Estimation of the Topographic Effects of Mt. Ikenoyama

Kouseki Miyo,

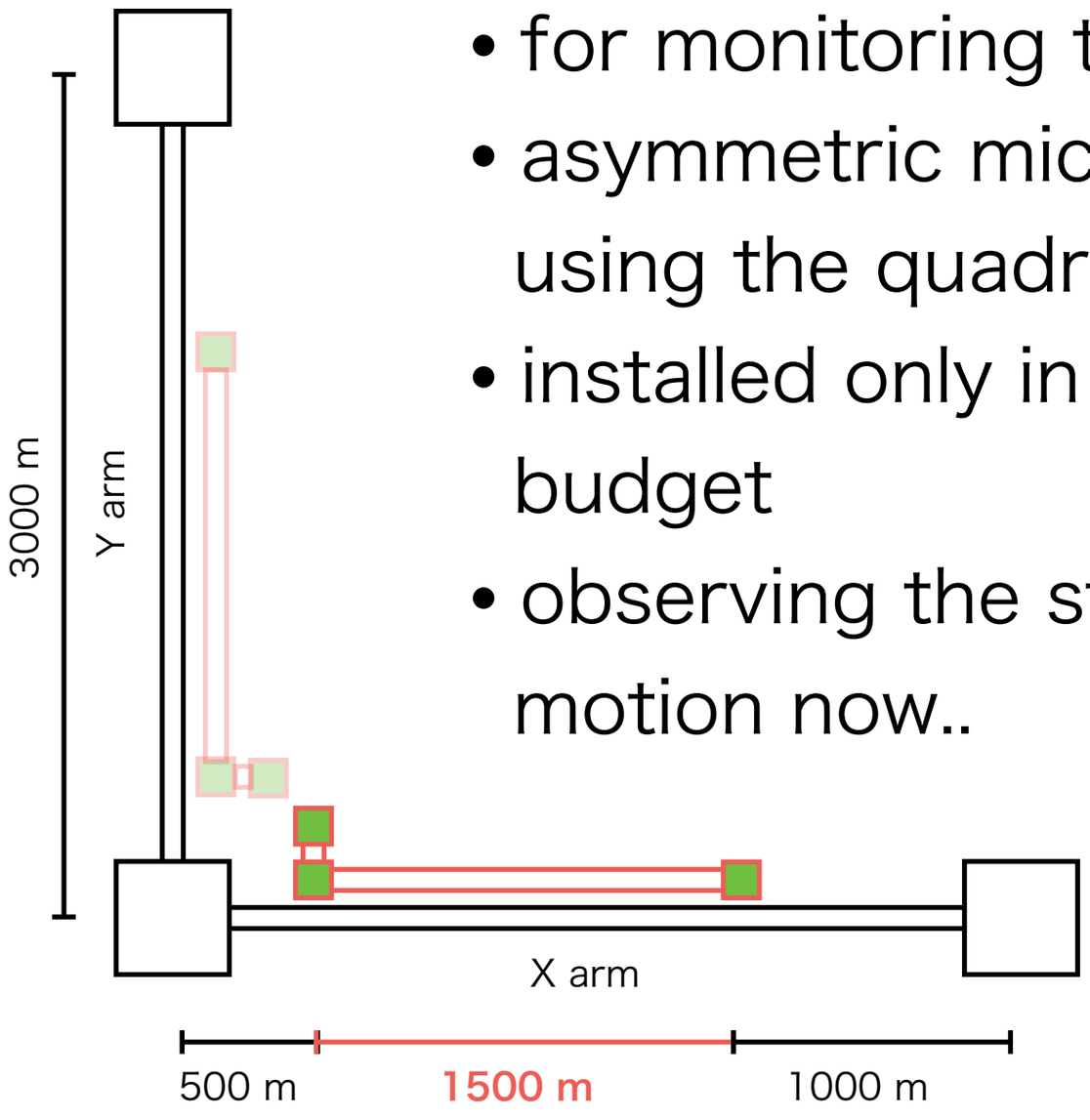
Akito Araya, Akiteru Takamori, Wataru Morii, Masatake Ohashi

Mar 30, 2017

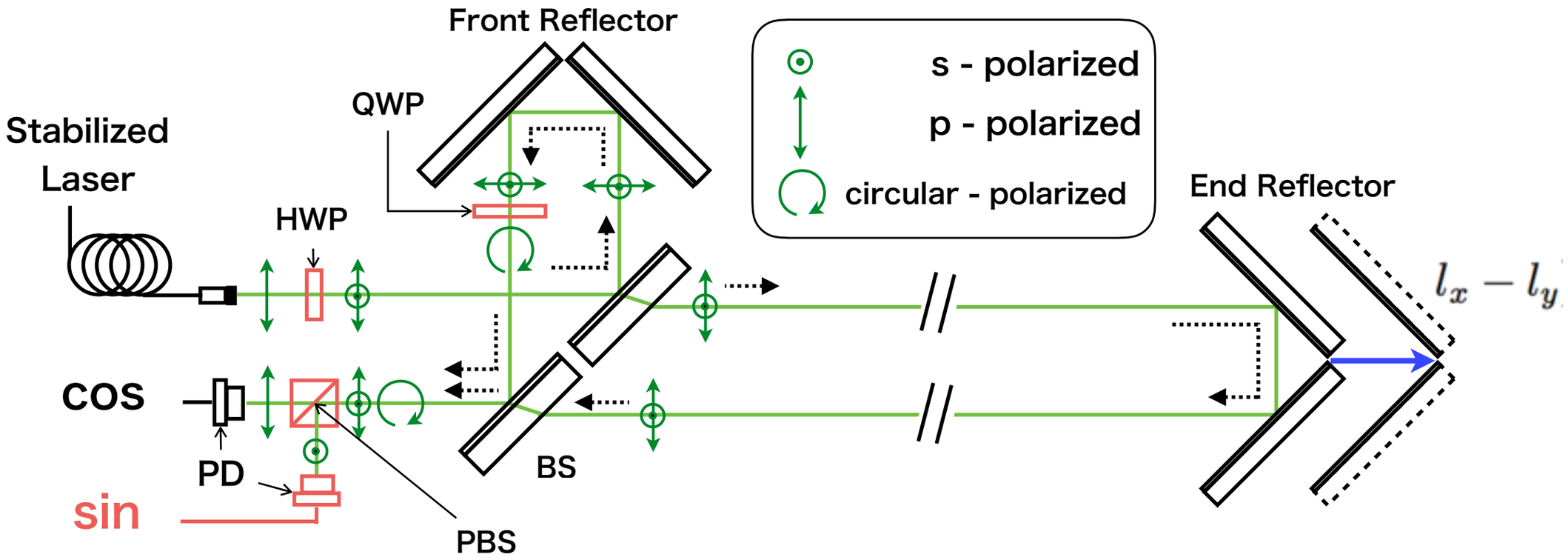
/About Geophysics Interferometer (GIF)

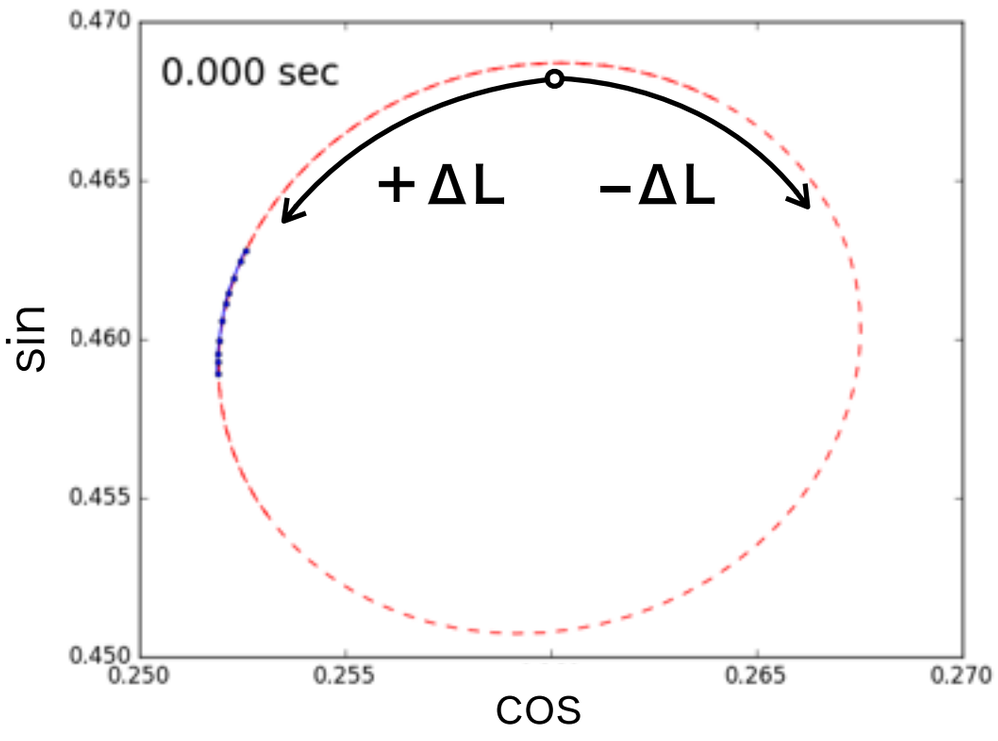
GIF is ..

- for monitoring the strain of the KAGRA arm
- asymmetric michelson interferometer using the quadrature phase detection
- installed only in X-arm due to a limited budget
- observing the strain caused by the crustal motion now..



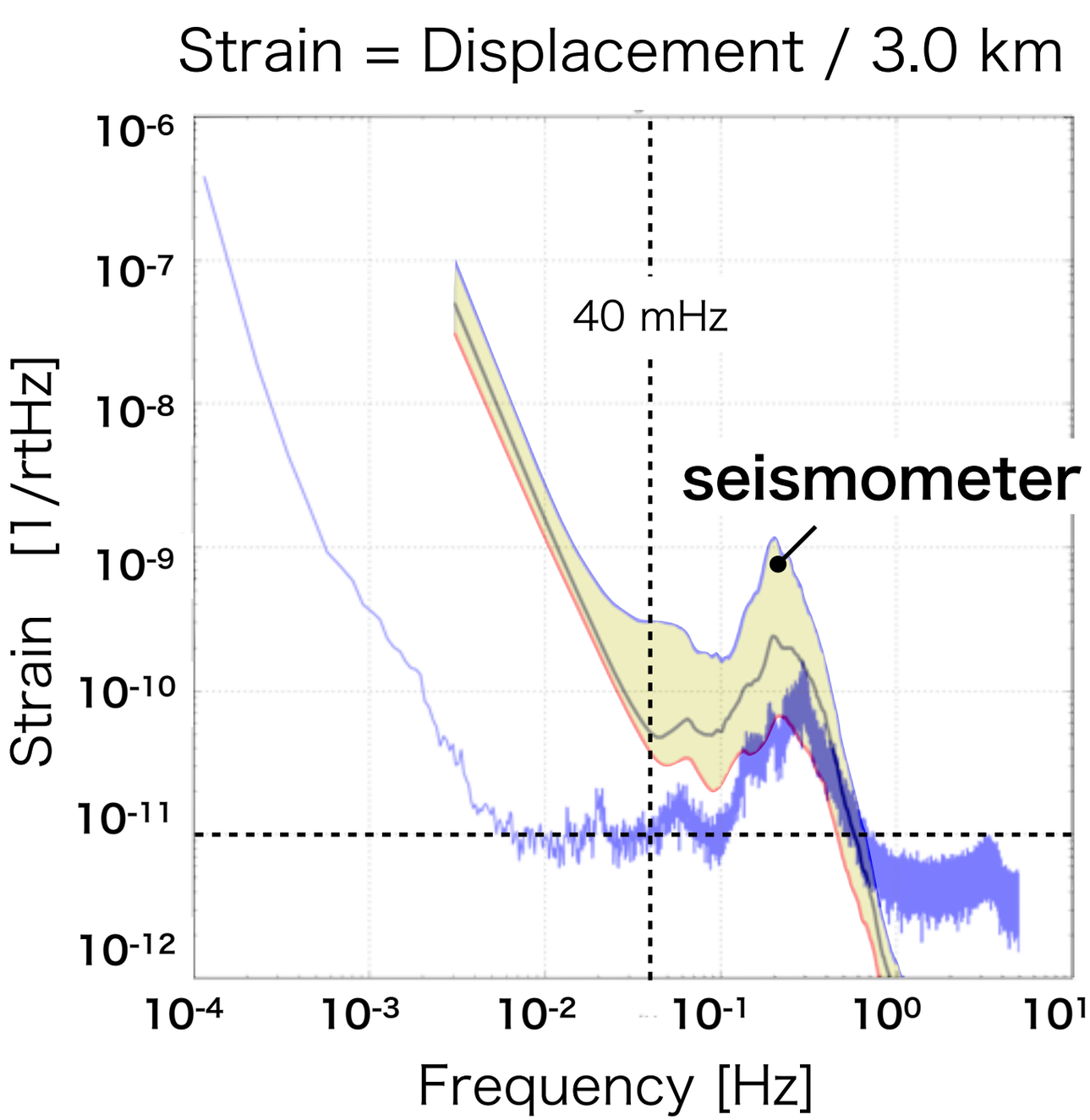
/GIF/ Quadrature Phase Detection





The displacement corresponds to the rotation of the fringe

/GIF/ High sensitivity strain-meter for KAGRA



- Seismometer is poor sensitivity bellow 40 mHz.
- GIF can observe the displacement up to 10^{-11}.
- High Sensitivity at low frequency

/Estimation of the Coupling Matrix

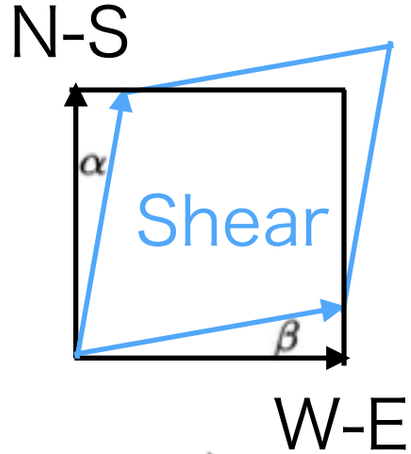
- Mountain is not homogeneous and KAGRA is in the tunnel, then, KAGRA arms are affected by "**Topographic Effect**".
- This effect relates to the spatial distribution of the mechanical properties of the rock
- Mountain response is given by the matrix multiplication below
- CLIO's GIF have already estimated this effect.

mountain response ↓ tidal motion ↓

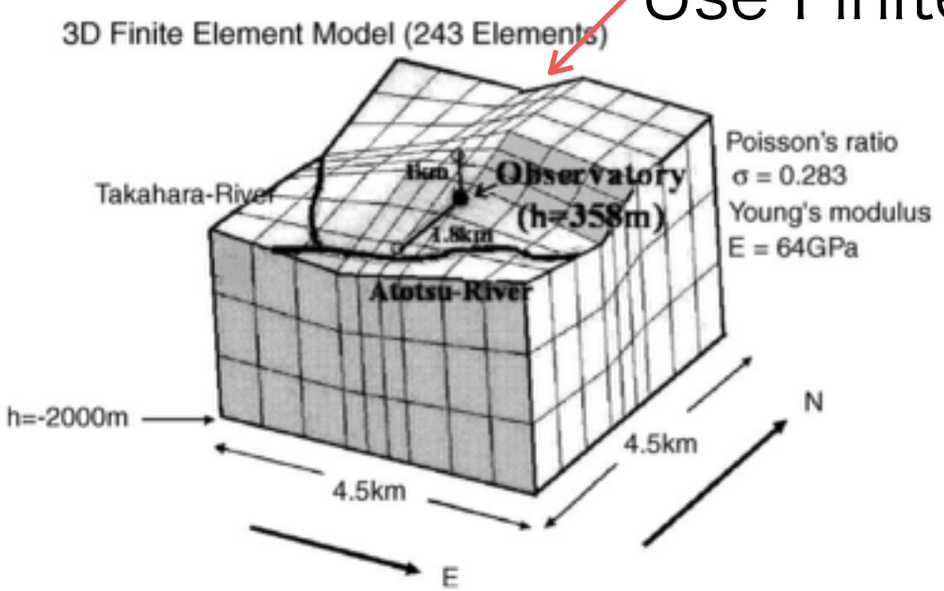
$$\begin{pmatrix} e'_1 \\ e'_2 \\ e'_3 \end{pmatrix} = \begin{pmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{pmatrix} \begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix}$$

← N-S strain
← W-E strain
← Shear strain

Shear $= \alpha + \beta = \dfrac{\partial u_y}{\partial x} + \dfrac{\partial u_x}{\partial y}$



Use Finite Element Model



solve →

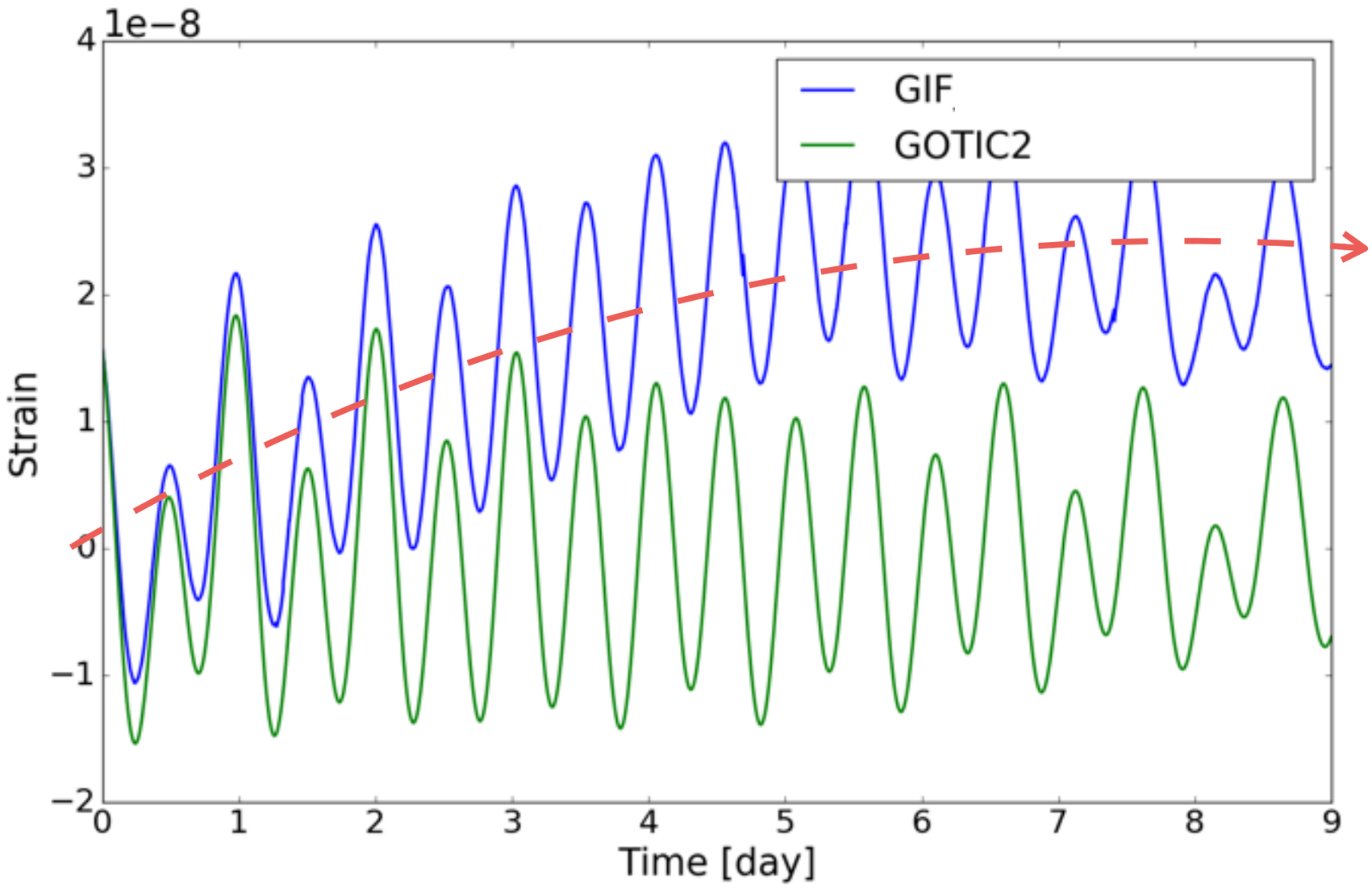
$$\begin{pmatrix} 0.845 & -0.011 & 0.025 \\ 0.006 & 0.901 & 0.009 \\ 0.076 & 0.045 & 0.877 \end{pmatrix}$$

/Estimation/

- If KAGRA had two GIFs, it would be possible to observe the shear strain
- Because of limited budget, we have only X-arm.. → Only 1-axis strain data
- Thus, we can not investigate the matrix of coupling coefficients..
  - Fortunately, shear component does not affect GW detection.

- First of all, we can try to measure the inhomogeneity along the X-arm.

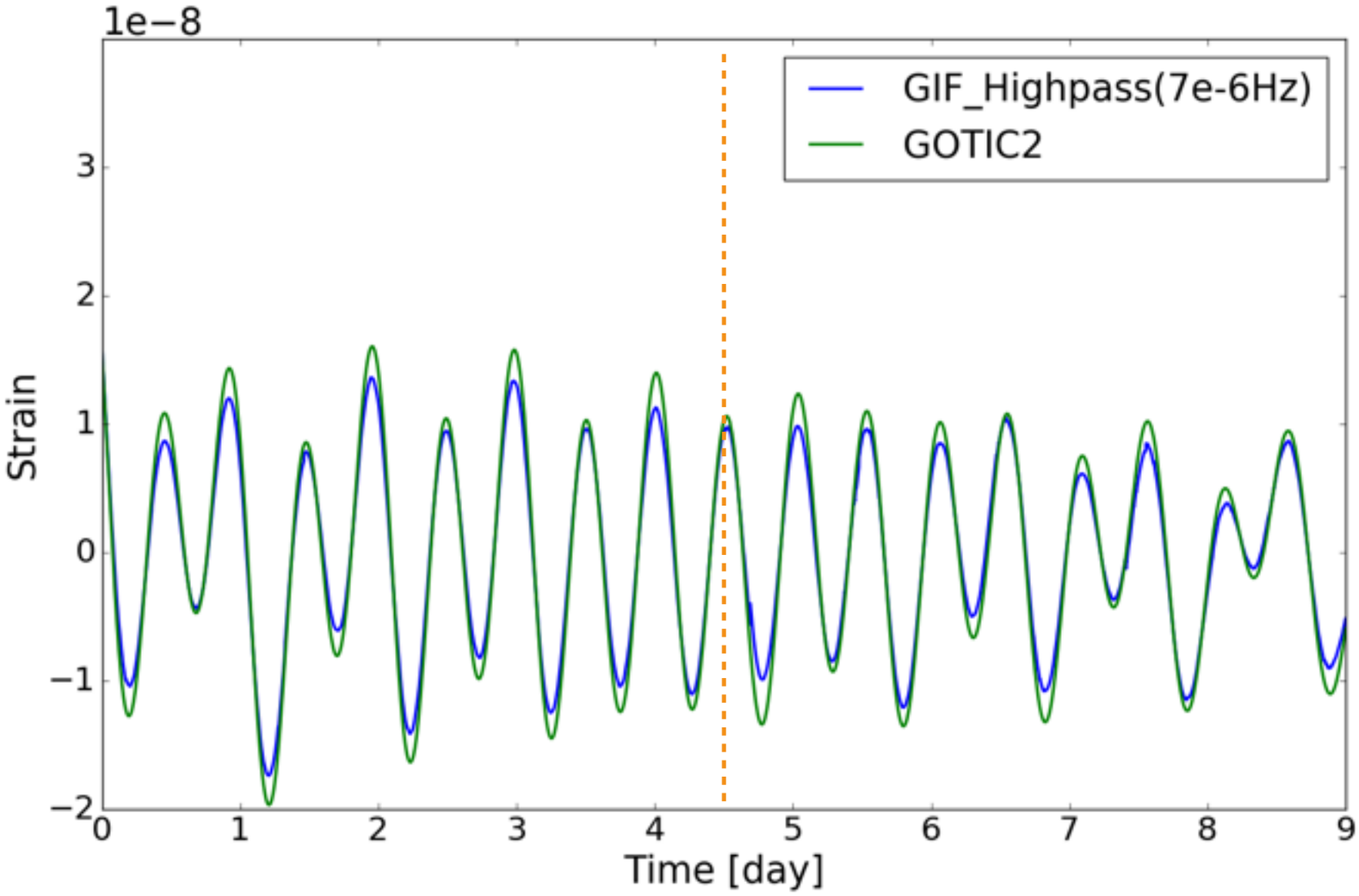
/Estimation/ Observation Data (Raw)



- Raw data have a trend (red dotted line)
- This trend is caused by local environment changes (air pressure?)

- Remove this trend to compare the tide movements of GIF and GOTIC2, a simulation of the tidal motion

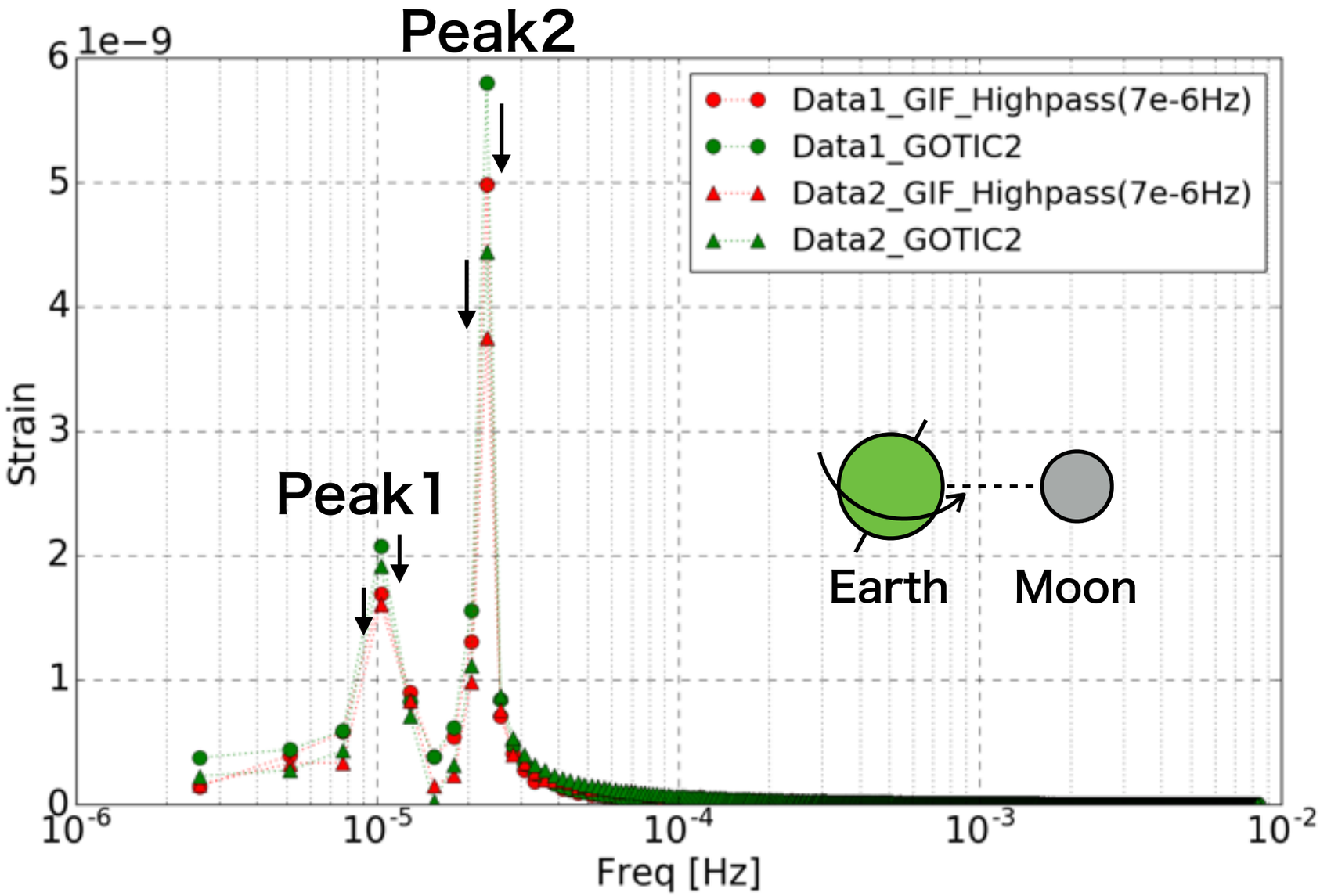
/Estimation/ Observation Data



- Filter is 5th-order butterworth, and cutoff frequency is 7×10^{-6} Hz.
- GIF amplitude is less than GOTIC2

- To obtain the ratio of the amplitudes, divide it into 2 sections, and do FFT.

/Estimation/ Comparison of Amplitude



- Peak2 is caused by the earth rotation (1/2 day period).
- Peak1 is caused by inclined earth rotation axis (1 day period).

GIF÷GOTIC2 =

	Peak1	Peak2
Data1	0.98	0.84
Data2	0.78	0.88

- Ratio of the amplitudes < 1 means that KAGRA tunnel is difficult to stretch and shrink.
- Could this data suggest inhomogeneity?

/Estimation/ Dose it suggest inhomogeneity?

- Basically, GIF does not monitor only tidal motion also local environment changes.
  - To estimate the topographic effect precisely, we need to remove local changes.
  - We suspect air pressure is a criminal.
    - We have deployed barometers in the tunnel.
- For more understanding, we can use other oscillation modes which arise from asymmetric rotation. (degeneracy is removed)
  - To distinguish these peaks, we need long term data for more enough frequency resolution.

/Summary

- GIF is strain-meter for KAGRA.
- Tidal motion is very known crustal motion, so we can estimate the topographic effect using the GIF observation of Mt. Ikenoyama's mechanical response.
- For a better estimation, we need to eliminate other local motion.
- Long term and stable observation is needed.