Type B Seismic Attenuation System

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

Tsang Terrence Tak Lun
The Chinese University of Hong Kong

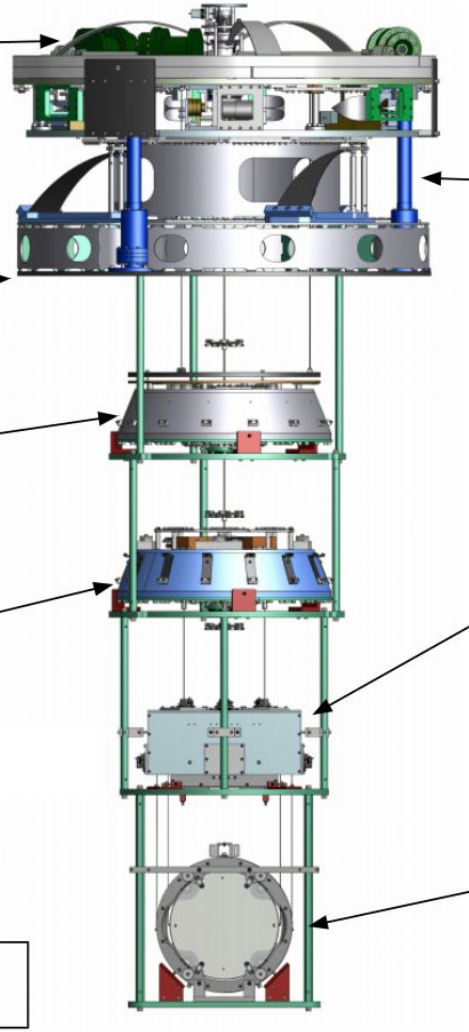
On behalf of the VIS Type B team

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

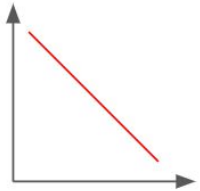
6. Optic (Test Mass/Recoil Mass)

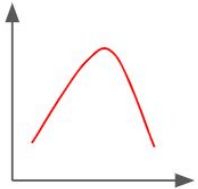
- Longitudinal
- Pitch
- Yaw

- Actuatable degrees of freedom

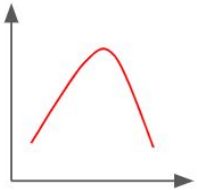
Local Control Required

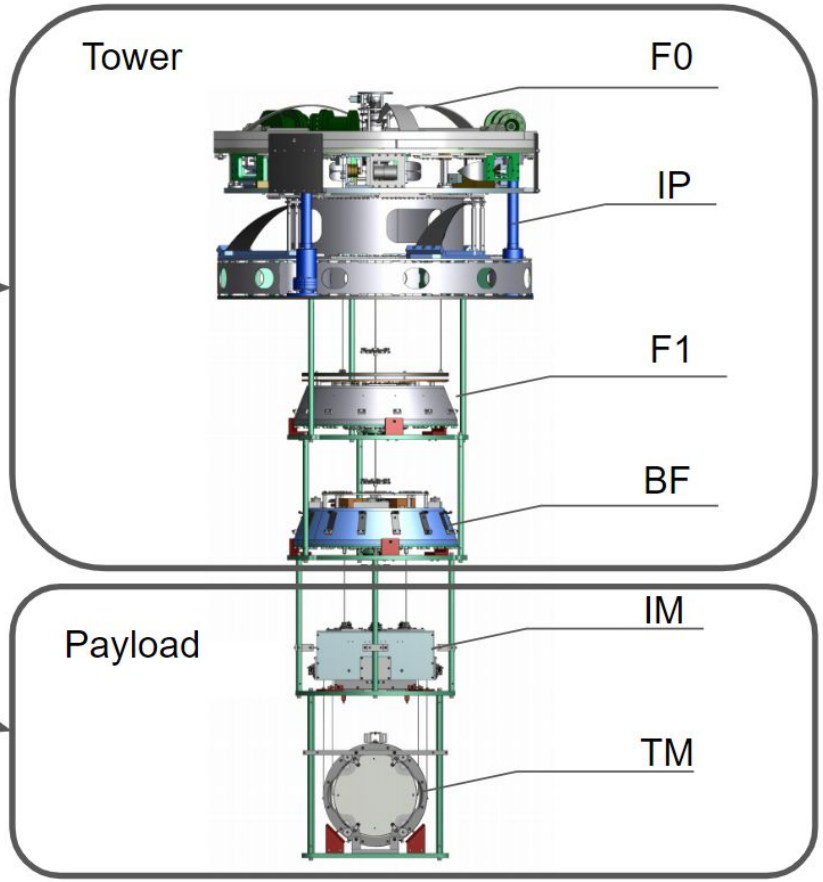
Displacement control* + Damping control





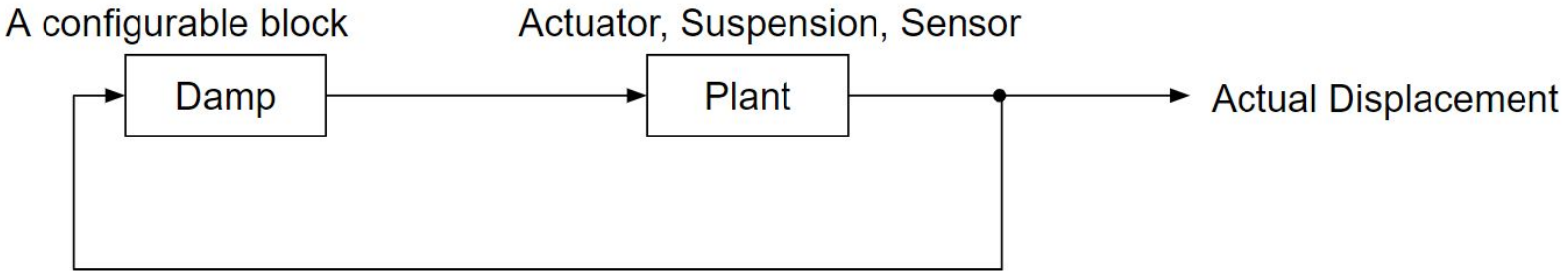
Damping control**



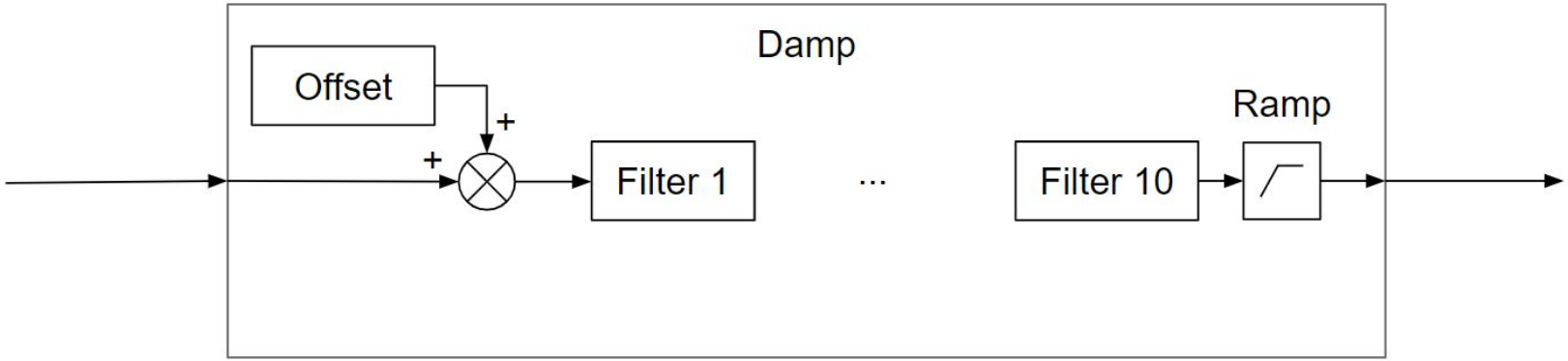


* A.K.A DC control/Integral control/Integrator
** Plus IM to TM angular displacement control, not to be discussed.

Control Topology (Previous)

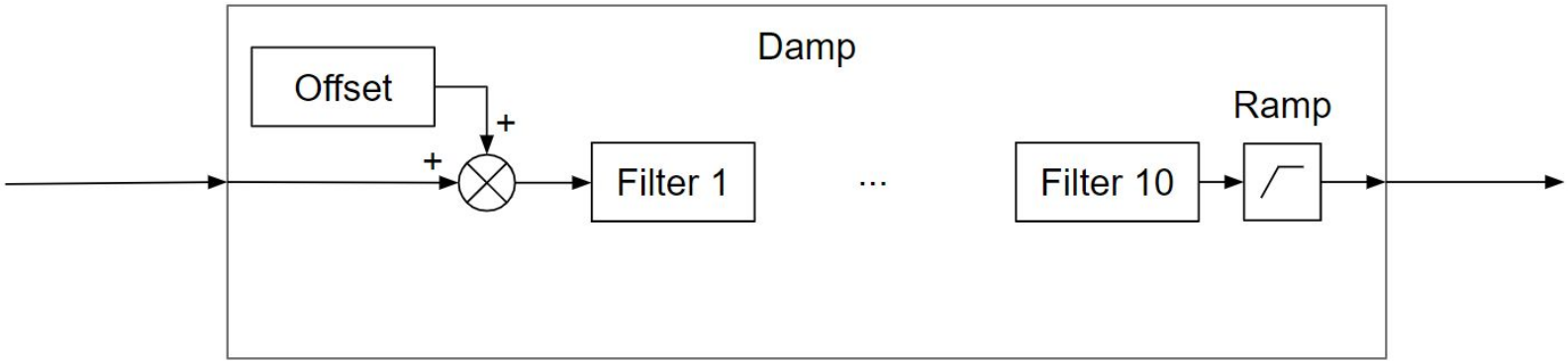


Inside the “Damp” block:



Control Topology (Previous)

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



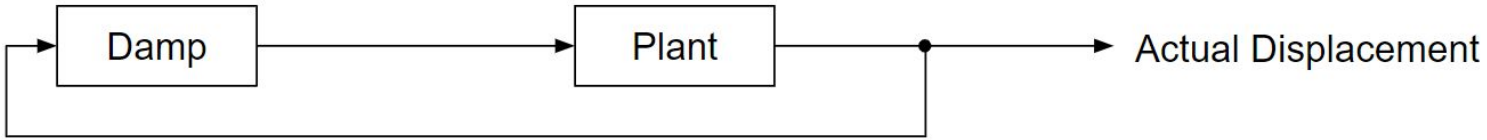
Control Topology (Previous)

Problems:

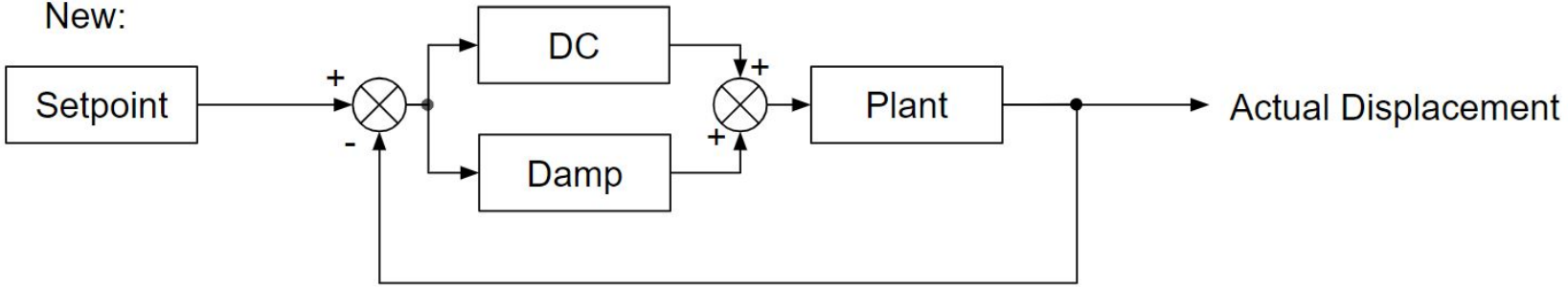
1. Requires -1 in every block.
2. Change of setpoint is sharp.
3. Offset is NEGATIVE setpoint
4. Displacement control and Damping control are coupled.

Changes in the Control Topology

Old:

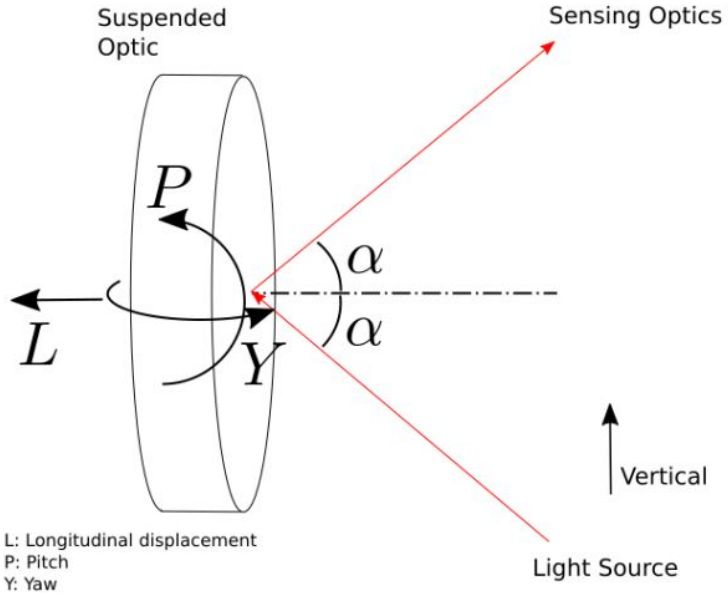


New:

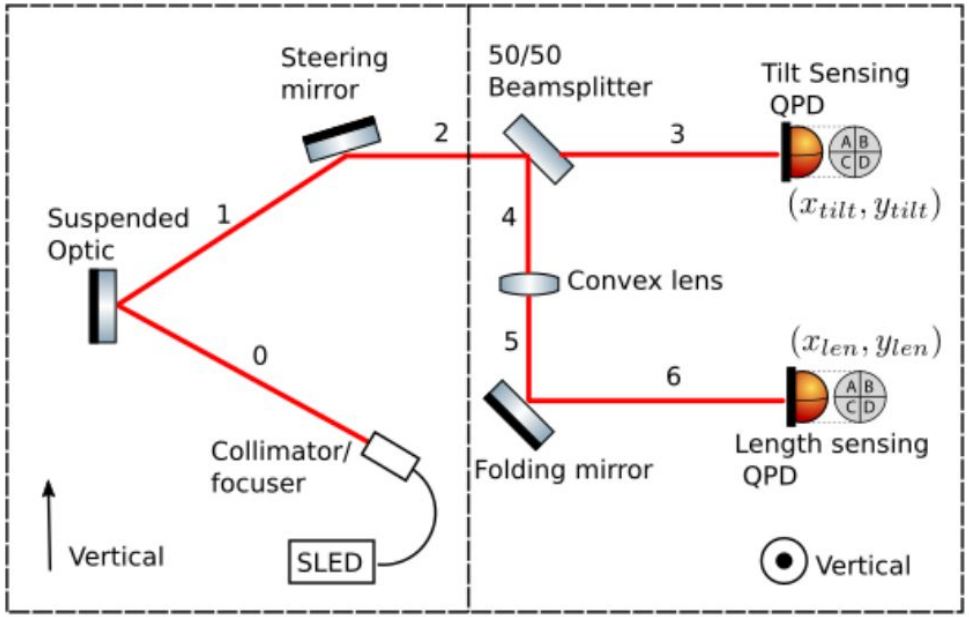


*Actual signs are flipped so the actual displacement readout is accessible

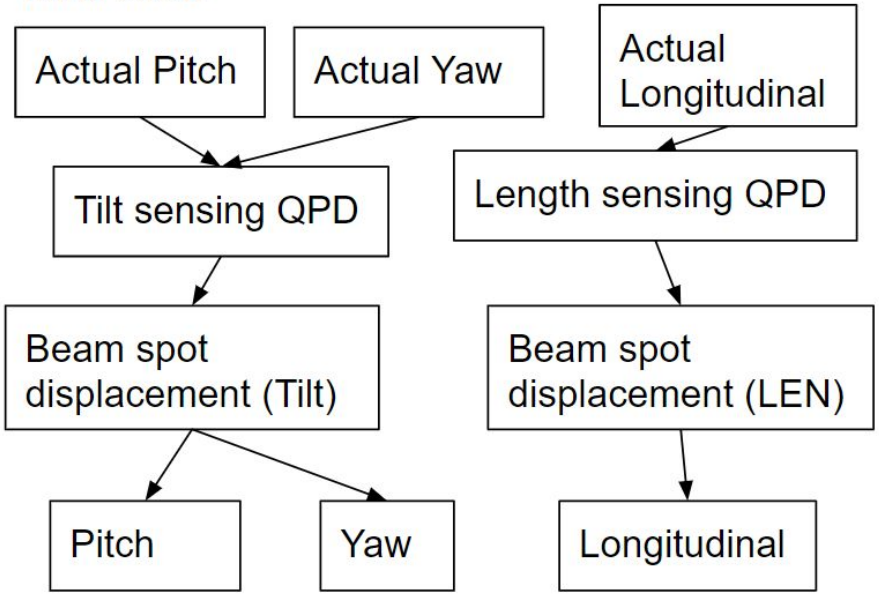
TM Displacement Sensing (Optical Lever)



TM Displacement Sensing (Optical Lever)



Ideal case:



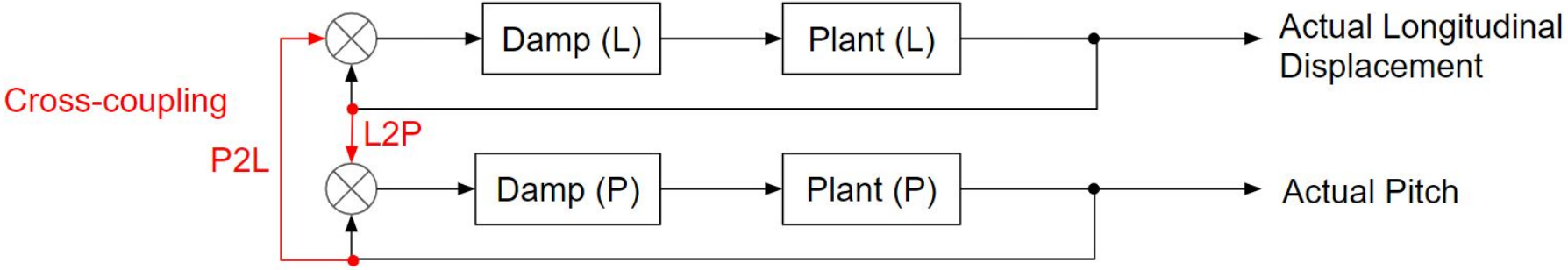
Reality: Measured L, P and Y are all cross-coupled

Require Diagonalization!

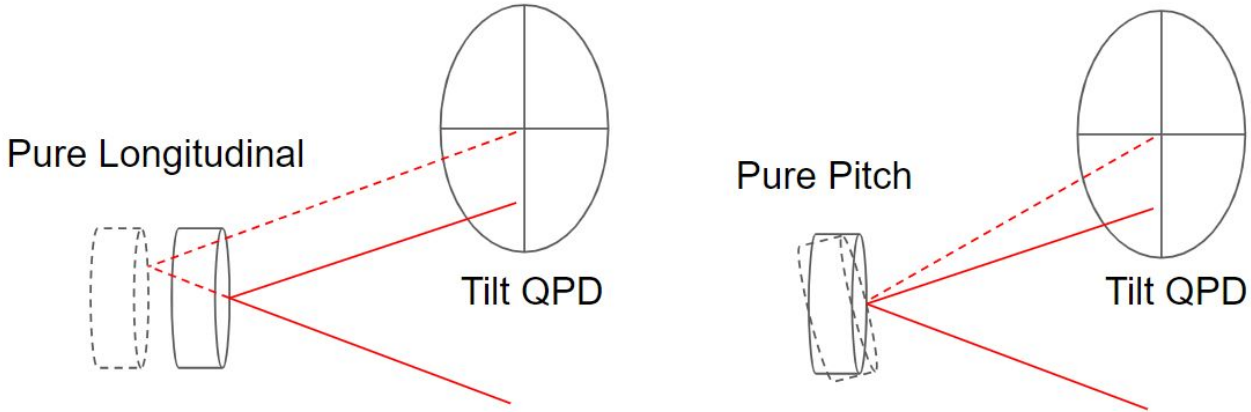
QPD: Quadrant photodiode

Diagonalization why?

1. Damping control

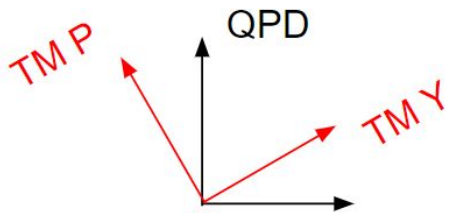


2. Alignment



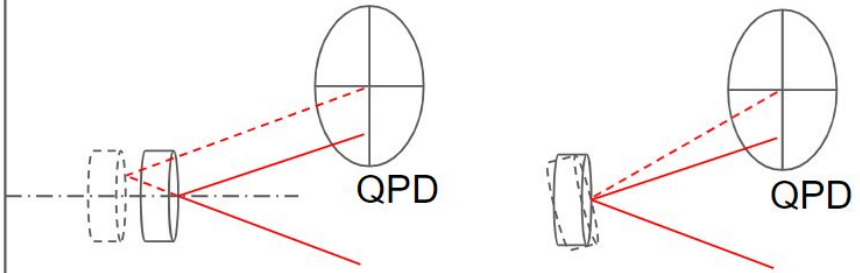
Cross-coupling Mechanisms

1. Pitch to Yaw/ Yaw to Pitch



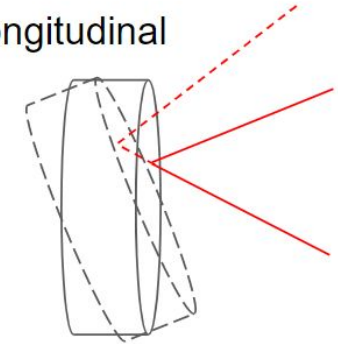
Due to misalignment. (Tilt in steering mirror, etc)

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

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

Optic displacement
Longitudinal, Pitch and Yaw

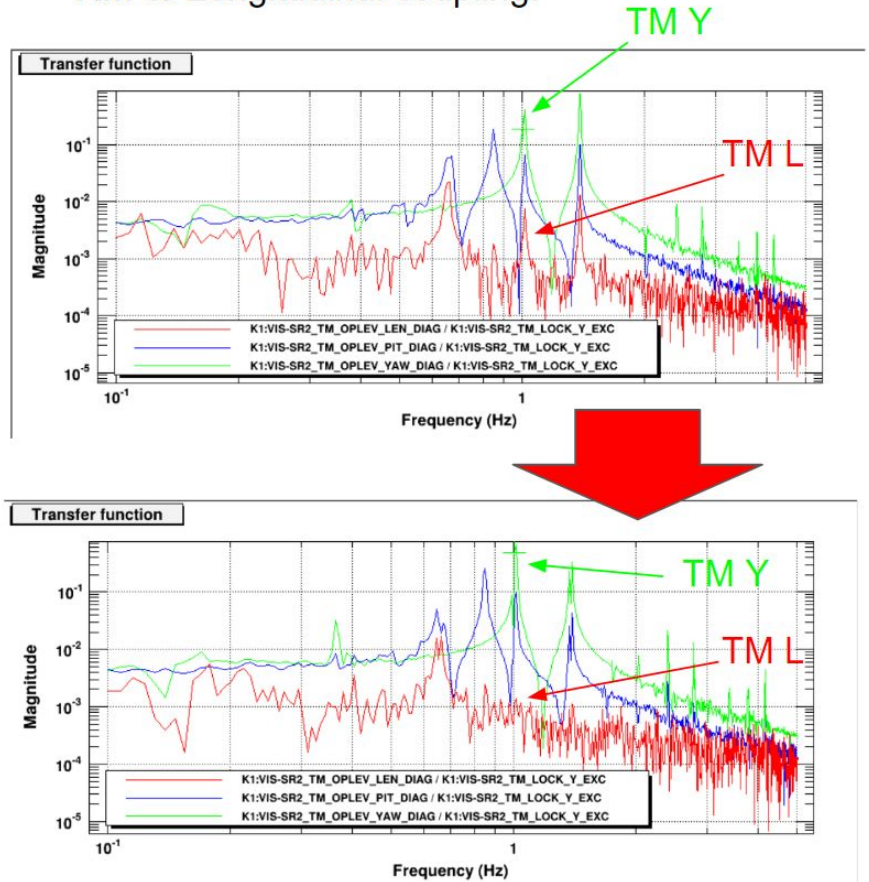
Diagonalization matrix

QPD readouts

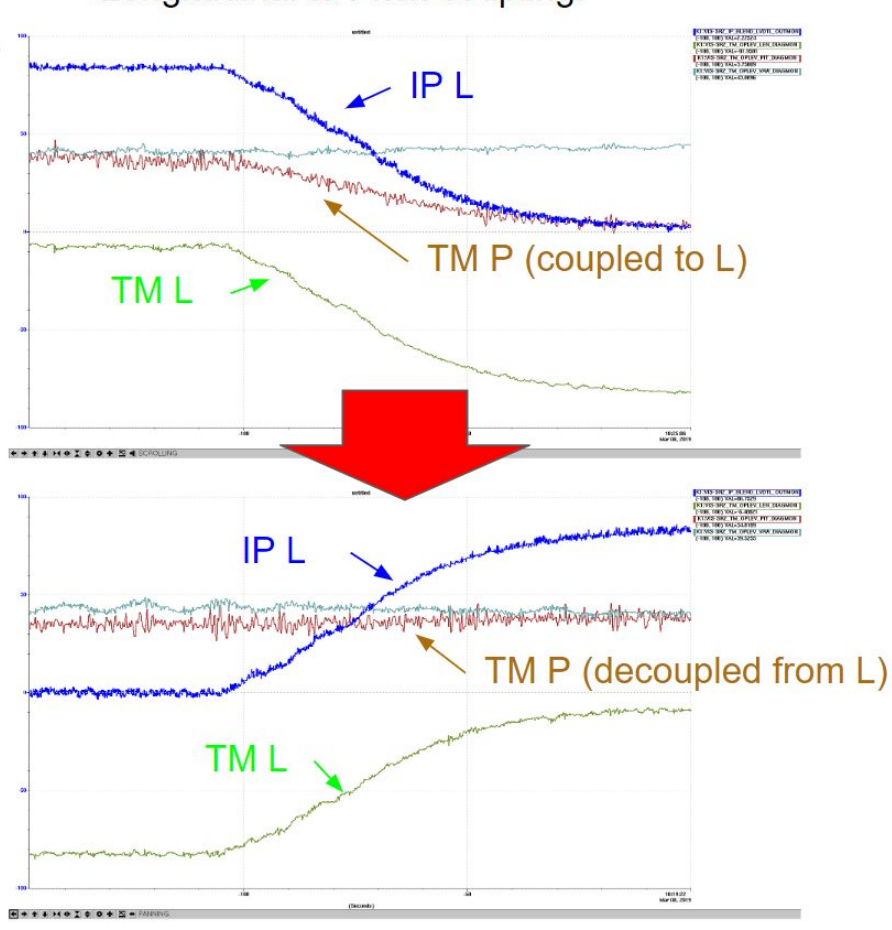
α,β: angle of incidence
δy,δp: off-center displacement
f: focal length of convex lens
r: arm length
θ: rotation angle for the transformation

Result: All coupling ratios well below 0.01

Yaw to Longitudinal coupling:



Longitudinal to Pitch coupling:



Thank you.