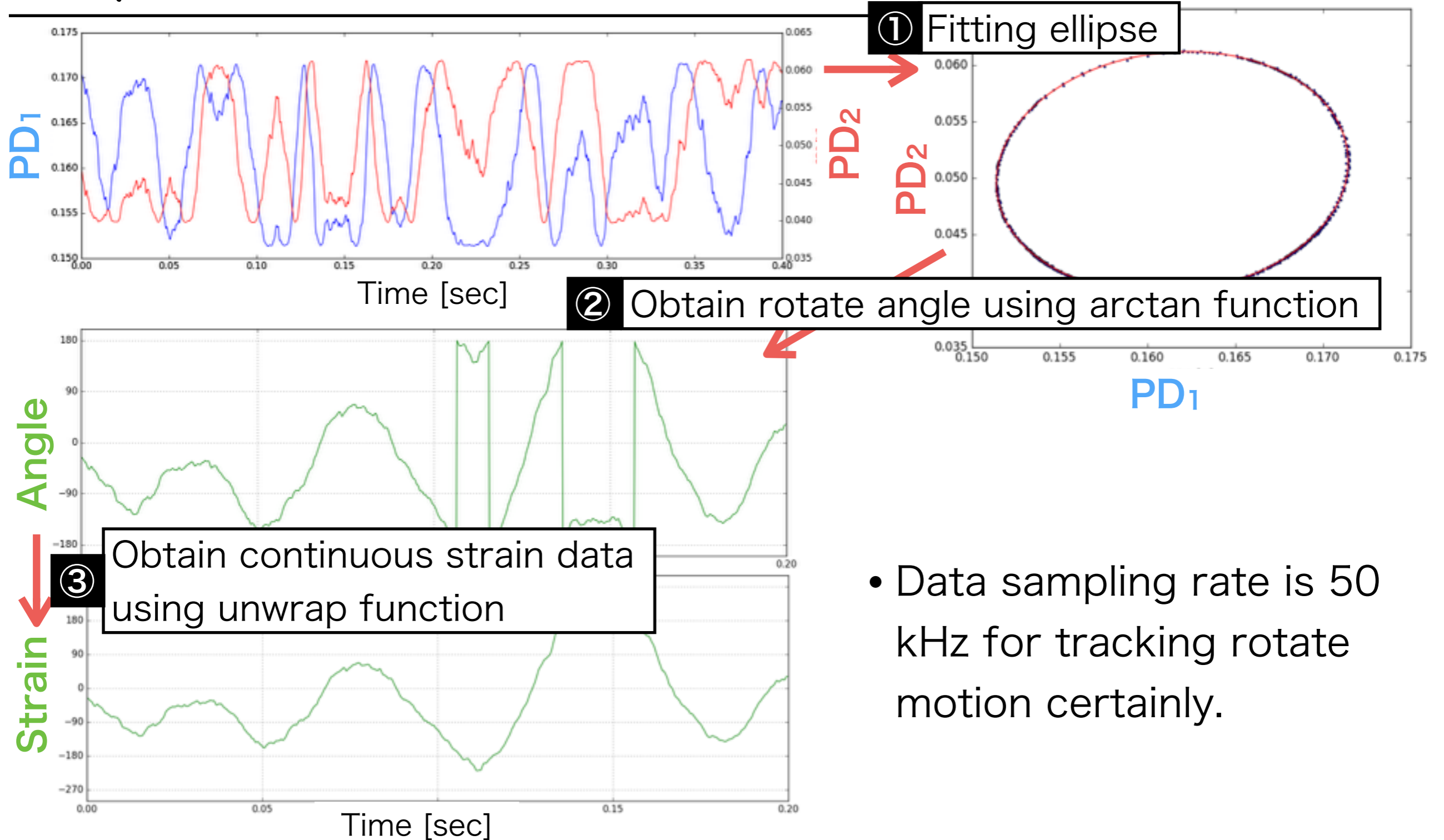
- Data sampling rate is 50 kHz for tracking rotate motion certainly.

Basically, measurement range is not limited. Wide range measurement.

GIF/ DAQ

Outside mine

Strage Server **Strain Converter**
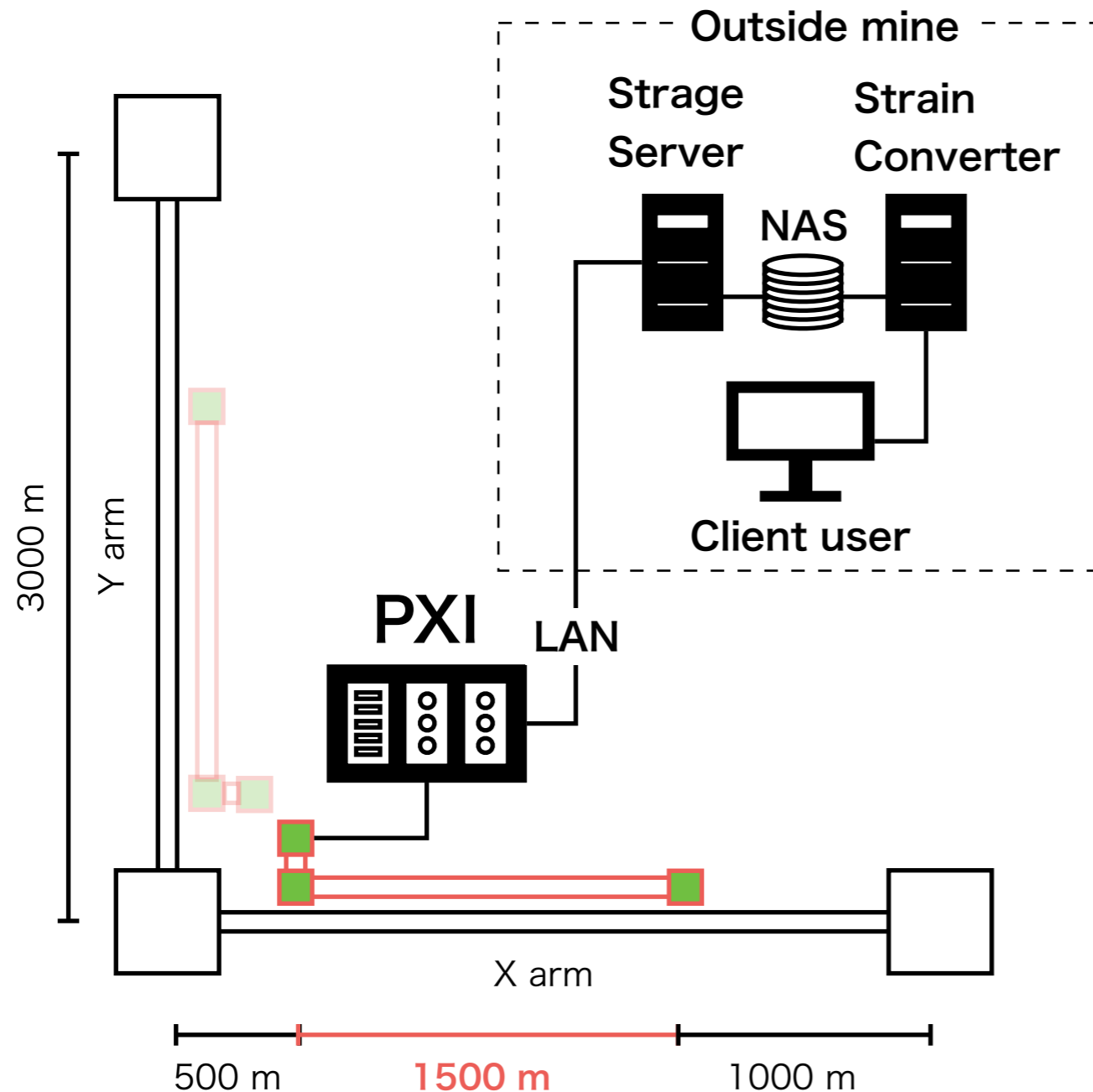
NAS

Client user

PXI LAN

3000 m Y arm

X arm

500 m **1500 m** 1000 m

- PXI is for ADC and laser control.
- Client user can get the strain data outside of KAGRA.
- Strain data is almost realtime (1 minutes delay due to a converting time).
- DAQ is designed independently from KAGRA

- We are taking the strain data from last August.

Observation result/

Dec 5, 4:30 - Dec 4, 08:30

Strain

1.3e-7

4000 km

- We could observe strain signal which contains earthquake.
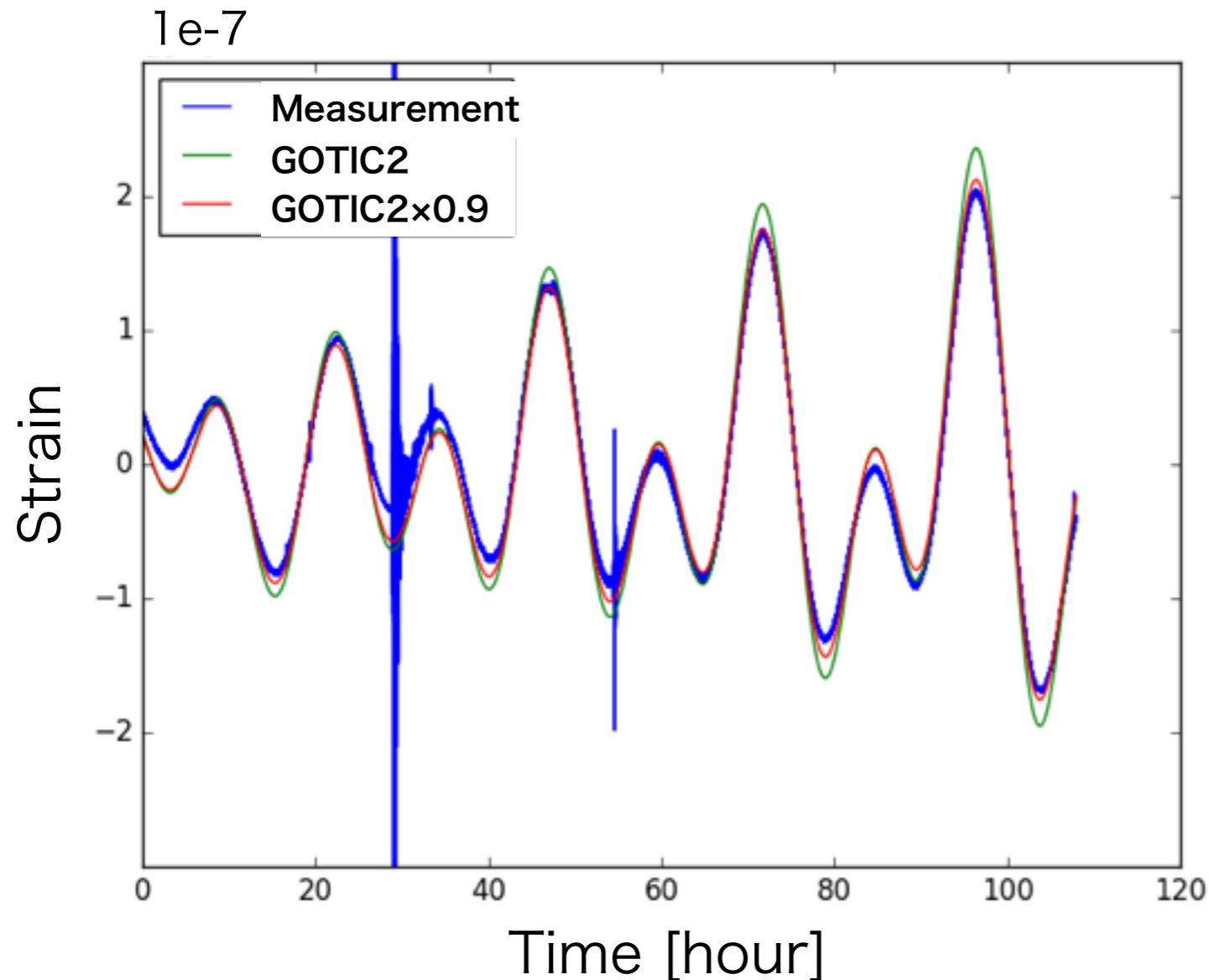
Solomon Islands M6.9
2016-12-09 19:10:06 UTC

Solomon Islands M7.8
2016-12-08 17:38:46 UTC

7.33 hour

Time

DAQ monitor

# Result/ Comparison of Theoretical model

- Measured strain signal consistents with theoretical model (GOTIC2) which includes under ground effect (× 0.9).

- This effect was evaluated by 100 m laser strainmeter located on same KAGRA mountain. (Takemoto et al. 2006)

- GIF observed local place effect.
- We are evaluating the underground information e.g. inhomogeneous, shape of the tunnel.

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Observation result/ Sensitivity
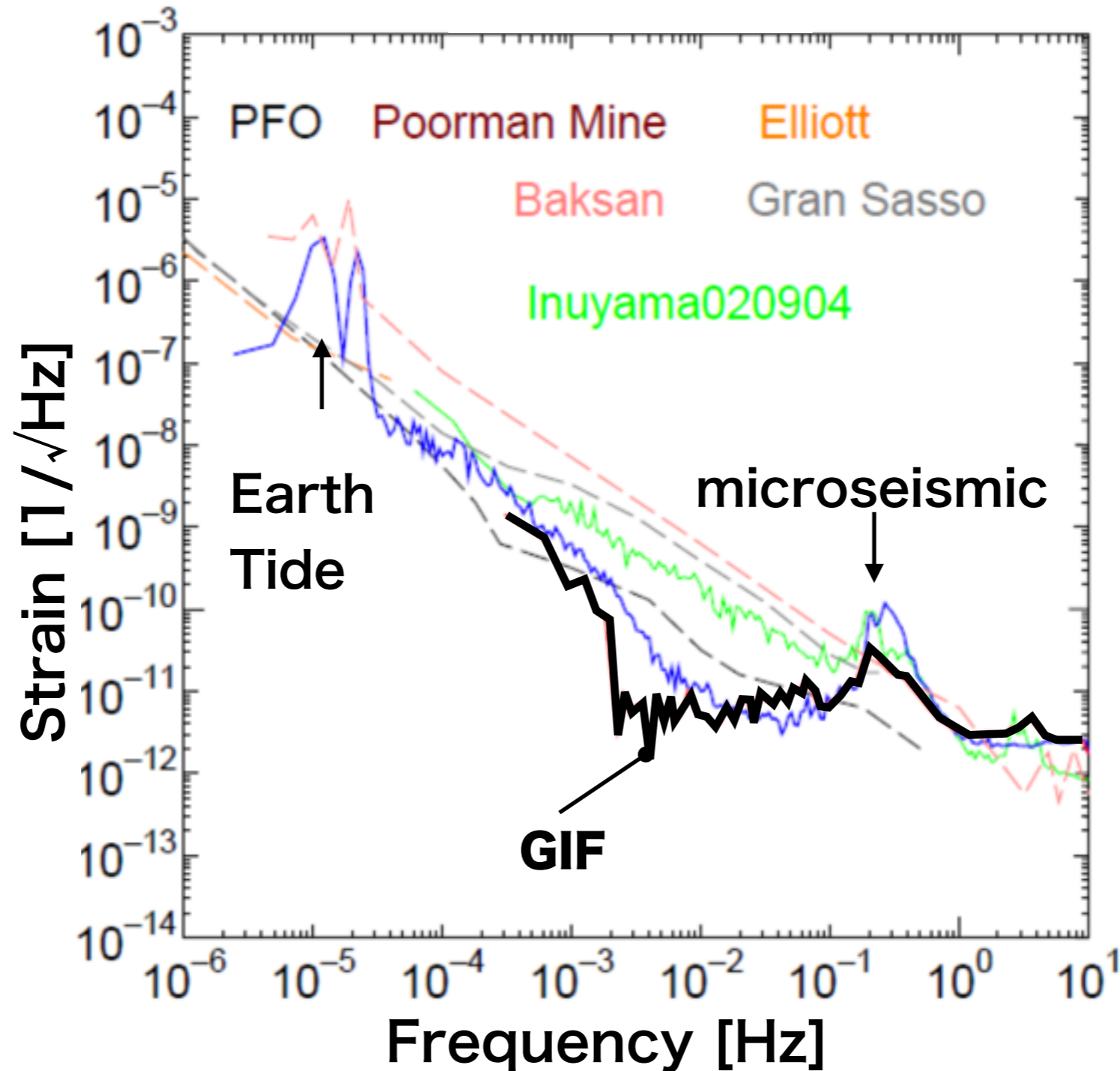
- Lowest back ground, especially around 1-10 mHz

Baseline Monitor for KAGRA

- The same as GW detector, GIF's sensitivity is getting worse above a few Hz. (~ 7 Hz).
- Fortunately, We can directly measure microseismic (~ 0.1 Hz < 7 Hz) which is the biggest reason of GW detector instability.
- GIF also measure lower frequency crustal motion. Seismometer can't measure below mHz.

- Because GIF can measure low frequency and directly unlike seismometer, GIF data is a good baseline monitor for KAGRA.
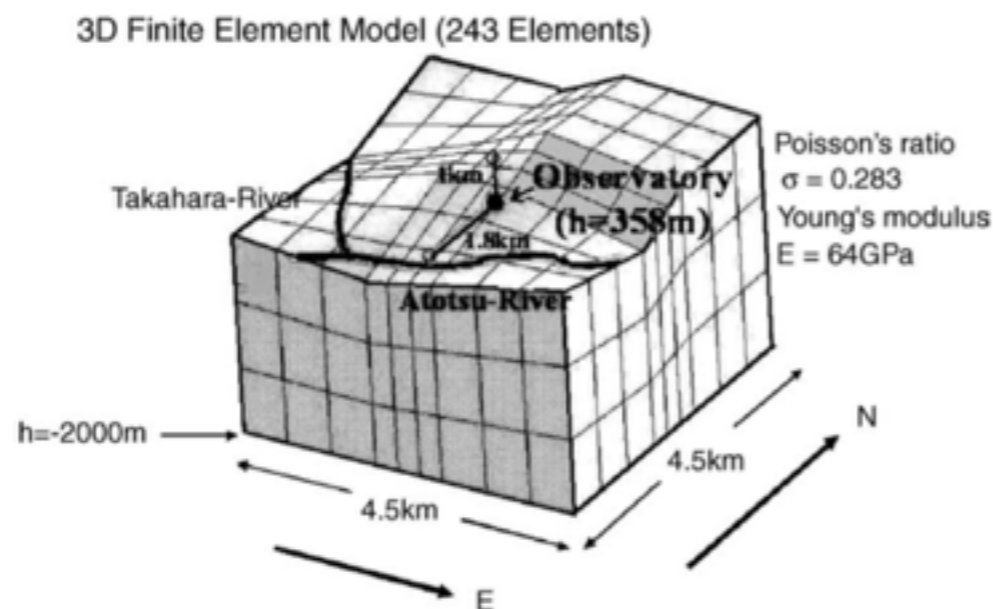
Baseline Monitor/ Crustal Motion Compensation

- Feedforward CARM and DARM which converted from the X and Y arm crustal motion signal to wide range actuator e.g. LVDT at Type-A.

- However, we have only X arm.
- First, We compensate only CARM.
- We can calculate CARM using coupling matrix of KAGRA mountain (Takemoto et al. 2006)

3D Finite Element Model (243 Elements)

Takahara-River

1km. Observatory (h≈358m)

1.8km

Atotsu-River

Poisson's ratio
σ = 0.283
Young's modulus
E = 64GPa

h=-2000m

4.5km

4.5km

N

E

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Baseline Monitor/ Plan

Now

Non-Realtime Observation

Some adjustment for
suppressing air fluctuation

Restart Observation

Build Compensation system

Prepare KAGRA DAQ
Make Program for realtime phase converter
Complete baseline monitor for KAGRA

Design Control Scheme
Commissioning
Activate Crustal Motion Compensation System

KAGRA schedule

Observation
Phase-3 （Commissioning）
Phase-2 （Full configuration）
Phase-1 （Cryo Michelson）

2017
Apl

2018
Apl

2019
Apl

2020
Apl

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Summary

- GIF is a baseline monitor for KAGRA
- We installed X arm. We are observing crustal motion
- We are planning the crustal motion compensate system