

Type B Seismic Attenuation System

Local Control Systems and Displacement Sensing of the Suspended Optic (Optical Lever)

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On behalf of the VIS Type B team

Content

Overview of the Type B suspensions - Actuatable degrees of freedom

Local control systems - Changes and Motivations

TM Displacement sensing (Optical Lever) - Introduction and Diagonalization.

2. Top Filter (F0)

- Vertical

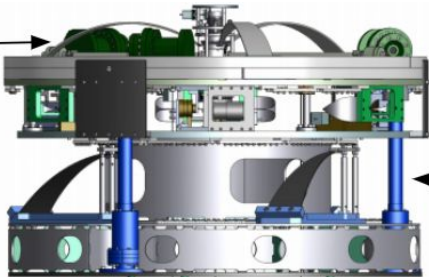
0. Ground

3. Standard Filter (F1)

- Vertical

4. Bottom Filter (BF)

- Vertical



1. Inverted Pendulum (IP)

- Longitudinal
- Transverse
- Yaw

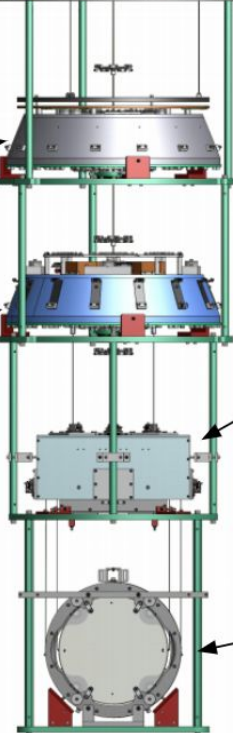
5. Intermediate Mass/Recoil Mass

- Longitudinal
- Transverse
- Vertical
- Roll
- Pitch
- Yaw

6. Optic (Test Mass/Recoil Mass)

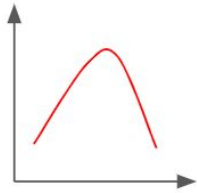
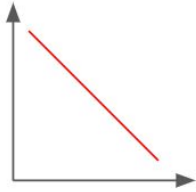
- Longitudinal
- Pitch
- Yaw

● Actuable degrees of freedom

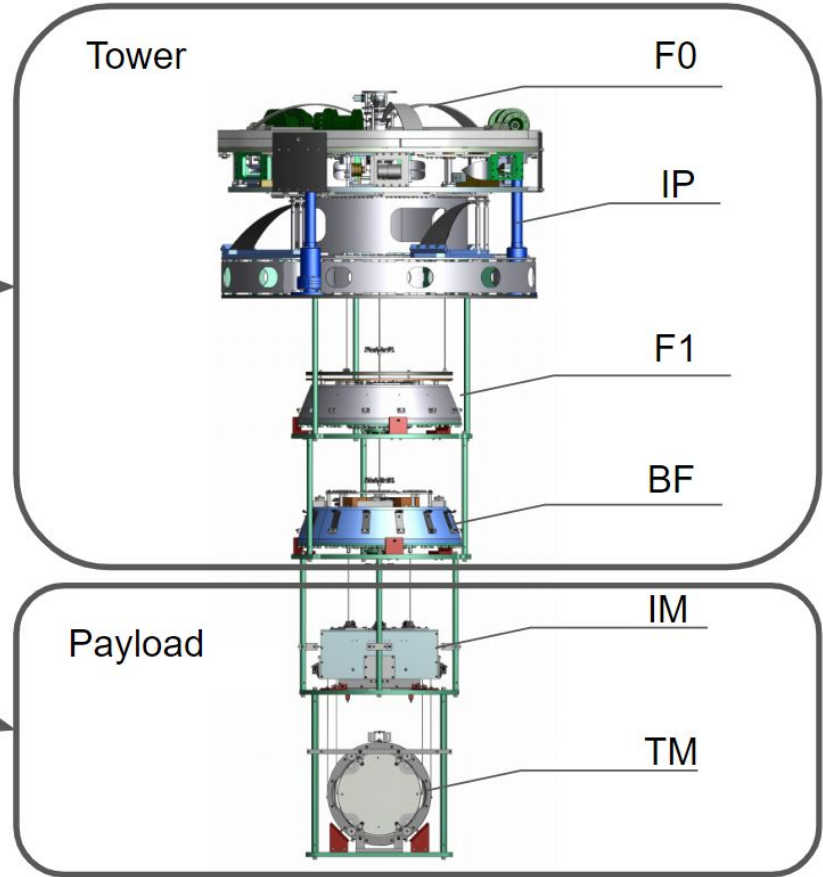
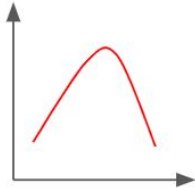


Local Control Required

Displacement control* + Damping control



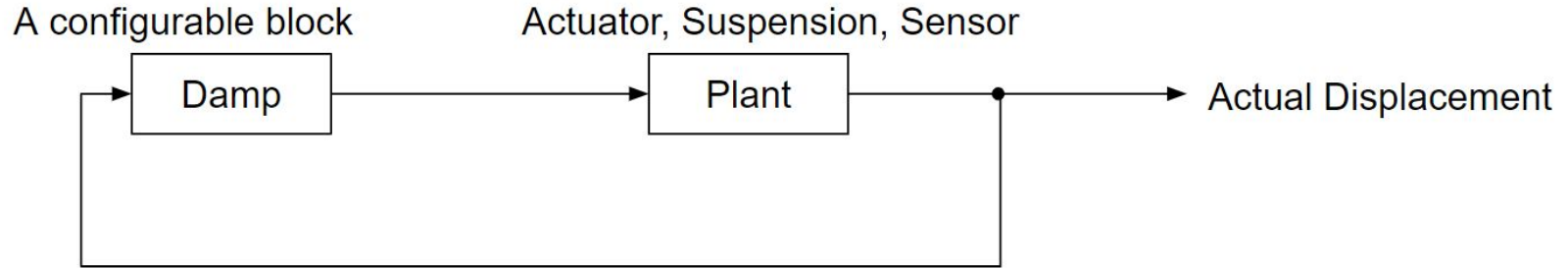
Damping control**



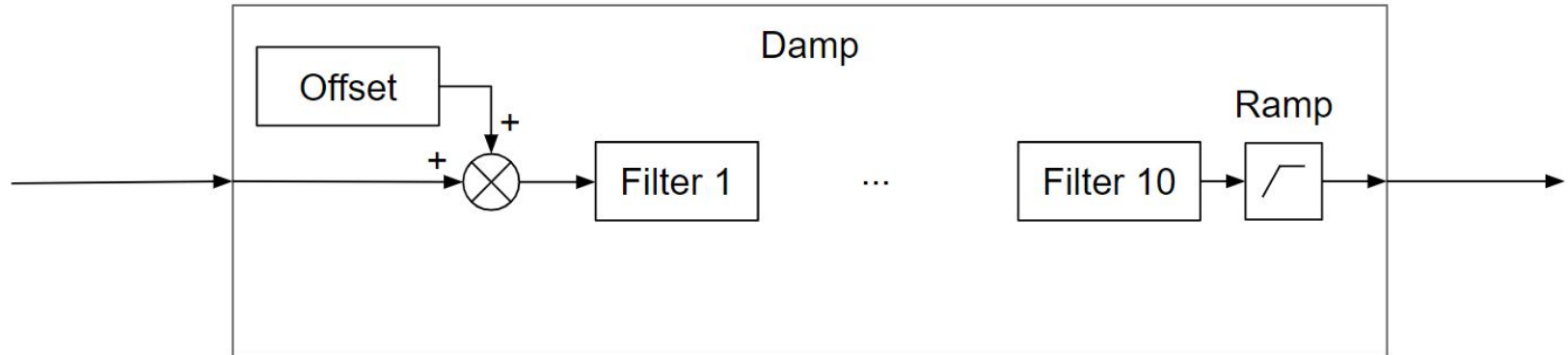
* A.K.A DC control/Integral control/Integrator

** Plus IM to TM angular displacement control, not to be discussed.

Control Topology (Previous)

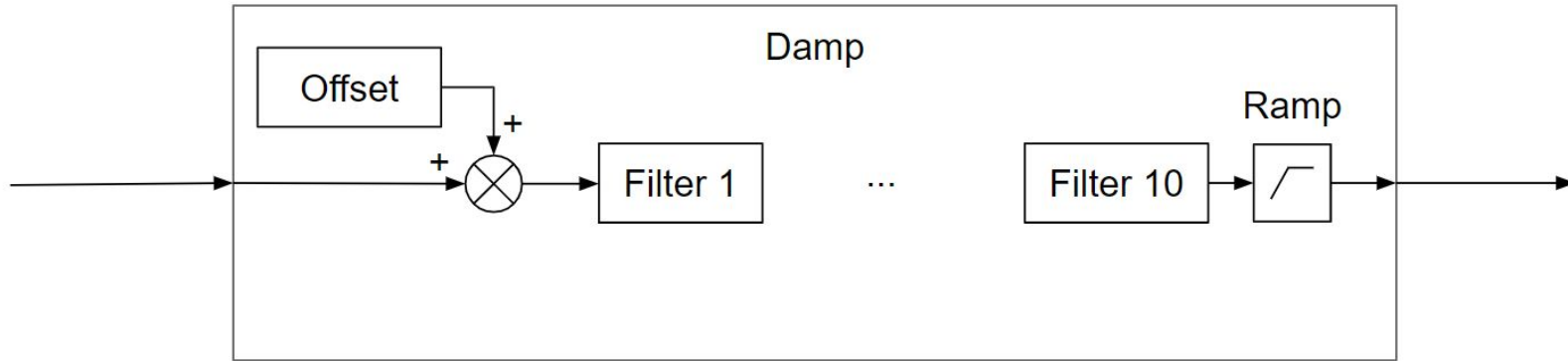


Inside the “Damp” block:



Control Topology (Previous)

Block	Filter 1	Filter 2	Filter 3	Offset
Usage	-1	Damp (?)	DC	Setpoint (-)



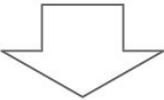
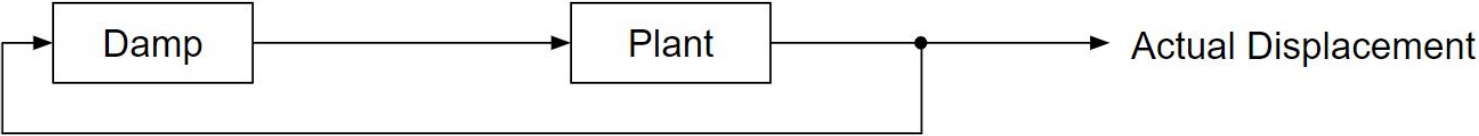
Control Topology (Previous)

Problems:

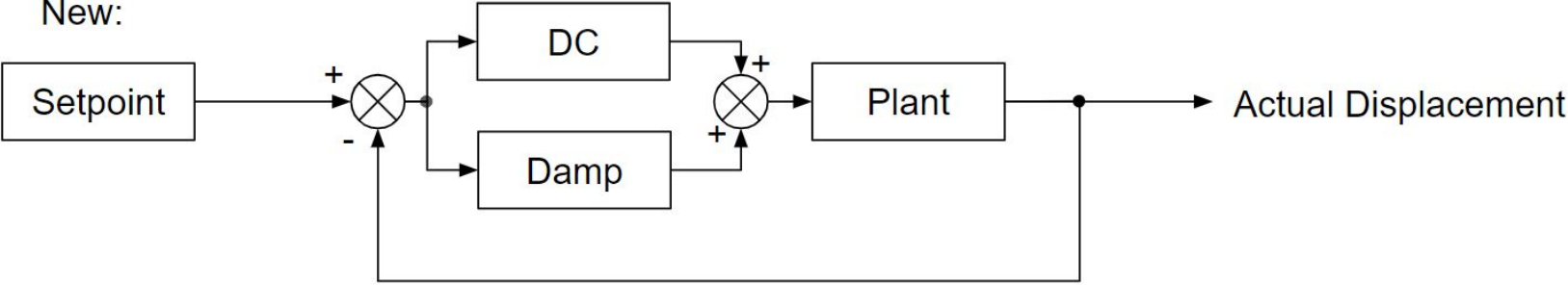
1. Requires -1 in every block.
2. Change of setpoint is sharp.
3. Offset is NEGATIVE setpoint
4. Displacement control and Damping control are coupled.

Changes in the Control Topology

Old:

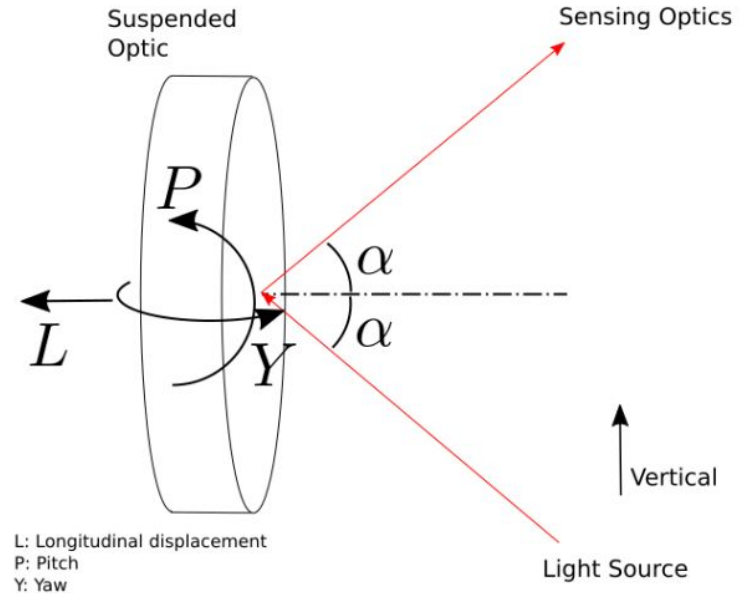


New:

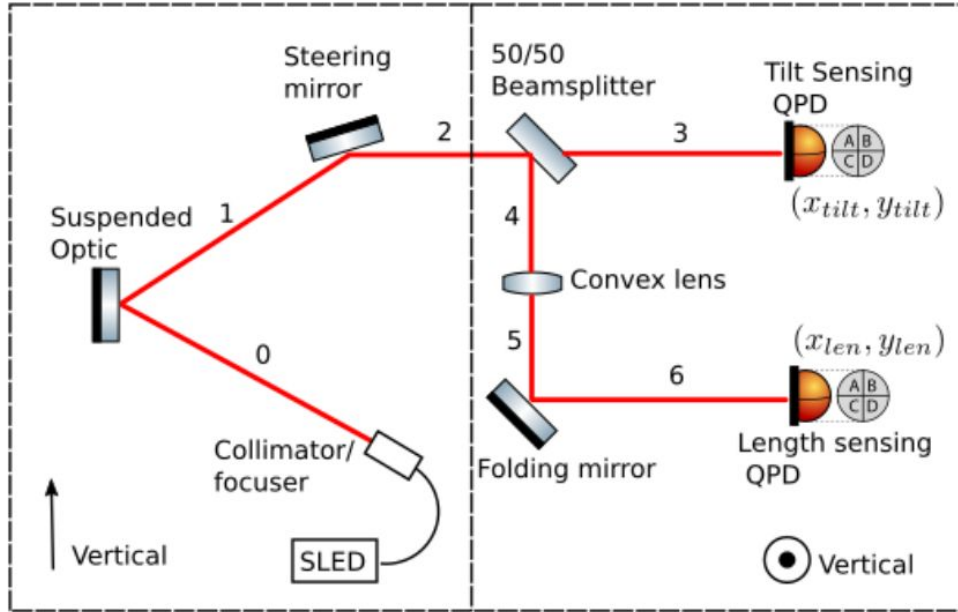


*Actual signs are flipped so the actual displacement readout is accessible

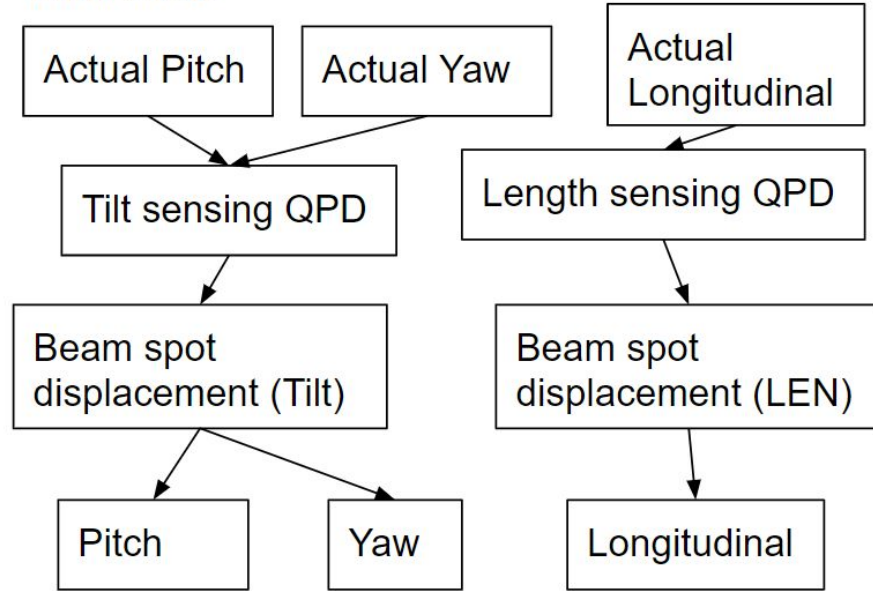
TM Displacement Sensing (Optical Lever)



TM Displacement Sensing (Optical Lever)



Ideal case:

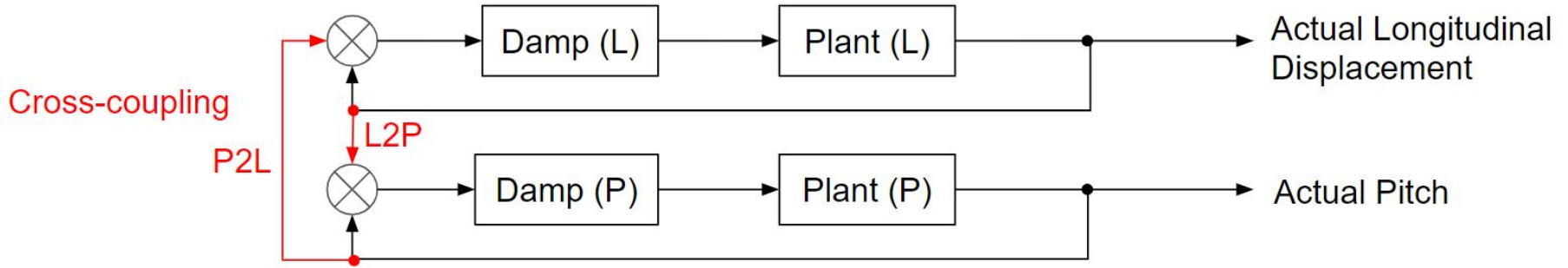


Reality: Measured L, P and Y are all cross-coupled

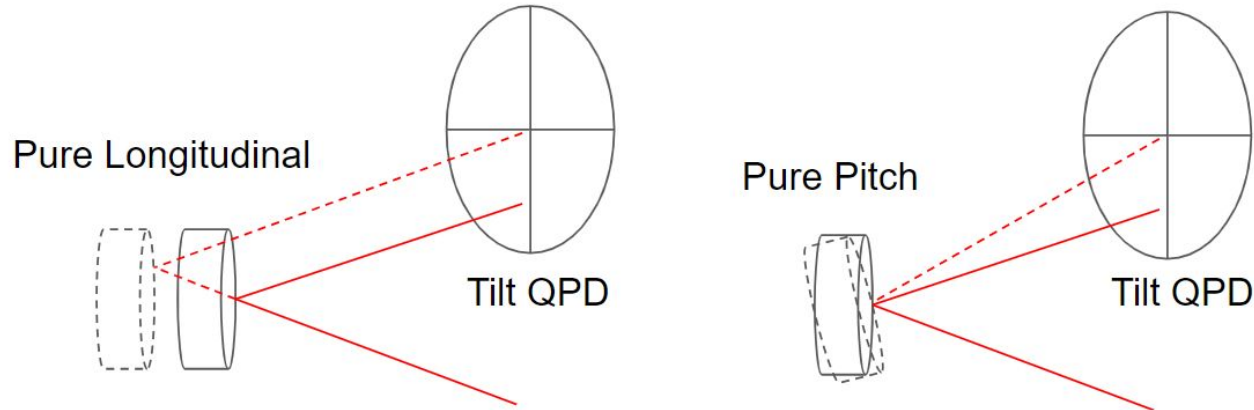
➔ Require Diagonalization!

Diagonalization why?

1. Damping control

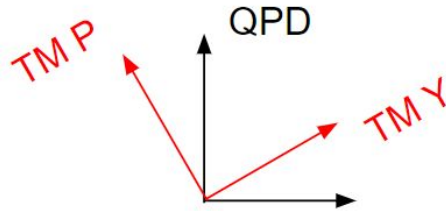


2. Alignment



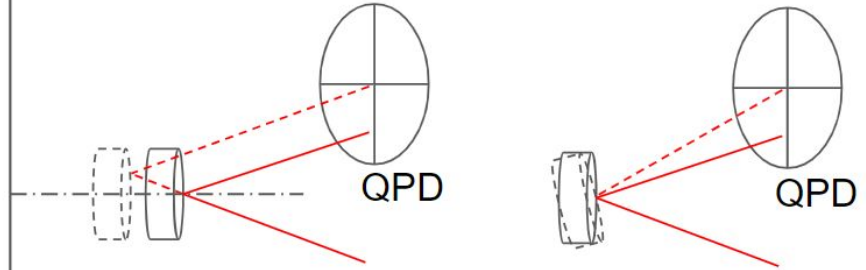
Cross-coupling Mechanisms

1. Pitch to Yaw/ Yaw to Pitch



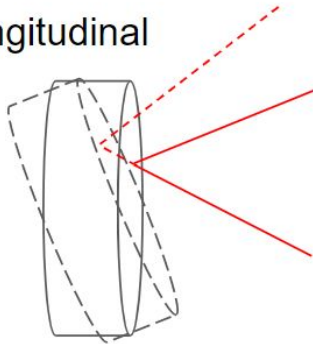
Due to misalignment. (Tilt in steering mirror, etc)

2. Longitudinal to Tilt



Due to non-zero angle of incidence. (P and Y)

3. Tilt to Longitudinal



Due to off-centered beam

4. Others

E.g. Misplacement of Length sensing QPD, etc.

Diagonalization Matrix

$$\begin{pmatrix} L \\ P \\ Y \end{pmatrix} = \left(\begin{pmatrix} 2 \sin \beta & 2\delta_P \sin \beta & 2r_Y + 2\delta_Y \sin \beta \\ 2\delta_Y \sin \alpha & 2r_P + 2\delta_P \sin \alpha & 2 \sin \alpha \\ \frac{-2f \sin \alpha}{r_l - f} & \frac{-2f\delta_P \sin \alpha}{r_l - f} & \frac{-2f\delta_Y \sin \alpha}{r_l - f} \end{pmatrix}^{-1} \begin{pmatrix} \cos \theta_t & \sin \theta_t & 0 & 0 \\ -\sin \theta_t & \cos \theta_t & 0 & 0 \\ 0 & 0 & -\sin \theta_l & \cos \theta_l \end{pmatrix} \begin{pmatrix} x_{tilt} \\ y_{tilt} \\ x_{len} \\ y_{len} \end{pmatrix} \right)$$

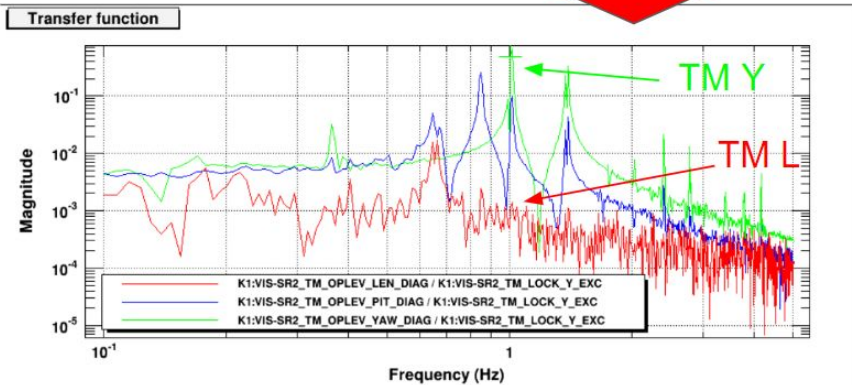
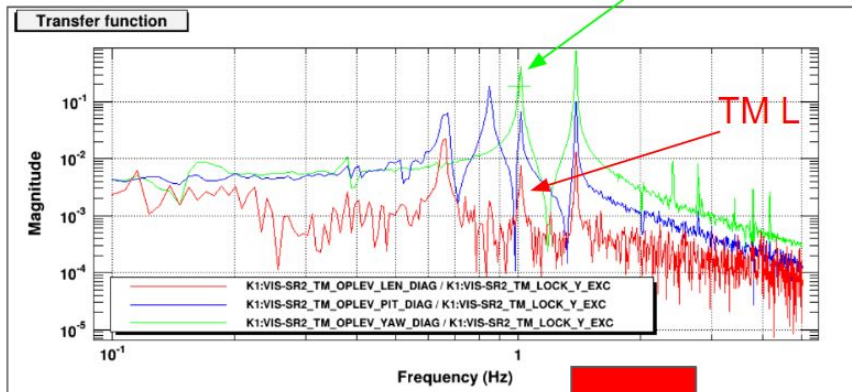
↑
 Optic displacement
 Longitudinal, Pitch and Yaw

↑
 Diagonalization matrix

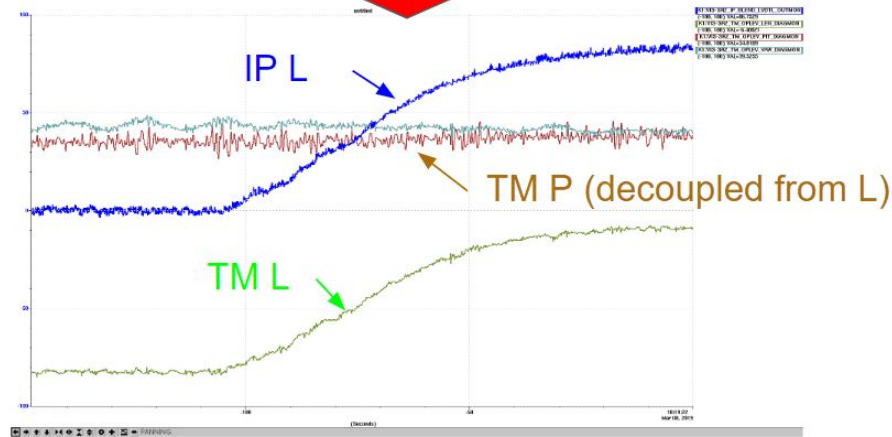
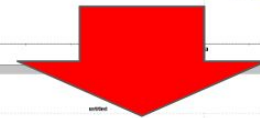
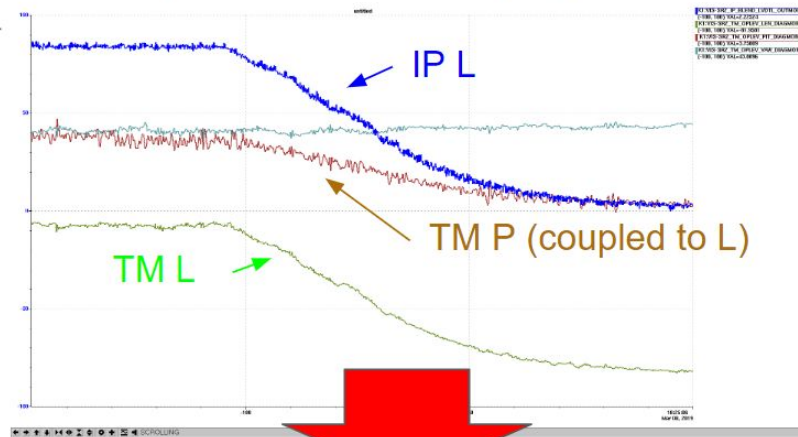
↑
 QPD readouts

Result: All coupling ratios well below 0.01

Yaw to Longitudinal coupling:



Longitudinal to Pitch coupling:



Thank you.