Control optimization for Cryogenic Suspension in KAGRA

KAGRA

ICRR Institute for Cosmic Ray Research University of Tokyo
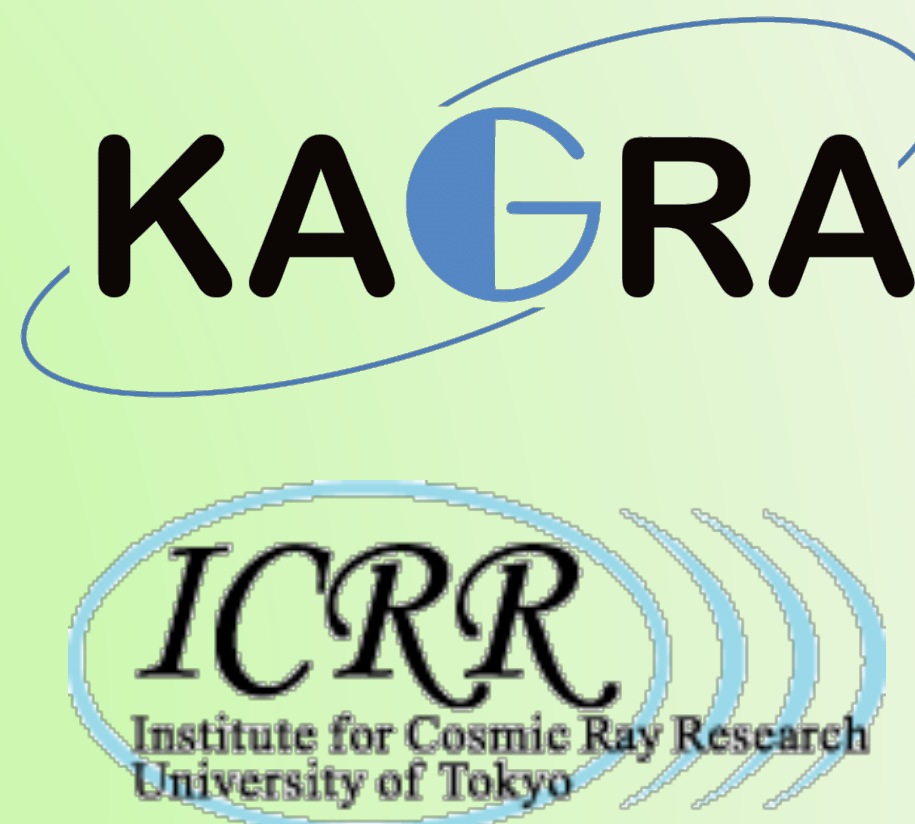
Masahide Tamaki A,B,*, Takafumi Ushiba B, Hirotaka Yuzurihara B,

Takayuki Tomaru C, Ryutaro Takahashi C, Shinji Miyoki B

Phys. S. U. T A, ICRR B, NAOJ C   * tamaki83@icrr.u-tokyo.ac.jp
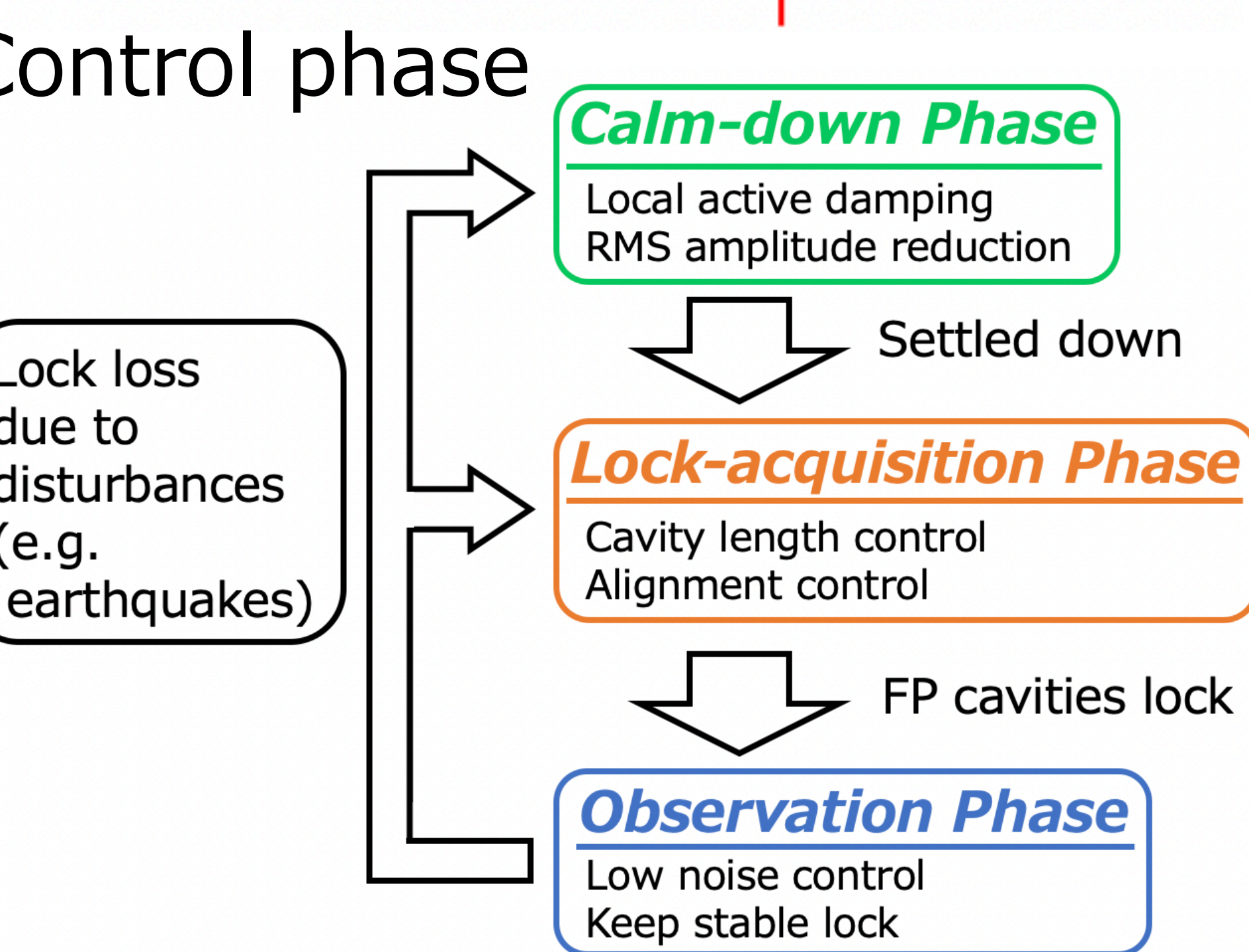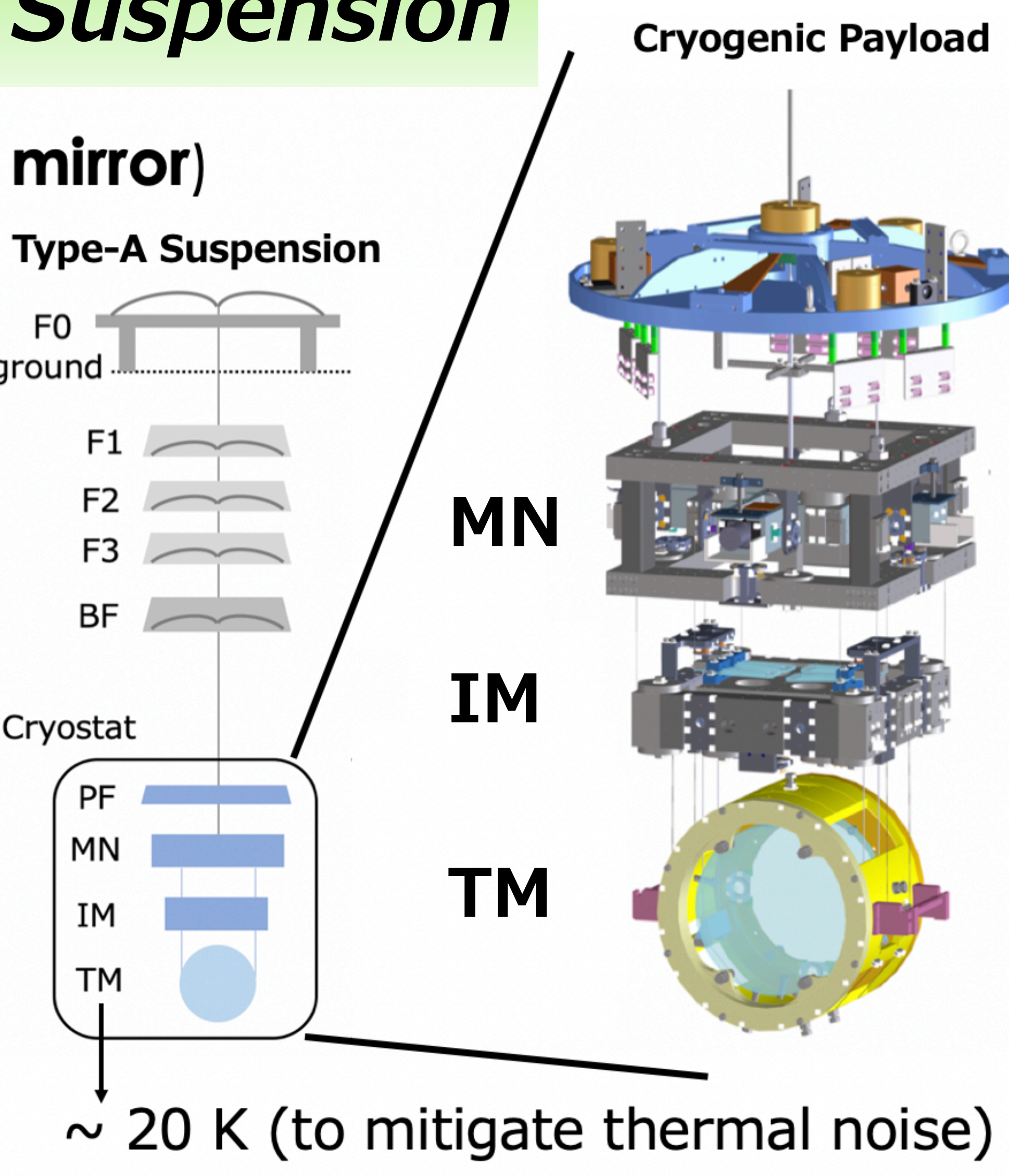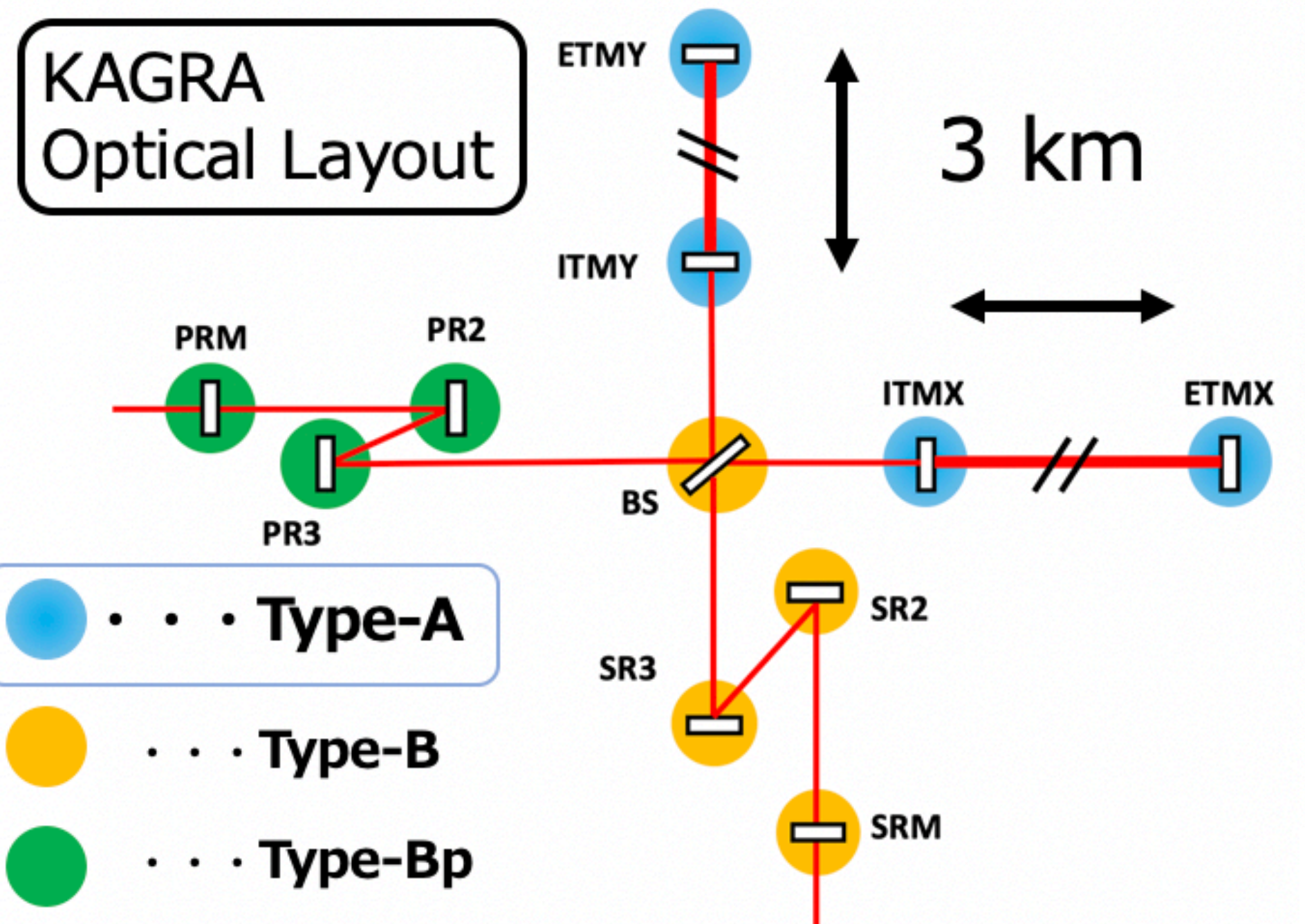
Abstract

To satisfy the requirement for stable interferometer operation in lock-acquisition phase, we made damping control filters for cryogenic payload, and made sure that they worked well. However, the low noise control is necessary in Observation phase, so we optimized them and confirmed that they produce less noise than the old one.
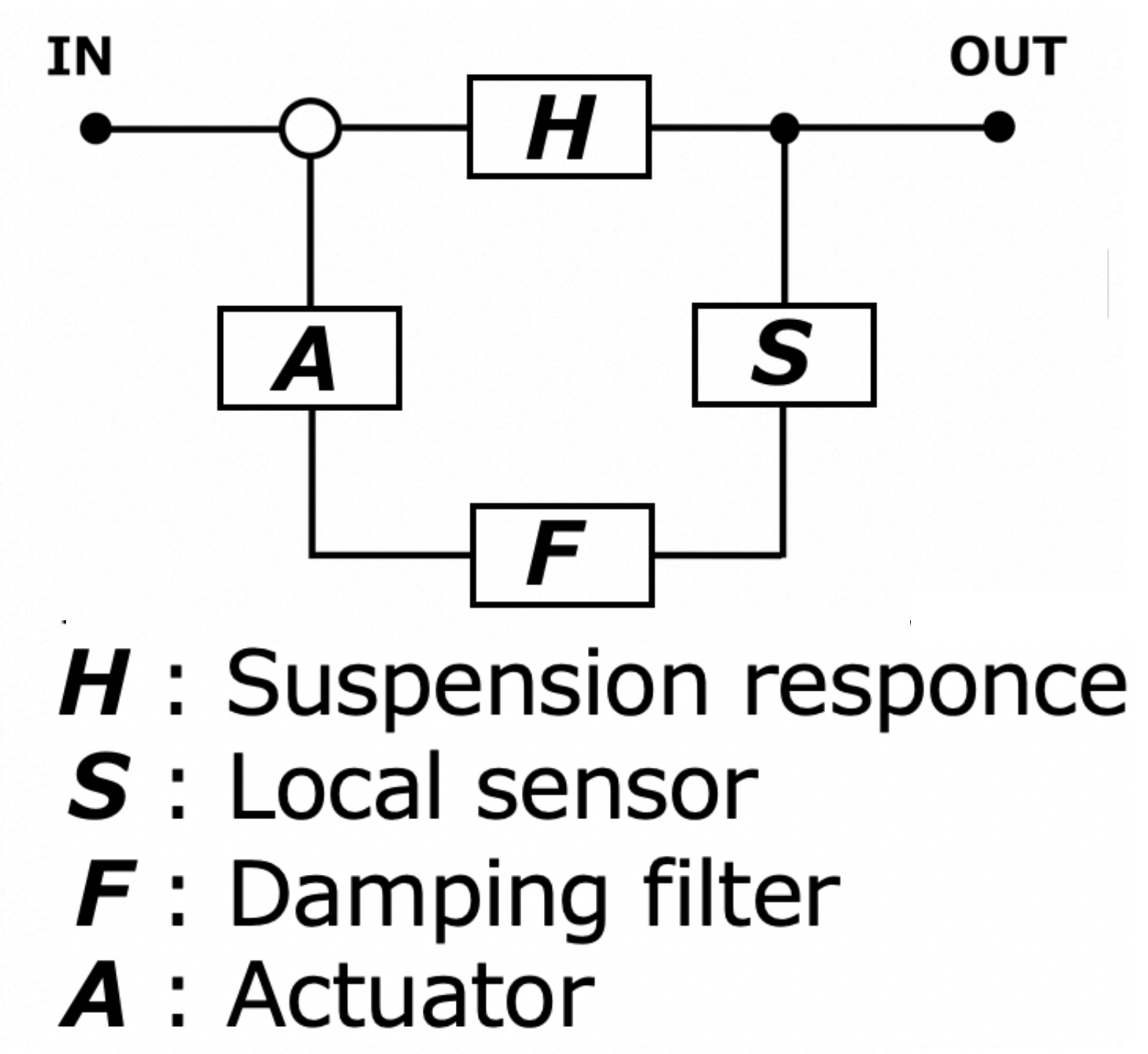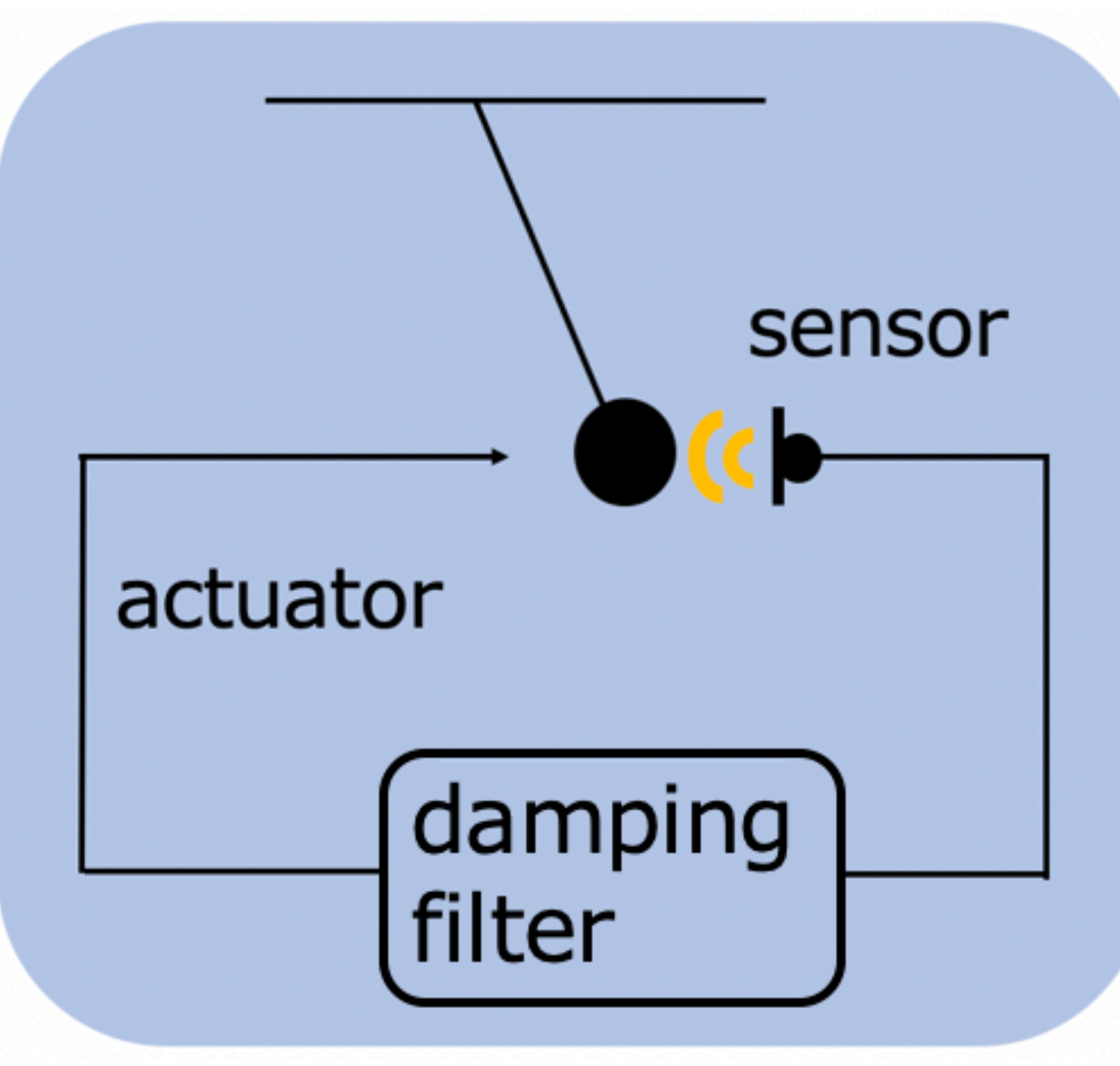
Overview of Cryogenic Suspension

Type-A Suspension (for **sapphire mirror**)

Largest suspension (9 stages 13.5 m)
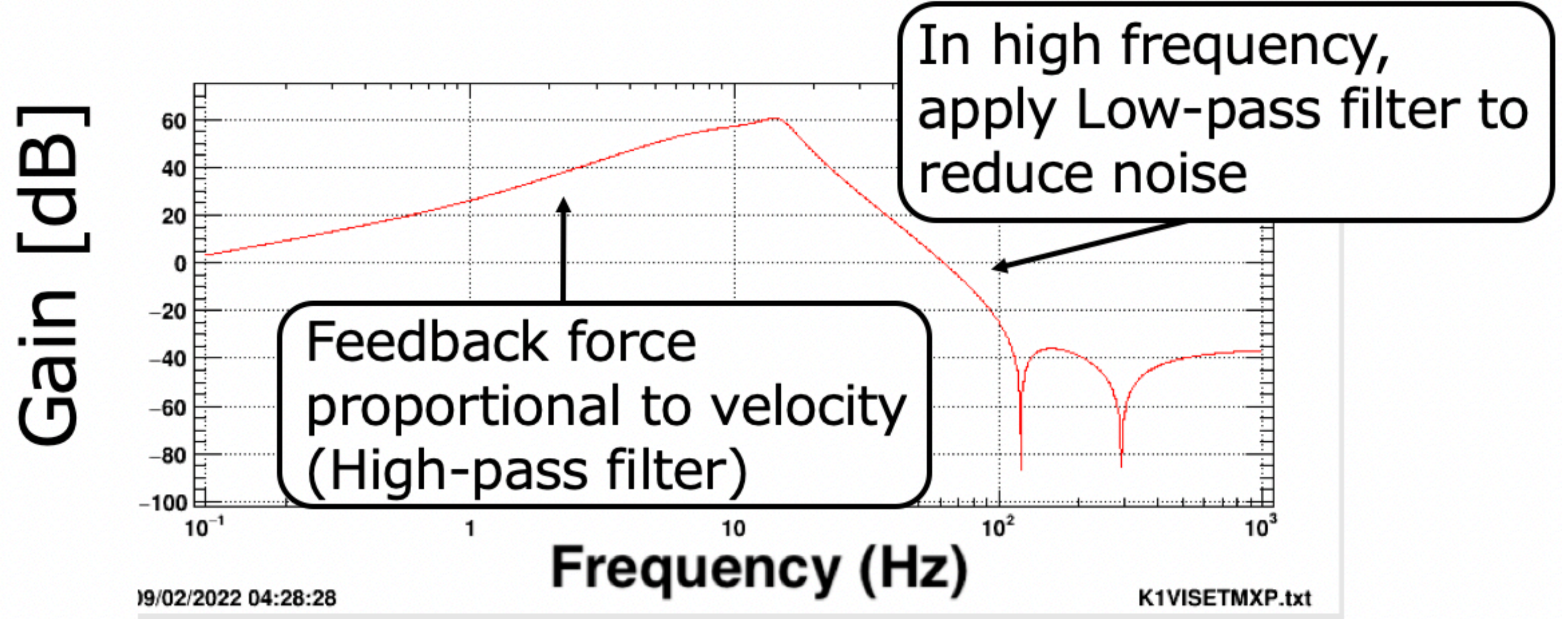→ local motion of the test masses directly couples to the change of differential arm length

KAGRA Optical Layout

3 km

- ● · · · **Type-A**
- ● · · · **Type-B**
- ● · · · **Type-Bp**

Cryogenic Payload

Type-A Suspension

F0 ground
F1
F2
F3
BF

Cryostat
PF
MN
IM
TM

MN
IM
TM

~ 20 K (to mitigate thermal noise)

Passive vibration isolation

Vibrations are amplified at resonant frequencies → **Damping Control**

Control phase

Lock loss due to disturbances (e.g. earthquakes)

Calm-down Phase
Local active damping
RMS amplitude reduction

Settled down

Lock-acquisition Phase
Cavity length control
Alignment control

FP cavities lock

Observation Phase
Low noise control
Keep stable lock

Damping control (in Lock-acquisition phase)

- **H** : Suspension responce
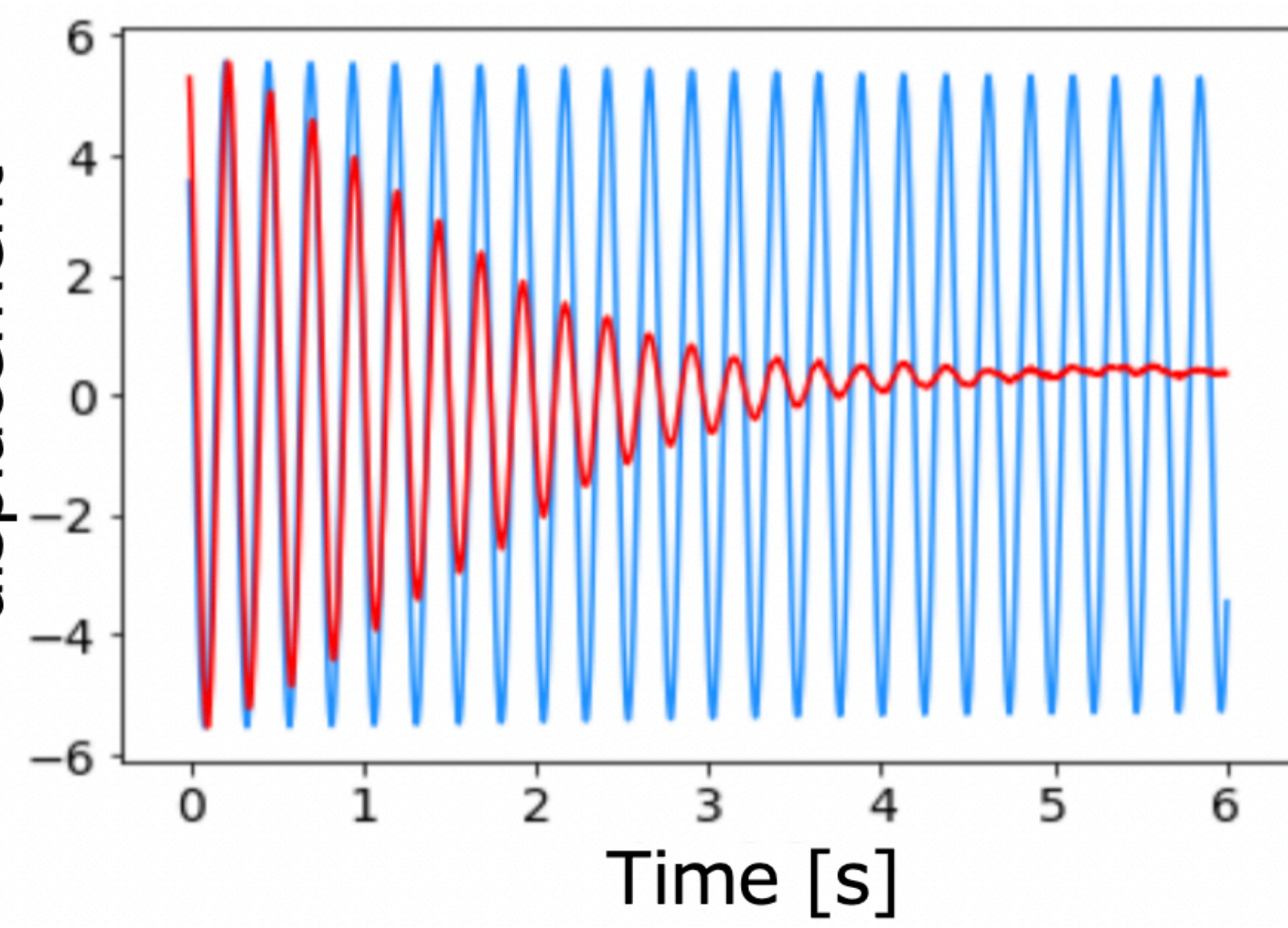- **S** : Local sensor
- **F** : Damping filter
- **A** : Actuator

1. detect suspension displacement by local sensor
2. Force proportional to the velocity of the mass is fed back by actuator

Damping filter (e.g. ETMX MN Yaw)

In high frequency, apply Low-pass filter to reduce noise

Feedback force proportional to velocity (High-pass filter)

1/e decay time (e.g. ETMX MN Yaw 4th mode)
→ Requirement in Lock-acquisition phase: **60 s**

without filter $\tau = 97.1 \pm 0.4$ s
with filter $\tau = 2.07 \pm 0.21$ s

* Fitting the envelope with
$$y = a \exp\left(-\frac{t}{\tau}\right) + b$$
($\tau \cdots$ time constant)

This damping control satisfies the requirement

othre modes

- ● without filter
- ● with filter
- — requirement (60 s)

Modes
1 · · · 0.38 Hz
2 · · · 1.66 Hz
3 · · · 3.12 Hz
4 · · · 4.08 Hz
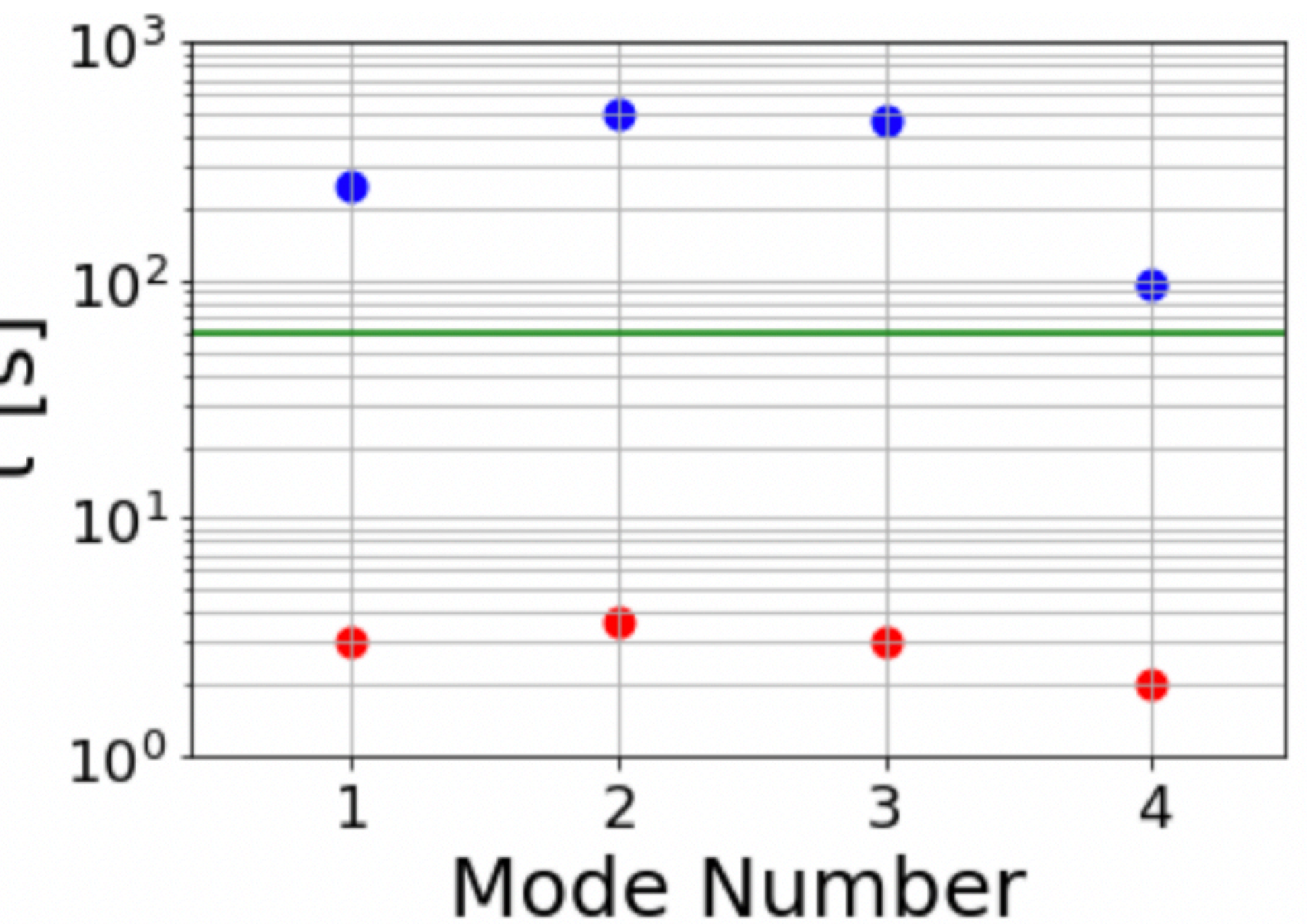
Control optimization

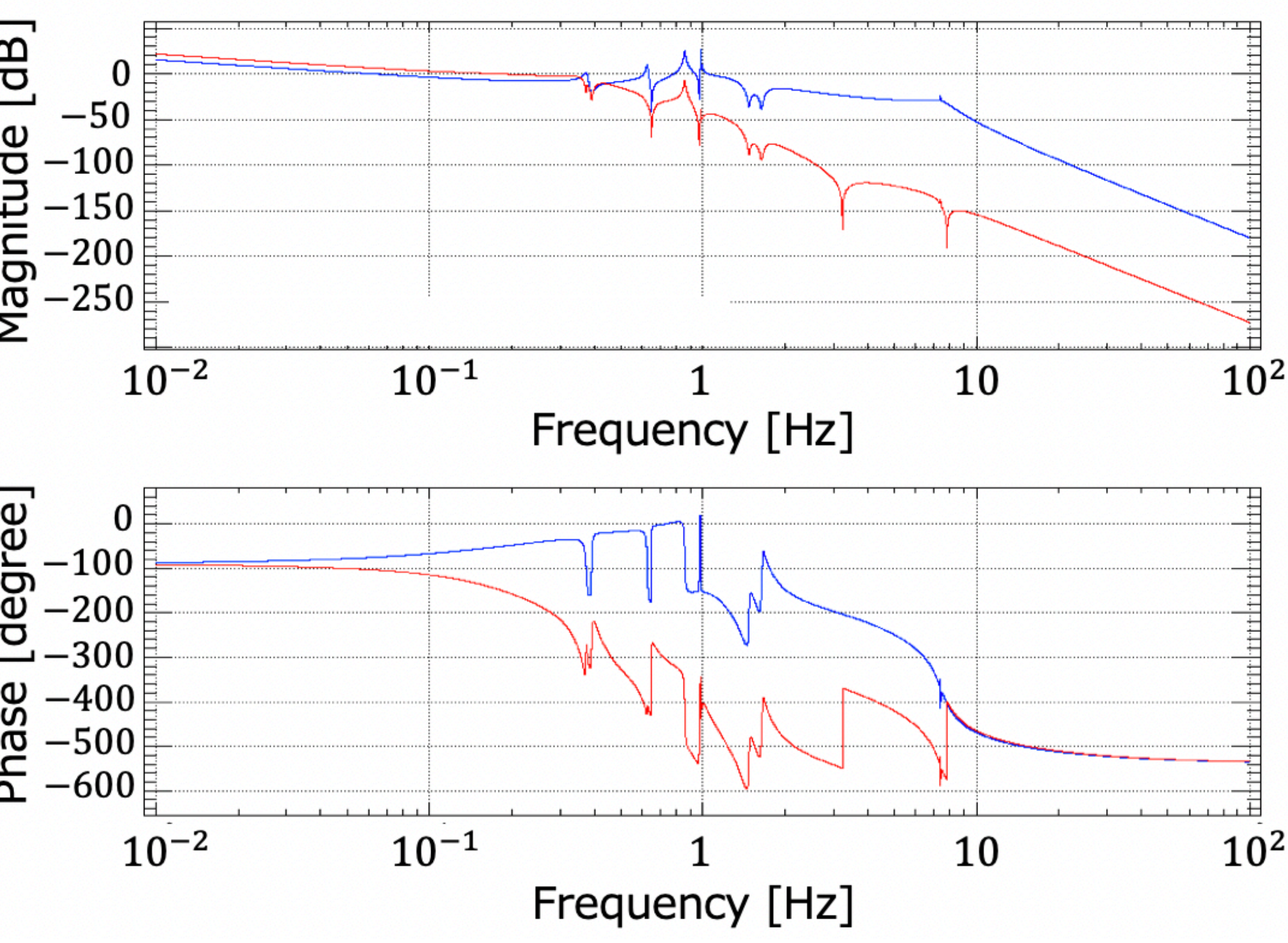disturbance suppression ← Trade off → low noise

Lock-acquisition phase
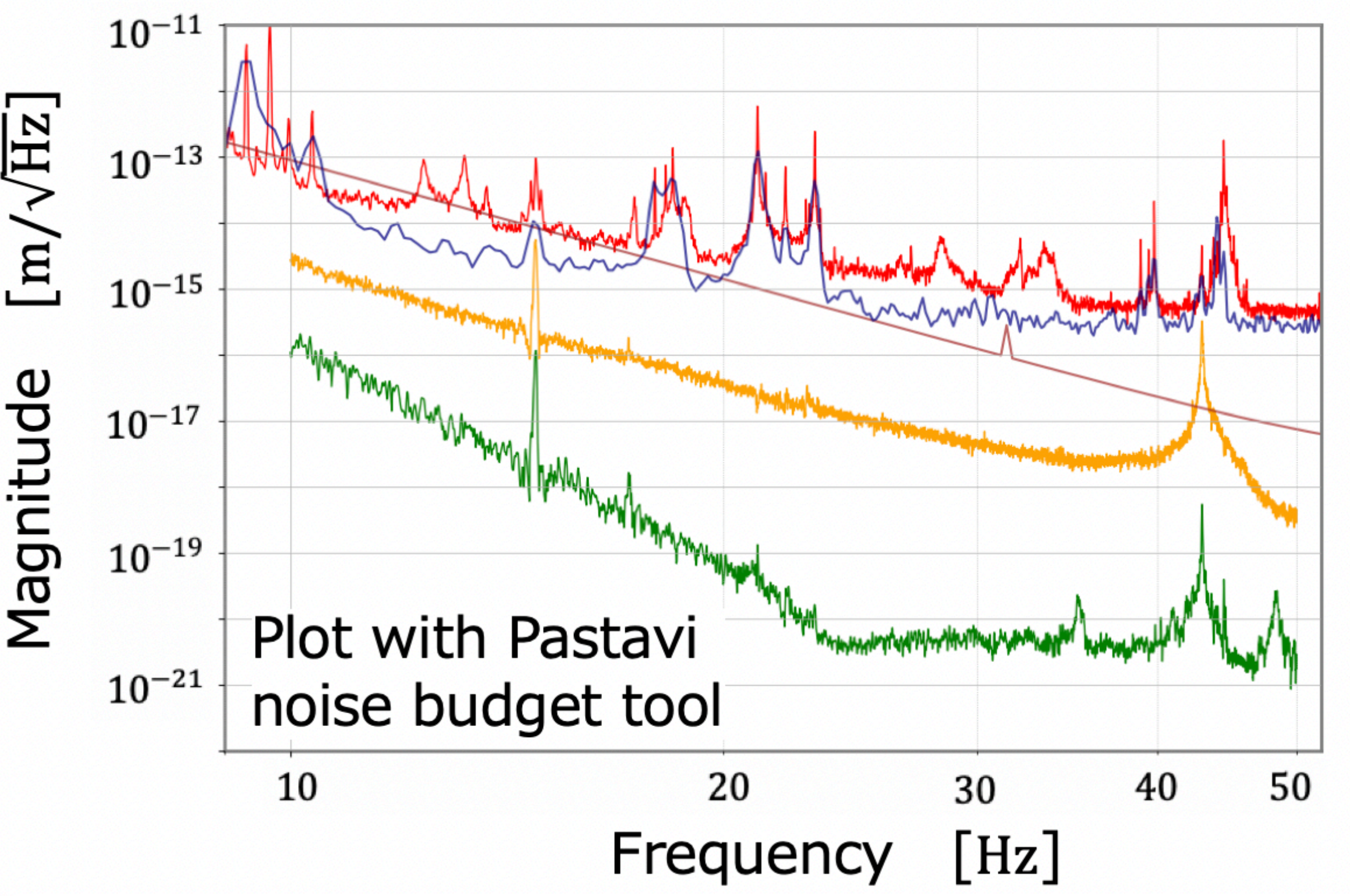Priority
disturbance suppression

Observation phase
Priority
low noise control
→ control optimization

e.g. ETMY MN P

Old control (no change as LOCK_ACQUISITION state)

Elliptic filter (from 0.4 Hz, order: 4)

notch filter (0.613 Hz, 0.724 Hz, 0.981 Hz)

Current control (OBSERVATION state)

Improvement of control noise (e.g. ETMY MN P)

- **DARM** (2022_11_03)
- **BEST** (2022_10_09)
- **ETMY_MN_SUMOUT_P with Old control** (2022_10_13)
- **ETMY_MN_SUMOUT_P with New control** (2022_10_13)

Plot with Pastavi noise budget tool

Future Works

EX L and **EX P** are the most noisy

IX L and **IX Y**, **EY Y** are still noisy