

# A study of Arm Length Stabilization in KAGRA

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# Reference

## **Fiber Phase Noise Measurements at LHO**

[1] LIGO-T0900376-v1

## **Development of Auxiliary Lock Acquisition Procedures at the Caltech 40m Interferometer**

[2] <https://dcc.ligo.org/LIGO-T080202/public>

## **Study by Tatsumi-san et al. in 2011-2012**

[3] <https://granite.phys.s.u-tokyo.ac.jp/svn/Private/trunk/LCGTbackup/GreenLock/>

[4] <http://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/ShowDocument?docid=788>

[5] <http://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/ShowDocument?docid=1268>

## **Arm Length Stabilization Conceptual Design**

[6] <http://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/ShowDocument?docid=5353>

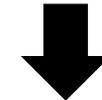
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- Arm length stabilization(ALS) Configuration
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# Overview

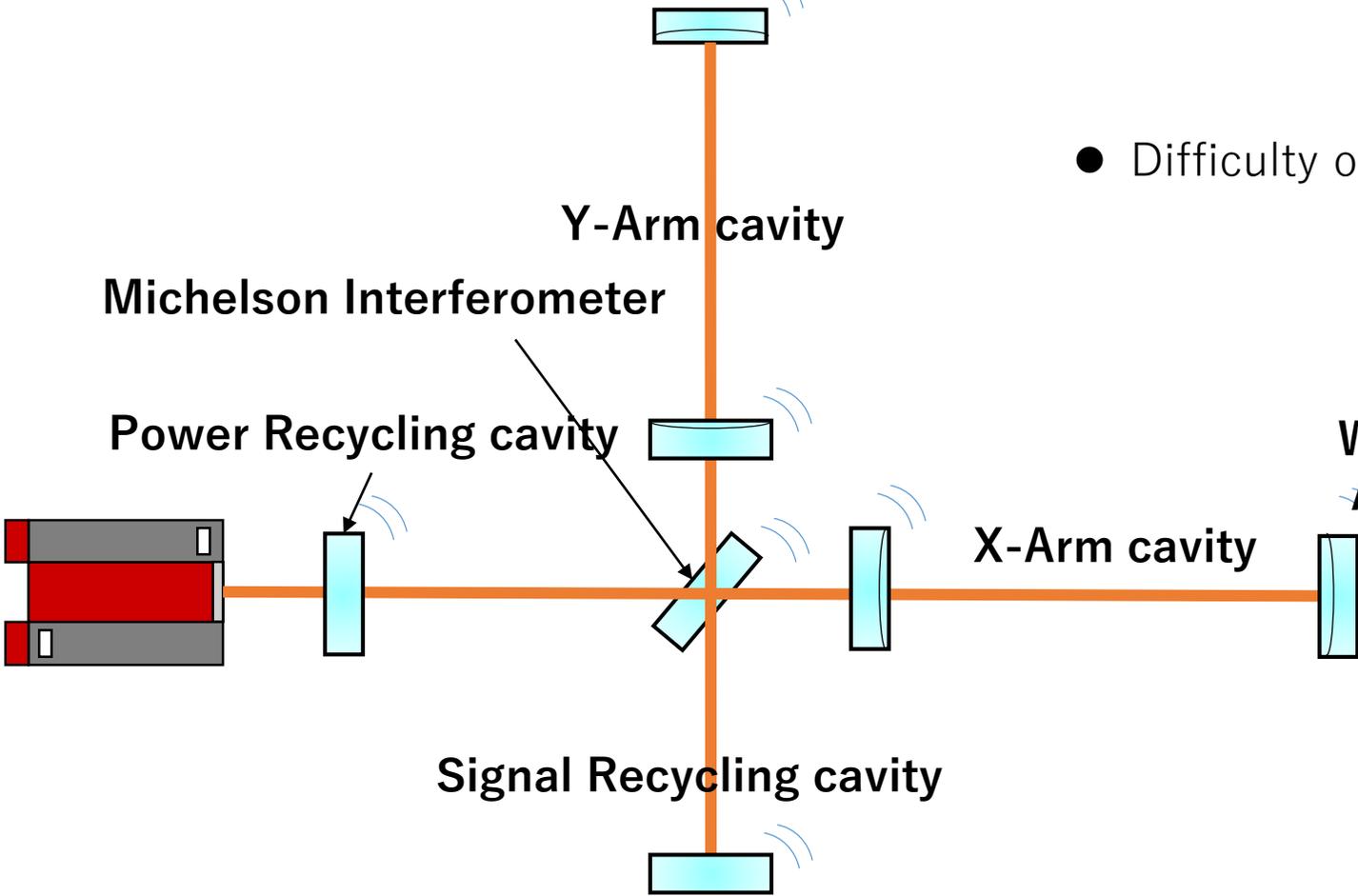
~To lock is too difficult!!!~

- Difficulty of locking interferometer with **5 degree of freedom**



We need to lock in order

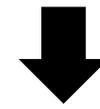
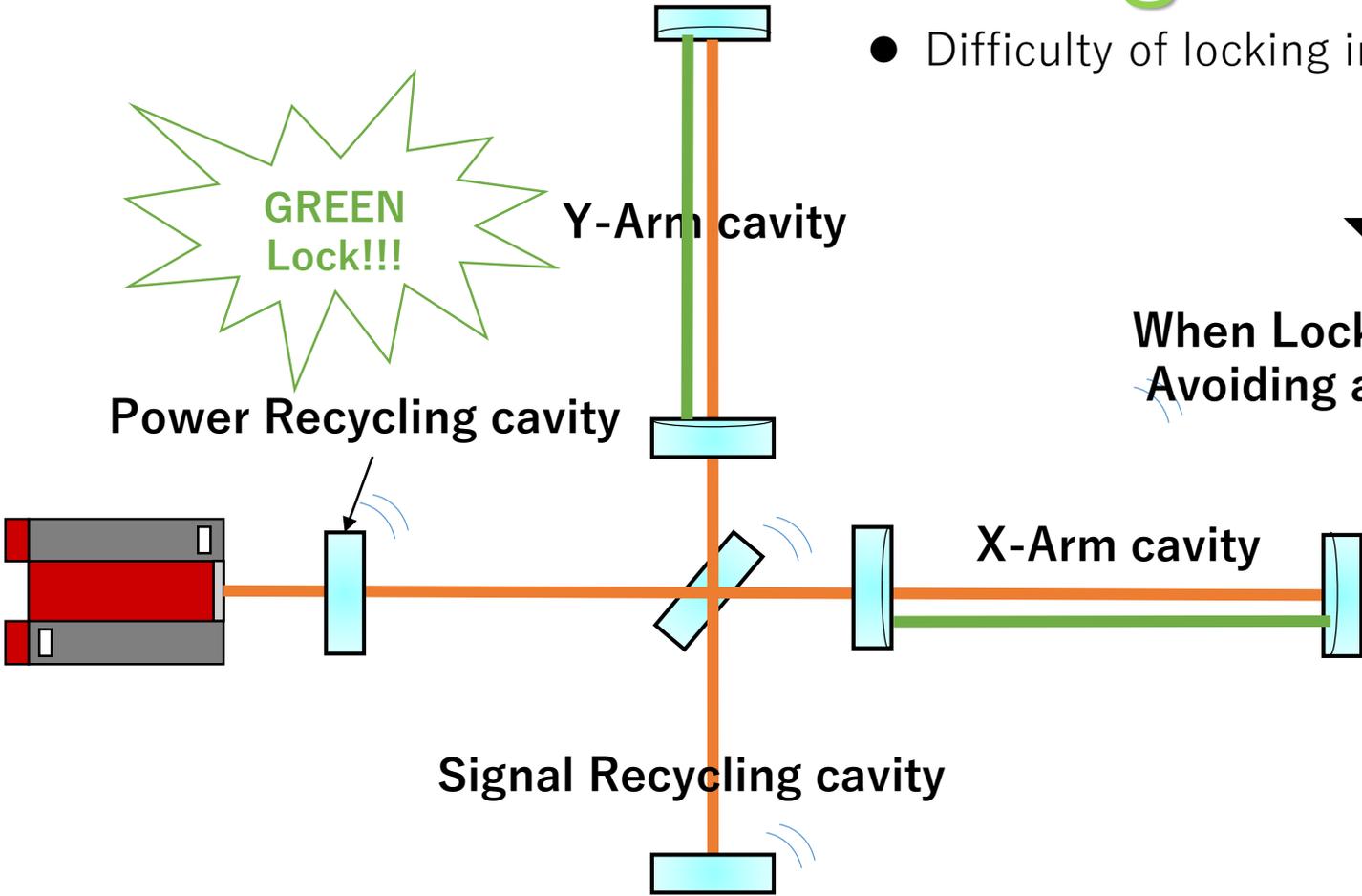
When Locking Power or Signal Recycling Cavity,  
Avoiding accidental resonance of Arm cavity



5 degree of freedom

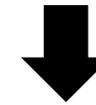
# Overview ~Arm Length Stabilization(ALS)~

- Difficulty of locking interferometer with **5 degree of freedom**



We need to lock in order

When Locking Power or Signal Recycling Cavity,  
Avoiding accidental resonance of Arm cavity



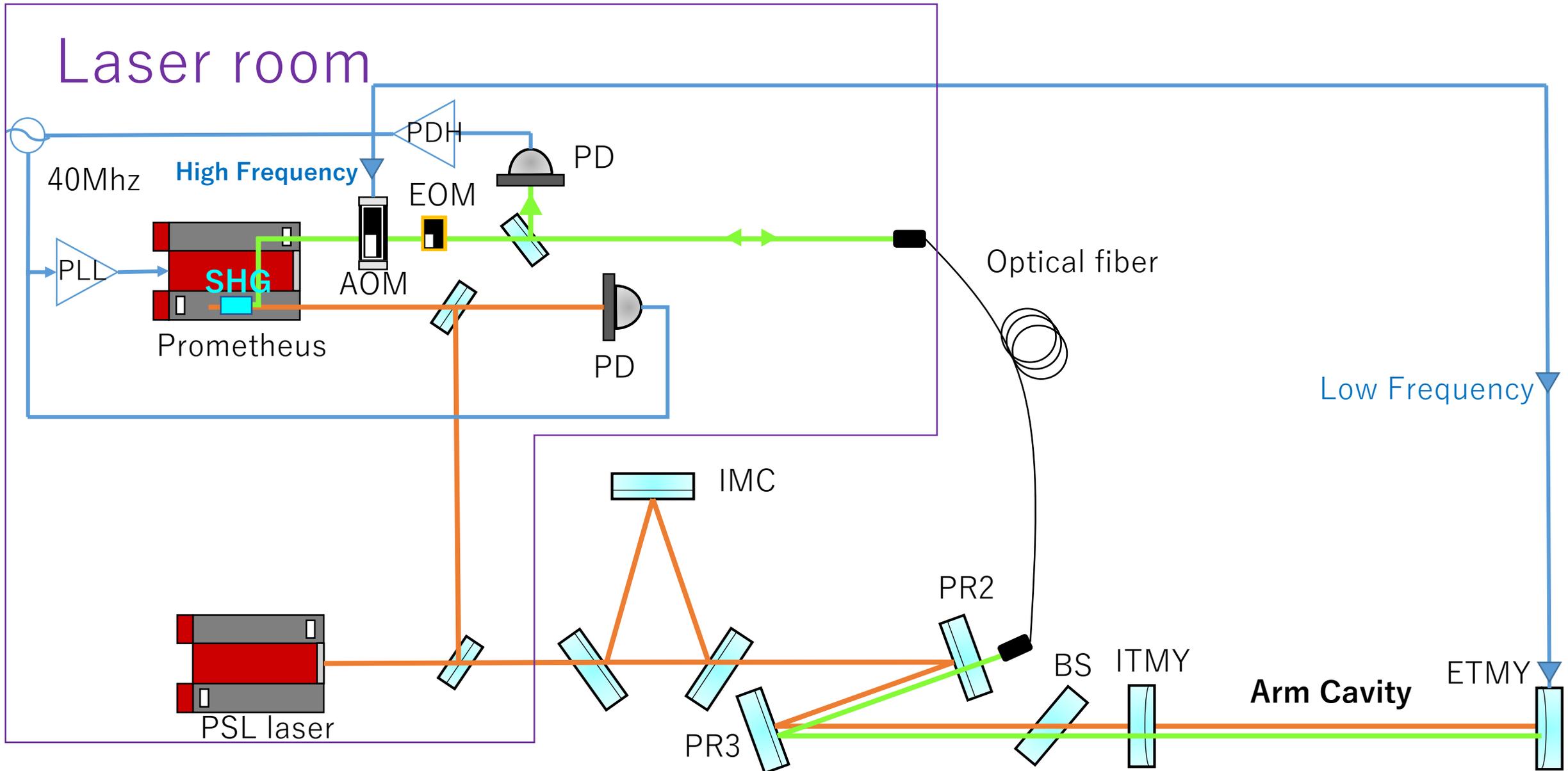
Locking arm cavity by Green laser using PDH  
Frequency of Green laser stabilized by PLL



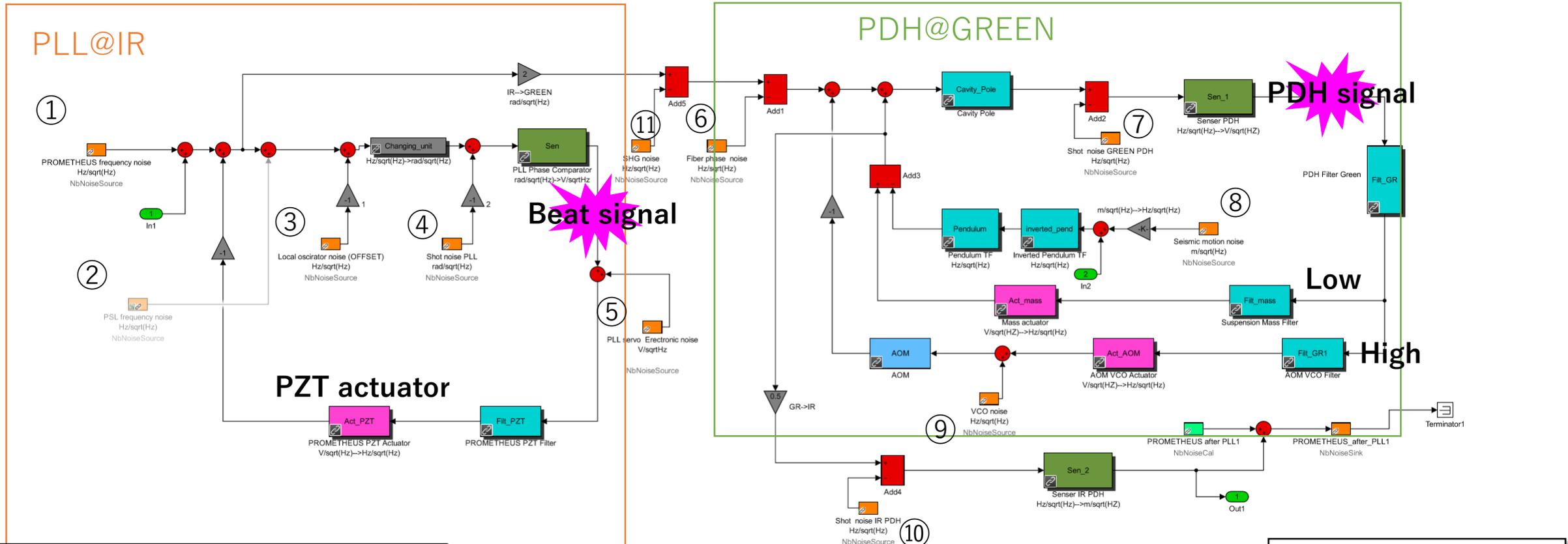
**3 degree of freedom!!**

**Arm Length Stabilization System(ALS)!!!!!!**

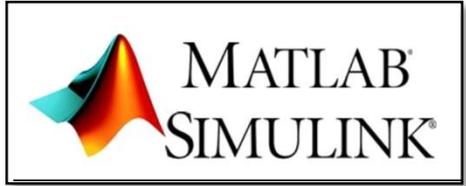
# ALS Configuration (Y-arm)



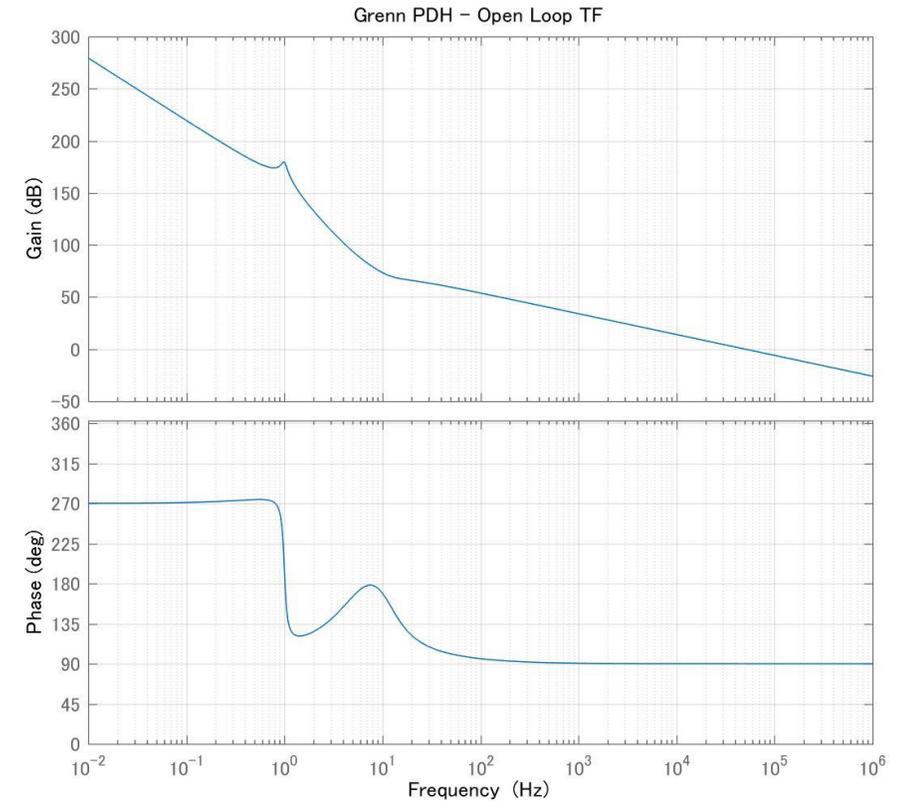
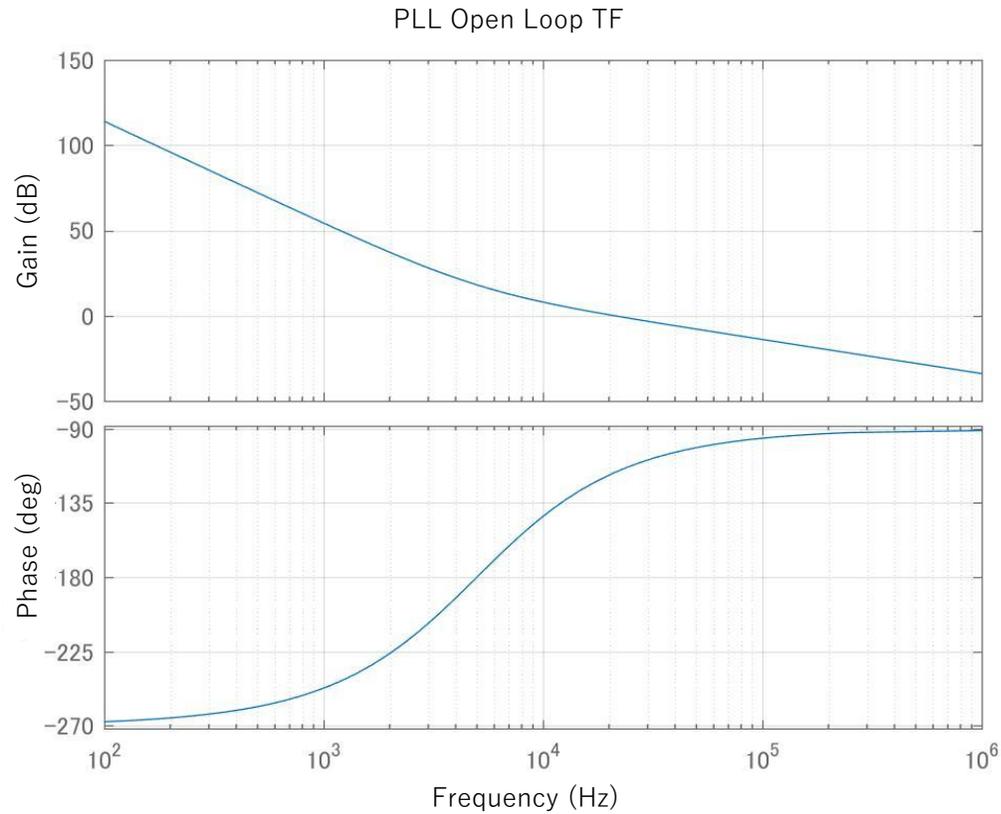
# ALS Configuration by Simulink Noise Budget



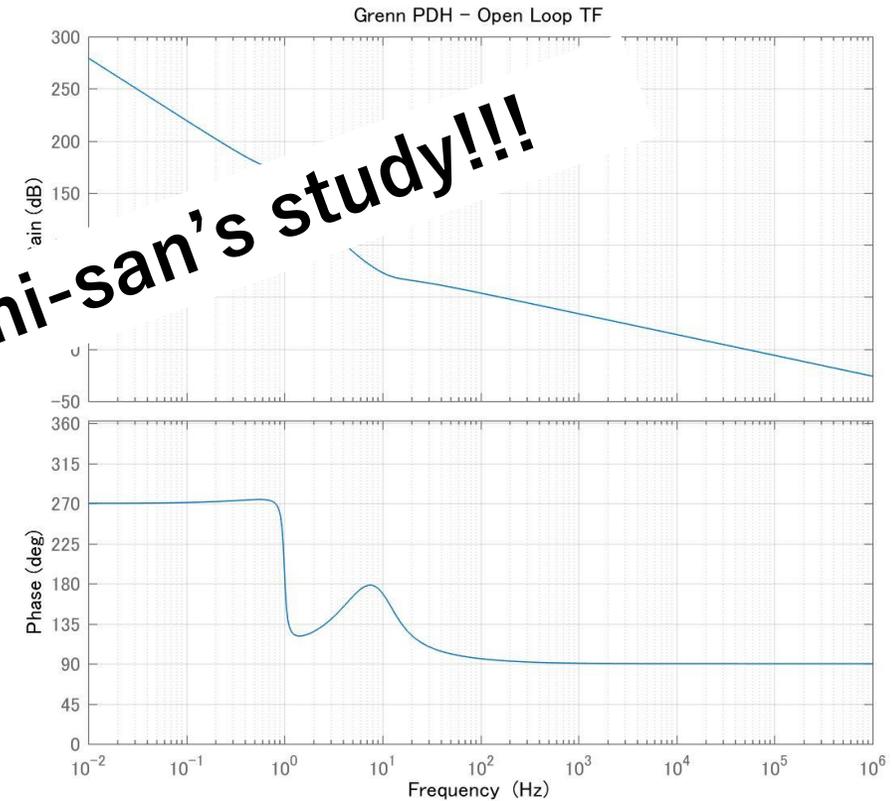
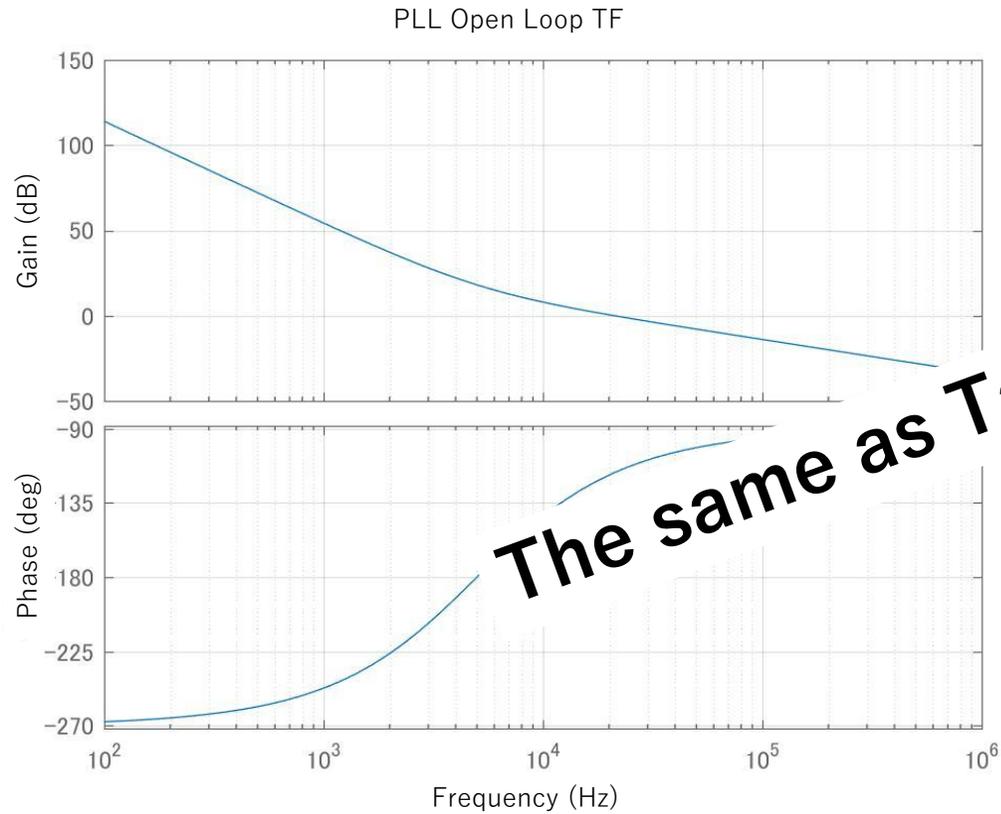
**Green Block : Photo detector**  
**Pink Block : Actuator**  
**Blue Block : Filter**  
**Orange Block : Noise**



# Open-loop Transfer Function



# Open-loop Transfer Function



**The same as Tatsumi-san's study!!!**

# Amount of noise source estimation

① **PROMETHEUS frequency noise**

$$=10000/f \text{ Hz}/\sqrt{\text{Hz}} \text{ **Prometheus catalog spec}$$

② **PSL frequency noise**

$$=1.0654e-6 \times f^{-2}/(1+(2/f)^{-8}) \text{ Hz}/\sqrt{\text{Hz}} \text{ **modeled}$$

③ **Local Oscillator noise**

$$=5e-5/f \text{ Hz}/\sqrt{\text{Hz}} \text{ **Agilent E8663D-UNX catalogue spec}$$

④ **Shot noise PLL**

$$=2.5e-8 \text{ rad}/\sqrt{\text{Hz}} \text{ **[5]}$$

⑤ **PLL servo Electronic noise**

$$=100e-9 \text{ V}/\sqrt{\text{Hz}} \text{ **[5]}$$

⑥ **Fiber phase noise**

$$=1 \text{ Hz}/\sqrt{\text{Hz}}@4\text{km} \text{ **[1]}$$

⑦ **Shot noise GREEN PDH**

$$=8e-6 \text{ Hz}/\sqrt{\text{Hz}} \text{ **[5]}$$

⑧ **Seismic motion noise**

$$=1e-9/f^2 \text{ m}/\sqrt{\text{Hz}} \text{ **[5]}$$

⑨ **VCO noise**

$$=5e-5/f \text{ Hz}/\sqrt{\text{Hz}} \text{ **E8663D-UNXcatalogue spec}$$

⑩ **Shot noise IR PDH**

$$=8e-7 \text{ Hz}/\sqrt{\text{Hz}} \text{ **[5]}$$

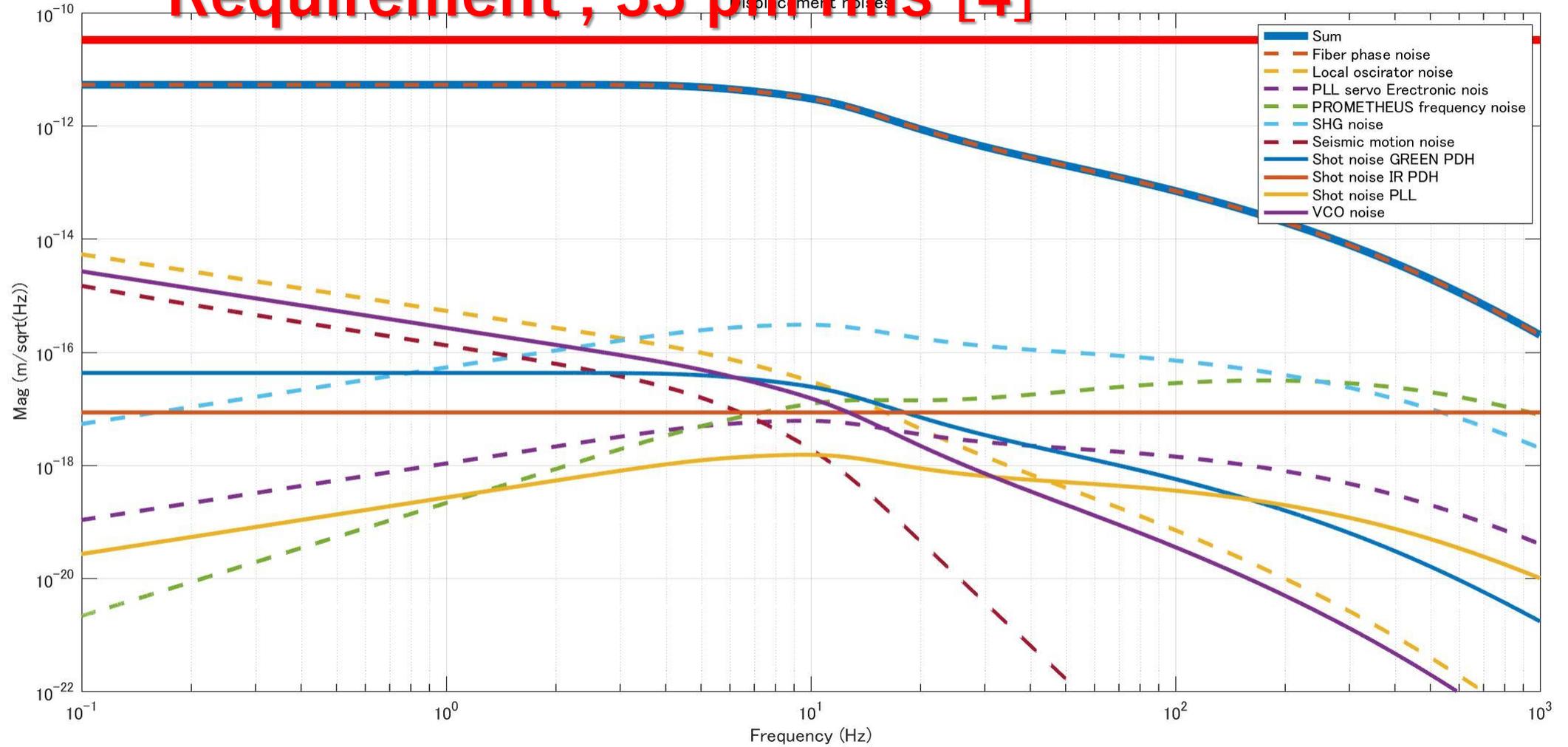
⑪ **SHG noise**

$$=1e-5 \text{ Hz}/\sqrt{\text{Hz}} \text{ **[5]}$$

**Red is checked value by myself**

# Result : Displacement noises at IR Error

**Requirement ; 33 pm rms [4]**



# Conclusion

- I can reproduce the ALS system noise simulation which was calculated by Tatsumi-san **using a different method ; Noise Budget!!**.
- I need to check the all noise sources.
- The main displacement noise is **Fiber noise**. In this simulation, the displacement noise level is under the requirement value. I simulated the noise using 4 km optical fiber, but practically we need only **50m fiber** in KAGRA, so I think **the noise level will decrease**.

# Future Works

- Table-top ALS experiment at University of Toyama
- Calculation remaining noise values
- PLL circuit will be designed by Doi-san