Suspension Control in KAGRA
- Gravitational Wave Detector -

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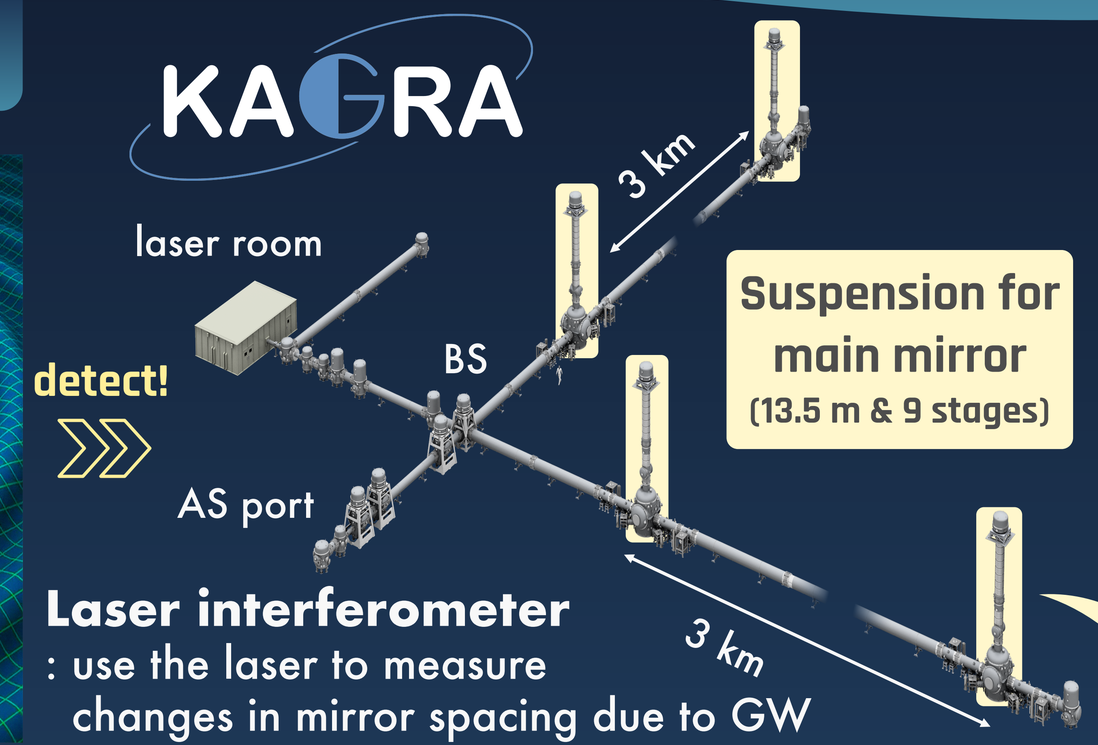
INTRODUCTION

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

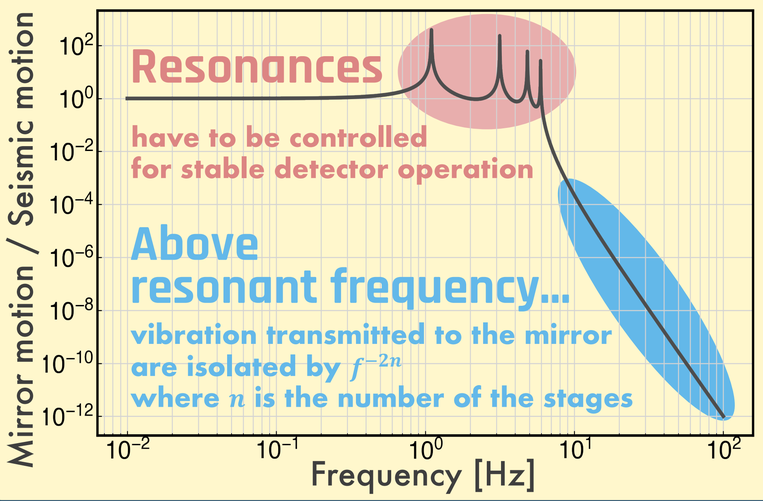
To reduce seismic noise, detector is constructed underground where ground vibrations are small (Kamioka-cho, Hida-city, Gifu-prefecture)

Cryogenic

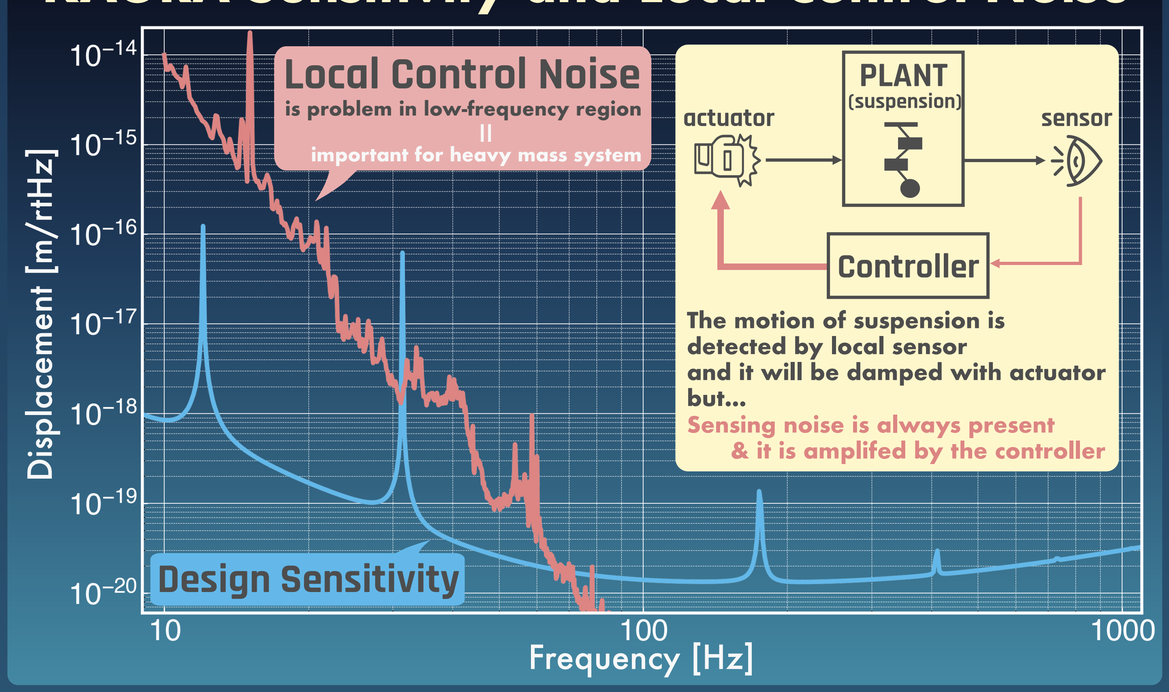
To reduce thermal noise, main sapphire mirror is cooled down to about 20 K
(sapphire has less thermal conduction and mechanical loss when cooled to cryogenic temperature)

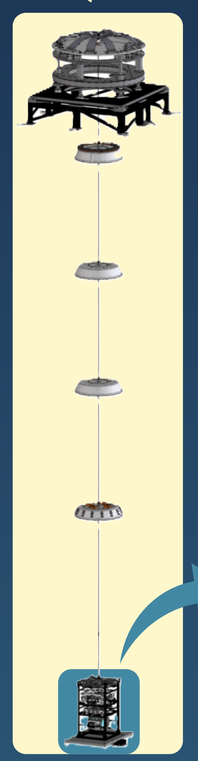
MOTIVATION

Pendulum for vibration isolation

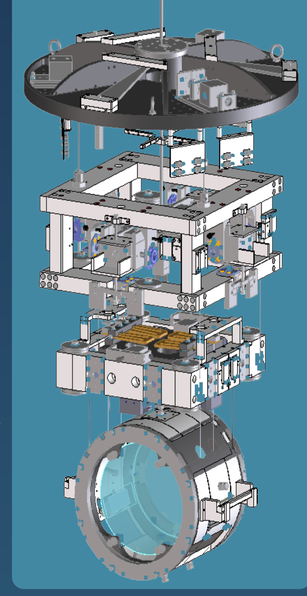


KAGRA Sensitivity and Local Control Noise



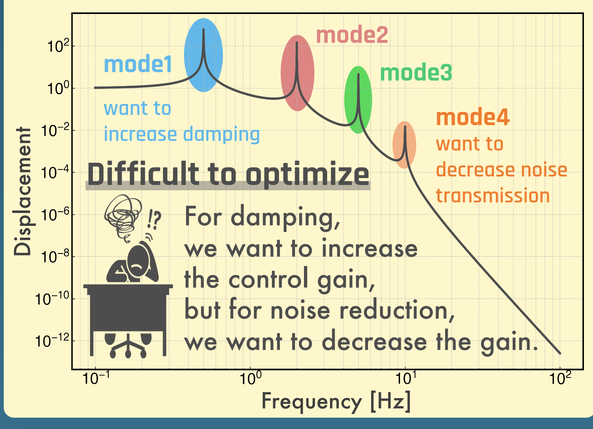


Cryogenic payload
(1.2 m & 4 stages)



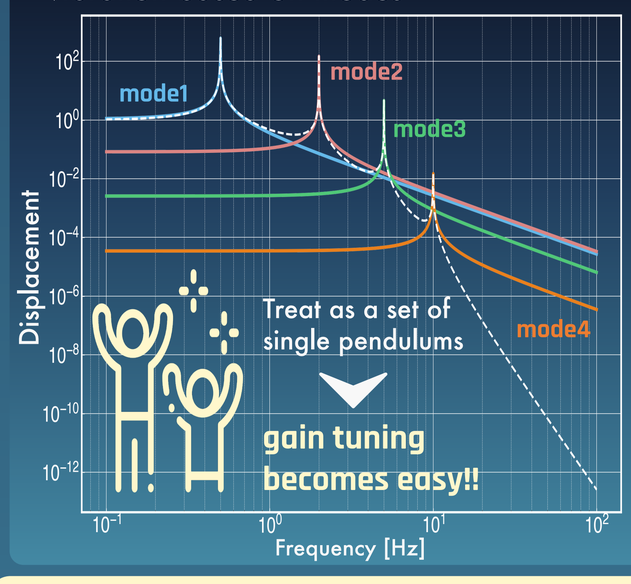
METHODS

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



Modal Control

: Decompose and control vibration based on modes



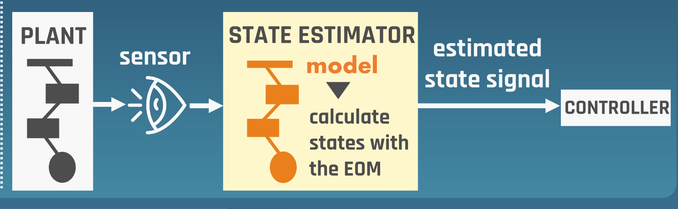
State Estimator

Full state for modal control ⟶ sensing at every stage

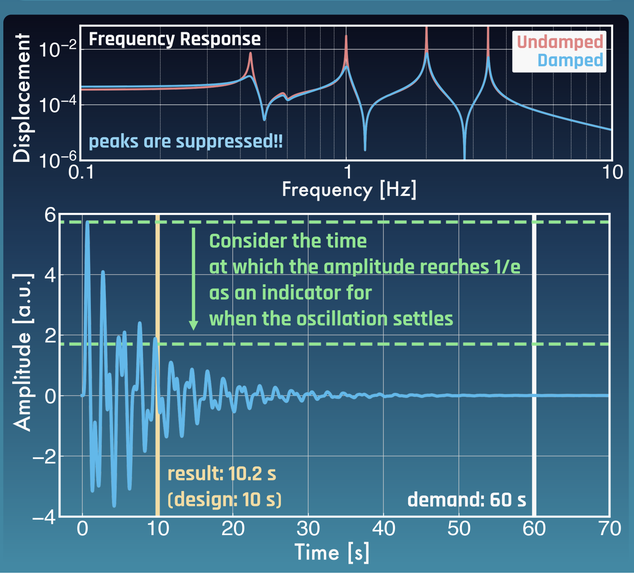
Less sensor noise ⟶ reduce sensing as much as possible

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

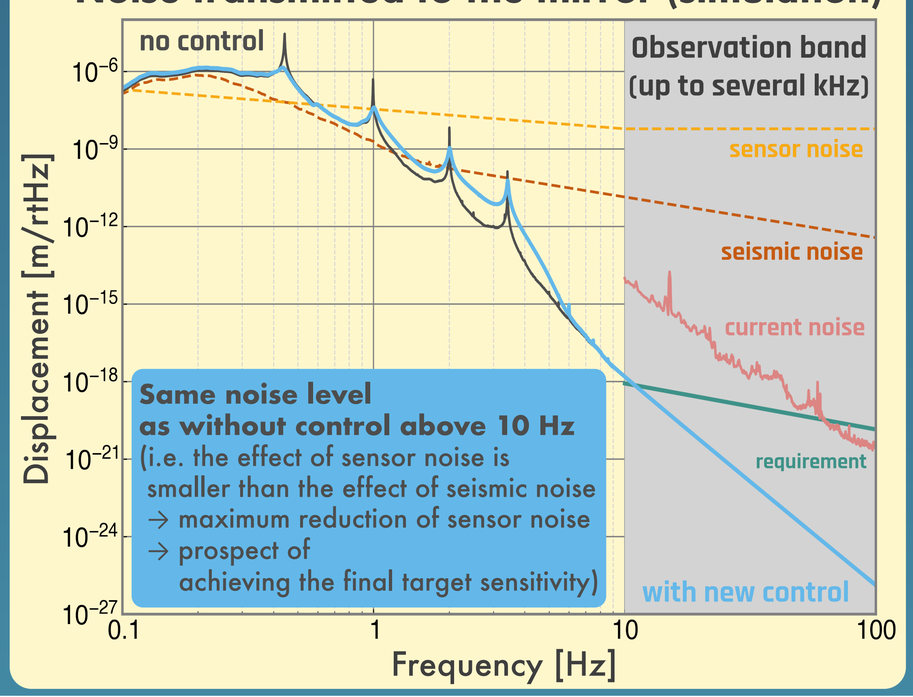
Design an estimator that minimises estimation error and sensor noise transmission by solving a quadratic optimisation problem



RESULTS



Noise transmitted to the mirror (simulation)



OUTLOOK

Test with prototype in KEK

- **Assembly is (almost) done**
- **Suspend the payload in vacuum chamber**
  ⋙ **control test at room temp.**
  ⋙ **also at cryogenic temp.**

Suspension characteristics change as it cools down, and the controller is changed each time in KAGRA, but this is time consuming

→ It is possible to use this KEK prototype to test autotuning of the controller according to the temperature change