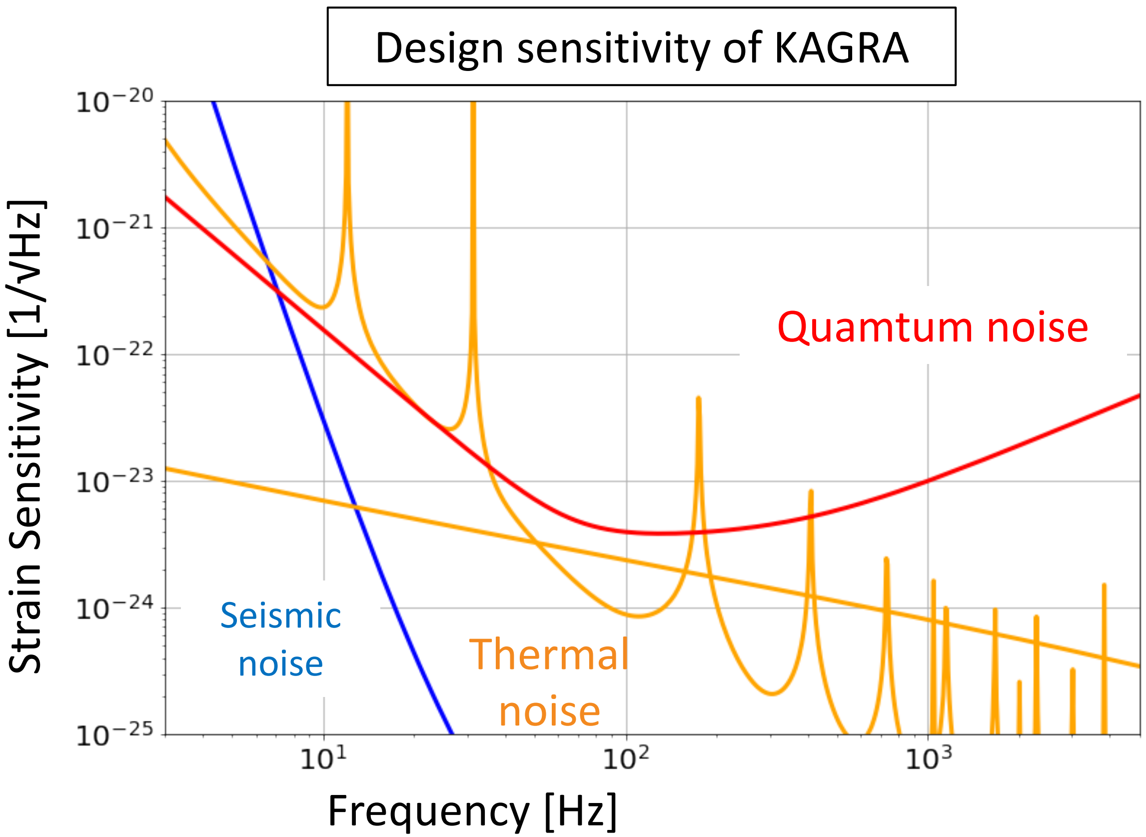
Works in Laser (LAS) group

2021/5/14 and 28(Fri.)

Osamu Miyakawa

Sensitivity of gravity wave detectors

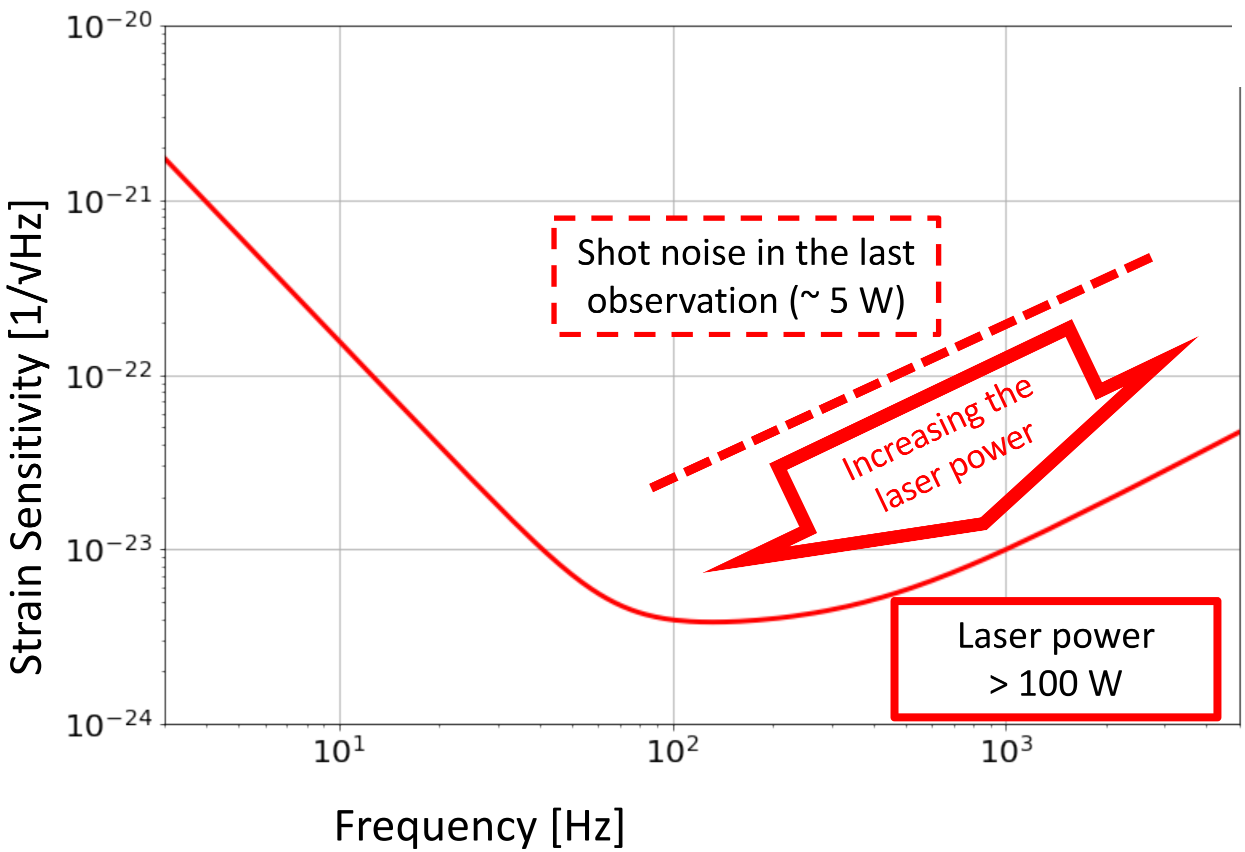
The sensitivity of the detector is basically limited by three principle noises



- Quantum noise:
  - Radiation pressure noise:
    Noise due to mirror fluctuations caused by laser photons randomly hitting the mirrors at low frequency.
  - Shot noise:
    Noise due to fluctuations in the number of photons in the laser at high frequency .

Reduction of quantum noise is necessary to increase the sensitivity.

Reduction of shotnoise



Shot noise is inversely proportional to the square root of laser power

$$(\text{shotnoise}) \propto \frac{1}{\sqrt{P_{\text{laser}}}}$$

Increasing the laser power reduces shot noise.

For better sensitivity, a high-power laser is needed.

Objectives of the LAS Group

- To provide a stable and high power laser to KAGRA.
  - Development of laser light sources
  - Laser stabilization
  - Laser maintenance

Main locations and members

- Moriwaki-Lab. at Toyama Univ.
  - Intensity Stabilization Servo (ISS)
  - Next high-power laser test (60W -> 120W)
- KAGRA site
  - High power laser installation and maintenance
  - Noise hunting (intensity noise, frequency noise)

- Main members:

  Mio (chief), Moriwaki(sub-chief), Haino (sub-chief), Miyakawa, Yamashita (Toyama M2) Kato, Sako（Toyama B4）, Tanaka (Kajita group D2), Hirose (Niigata M2)

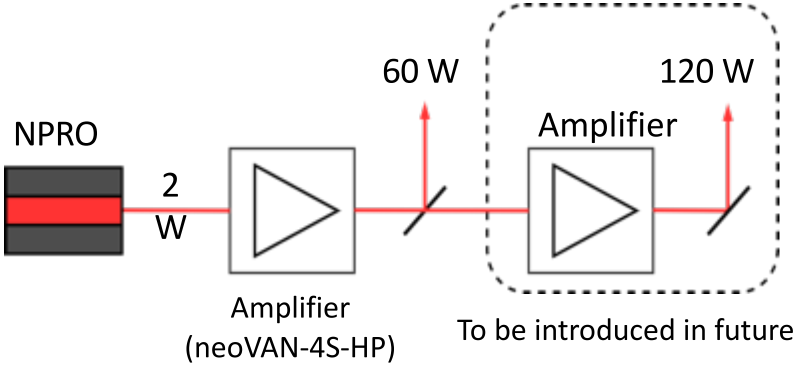
Development Item: High Power Laser

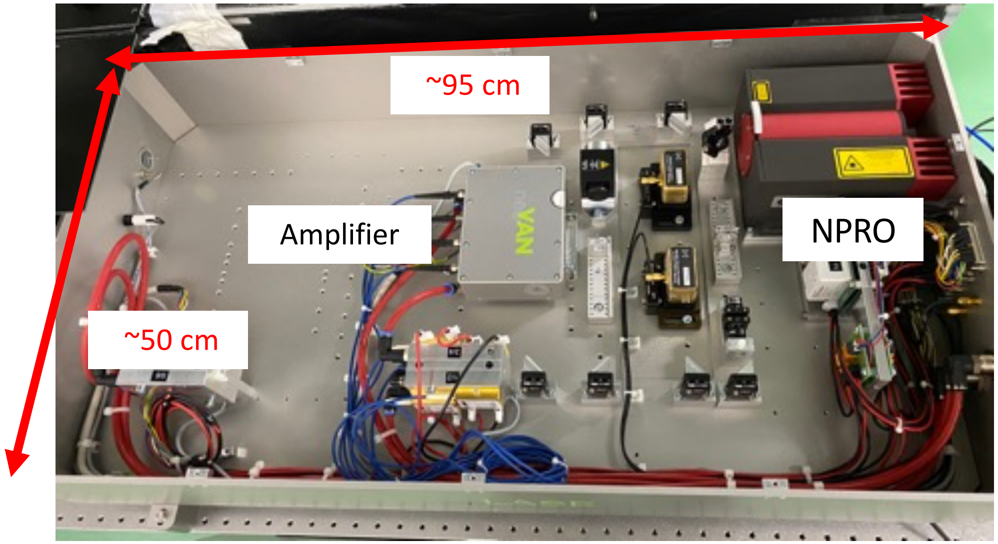
- Measuring laser modes using a ring cavity (by summer)
- Master laser replacement for the next high power laser and the characterizations (around summer)
  - Evaluation for free run intensity noise
  - Evaluation for free run frequency noise
  - Evaluation for beam prorfile
- Installation to KAGRA (Fall)
  - Movement from Toyama Univ. to KAGRA site
  - Switching from current laser to the new laser
- At KAGRA site (by O4)
  - Development of remote control (EPICS etc.)
  - Intensity stabilization
  - Frequency stabilization
- After O4, we will add an amplifier to increase the power to 120W.

Next high power laser @ Toyama Univ.

- Consists of an NPRO and two amplifiers (made by neoLASE)
- Same design as LIGO and Virgo
- Currently, one amplifier is installed.
- Output power can be controlled by changing the current going to the amplifier.
- Wavelength: 1064 nm, maximum power: 60 W (120 W in the future)

Laser controller (upper) and power supply (lower)

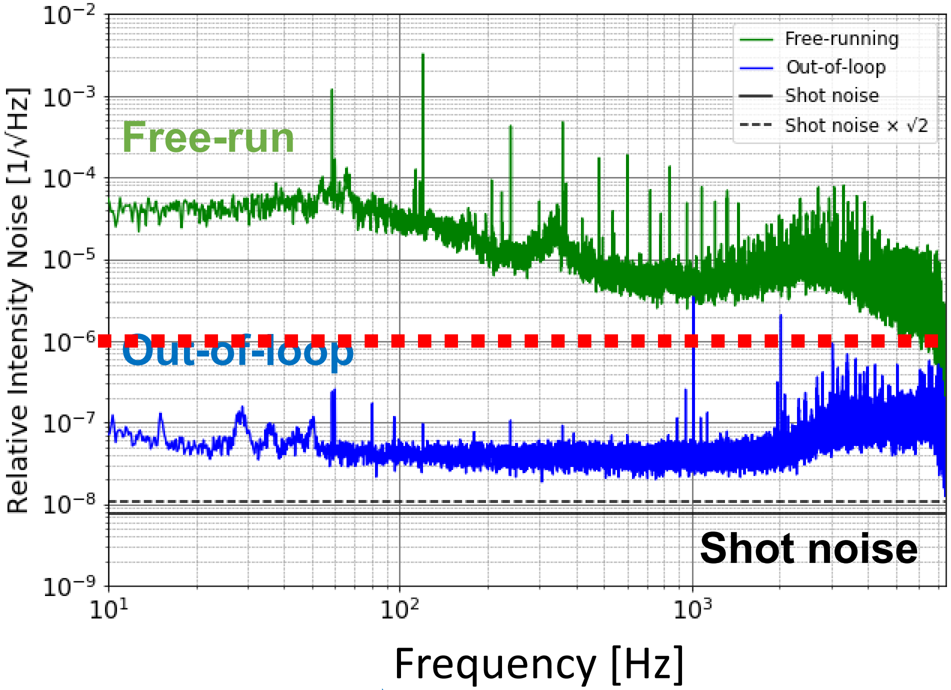




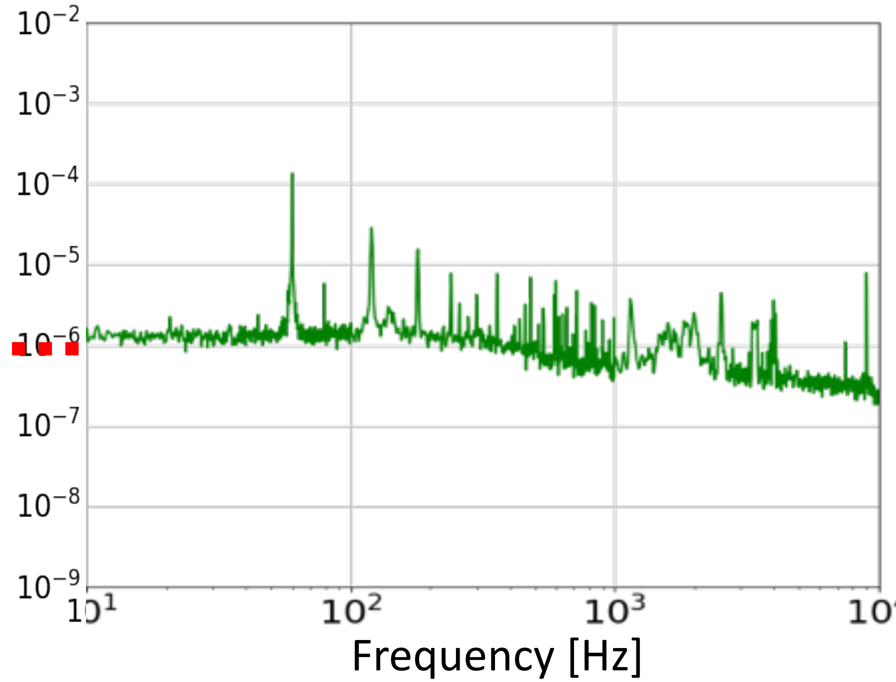
Laser box

Comparison with currently installed laser

Current laser intensity noise in KAGAR



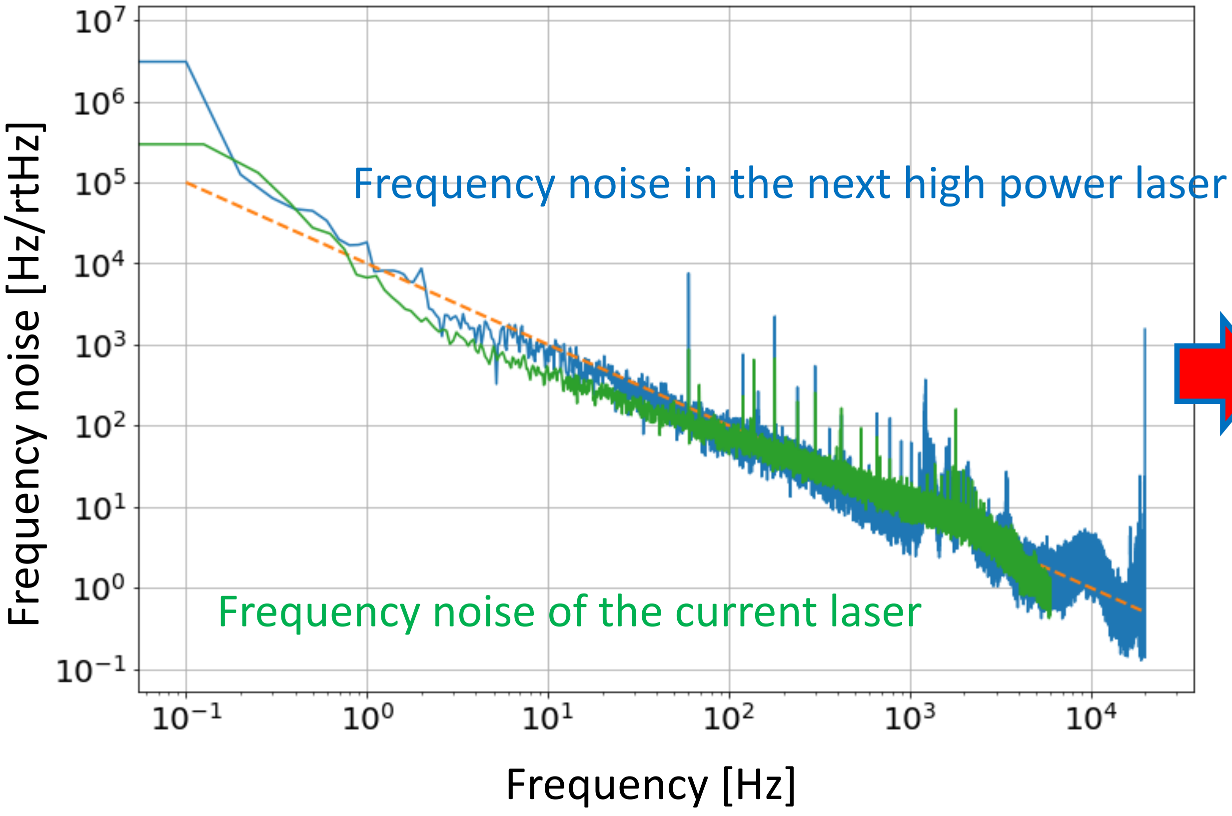
Intensity noise of the next high-power laser



Slide from Kyromiya (JGW-G2012322)

Next laser has 1-1.5 orders of magnitude lower intensity noise.

Comparison with currently installed laser



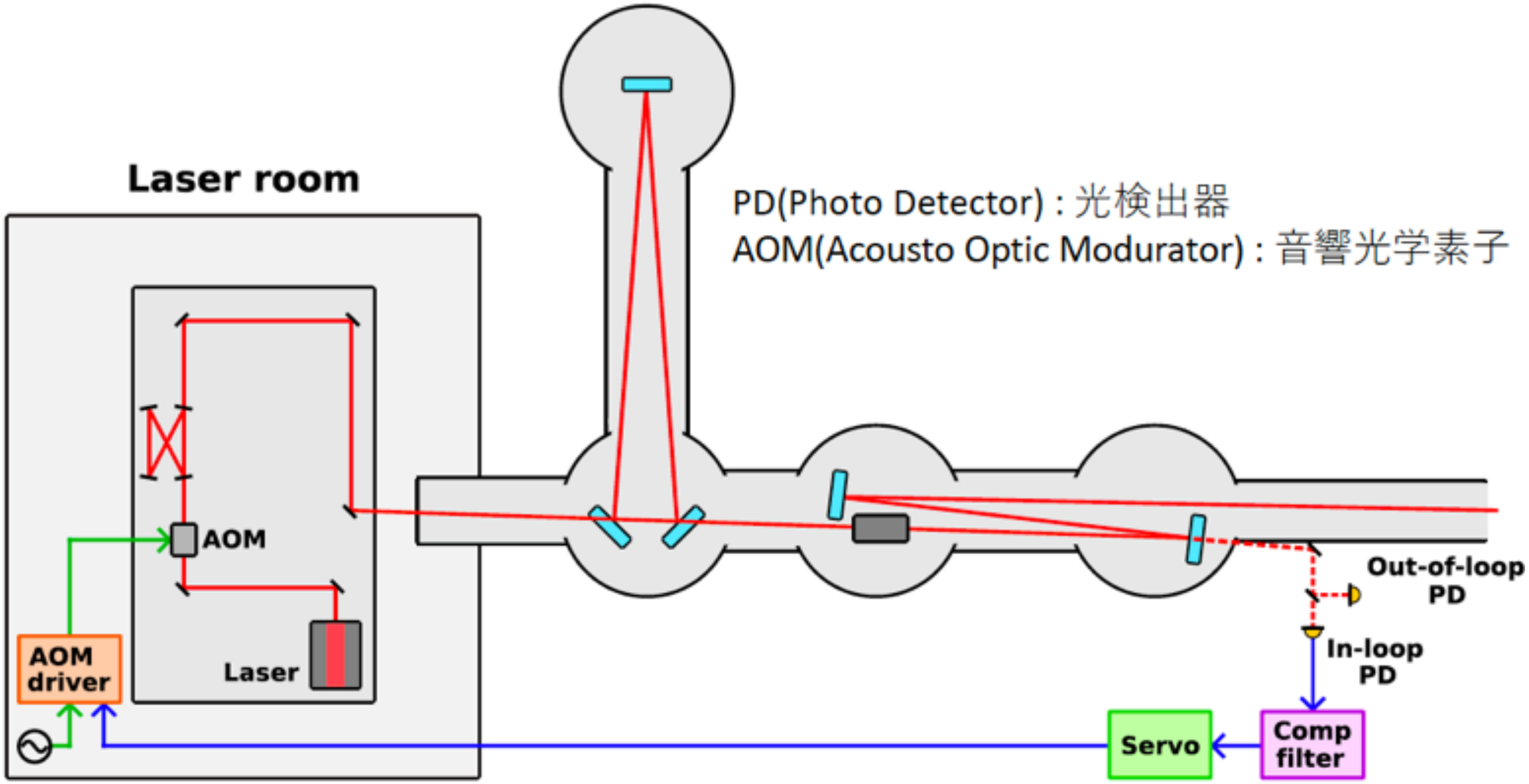
Same noise level as currently used laser

Development item: Intensity stabilization

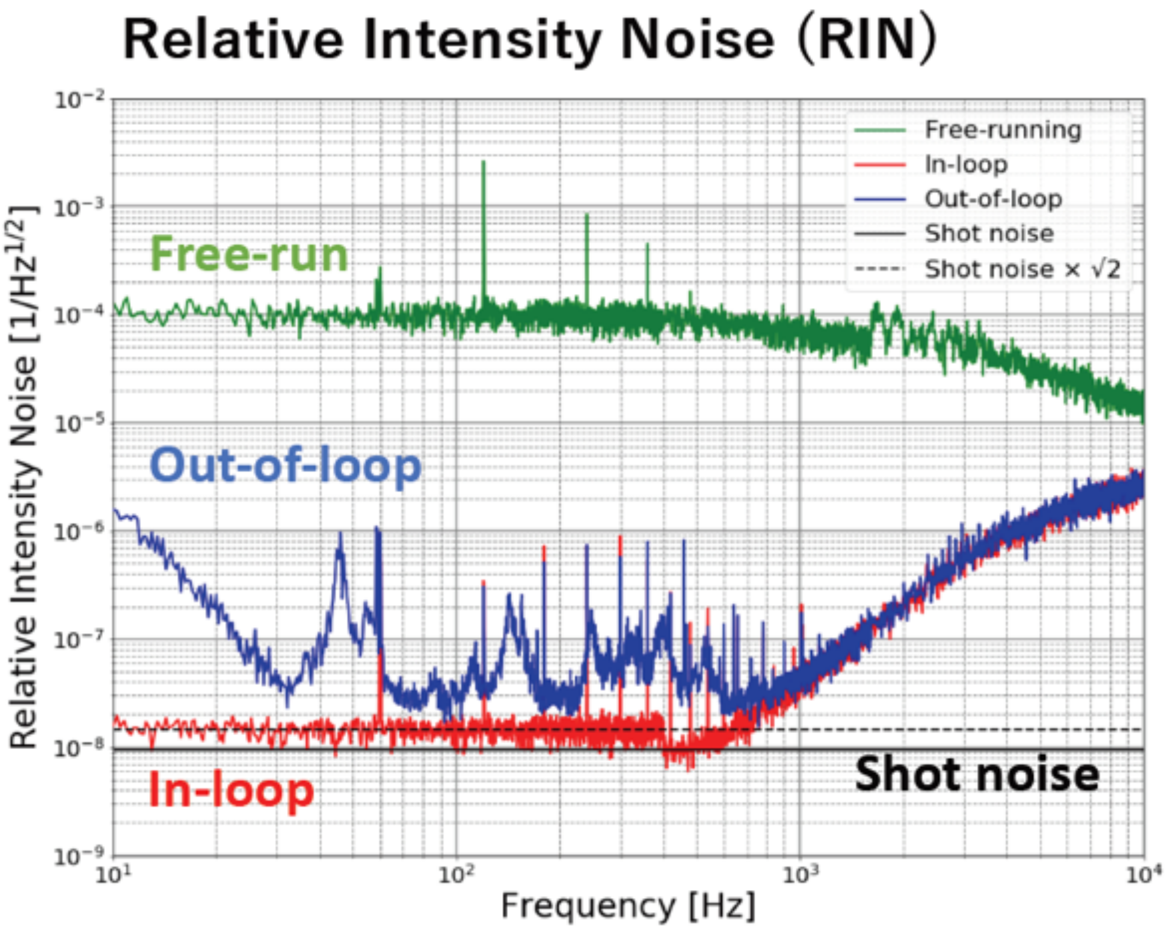
- At Toyama Univ. (by summer of 2021)
  - PD design and fabrication
  - Servo design
  - Circuit fabrication
  - Installation of digital control system
    - Development of control models, etc.
- At KAGRA site (~end of 2021)
  - Installation to KAGRA site (in air, by O4)
    - Development of control models, etc.
    - Intensity noise hunting downstream of IMC
  - Installation to KAGRA site (in vacuum, after O4)

Intensity noise stabilization loop

PD(Photo Detector) : 光検出器
AOM(Acousto Optic Modurator) : 音響光学素子



Intensity noise stabilization of the current laser



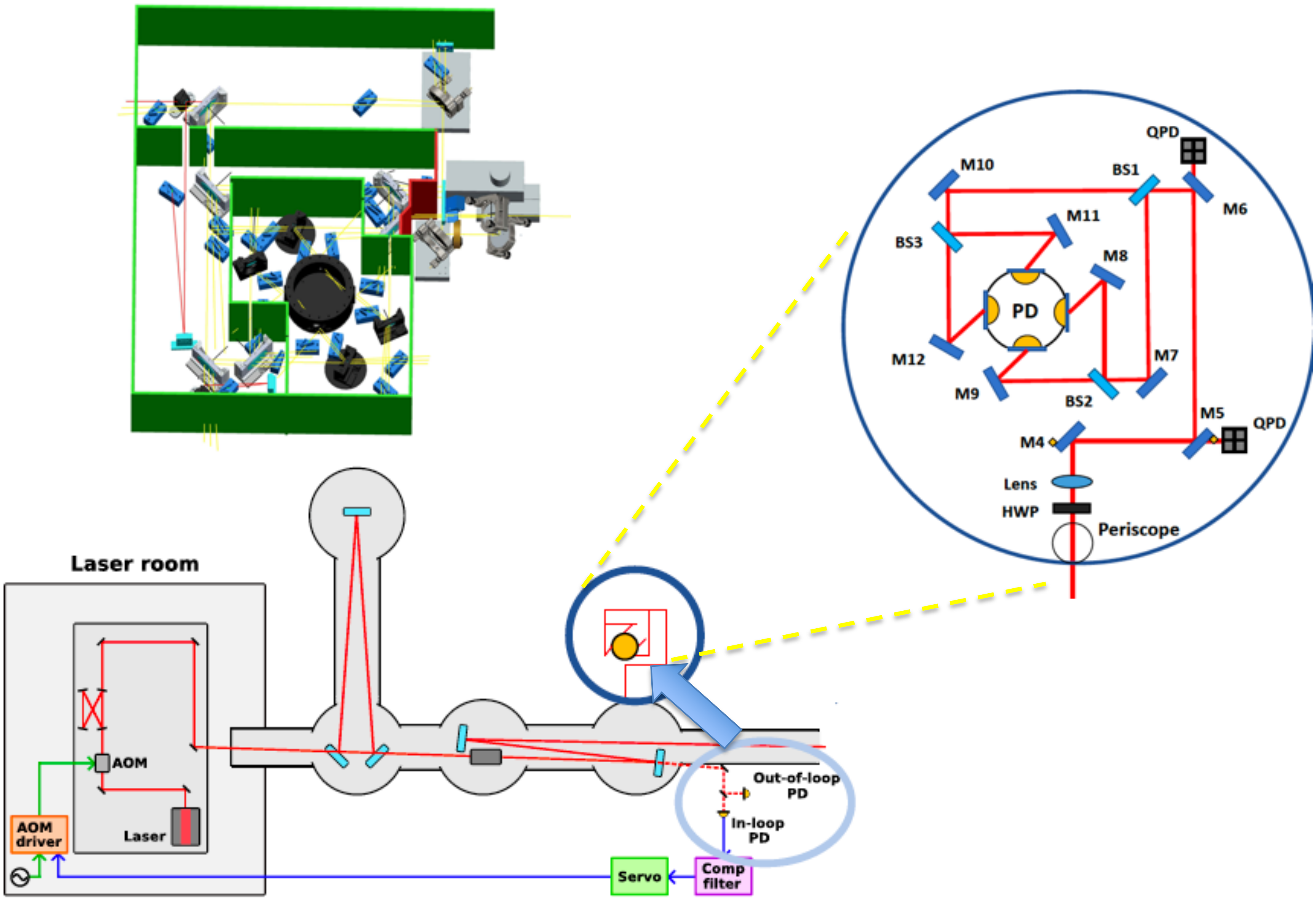
Requirement for O3
$1\times10^{-7}/\sqrt{\mathrm{Hz}}$

RIN is suppressed about three orders of magnitude from 25 Hz to 5 kHz.

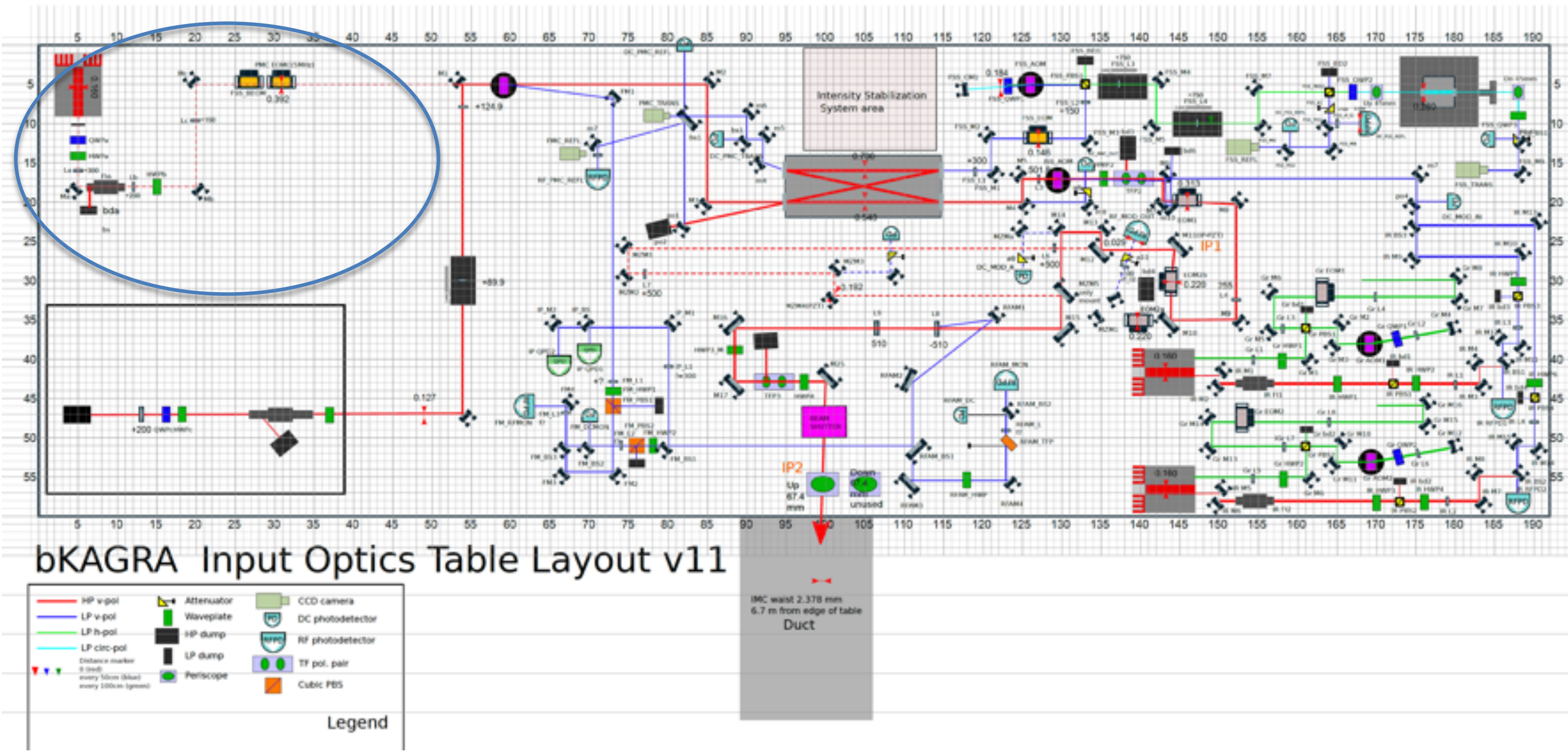
[Main Laser Power]
5.4 W

[Input Power]
In-loop PD : 5.7 mW
Out-of-loop PD : 4.8 mW

The next generation intensity strength stabilization @KAGRA site



Installation for new laser on PSL table



Contact with other groups

- IOO group
  - PSL table
  - PMC, IMC
  - Synchronization to green lasers
- ISS detectors are placed in the transmitted light of IMMT1
  - PMC, IMC will be inside the intensity stabilization loop
- Commissioning
  - Intensity stabilization, frequency stabilization

Summary: Major tasks for this fiscal year

- Toyama Univ.
  - Development of ISS, ~October
  - Measurement of high power laser, within this FY
  - High power laser master replacement, summer.
- KAGRA site
  - Installation of ISS, October~
  - Installation of high power laser end of this year~