Status of Type-A suspensions for KAGRA

Yoshinori Fujii for KAGRA collaboration
Status of Type-A suspensions for KAGRA

What is going on?

-- Mechanical installation

-- Servo filter implementation

-- Verification of suspension performance
Type-A suspensions?

For the test masses,
- Upper 5 stages: room-temperature
- Lower 4 stages: cryogenic-temperature
Type-A suspensions?

**Inverted Pendulum**

(\sim 70 \text{ mHz})

**Geometric-Anti Spring**

(\sim 0.4 \text{ Hz})
Type-A suspensions?

**INVERTED PENDULUM**

- with 3 horizontal LVDT & actuator units
- -- inertial sensors

**GEOMETRIC-ANTI SPRING**

- with 1 vertical LVDT & actuator unit
Type-A suspensions? (With collaboration of group in Pisa)

**Bottom-Filter Damper**

with 3 horizontal & 3 vertical LVDT & actuator units
Type-A suspensions?

Inside cryostat

payload

Heat-link VIS

(+ Wide-angle baffle)

Heat-link VIS

JGW-P1809347

13.5 m
Type-A suspensions?

- Platform
- Marionette Recoil Mass & Marionette
- Intermediate Recoil Mass & Intermediate Mass
- Mirror Recoil Mass & Mirror
- Blade Spring
- Moving Mass
- Heat link
- Optical lever
- Reflective photo-sensor & coil-magnet Actuator units

JGW-P1808219
Then, mechanical installation status for O3-observation
Mechanical installation has done! For all 4 of them!

(Finished, for all 4 of them)

(Still mechanical-wise repairing work remains though..)
**Mechanical installation has done! HOWEVER ..**

**ETMX & ETMY:**
- for ETMX - F2 GAS
- for ETMY - F1 & F2 GAS
- Hitting,, ~No oscillation
- Mass tuning, necessary but no accessibility.

**ITMX & ITMY:**
- for ITMX / ITMY – F0 GAS
- Newly made blades could not hold the system..
- Blade replacement, necessary but time consuming (etc).

*Images showing mechanical installation and the problems with ETMX and ETMY.*
Mechanical installation has done! HOWEVER..

According to a simulation, assuming 1% coupling,

"acceptable for the O3-run"
(should be)

Note:
-- Modeled w/o Heat-links
-- params are not tuned.
Servo filter implementation status
With displacement sensors, [ for damping ]

IP

DC+Damp

For L / T / Yaw

BF-damper

DC+Damp

For Yaw

For L / T

(DMouplev)

DC+Damp

For P / Y

5th KAGRA international workshop on February 14th 2019, Yoshinori Fujii
With displacement sensors, [ residuals ]

- **ETMX**
  - Pitch: 0.16
  - Yaw: 0.15

- **ITMX**
  - Pitch: 0.41
  - Yaw: 0.31

Locked! Thanks to Kamioka environment.
With displacement sensors, [ residuals ]

In bad weather

NOT locked..

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0.25

ETMX

0.56

ITMX

0.29

ETMX

0.55

ITMX

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WIT DISPLACEMENT SENSORS, [ RESIDUALS ]

IN BAD WEATHER

NOT LOCKED..
Candidate (main) resonant modes?  Preliminary

- damping at tower-part
+ decoupling / inertial damping

- damping at payload
Verification of suspension performance
Measurement:

Mechanical suspension performance with X-arm cavity
Vibration isolation ratio, \[ \text{Good news!} \]

From ground to TM
V to L coupling, [ System is not yet identified.. ]

From BF-GAS to TM

Real was not so simple..
Summary:

-- All the Type-A suspensions have been installed.
-- Damping controls are working properly, however, some resonances are not yet damped efficiently.
   - Implement damping controls at payload stages

-- Reducing RMS is necessary when the seismic noise is high.
   - Implement inertial damping at IP stage

For soon next:

- Do mode identification including the heat-link peaks
- Design the filters in the observation phase.
Backup
Seismic noise

Seismic noise (Tokyo)
Seismic noise (KAGRA site)
Target sensitivity

\[10^{-8}\]
Seismic attenuation

![Seismic attenuation diagram](image)

- Mirror displacement $x$ [m/√Hz]
- Frequency [Hz]
- KAGRA suspension
- Requirement
- Ground
- Single
- Double
- Triple
- 5-stage

Ex. KAGRA

3 m
Resonance damping

$\rightarrow$ Active control

Starting interferometer operation

Stable interferometer operation
Designing active control system / Control phase

1. Calm-down phase
   - Suppress large disturbance

2. Lock-acquisition phase
   - Reduce RMS velocity
   - RMS angle (Root-Mean-Square)

3. Observation phase
   - Keep position with low noise control
Type-A suspensions?

Inside cryostat

13.5 m

JGW-P1809347
Type-A suspensions?

CURRENT STATUS OF HLVIS INSTALLATION

13.5 m

will be installed in the end of Jan. 2019

JGW-P1809382
With displacement sensors, residuals

Seismic motion when the weather was normal/bad (From page #16)

\[ \text{EXV: } 2.4 \times 10^{-2} \text{ um/rtHz or } 1.2 \times 10^{-2} \text{ um} \]

\[ \text{IXV: } 2.6 \times 10^{-2} \text{ um/rtHz or } 1.2 \times 10^{-2} \text{ um} \]
Vertical transfer functions (fitted)

**ETMX**

**ITMX**
Measurement:

Mechanical suspension performance with X-arm cavity
Force transfer functions

From (TM-RM)-act to TM
Force transfer functions

From (IM-IMR)-act to TM
Force transfer functions

From (MN-MNR)-act to TM

Actuation

5th KAGRA international workshop on February 14th 2019, Yoshinori Fujii
Note: Measurement of mechanical suspension performance with X-arm cavity

<table>
<thead>
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<th>Excited stage name</th>
<th>Degree of freedom</th>
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<td>(L)</td>
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<tr>
<td>IP</td>
<td>L</td>
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**Excitation point:**

**Sensing point:**

All the local sensors for ETMX and ITMX

(*1) Some resonances have to be identified, as shown in the above.
(*2) measurement files are stored under /users/VISsvn/ though, Not much organized well now.. please let me know if you want to have them ASAP.
Type-A SAS,
‘TyrpeA180429_20K’
Eigen mode: 75 modes

Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Less interest now
Designing active control system / ex. Type-Bp SAS

1. Calm-down phase

- DC + Damp
- DC
- Damp
- Damp
- Optical sensors
- Displacement sensor (LVDT)
- Displacement sensor (OSEM)

2. Lock-acquisition phase

- DC + Damp
- DC
- Damp
- Damp
- Optical sensors
- Displacement sensor (LVDT)
- Displacement sensor (OSEM)

3. Observation phase

- DC + Damp
- DC
- Damp
- Damp
- Optical sensors
- Displacement sensor (LVDT)
- Displacement sensor (OSEM)
2. Decay time measurement

For damping resonances

1/e decay time

→ We have to measure the decay time constants w/ and w/o damping controls, in order to verify the damping control performance, FOR ALL THE TYPE-A/B/Bp SUSPENSIONS.

(Example)