Recent Progress of TAMA300

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on behalf of the TAMA collaboration

TAMA300 interferometer

● Laser interferometer GW detector

- Arm length: 300m
- Location: National Astronomical Observatory of Japan (Mitaka, Tokyo)

● Purposes

- Development of the detector capable to catch GW events in nearby galaxies

- Establishment of interferometer technologies for LCGT

Progress of TAMA300

1995-1997 Facility/Vacuum System Construction

Recombined Interferometer

1999-2001 6 times of observation runs
(Total 1370 hours)

Recycled Interferometer

2001 Implement of power recycling
2003-2004 3 times of observation runs
(Total 1740 hours)

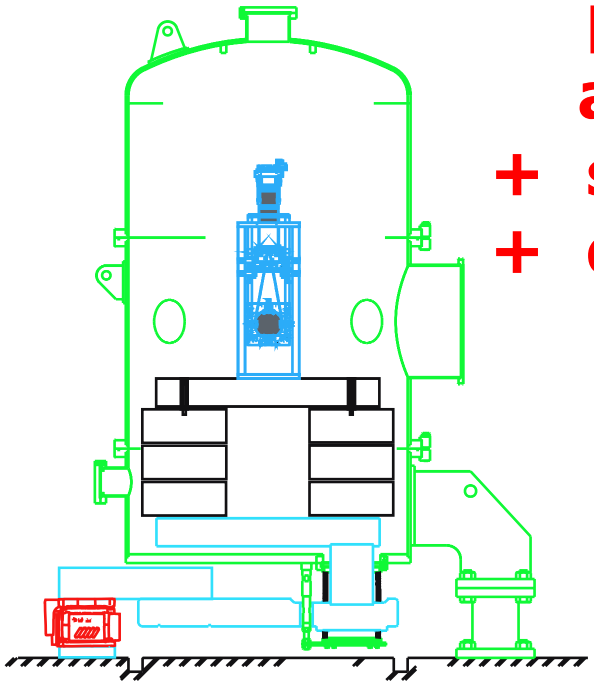
Seismic Attenuation System (SAS)

2005 Start installation of SAS
2007 Full interferometer lock with SAS

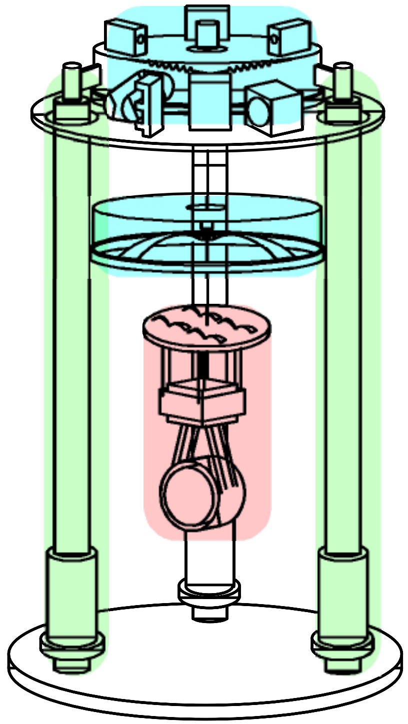
Current focus

- **Establishment of detector operation with SAS**

Replacement of the vibration isolation system



pneumatic
active isolator
+ stack
+ double pendulum



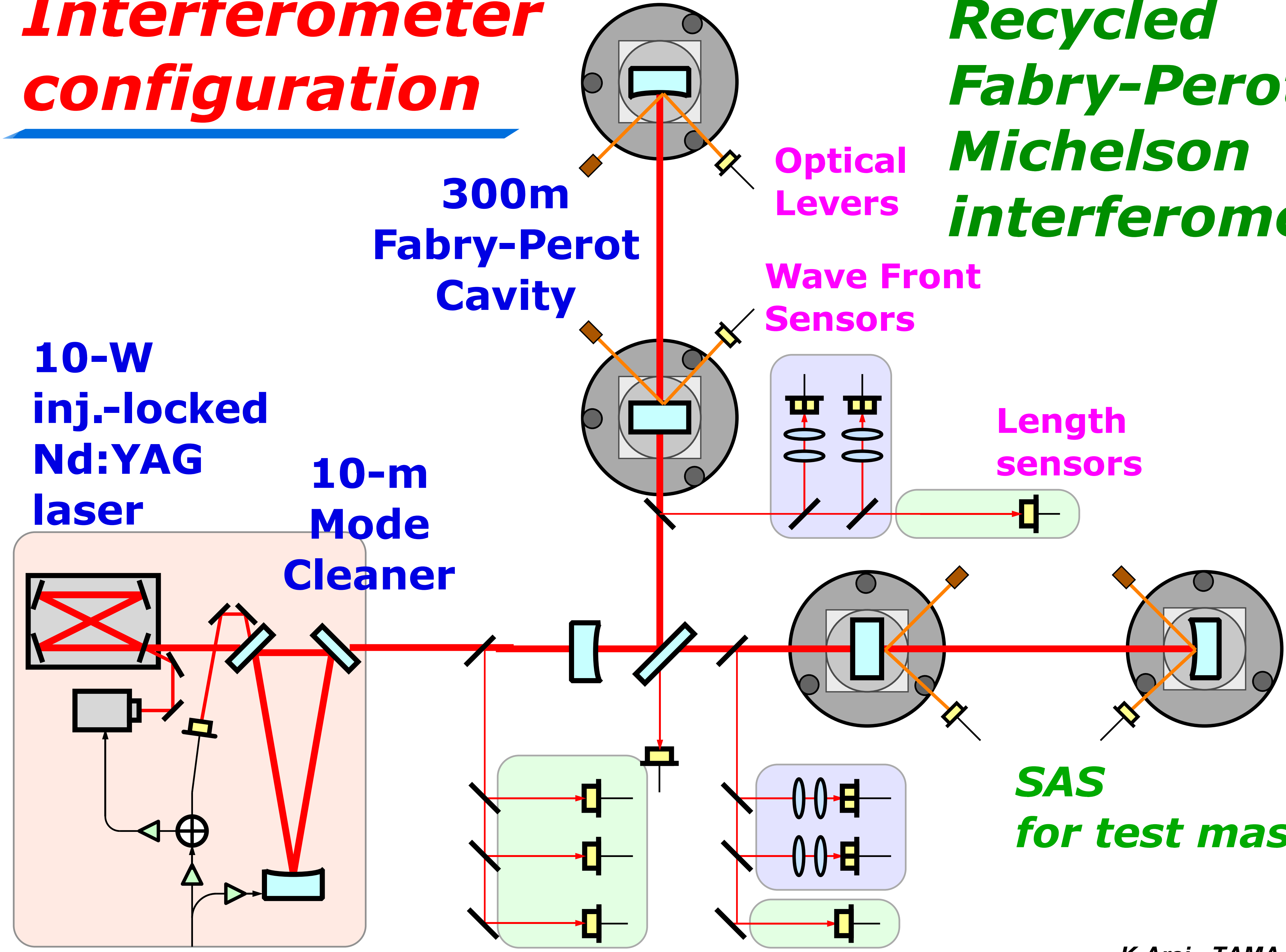
inverted pendulum
+ vertical filters
+ multiple pendulum

To realize the improvement

- Optimization of SAS control
- Optimization of interferometer control
- Application of digital control system
  =>Enables the complex servo system
  =>High level automatization of the operation

Interferometer configuration

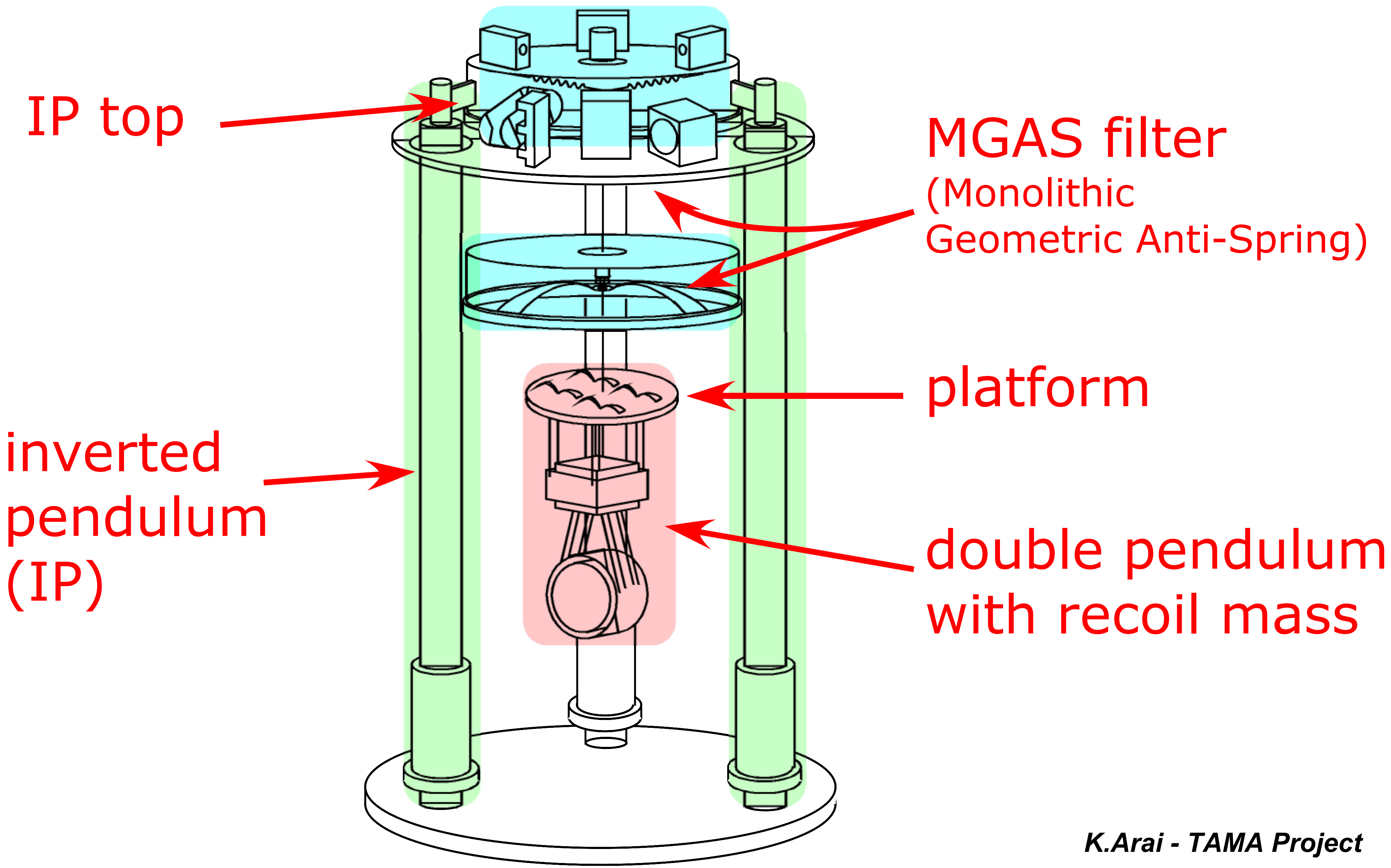
Recycled Fabry-Perot Michelson interferometer



Seismic Attenuation System

● Structure of SAS

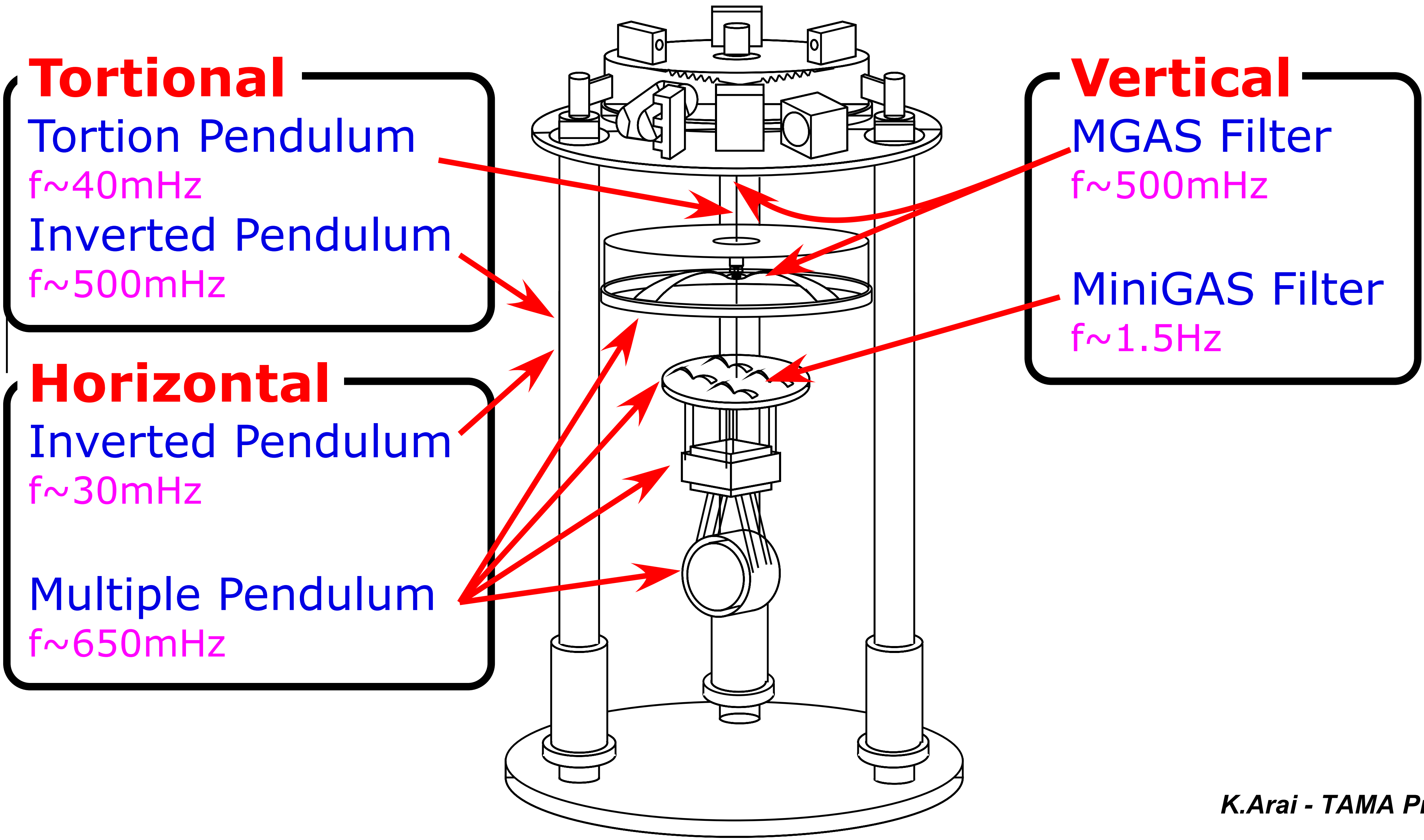
Multiple pendulum suspended from IP



Seismic Attenuation System

- **Vibration Isolation**

  Passive isolation with soft springs + active damping



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Seismic Attenuation System

- **Active Control of SAS**

  Local control stabilize the mirror motion

  => to enable lock of the interferometer

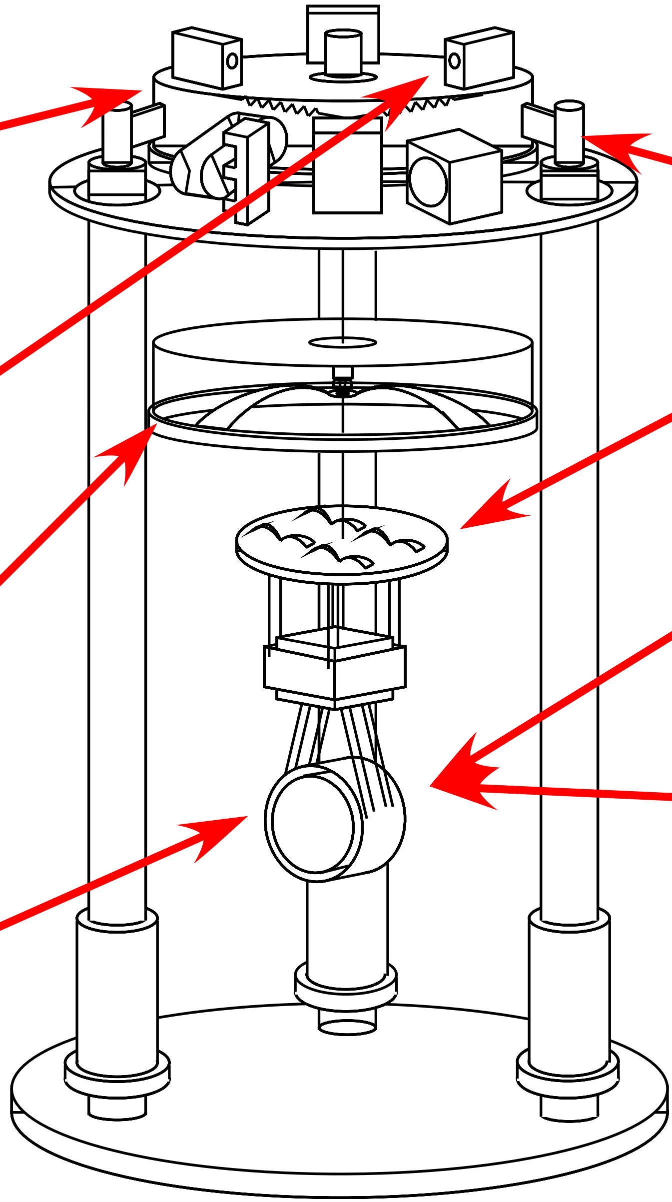
Local control

IP Position
Sensor: LVDT
Bandwidth: ~60mHz

IP Inertial damping
Sensor: Accelerometer
Bandwidth: 60m~2Hz

Tortion damping
Sensor: Photo Sensor
Bandwidth: 40mHz

Test mass servo
Sensor: Optical Lever
Bandwidth: ~2Hz



Global control

IP Position
Bandwidth: ~10mHz

Plat form
Bandwidth: ~10mHz

Test mass (angular)
Bandwidth: <3Hz

Test mass (Length)
Bandwidth: <1kHz

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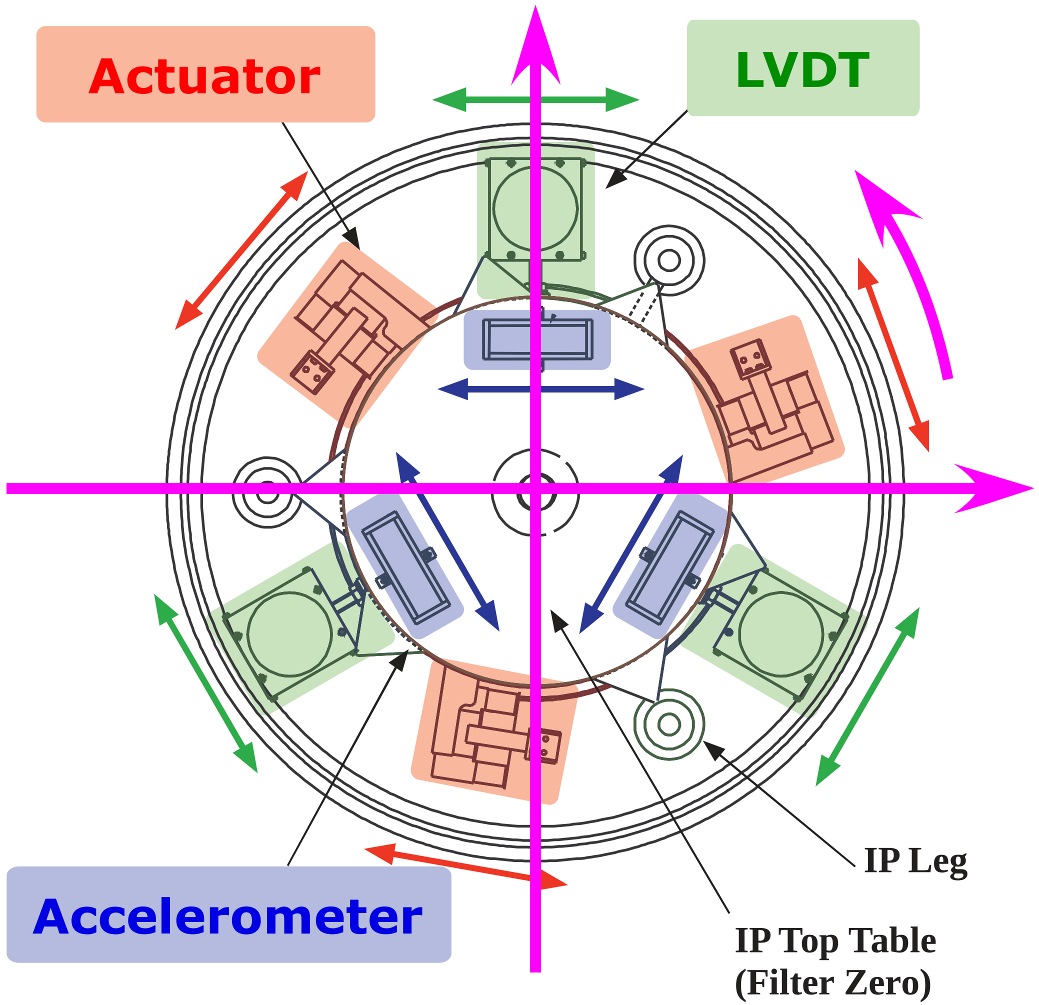
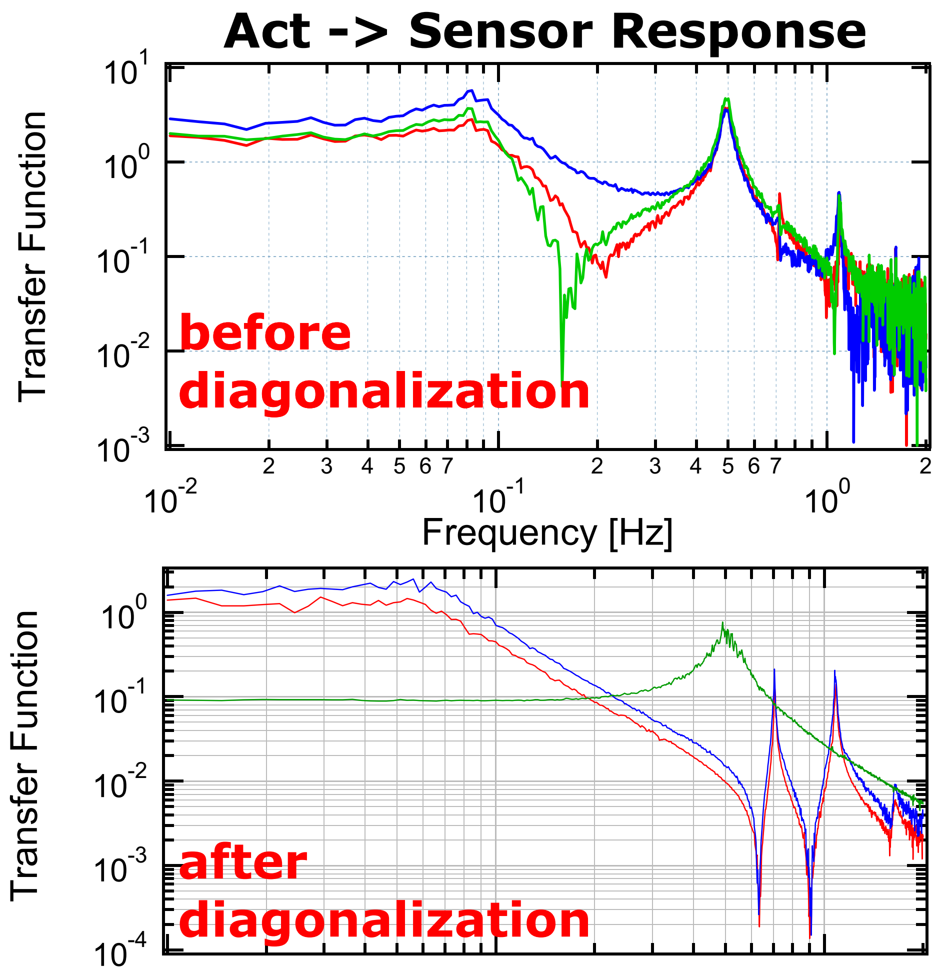
Inertial damping of IP

- **Diagonalization of Sensors / Actuators**

Decompose Actuator -> Sensor response into mechanical eigenmodes of IP

=> servo design becomes simpler
allows the different strategy for each modes





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Inertial damping of IP

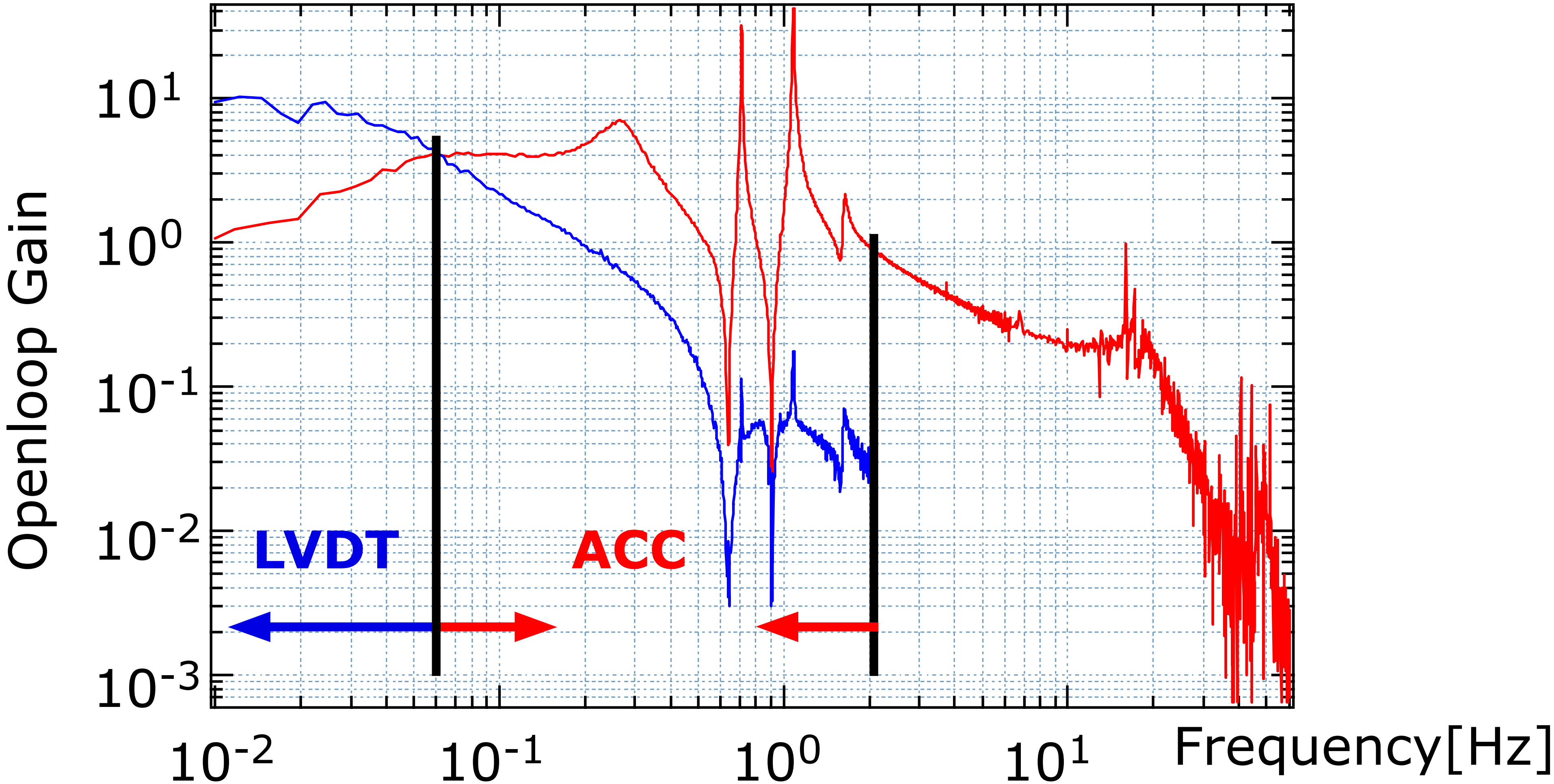
- **Two loop configuration**

LVDT loop (position sensing loop) f<60mHz

- drift control of the IP position

Accelerometer loop (inertial sensing loop) 60mHz<f<2Hz

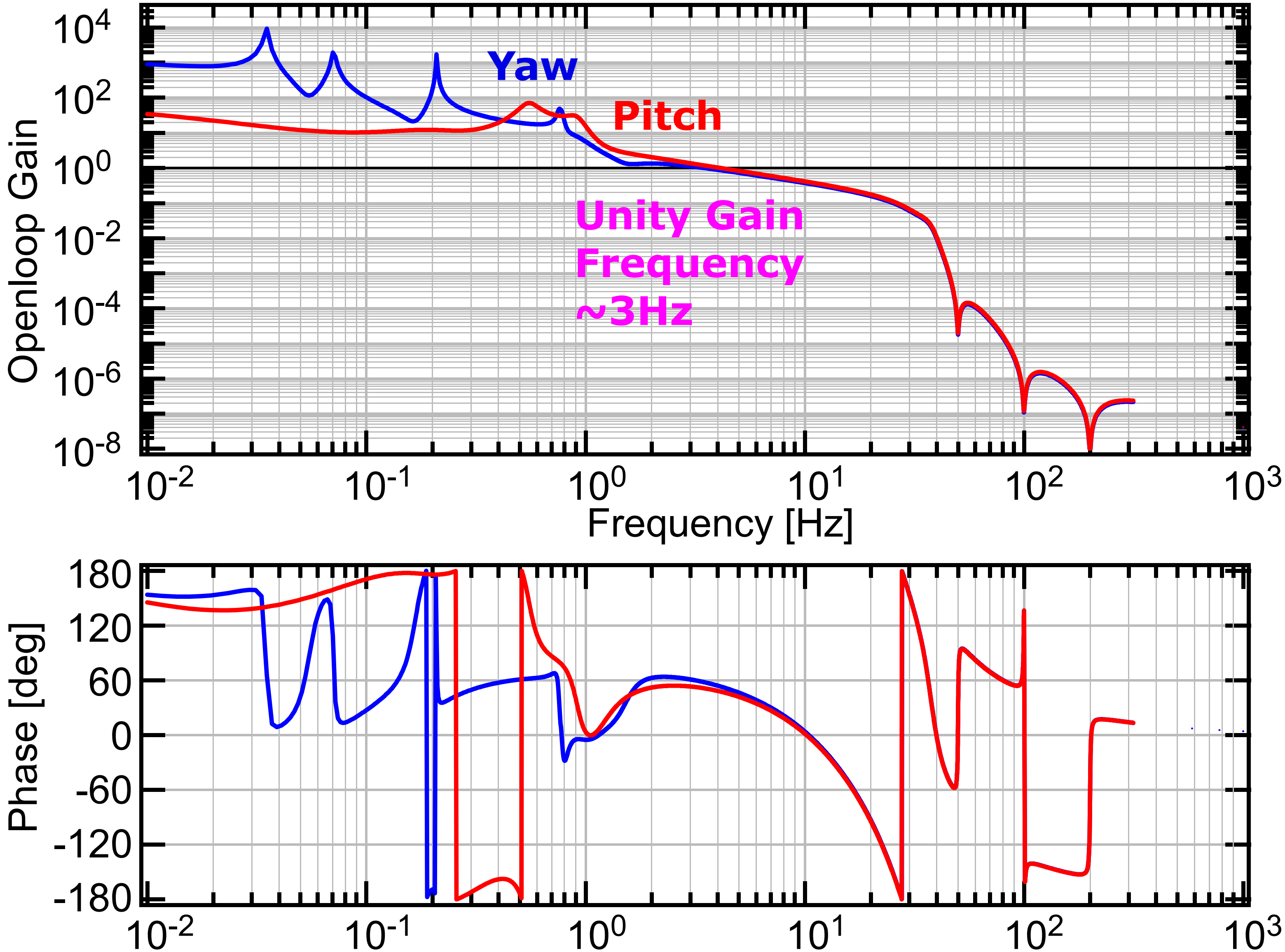
- stabilization of IP in terms of the inertial frame
- damping of the pendulum reactions at around 1Hz



Test mass control

● Optical lever servo

Rather complicated servo loops have been realized in virtue of digital control



Performance of SAS

● Test mass angular motion

Mirror angular motion: sub-μrad$_{RMS}$

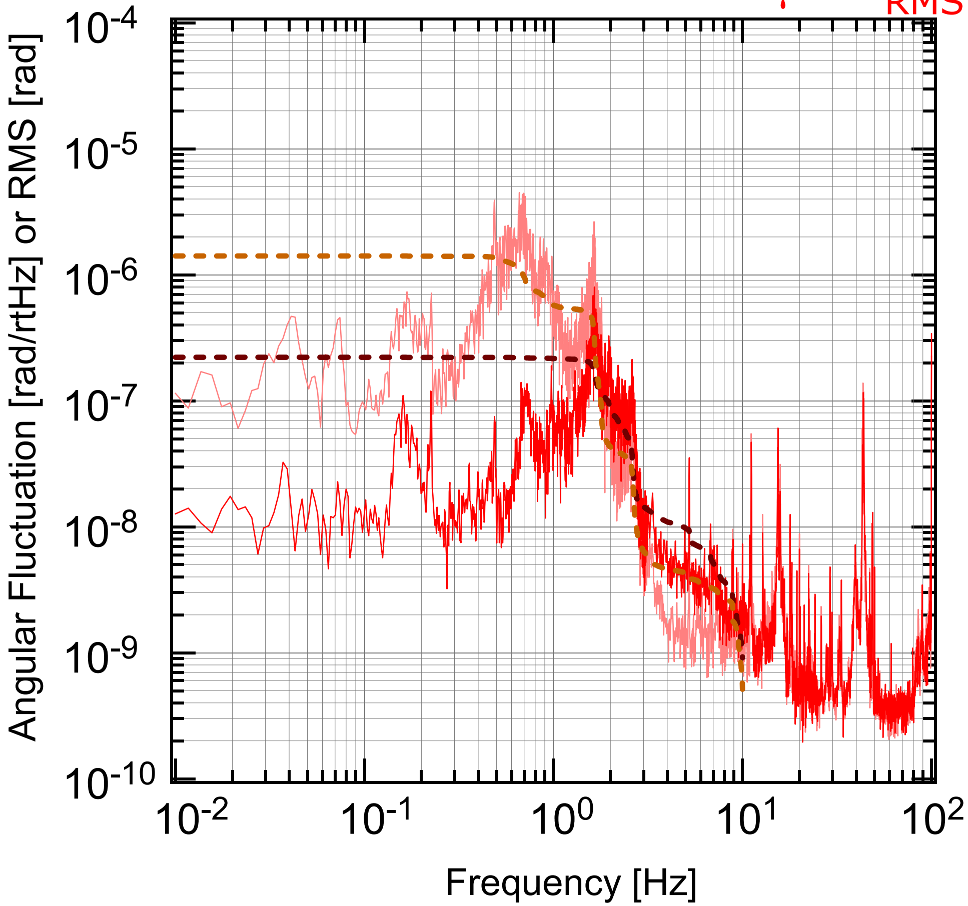
=> Sufficiently stable for interferometer operation

(with previous suspension system: 1.0 μrad$_{RMS}$)

Pitch

Free Run: 1.4 μrad$_{RMS}$

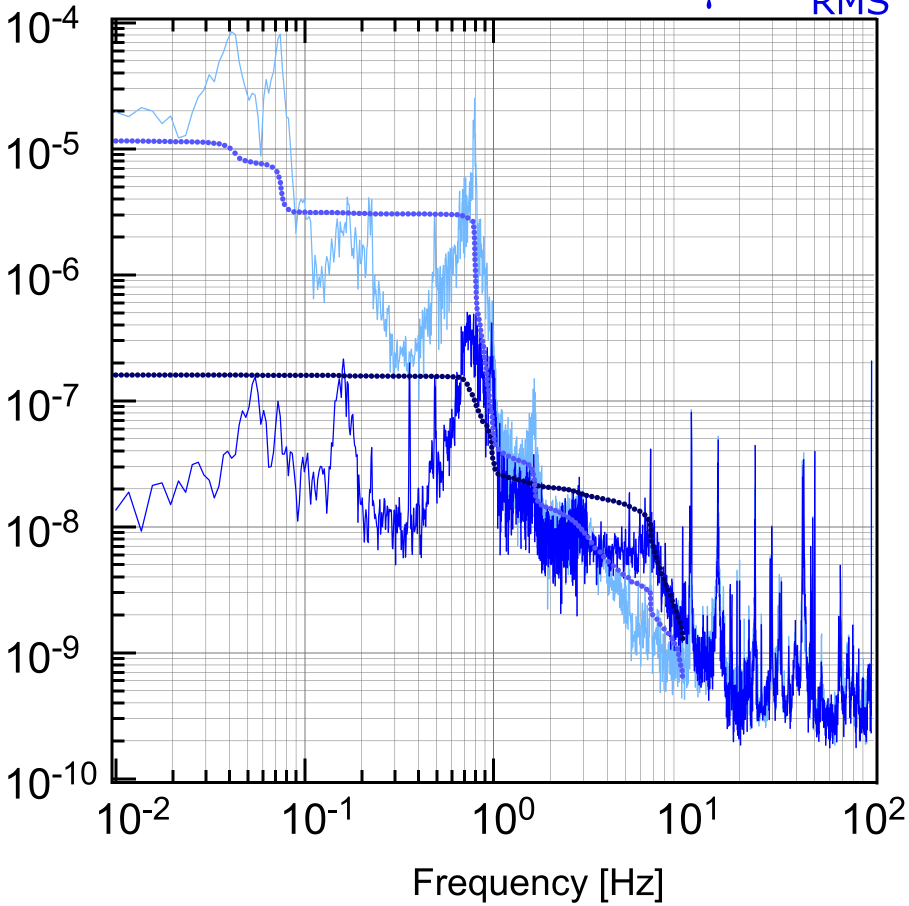
Controlled: 0.23 μrad$_{RMS}$



Yaw

Free Run: 12 μrad$_{RMS}$

Controlled: 0.16 μrad$_{RMS}$

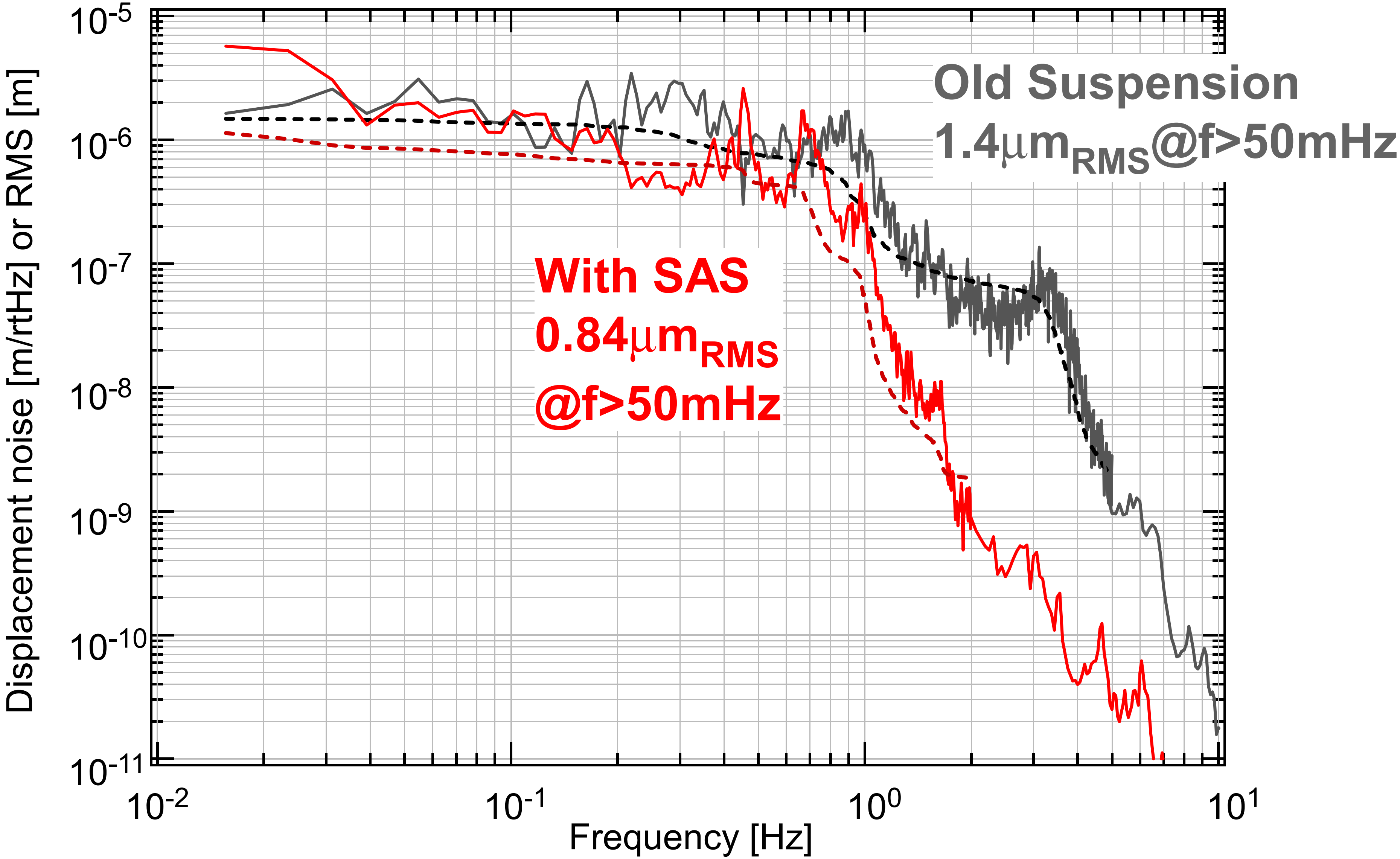


Performance of SAS

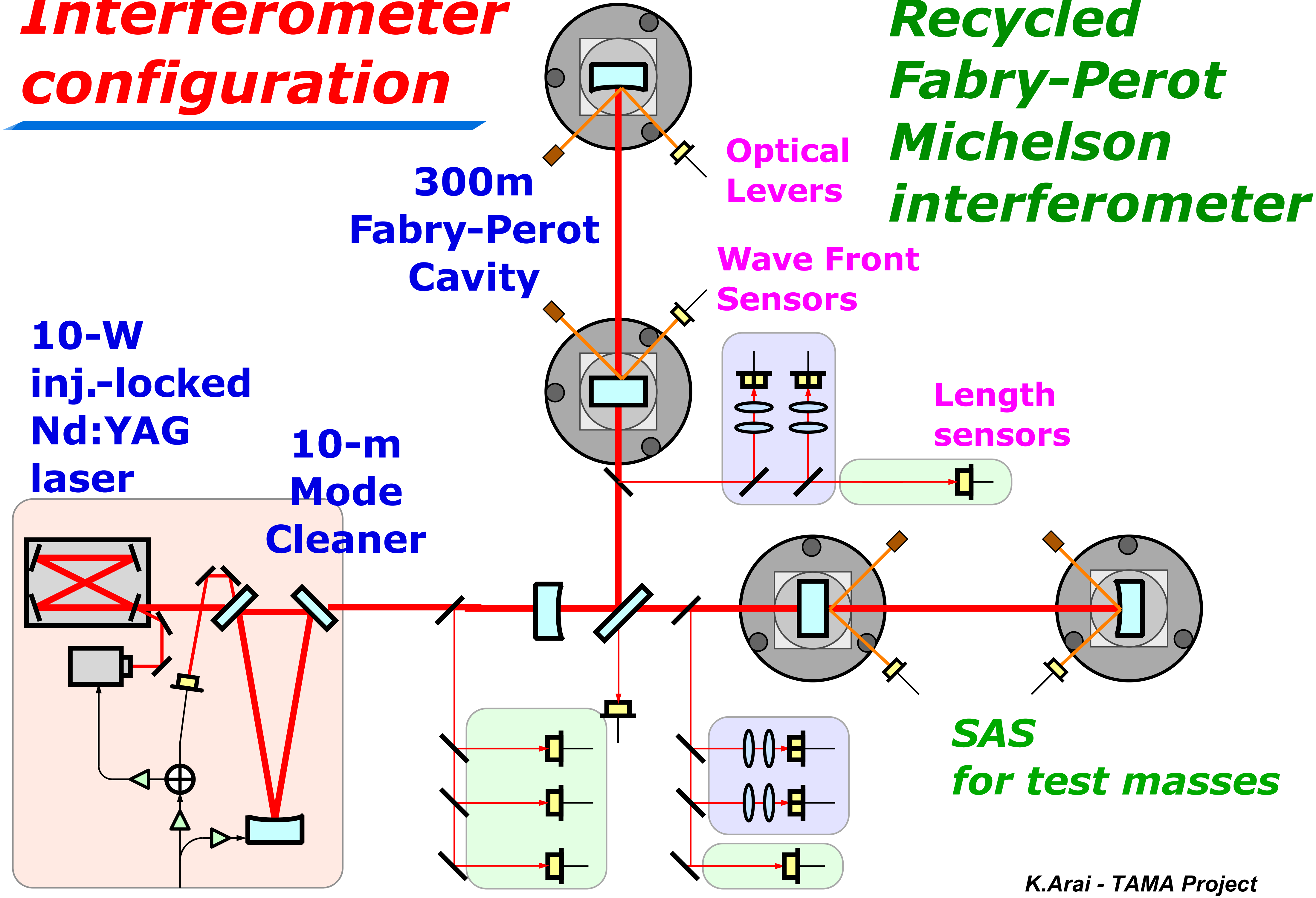
● Legth Fluctuation of 300-m arm

Comparison with the previous suspension system

=> **improvement above 0.1Hz was confirmed**



Interferometer configuration



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Interferometer Operation

- **Recycling operation with SAS was achieved in July**

- **Control configuration**

Test mass length control:

Analog based servo

DSP based digital filter
=> only for lock acquisition
=> switched to analog based system after the lock

Test mass alignment control:

LabView based digital control

Optical lever control for fast control

Wave Front Sensing for drift control

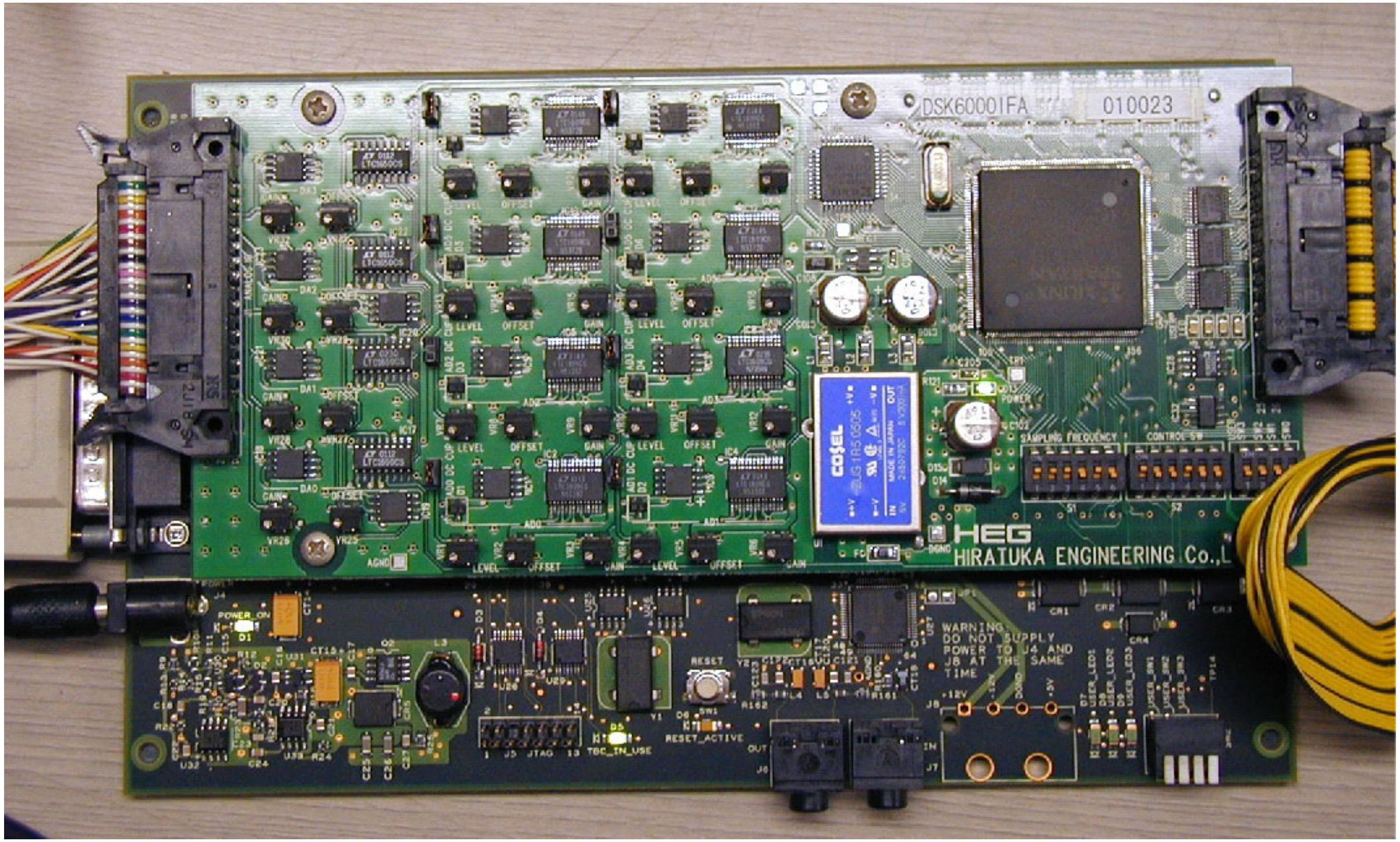
Digital mass lock filter

- **DSP based digital filter** (TI TMS32C6713 225MHz)

  Sampling freq: 200kHz

  Control BW: ~800Hz

Realized comperable bandwidth to analog filters



Digital mass lock filter

- **Some simple operations to the error signal**

  - Trigger at the resonance

    Eliminates glitches by sidebands/ higher order modes

  - Normalizaton of the error signal by cavity transmitted light

    Expands linear range (about x3)

  - Adaptive change of the digital filter coefficient

    Low frequency gain boost at the lock

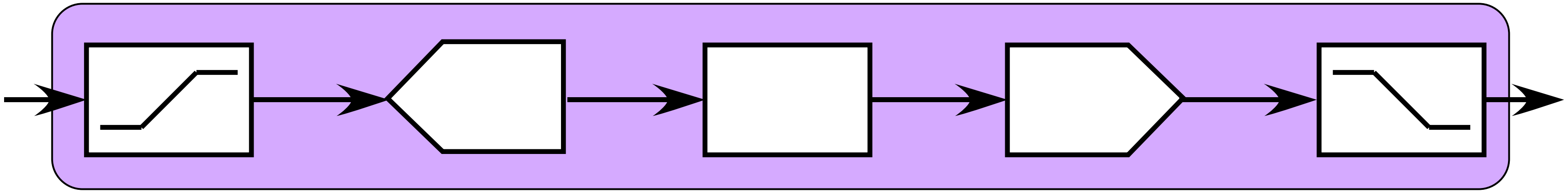
=> In combination with SAS, lock of RFPMI was realized even with 3 times weaker actuator

Pre-emphasis / De-emphasis

- **One of the demerits of the digital system**

  about 100-1000 times larger noise than analog circuits

- **Pre-emphasis/De-emphasis filter**

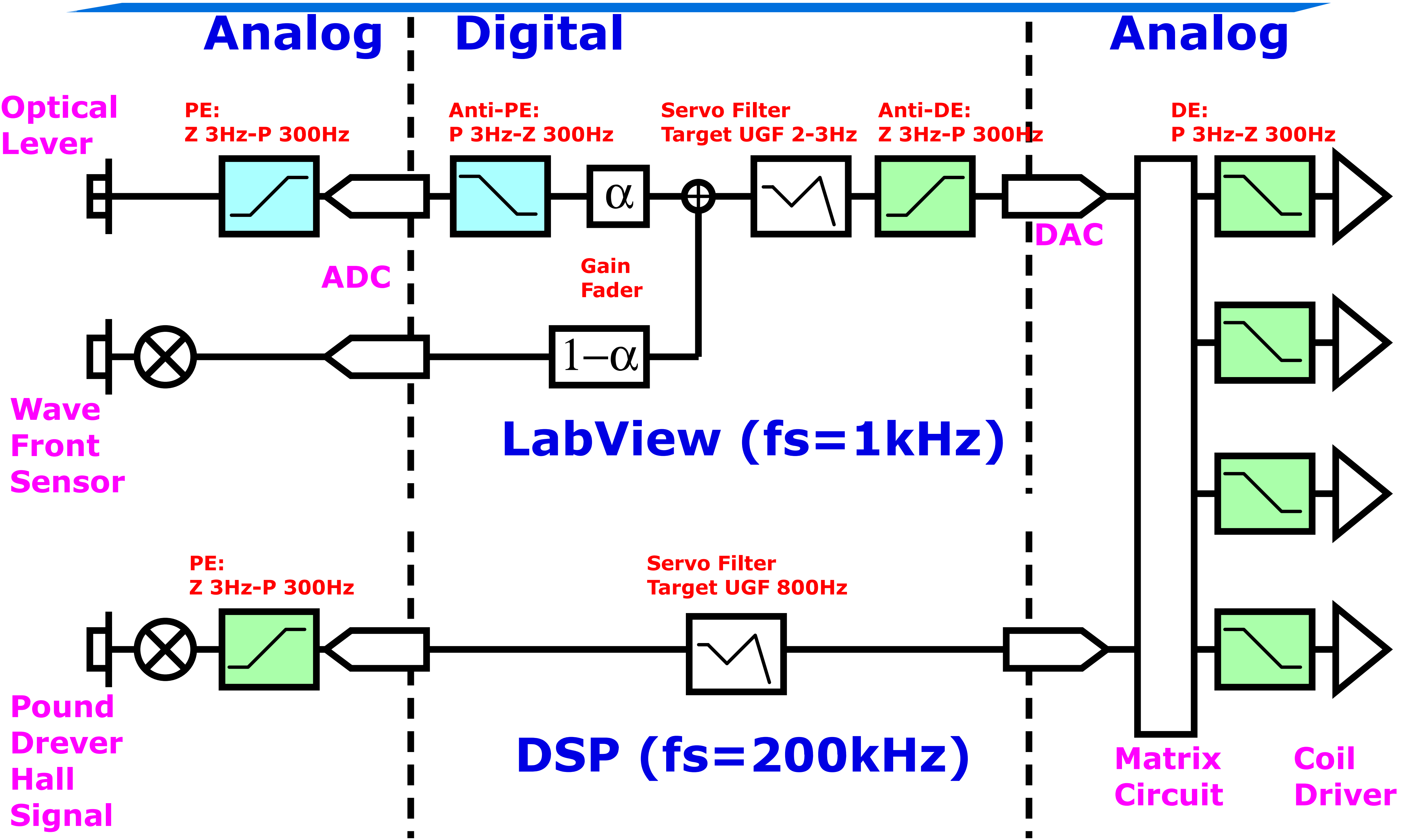


pre-emphasis *ADC* *Digital System* *DAC* *de-emphasis*

Signal level is enhanced
while the range at low frequency is preserved

pre-emphasis: effect of ADC noise is reduced
de-emphasis: effect of DAC noise is reduced

Pre-emphasis /De-emphasis



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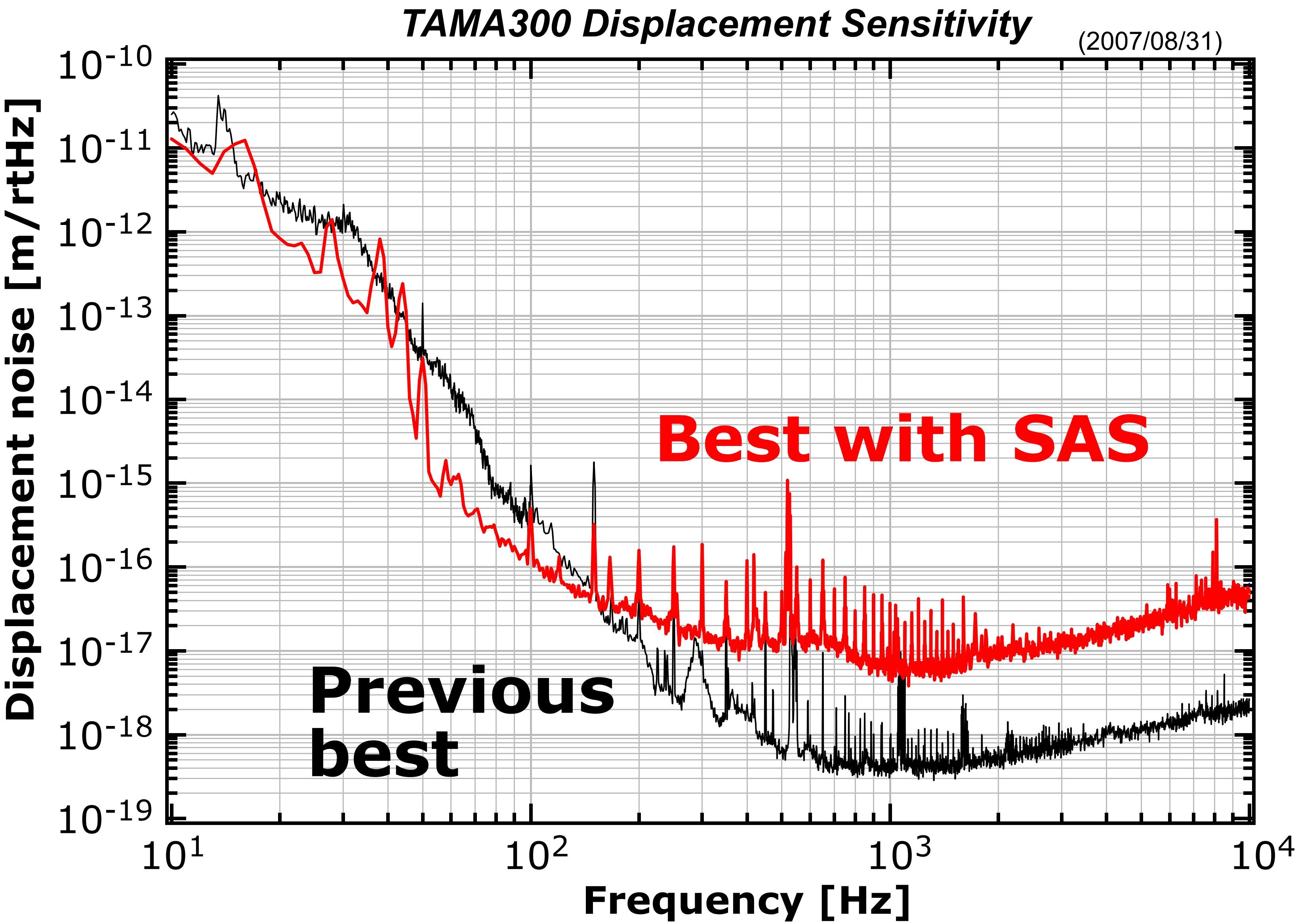
Sensitivity

- **Tuning of the system still underway**

  So far, improvement below 150Hz was confirmed



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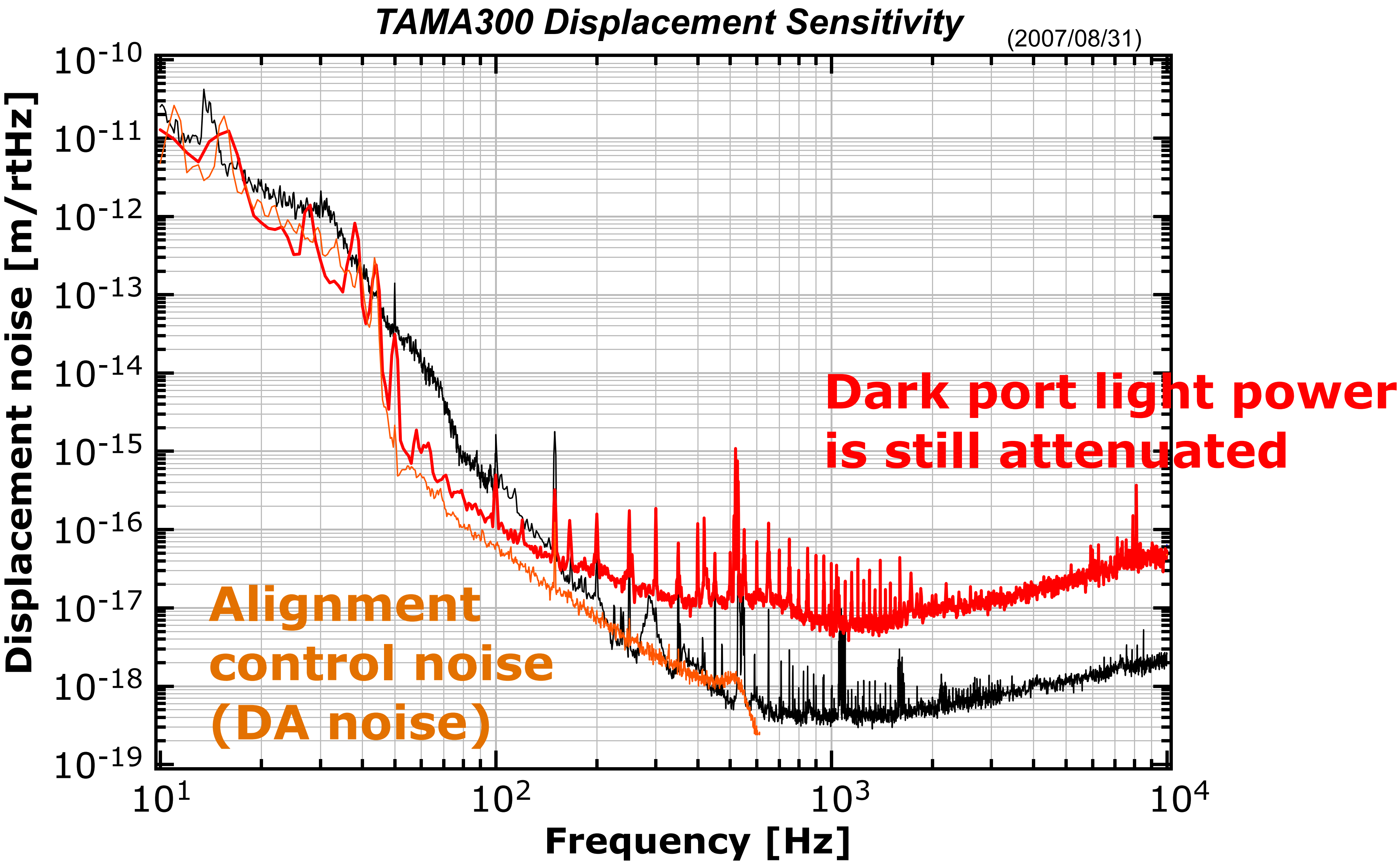

Plan

- **How to achieve further improvement**

  For alignment noise

  - Additional DA noise reduction is in progress
  - Activation of fast WFS servo (~x100 better sensing noise)

  For high frequency

  - more power at the dark port

  For further investigation

  - noise budgetting => needs more stability

  For further improvement of SAS

  - performance of SAS is limted by the accelerometers
  - => accelerometer study

Summary

- **Current status**
  - SAS is now functioning

  - Shaking down of the detector system
    Underway. Still a lot of things to do.

  - Improvement was partially confirmed
    Between 0.1 to 150Hz

  - Gradually getting familiar with digital systems

- **Plan**
  - Improved binary range
    -> participation to AstroWatch campaign