Suspension Control in KAGRA
- Gravitational Wave Detector -

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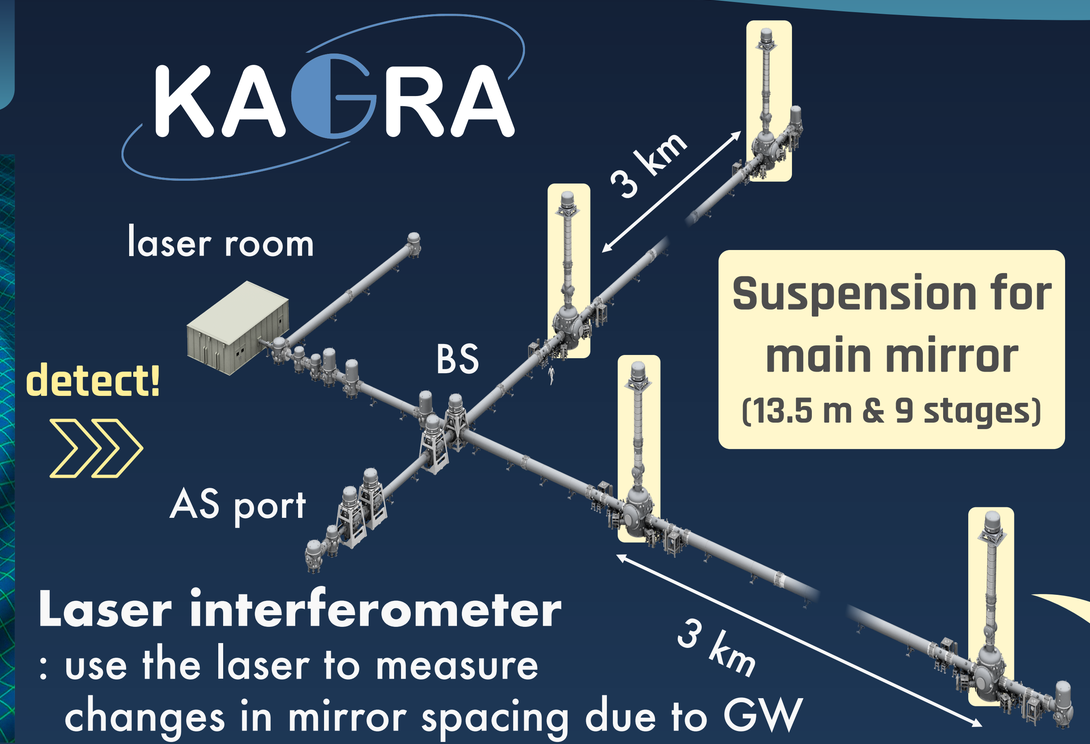
INTRODUCTION

Gravitational Wave

- Ripples of space-time transmitted at the speed of light
- Mainly observe GW from compact binary coalescences
  ||
  black hole, neutron star....



Laser interferometer
: use the laser to measure changes in mirror spacing due to GW

Particularly important characteristics of KAGRA

These are two unique features not found in other GW detectors

Underground

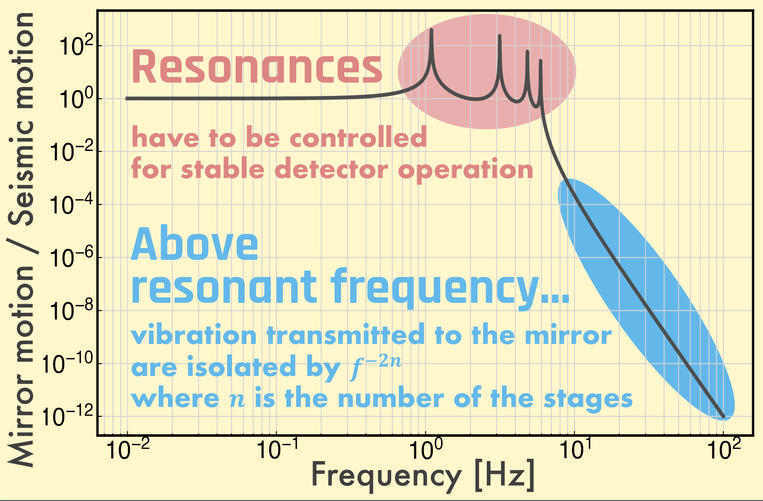
To reduce seismic noise, detector is constructed underground where ground vibrations are small (Kamioka-cho, Hida-city, Gifu-prefecture)

Cryogenic

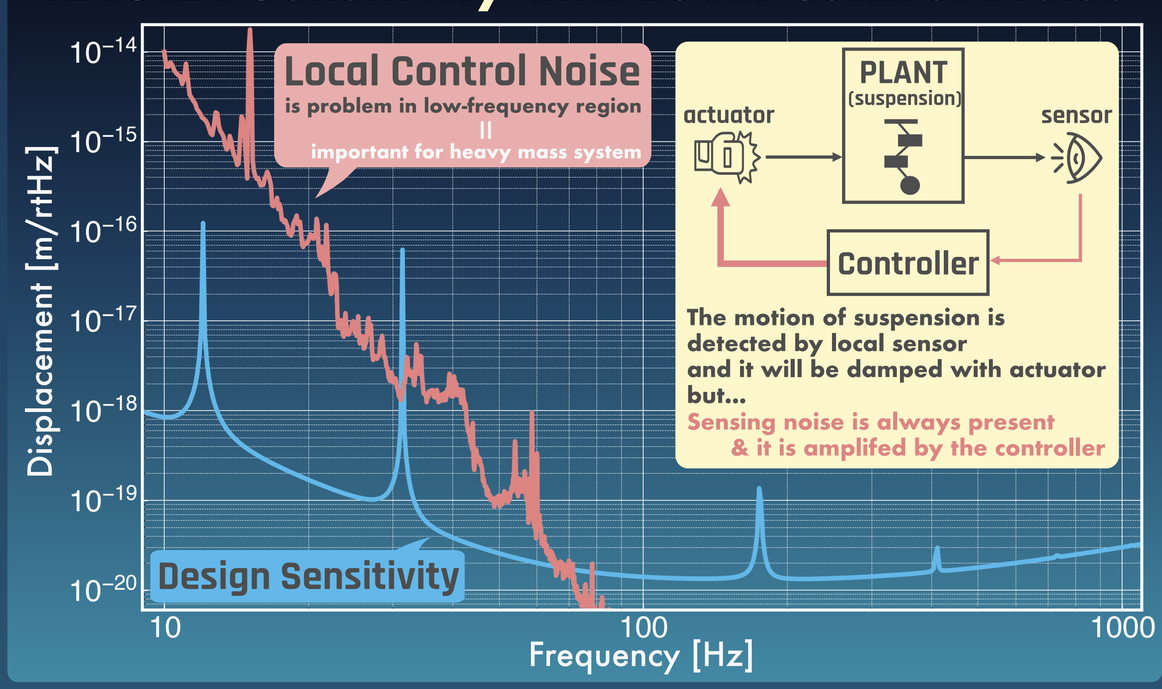
To reduce thermal noise, main sapphire mirror is cooled down to about 20 K
(sapphire has less thermal conduction and mechanical loss when cooled to cryogenic temperature)

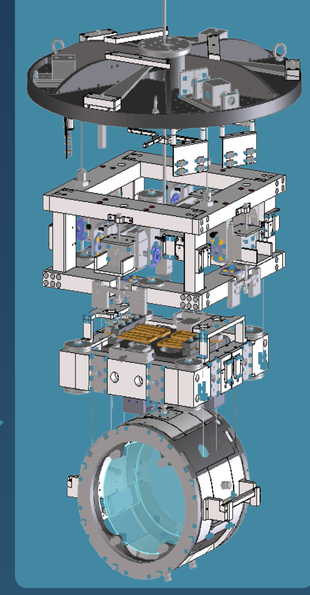
MOTIVATION

Pendulum for vibration isolation



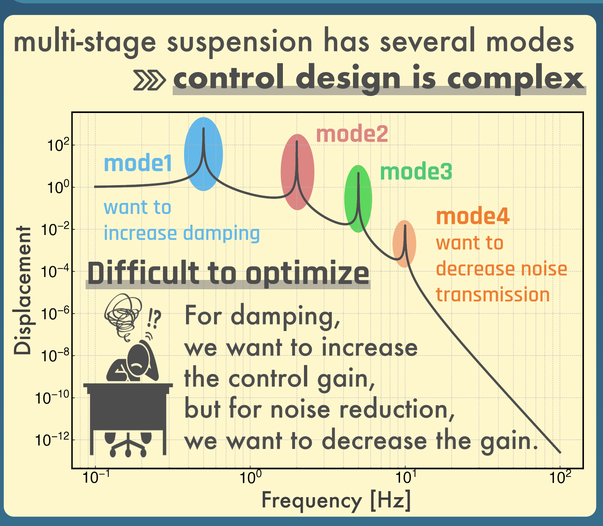
KAGRA Sensitivity and Local Control Noise





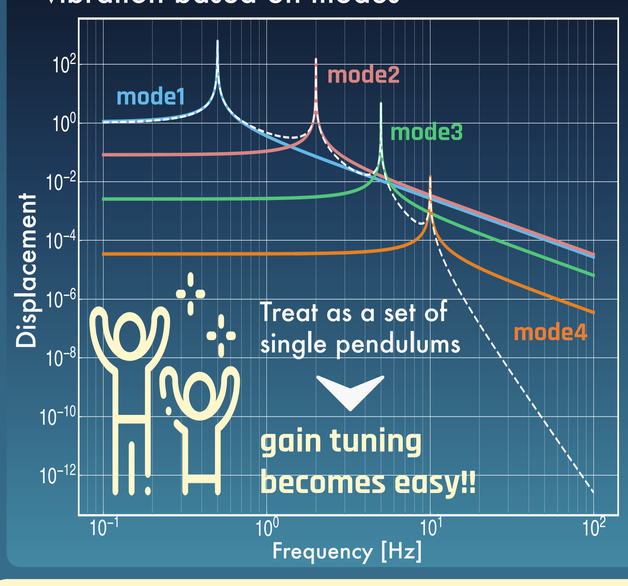
METHODS

multi-stage suspension has several modes
⋙ **control design is complex**



Modal Control

: Decompose and control vibration based on modes



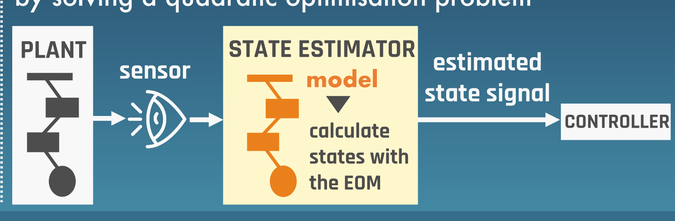
State Estimator

Full state for modal control ⟶ sensing at every stage

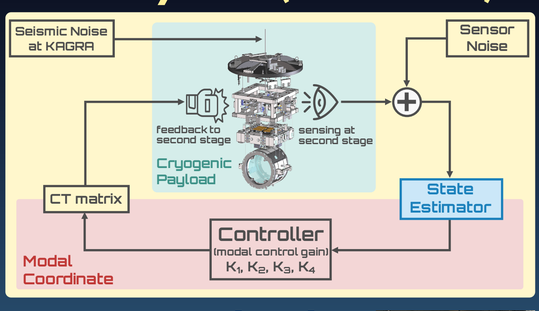
Less sensor noise ⟶ reduce sensing as much as possible

Solution
: control design with state estimator
= Estimates position and posture from a single-stage signal and uses it to control the system

Design an estimator that minimises estimation error and sensor noise transmission by solving a quadratic optimisation problem



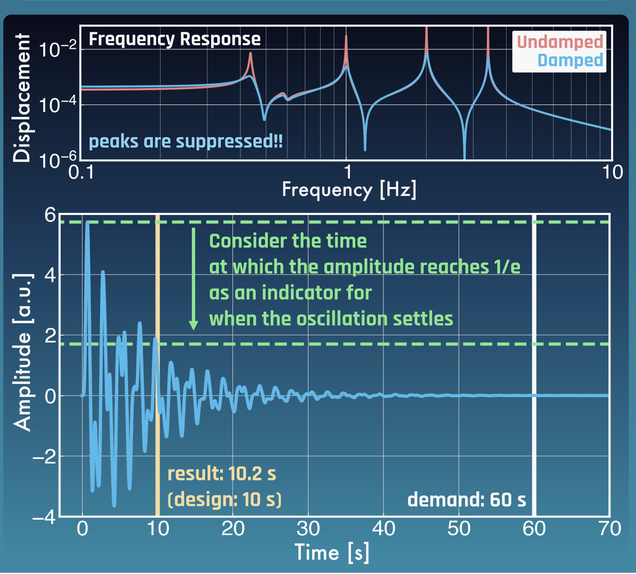
Whole system (simulation)



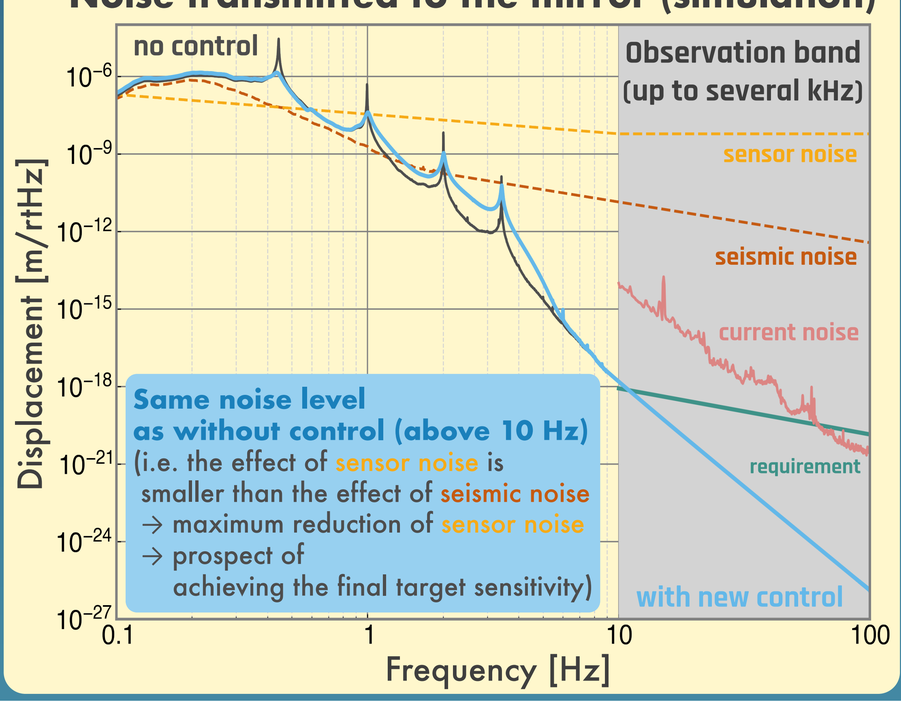
Dummy payload for experiment

- Preparation is ongoing (almost complete...!!)
- Althgough the actual one is not available due to next observing run (O4c), this is almost same configuration

RESULTS



Noise transmitted to the mirror (simulation)



OUTLOOK

- Noise level seems fine with this control
- However, when cooled, this control is not valid (and indeed needs to be adjusted at the site)

It would be useful to have a system that adaptively changes the controller to changes in suspension characteristics due to temperature variation

For example...

use environmental signals (thermometers) or measure suspension motion directly