Development and Characterization of Optical Follower Servo for Photon Calibrator for KAGRA Gravitational Wave Observation

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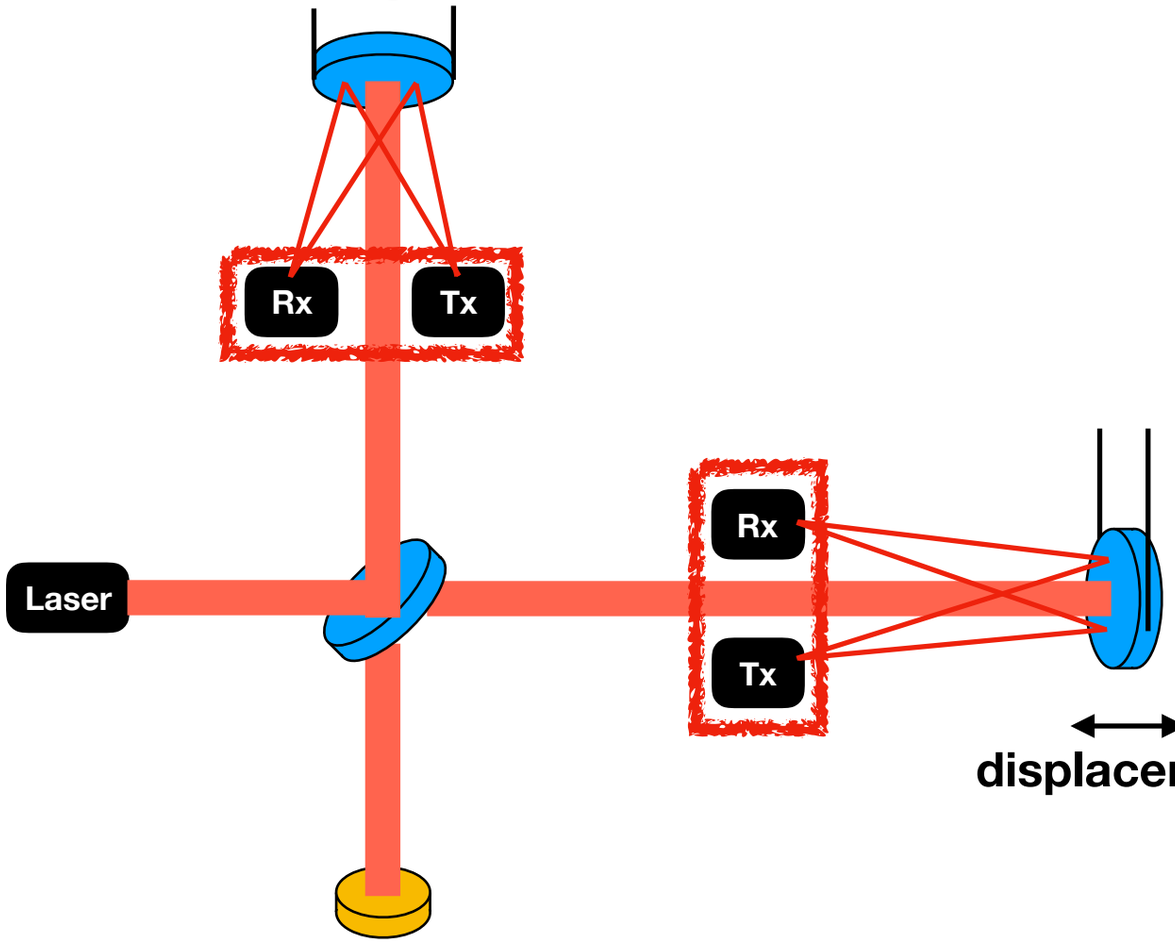
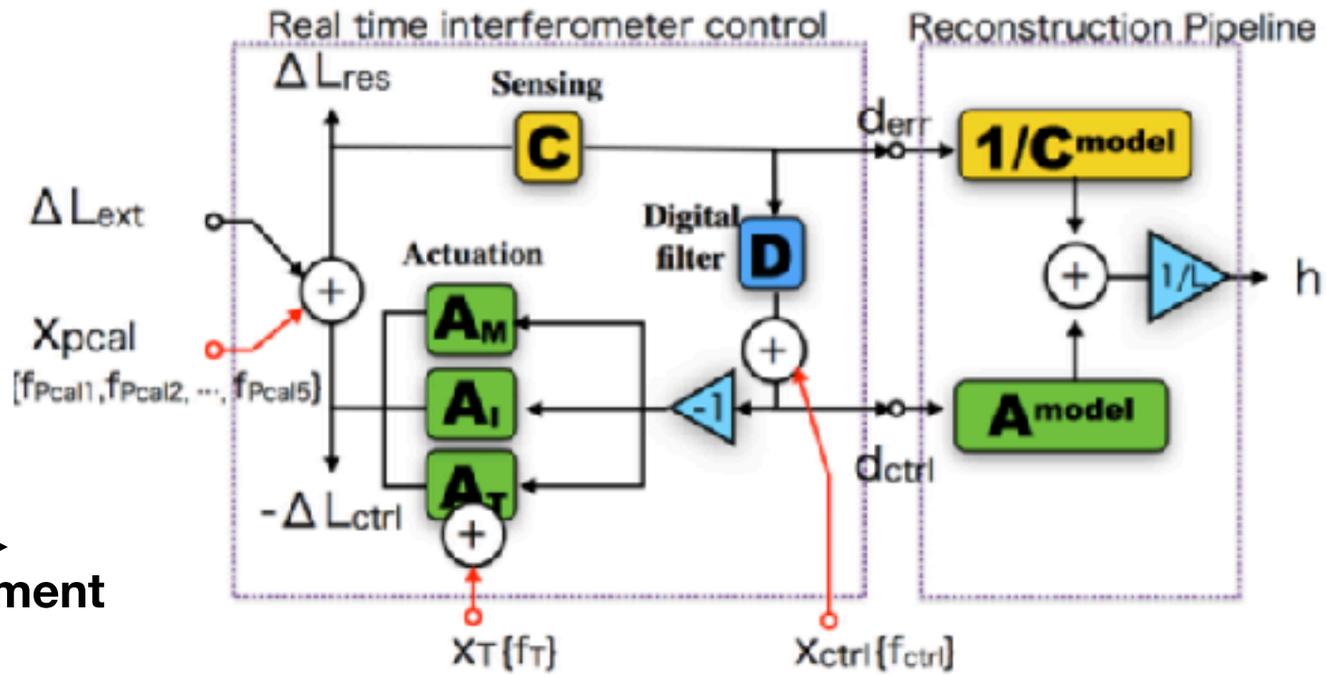
Outline

- Overview
- Instruments of Photon Calibrator
- Requirements
- Optical Follower Servo and feedback loop
- Calibration lines
- Summary

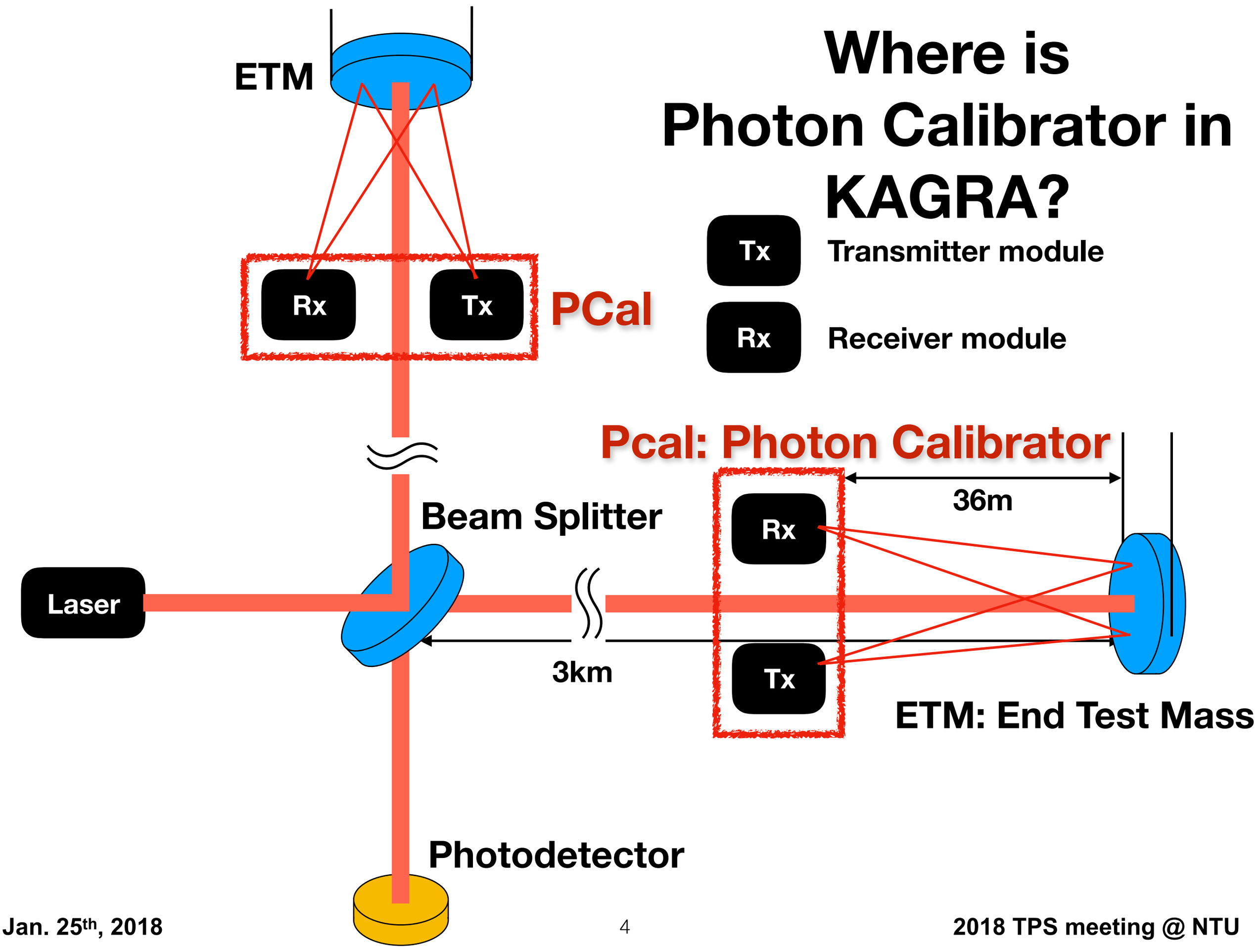
Why we need Photon Calibrator?



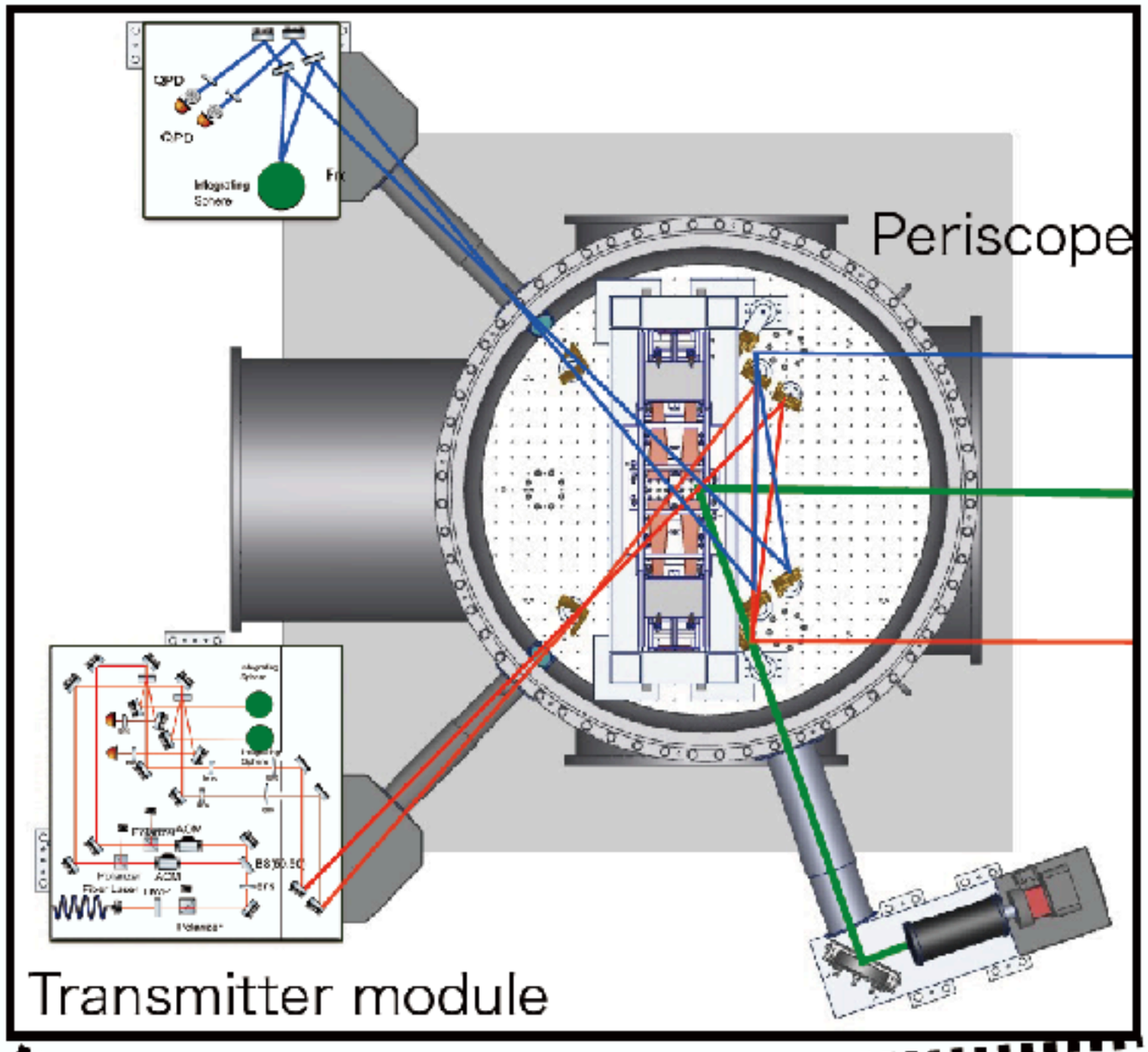


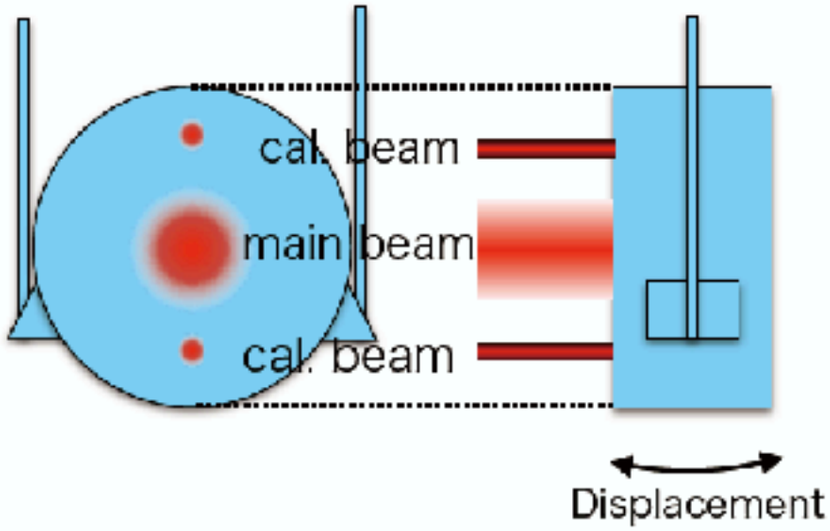
1. Characterize the displacement of mirror
2. Understand the parameter in realtime interferometer control in order to reconstruct the gravitational wave signal.

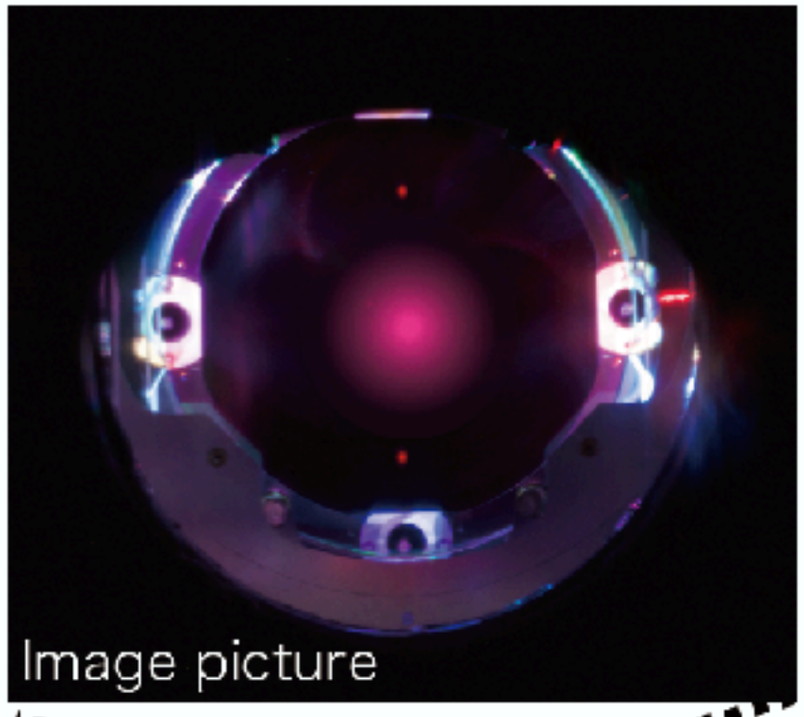
Where is Photon Calibrator in KAGRA?

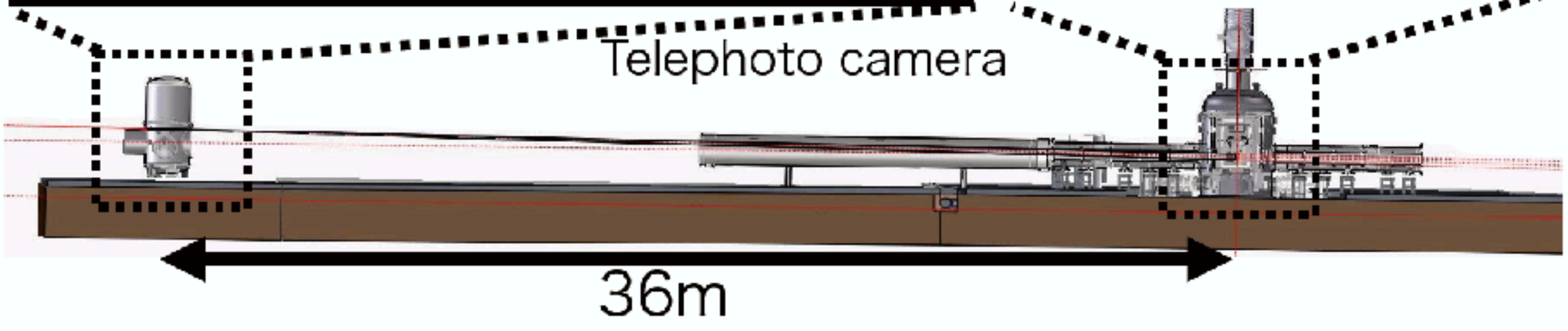


Receiver module

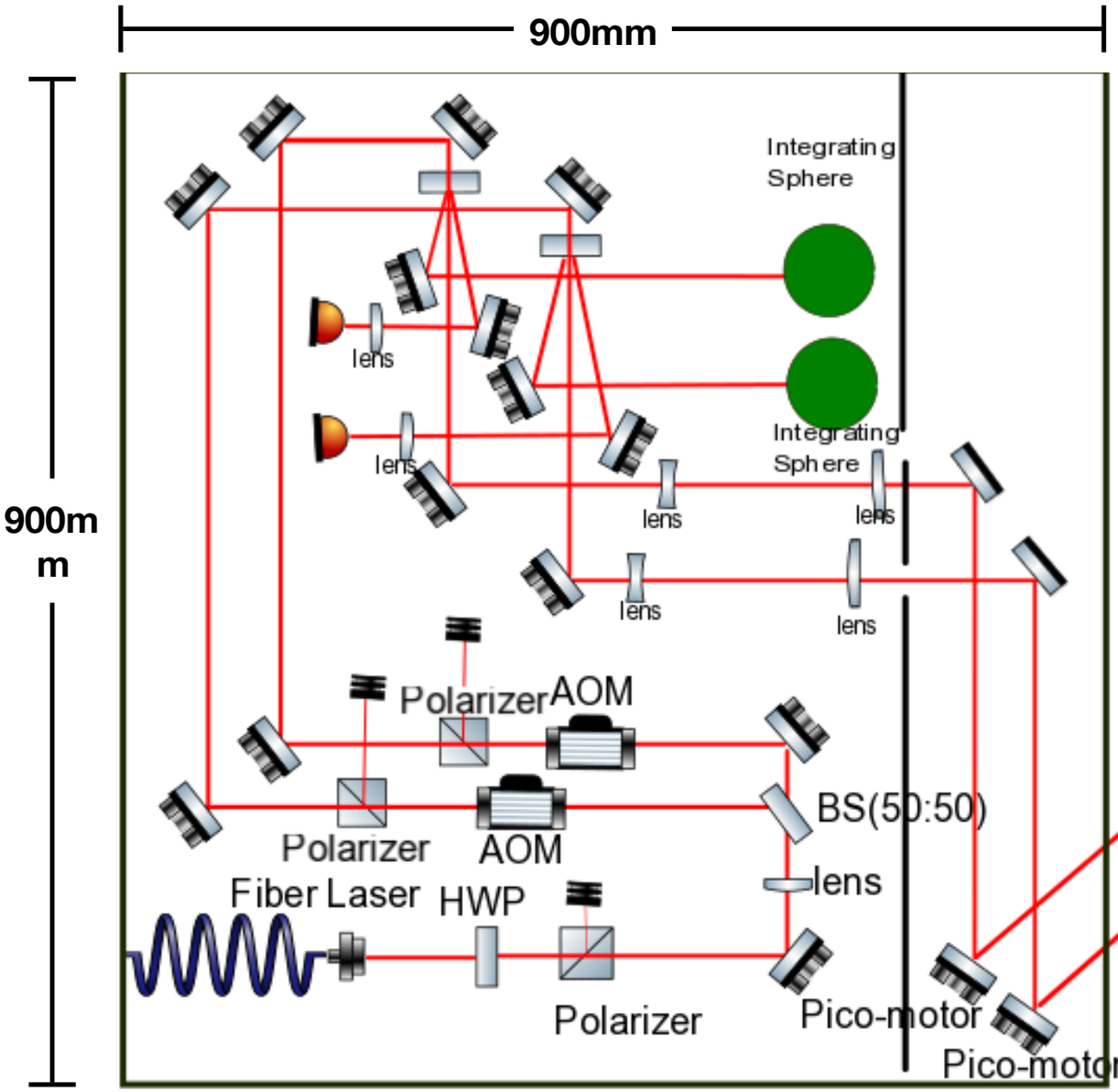


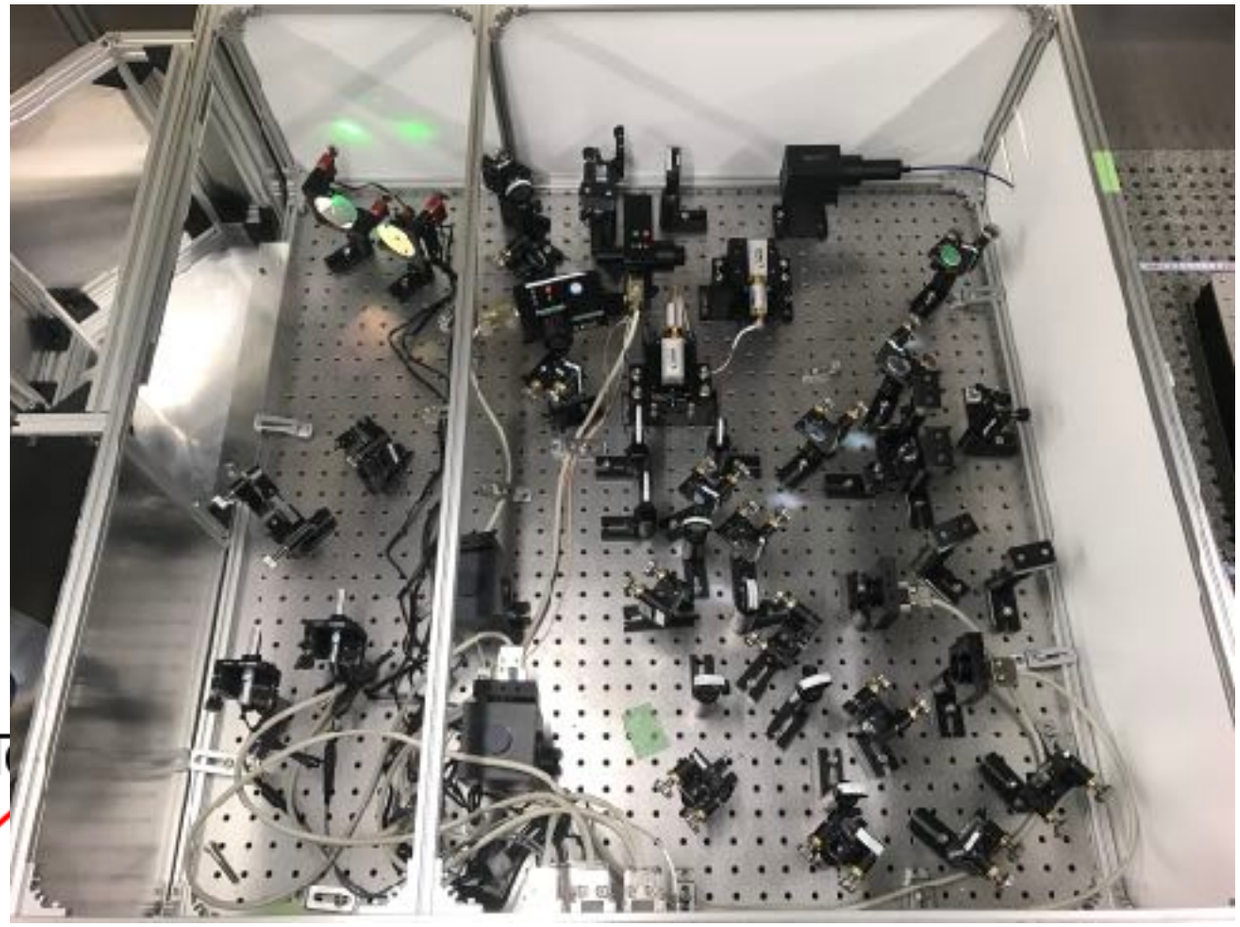




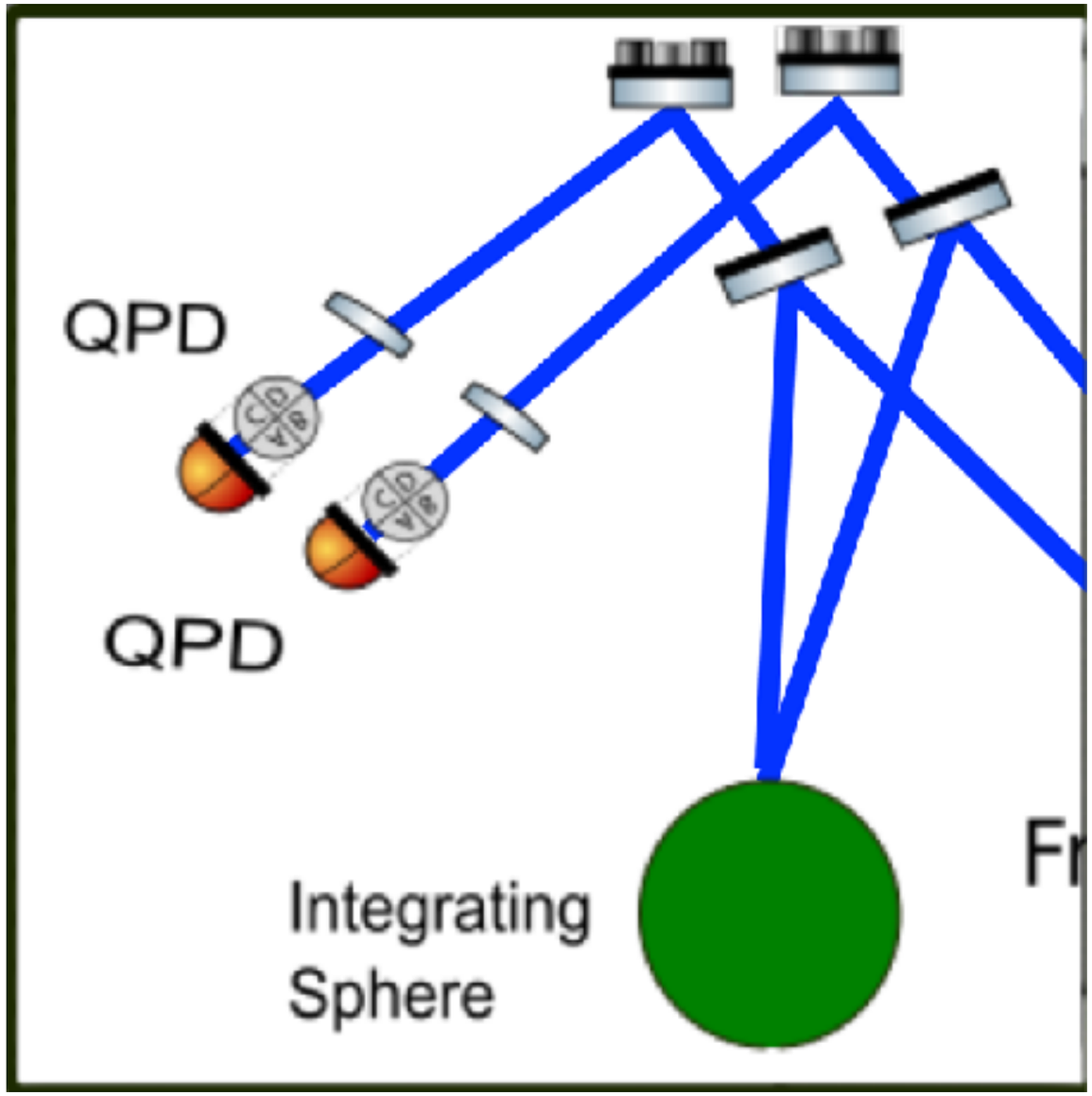


Transmitter Module





Receiver Module

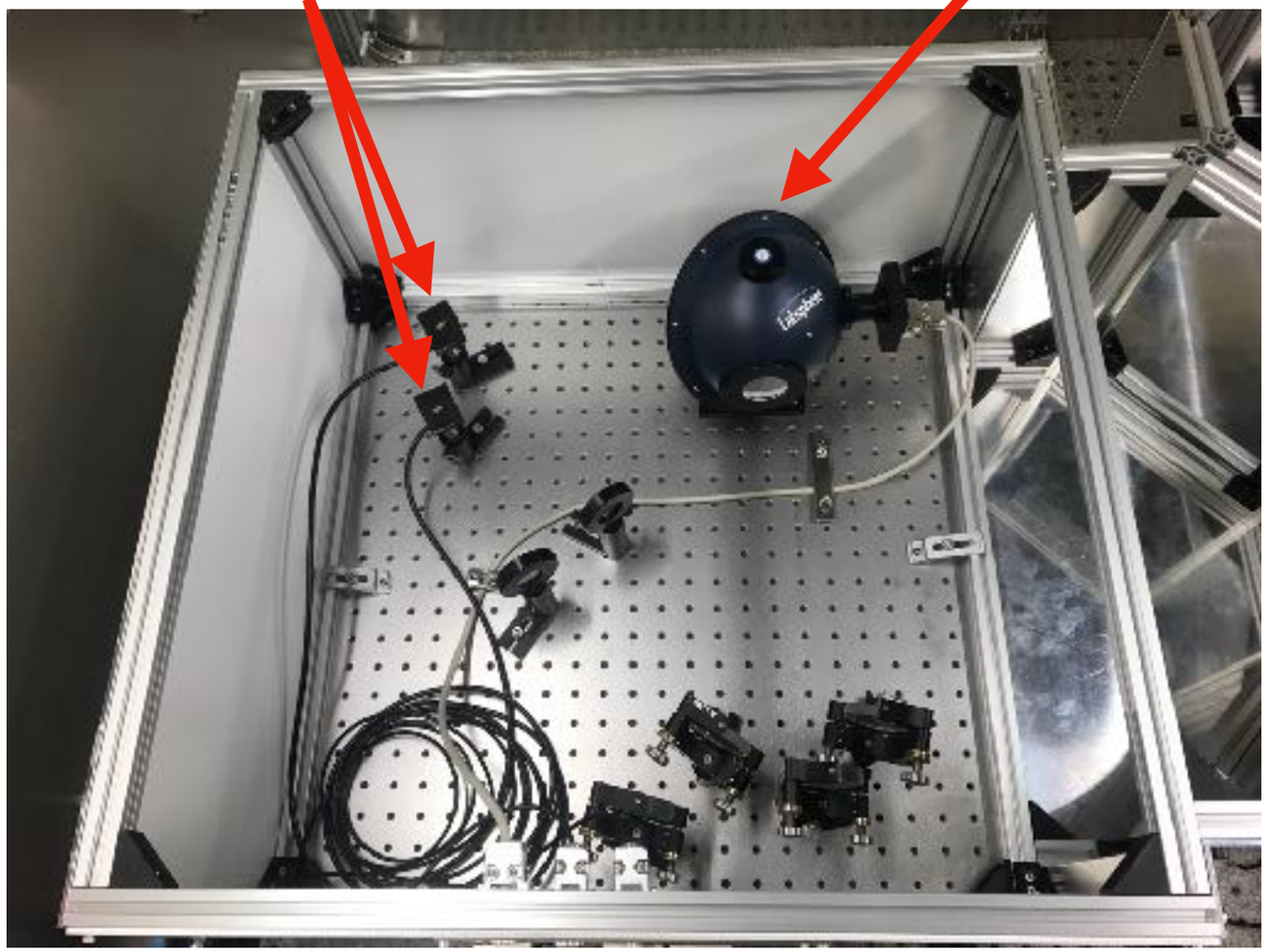


QPD

Quadrant Photo Diode: Monitoring the beam position

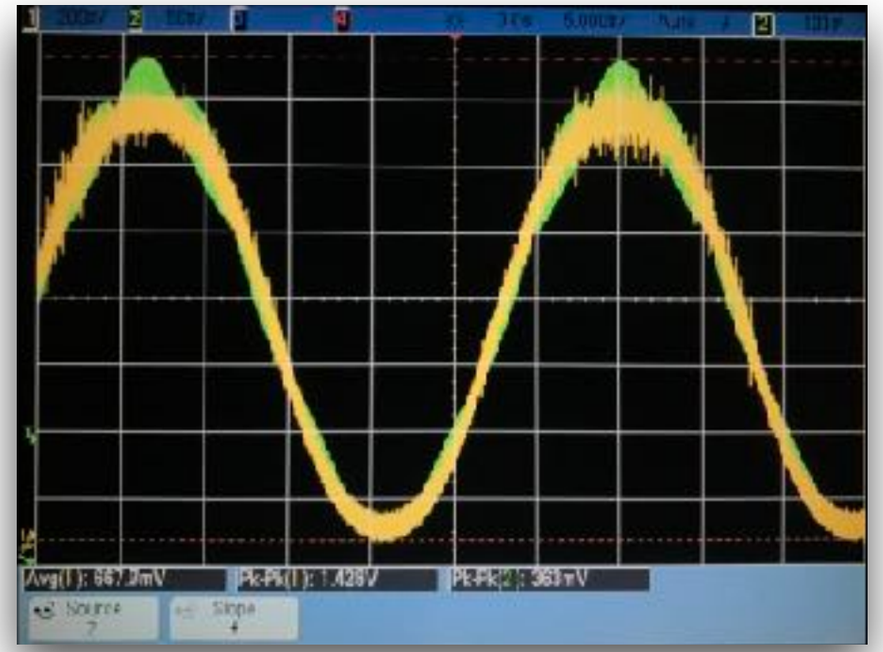
RxPD

Integrating sphere at Rx

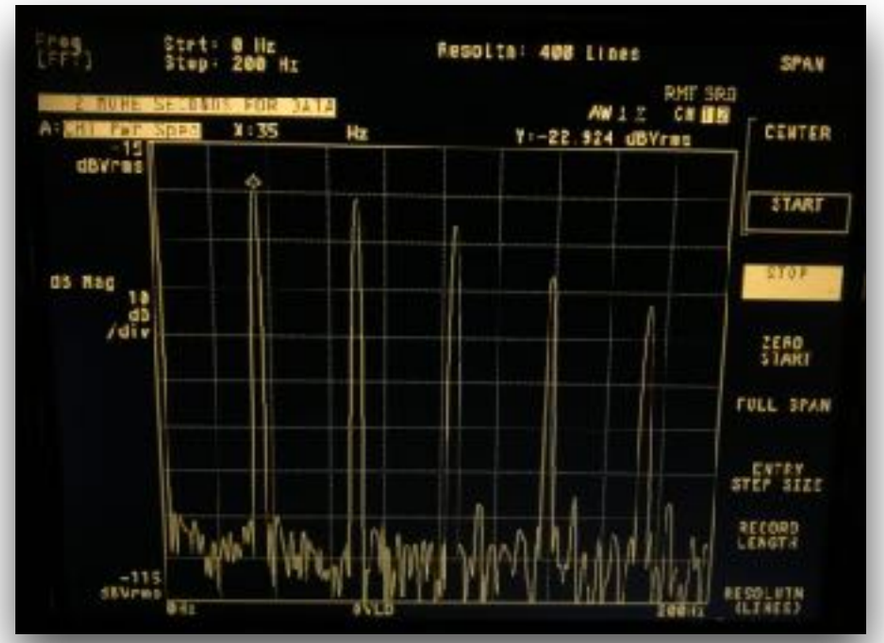


Requirements

Example of higher harmonics in 35Hz injection

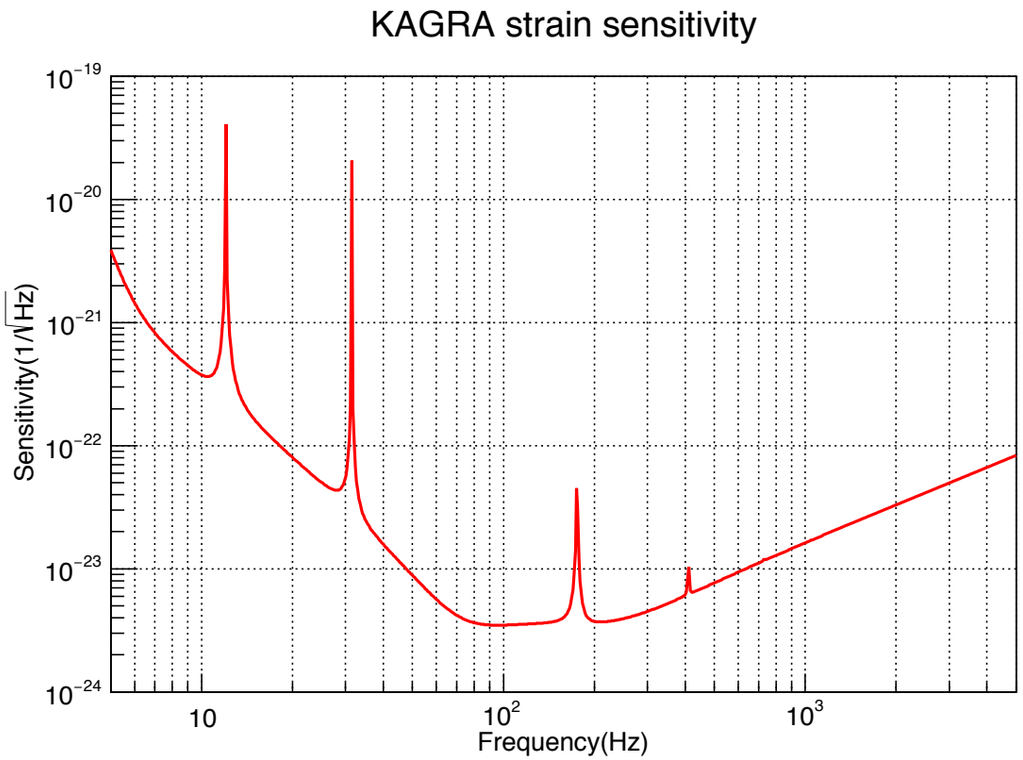


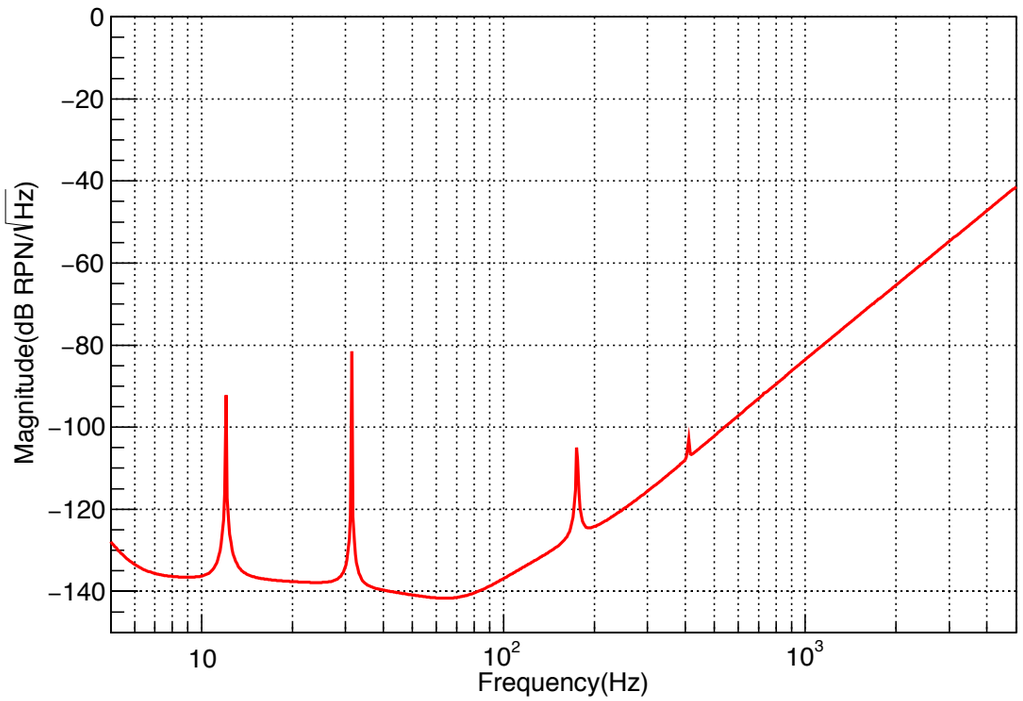
FFT



To decide whether the peak is within requirements or not, first we need to define the noise requirement of Photon Calibrator.

Requirements





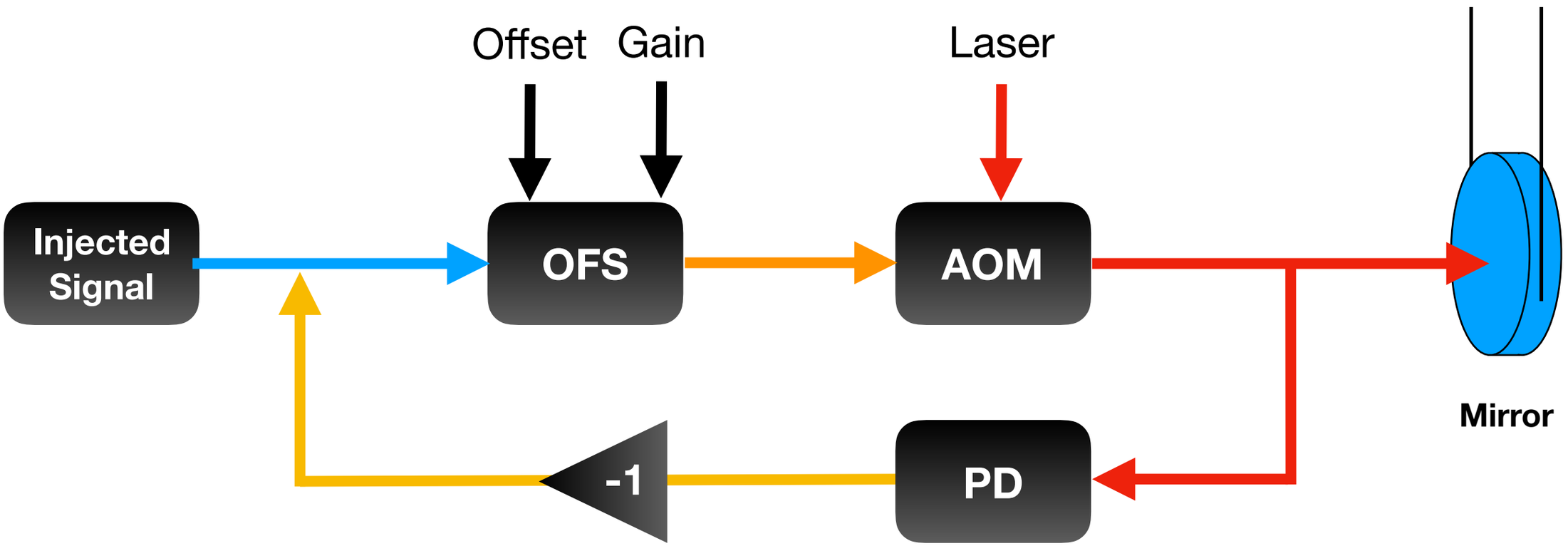
$$\Delta L(f) = \underbrace{\frac{2\Delta P\cos(\theta)}{c}}_{\text{Force}} \underbrace{\frac{1}{M(2\pi f)^2}}_{\text{Force to length transfer function}} < \frac{1}{10}\Delta h(f) L$$

strain sensitivity curve of KAGRA

$$RPN = \frac{\Delta P}{P} = \frac{Mc(2\pi f)^2 \Delta h(f) L}{20P\cos(\theta)}$$

M: ETM Mass (23kg)
c: Speed of light
L: Arm length of Interferometer (3km)
P: Laser Power (10W)

OFS feedback loop



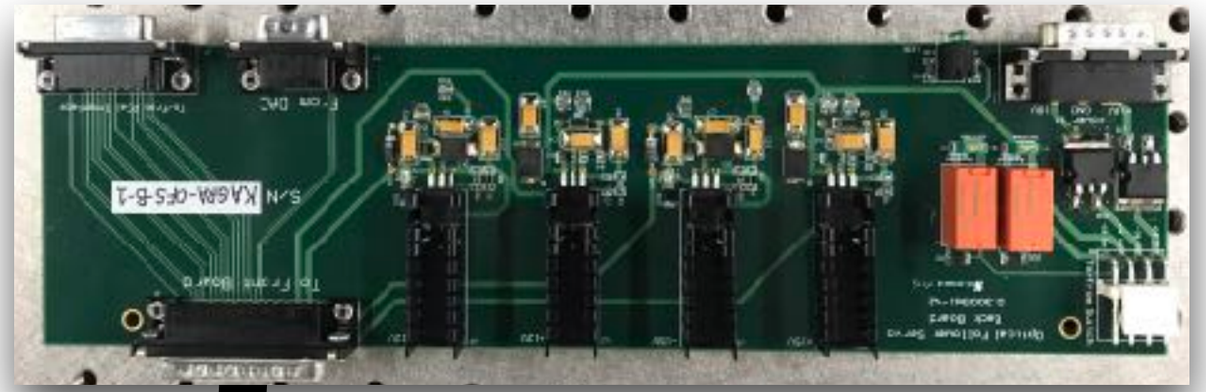
OFS **Optical Follower Servo** **AOM** **Acoustic Optic Modulator**

PD **Photodetector**

We use Optical Follower Servo and photodetector to make a closed-loop in order to reduce the noise of laser.

Optical Follower Servo

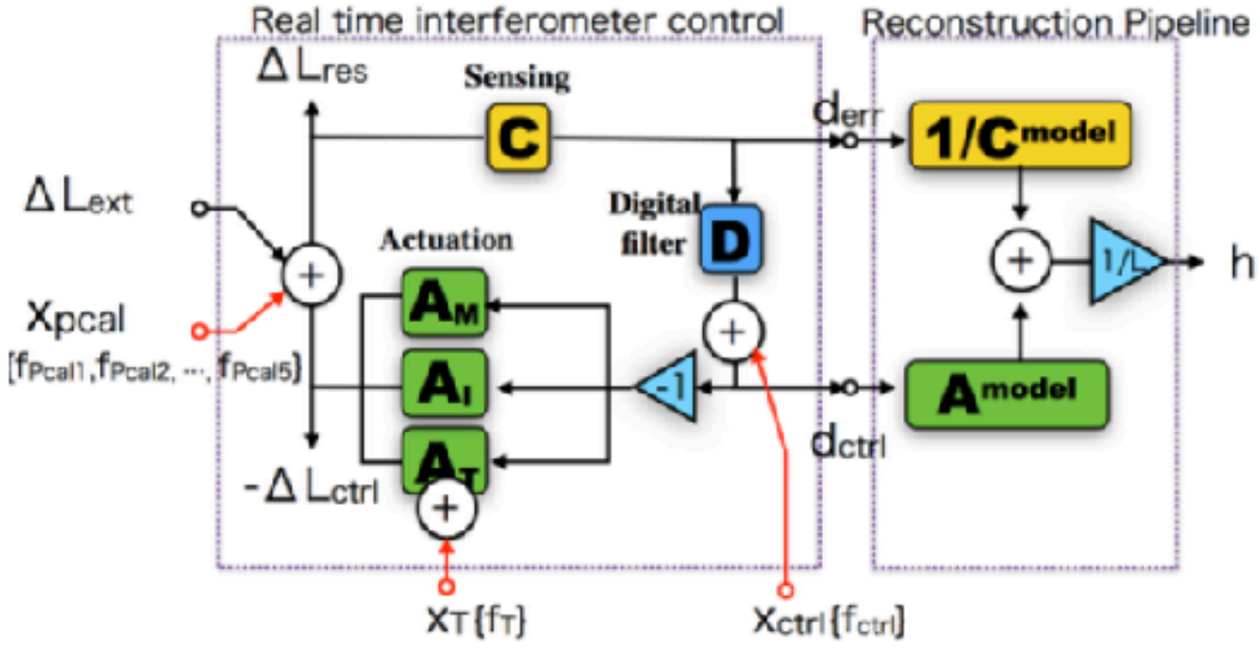
OFS Back Board
Ver. 1



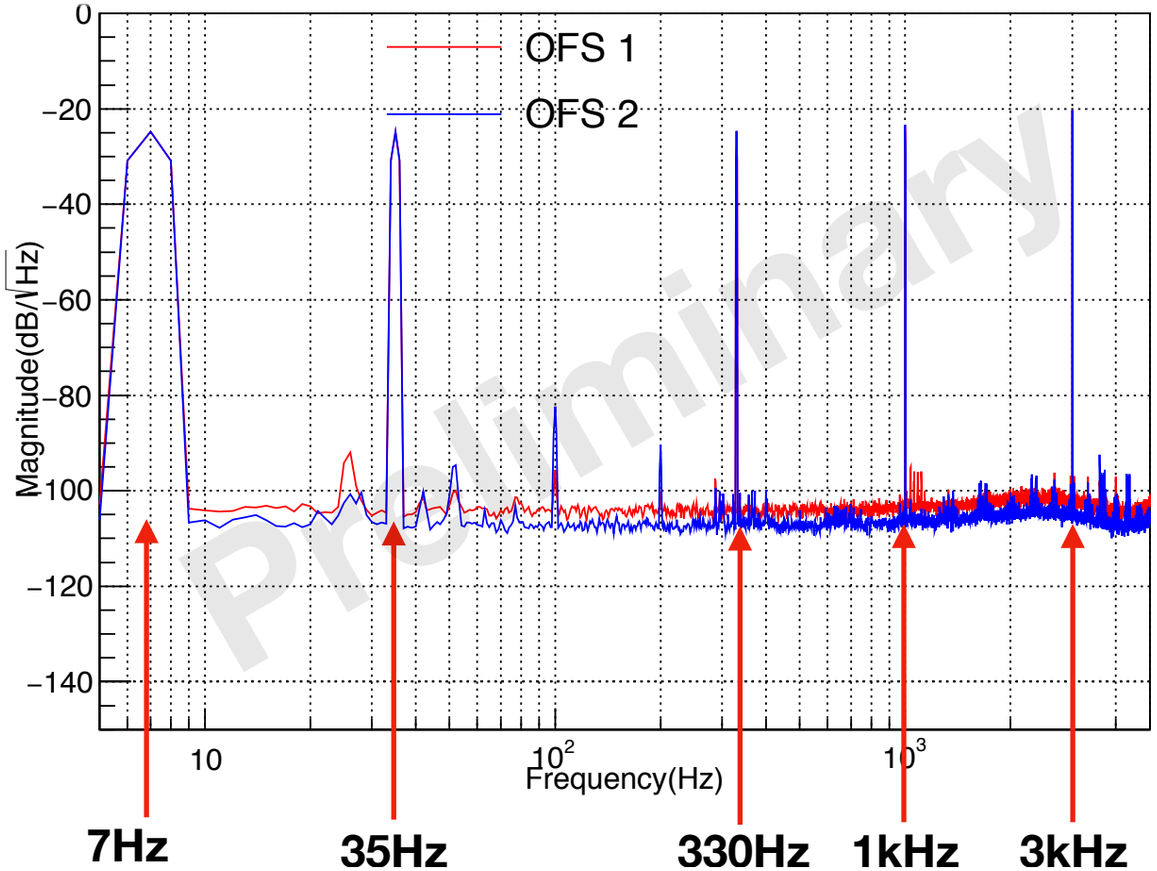
OFS Front Board
Ver. 4

OFS & Interface Chassis

Calibration Lines



Line name	Cal.	Frequenc
xpcal	f_{pcal1}	~7Hz
	f_{pcal2}	35Hz
	f_{pcal3}	~330Hz
	f_{pcal4}	~1000Hz
	f_{pcal5}	~3000Hz
xctrl	f_{ctrl}	~35Hz
xT	f_T	~35Hz



Future Plan

Measurement of:

- Power spectrum
- Transfer function
- Higher Harmonic peaks
- Peak stability

Summary

- We built a Photon Calibrator with 20W laser for reconstructing gravitational wave.
- We used Optical Follower Servo to make a closed-loop feedback control.
- We plan to inject calibration line to understand the parameters in the real-time interferometer control.