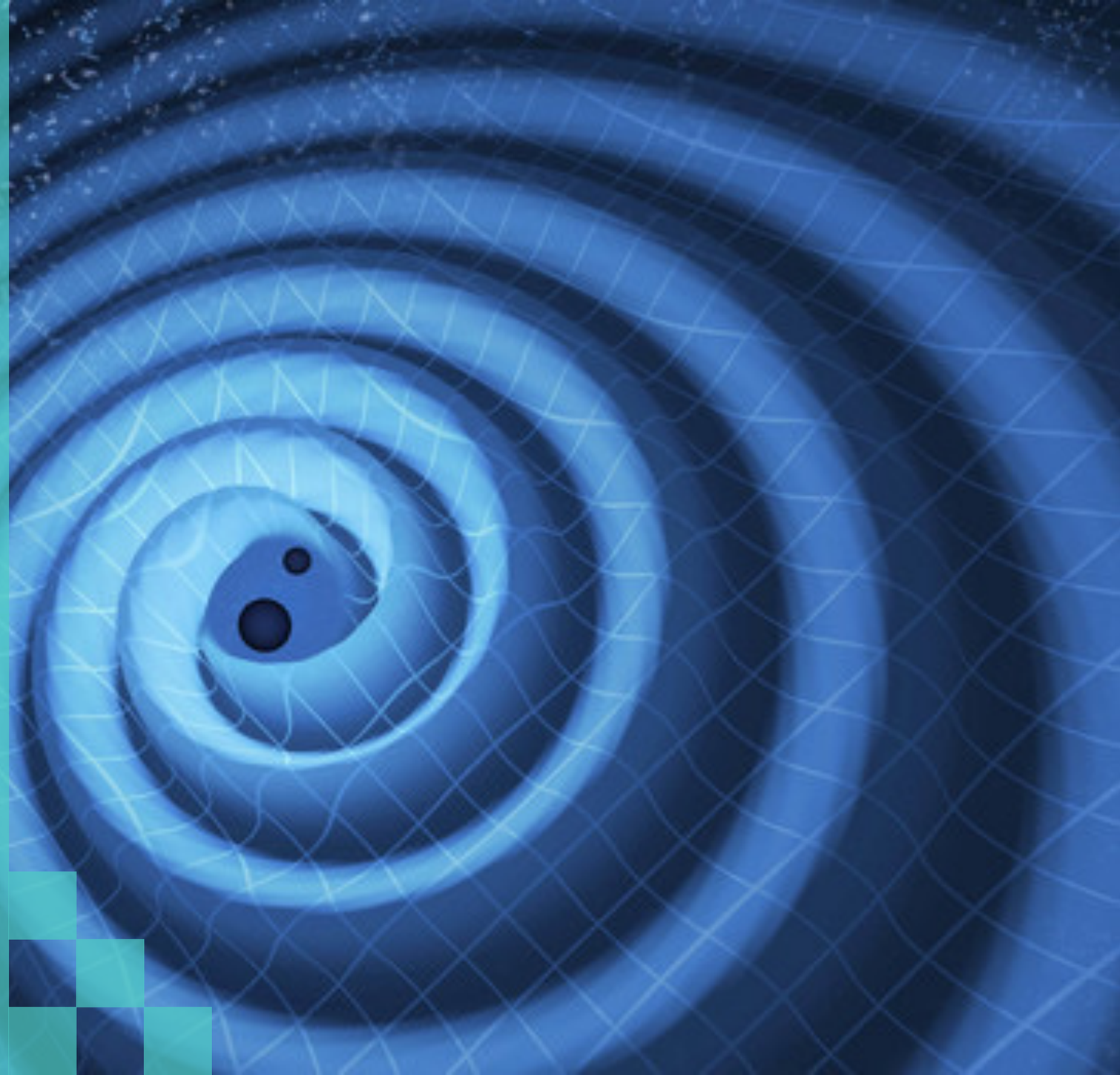
NCU Michelson Interferometer Test Facility

On behalf of NCU & AS Gravitational Waves Research Group

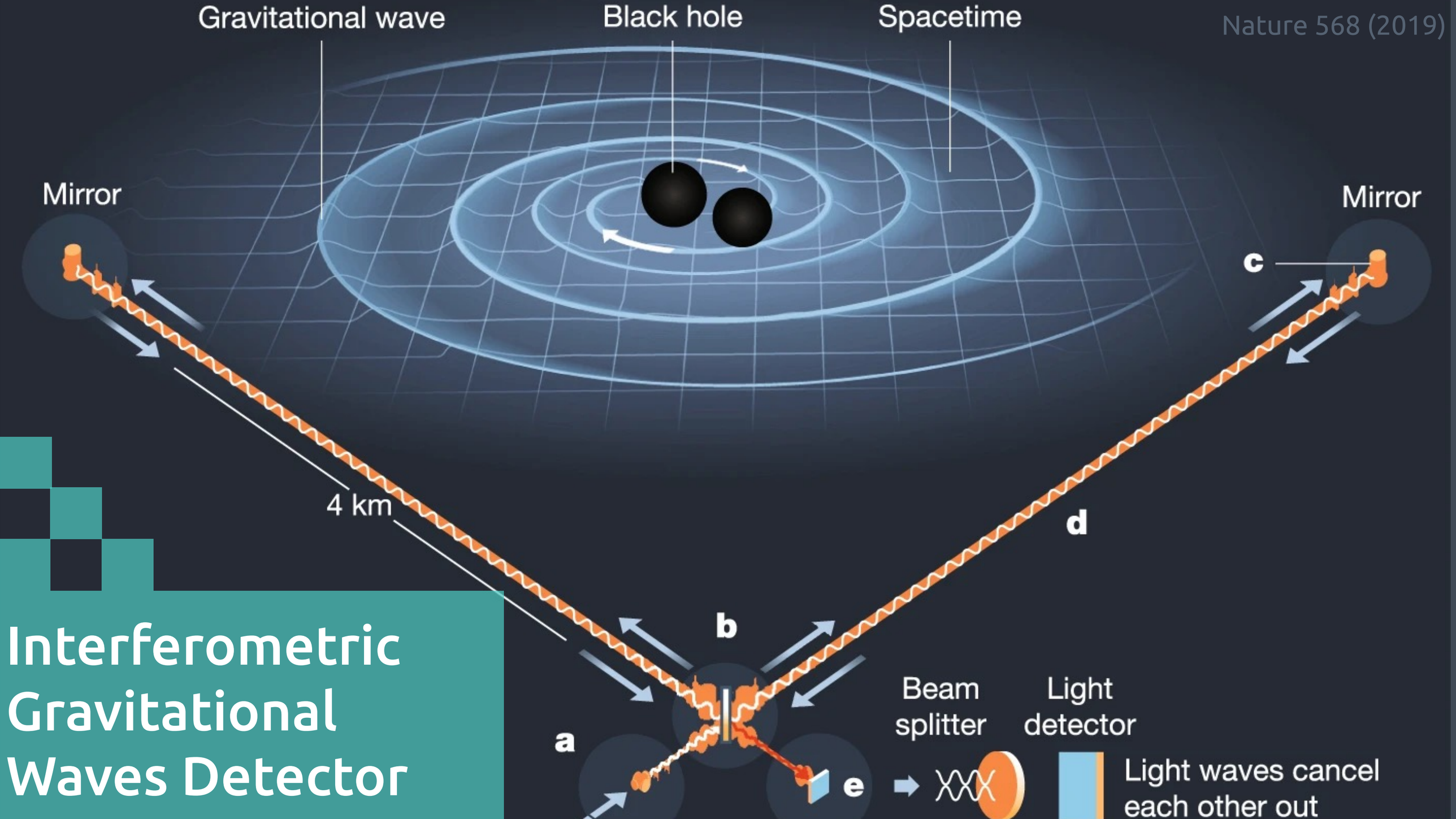
M. Ma'arif, A. Patel, D. Tanabe, F.K. Lin, H.C. Hsu, H.T. Wong,
H.Y. Huang, Y. Inoue, J. Chan, Y.S. Lin, T.C. Yu, Y.R. Lee

Gravitational Waves

'ripples' in space-time caused by some of the most violent and energetic processes in the Universe.

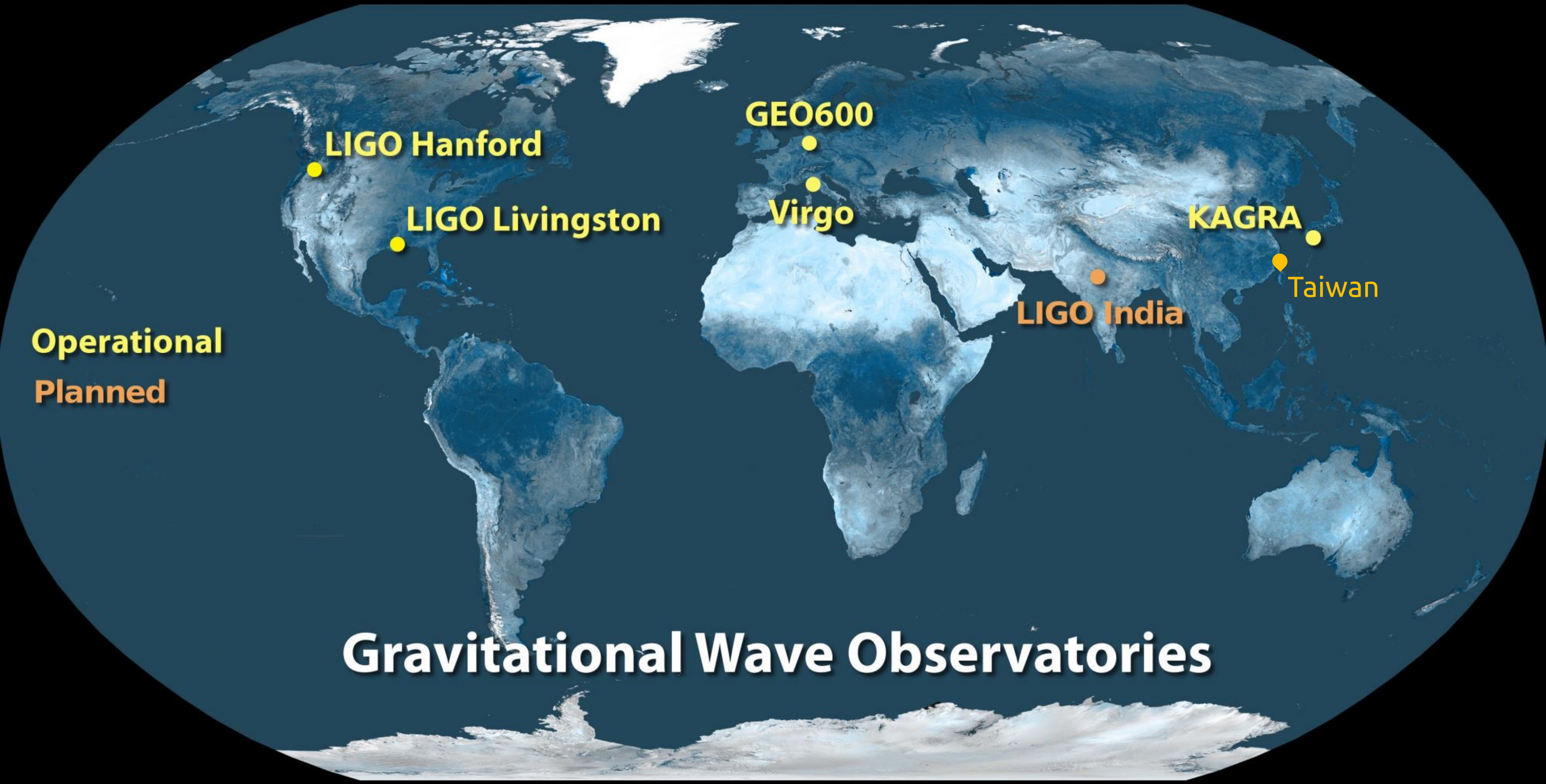


LIGO/T.Pyle



Nature 568 (2019)

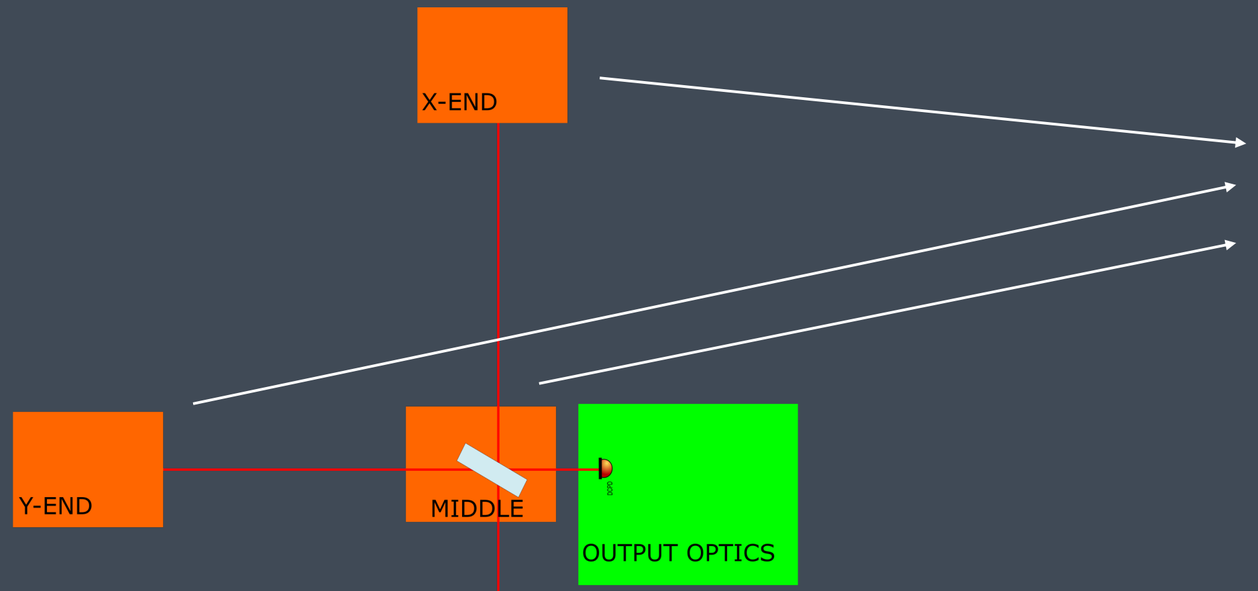
Interferometric Gravitational Waves Detector

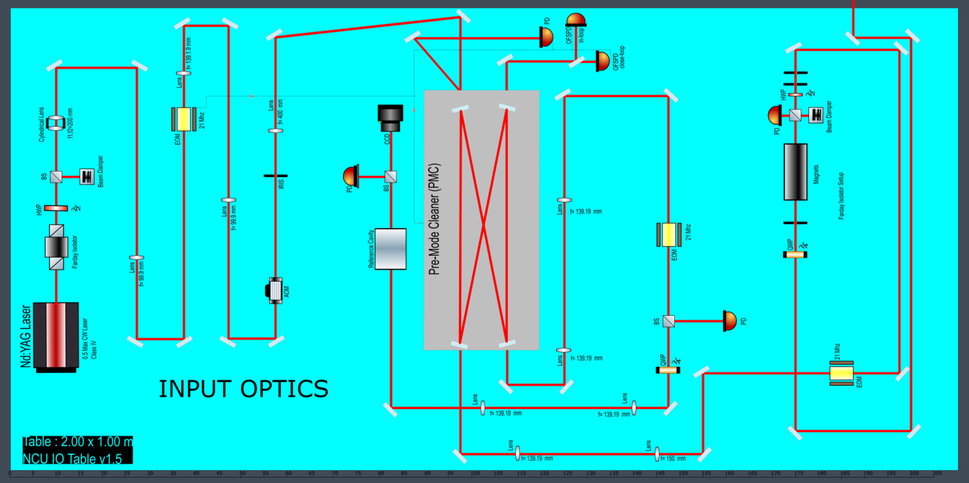


LIGO Caltecth

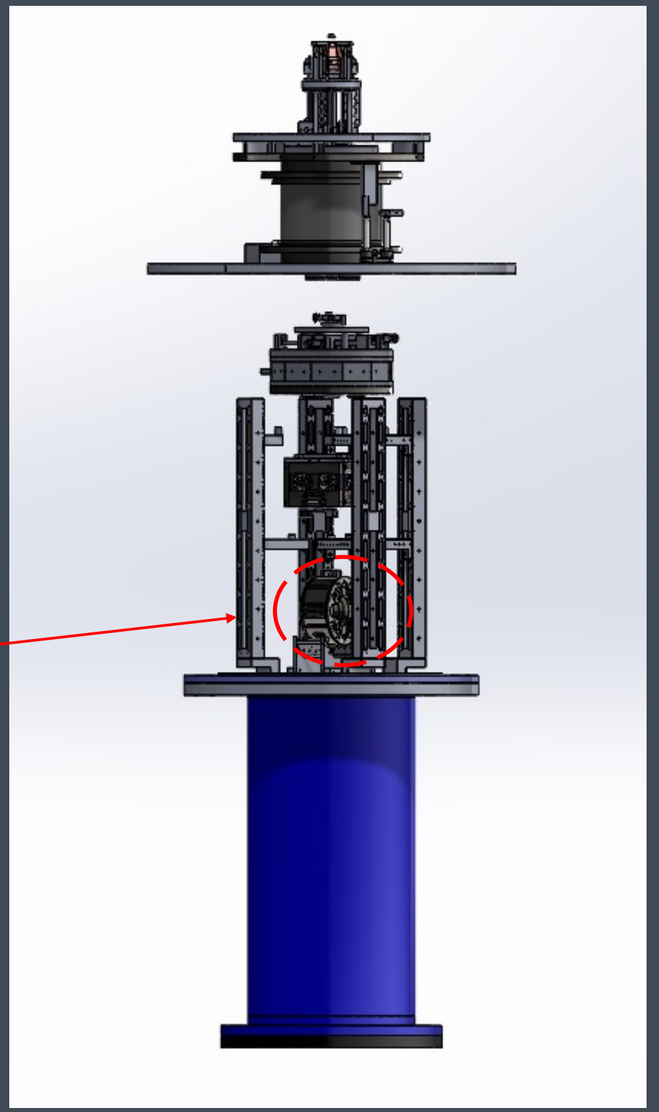
NCU Michelson Interferometer

NCU MIF

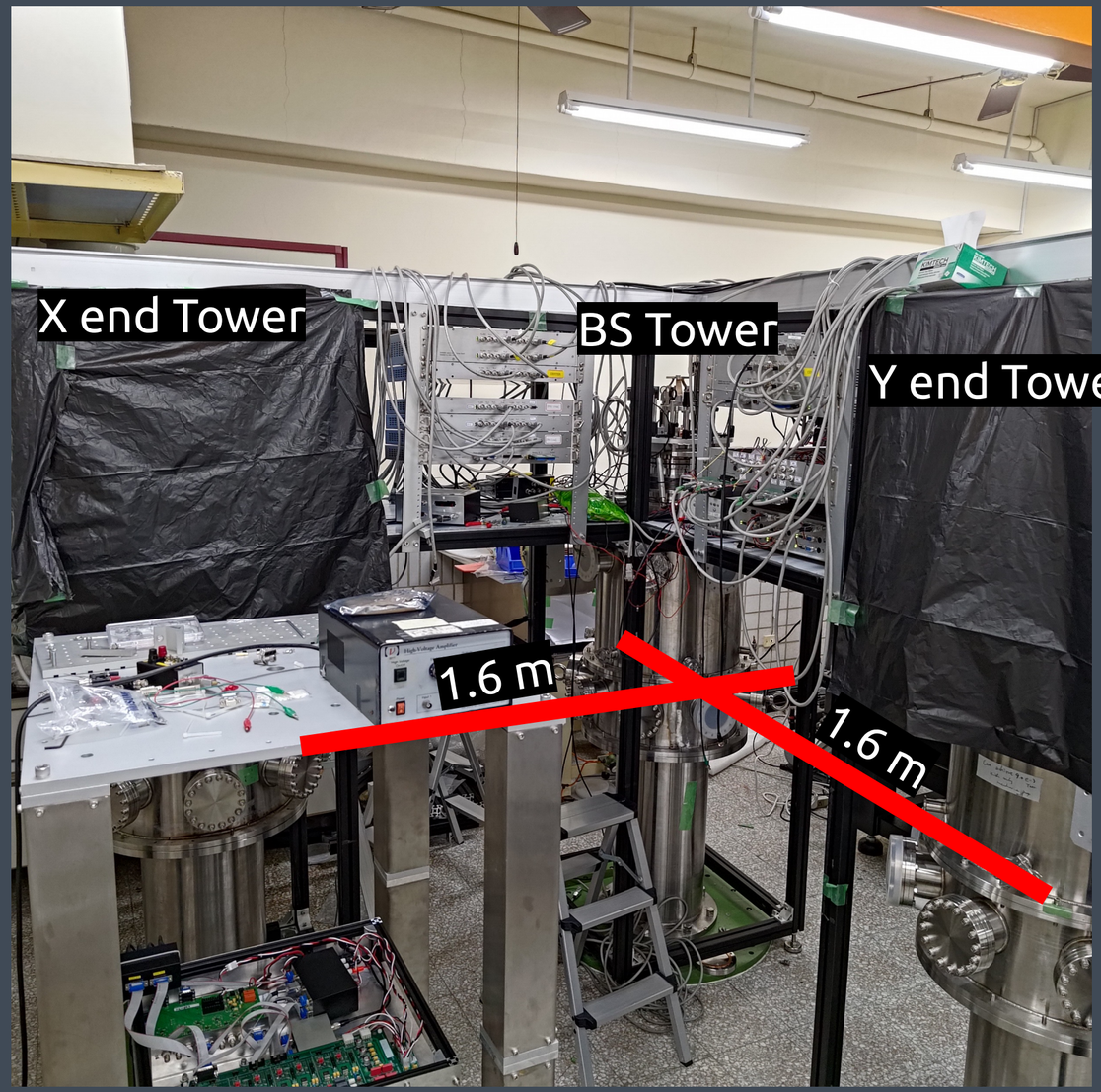


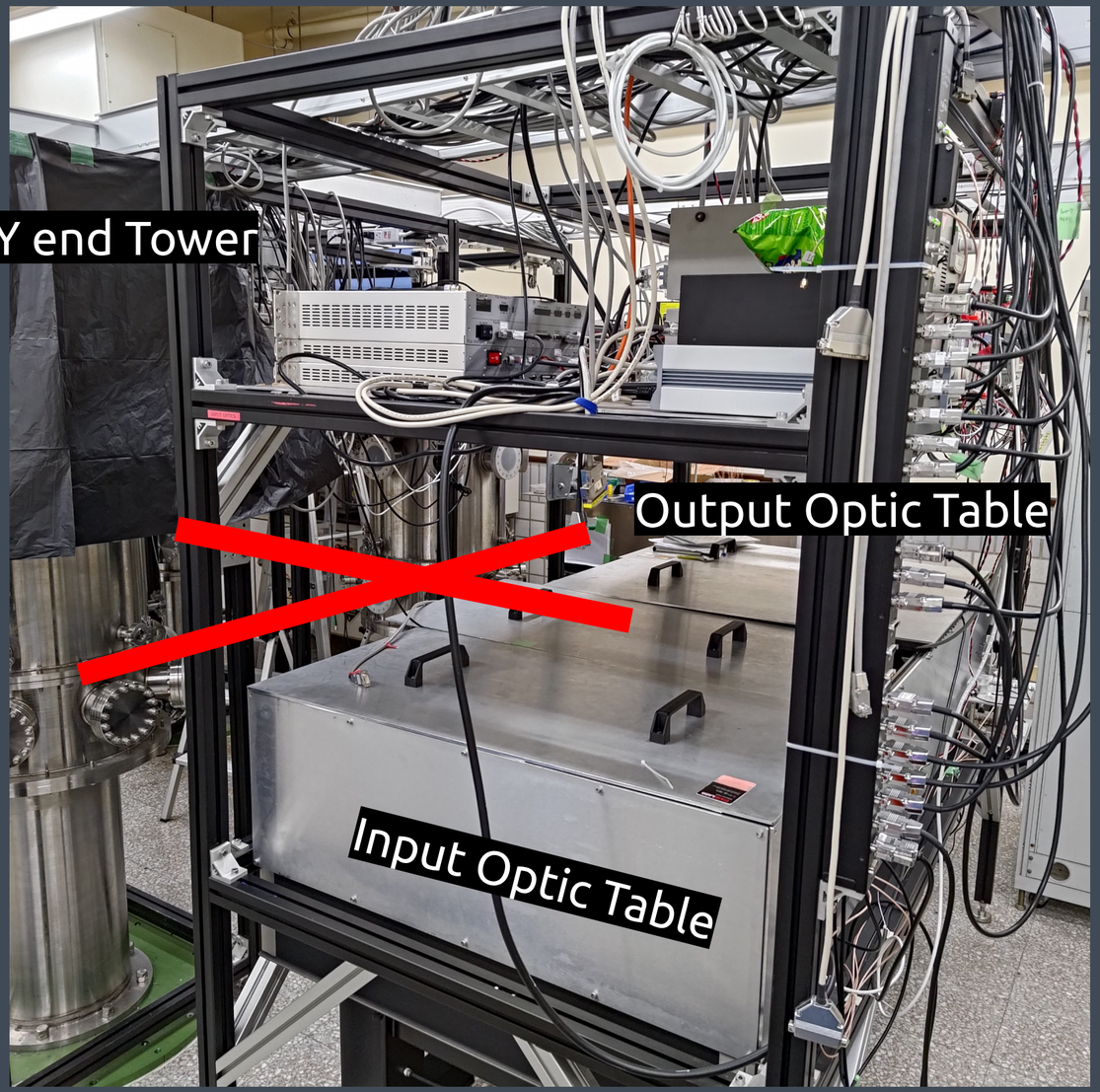


TM Mirrors and BS are suspended by multi-stages pendulum structure.

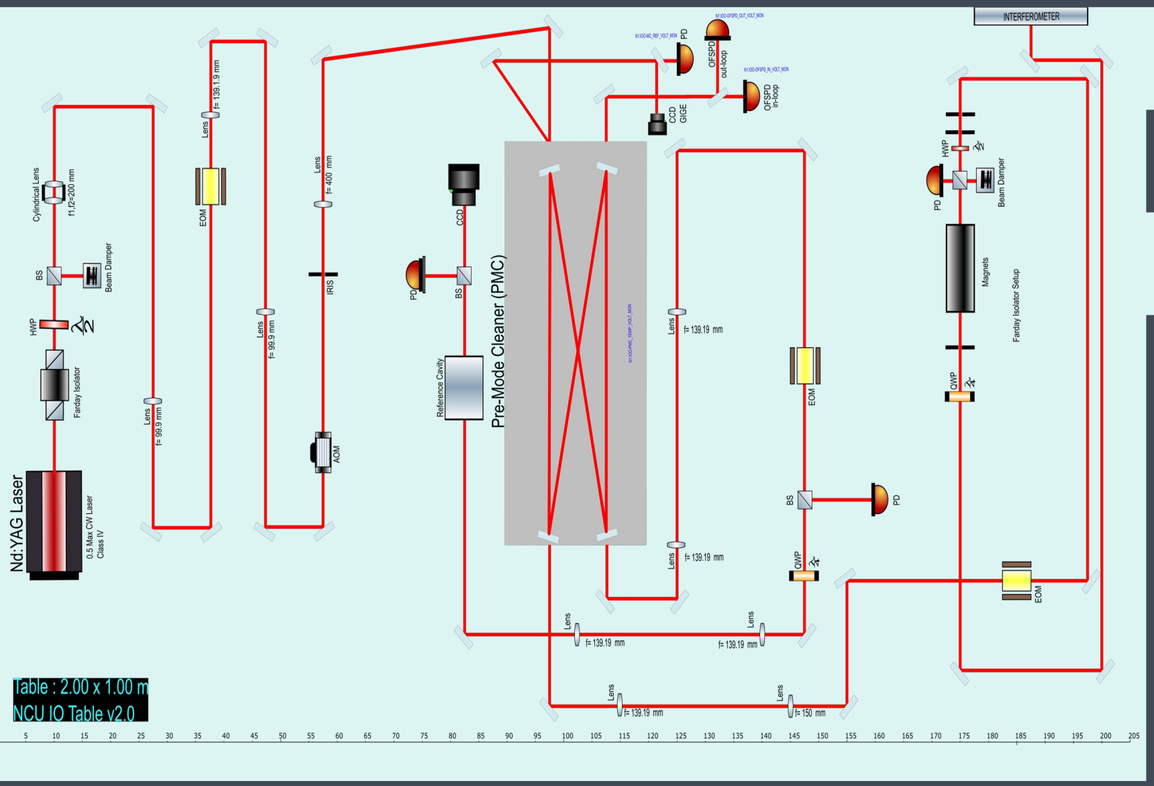


NCU Michelson Interferometer





Input Optic



$$E(x,y)=Aexp(i\omega t)$$

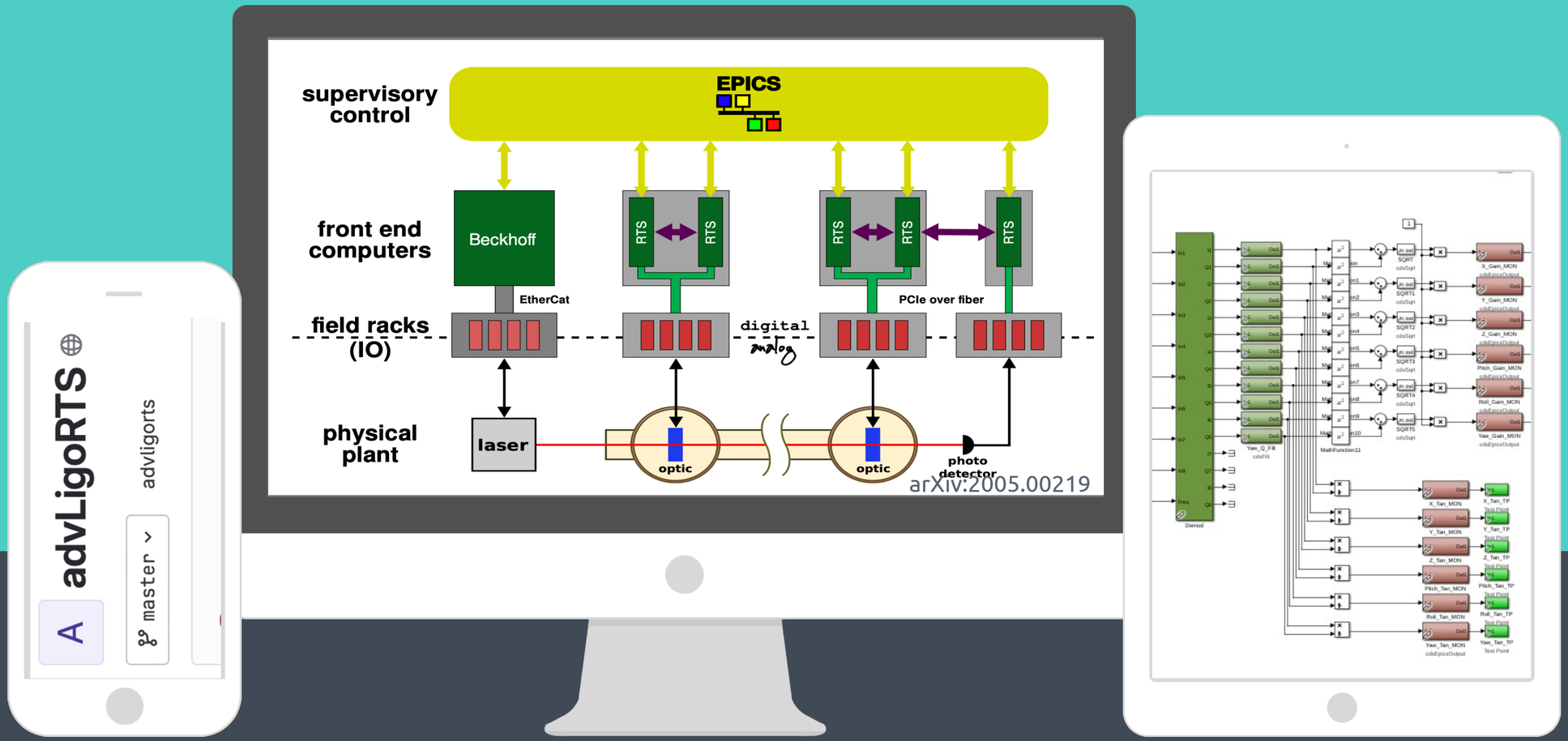
Beam Intensity Phase

Mode cleaner	Intensity Stabilization	Frequency Stabilization

Current work in progress for PMC locking
by John Chan (Msc student)

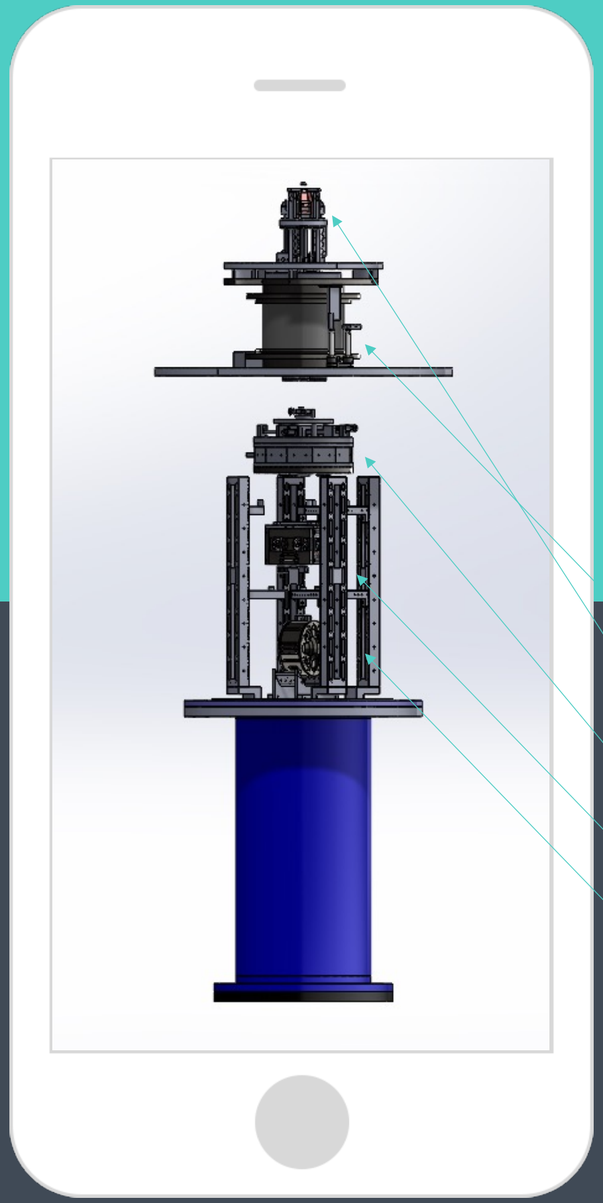
Digital Control System

Sensor/Actuator → AAAI → ADC/DAC → Server → Control PC



Digital Control System

Our computing system use Debian and advLigoRTS (The Advanced LIGO Real-Time Digital Control and Data Acquisition System) which also uses EPICS (Experimental Physics and Industrial Control System).



Vibration Isolation System

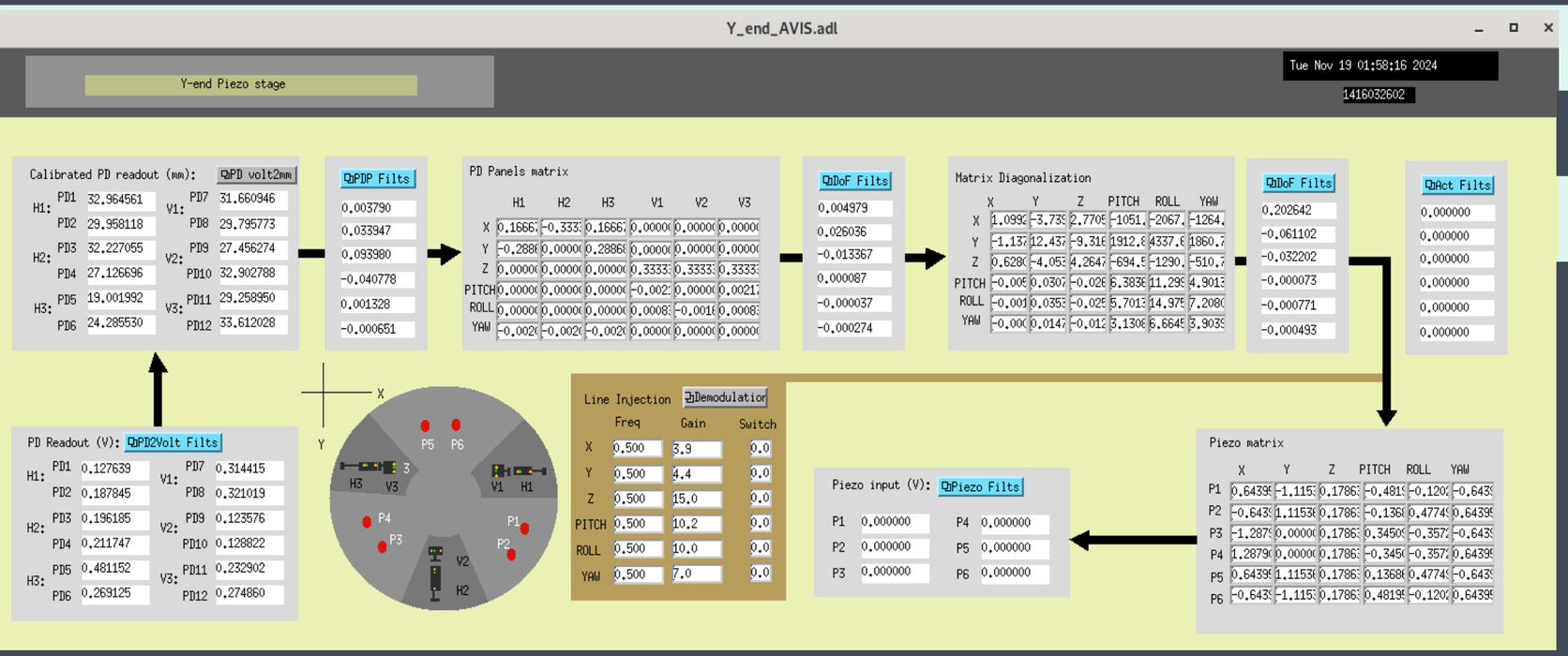
- Piezo Stage
- Top Stage (Inverted Pendulum Stage)
- PM Stage
- IM Stage
- TM Stage

To detect *h(t) GW, TM must remain as motionless as possible which should be isolated from the ground vibrational noise.*

Active Vibration Isolation System

- 6 Piezo + 6 PD Panel (3 vertical + 3 Horizontal)
- Based on these sensor and actuator, we can reconstruct the motion of top plate in 6 DoF to do the feedback control.

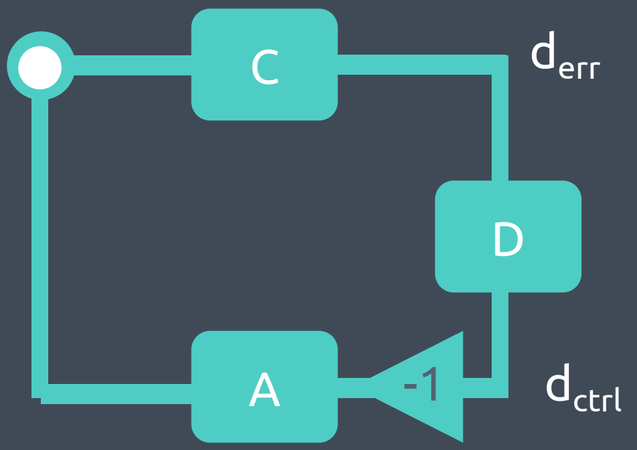
AVIS – Piezo Stage MEDM



MEDM

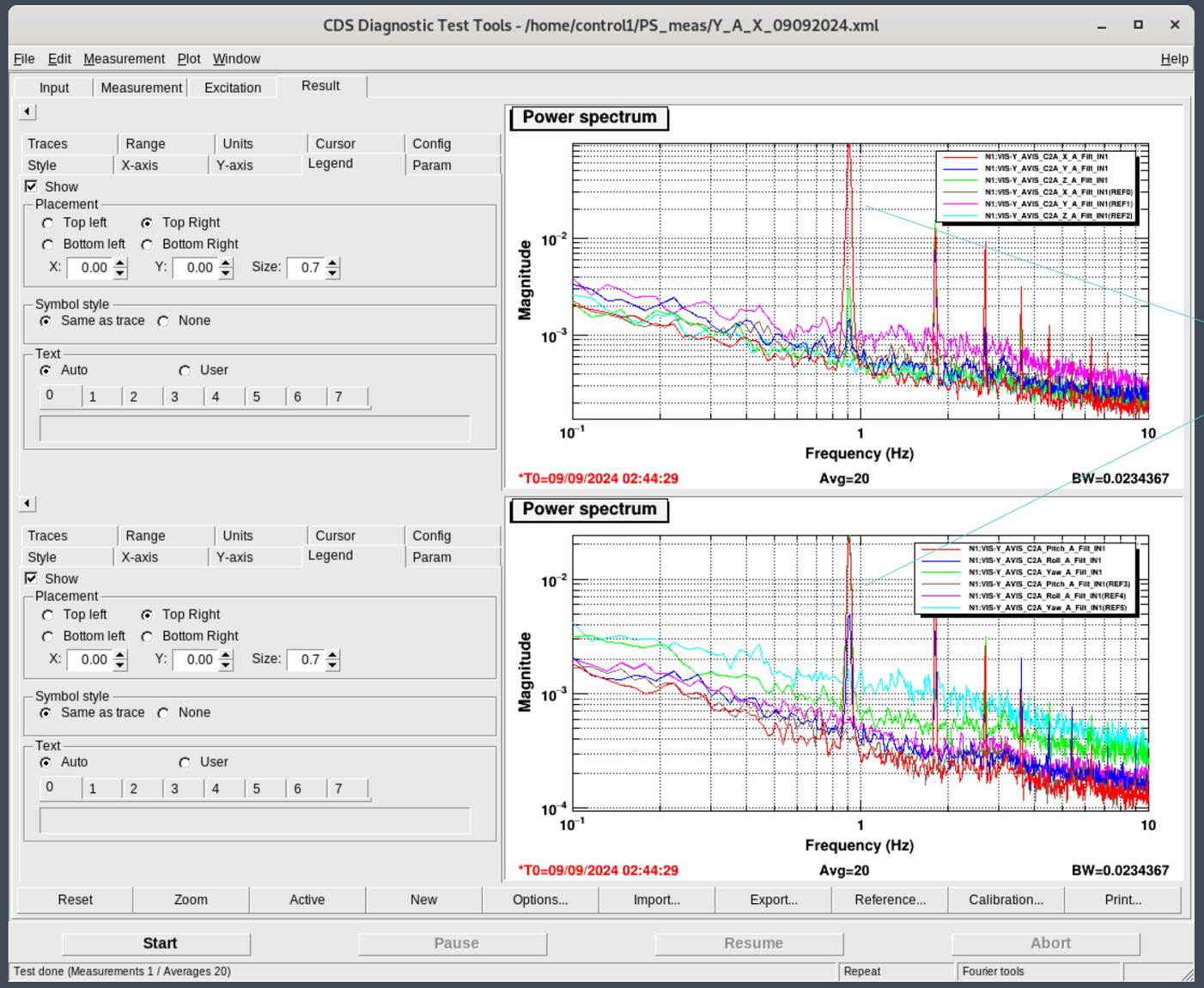
Motif Editor and Display Manager is a GUI for designing and implementing control screens which display the values of EPICS process variables.

We reconstruct 6DoF motion (X, Y, Z, Pitch, Roll, Yaw) based from the sensors and actuators.



Cross-Contamination on 6 DoF

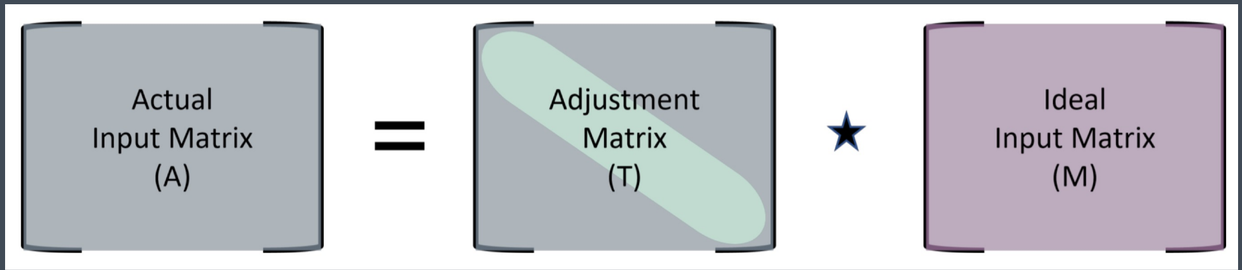
Diagonalization



We injected 0.9 Hz signal on X from the actuators, however from the output of sensor matrix, it showed 0.9 Hz peaks on all 6 DoF.

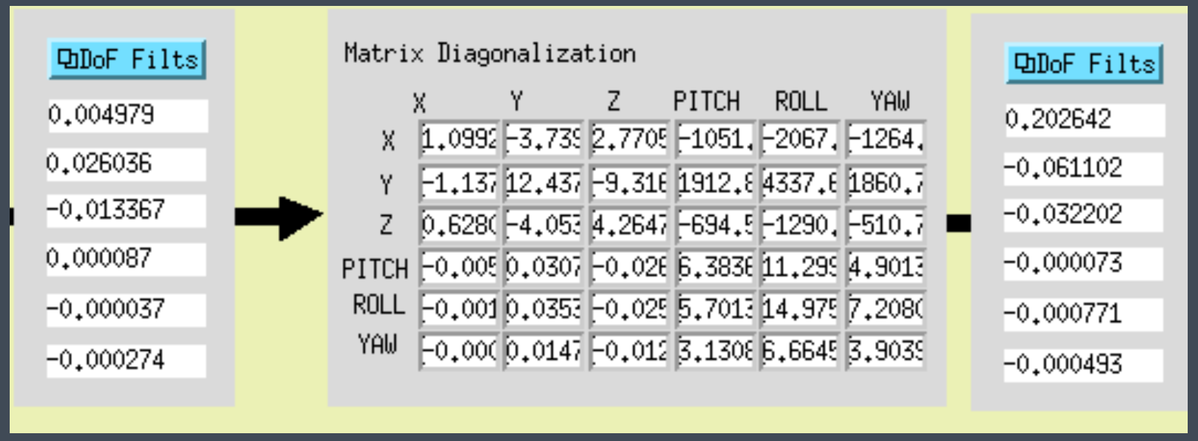
Diaggui – a tools developed by LIGO to measure power spectrum and transfer function.

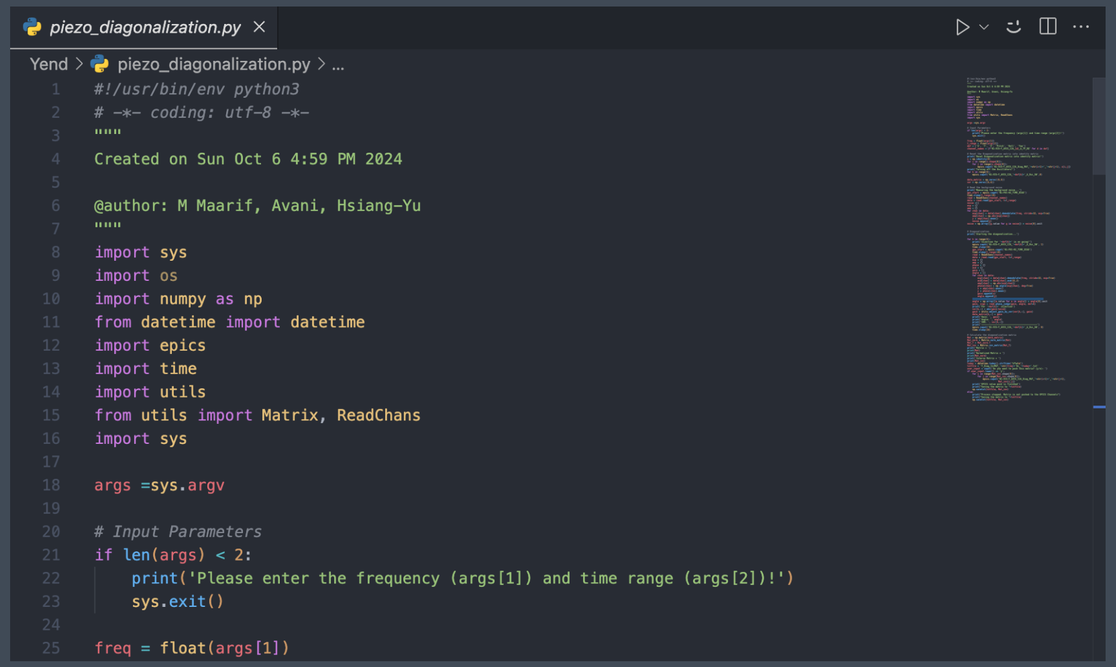
Diagonalization



H.C. Hsu

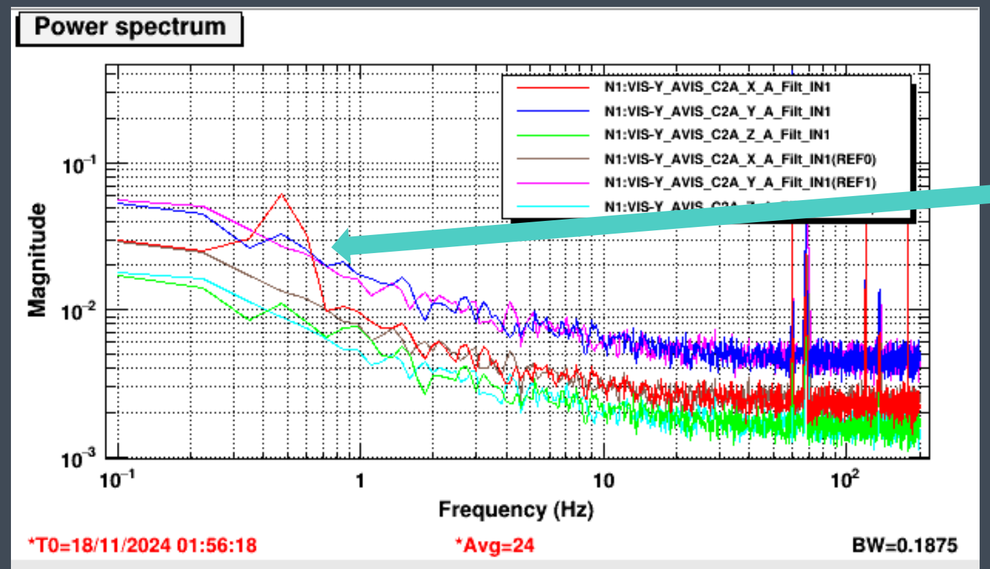
In reality, our actual input matrix is not equivalent to Ideal input matrix, therefore we need to measure the adjustment matrix to calculate its inverse matrix so that we can diagonalize our input matrix.

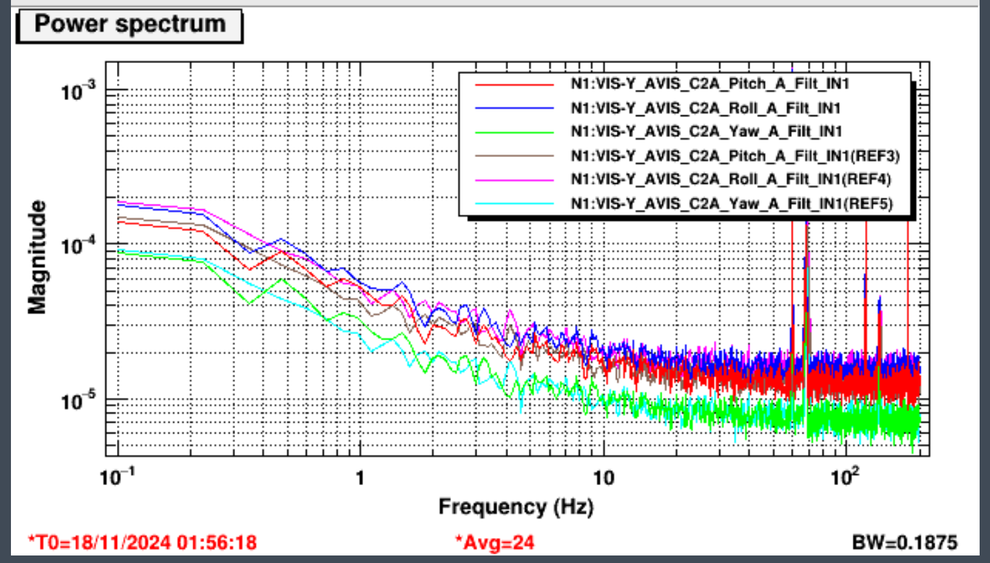




The process to calculate inverse matrix from demodulation is done automatically by python code.

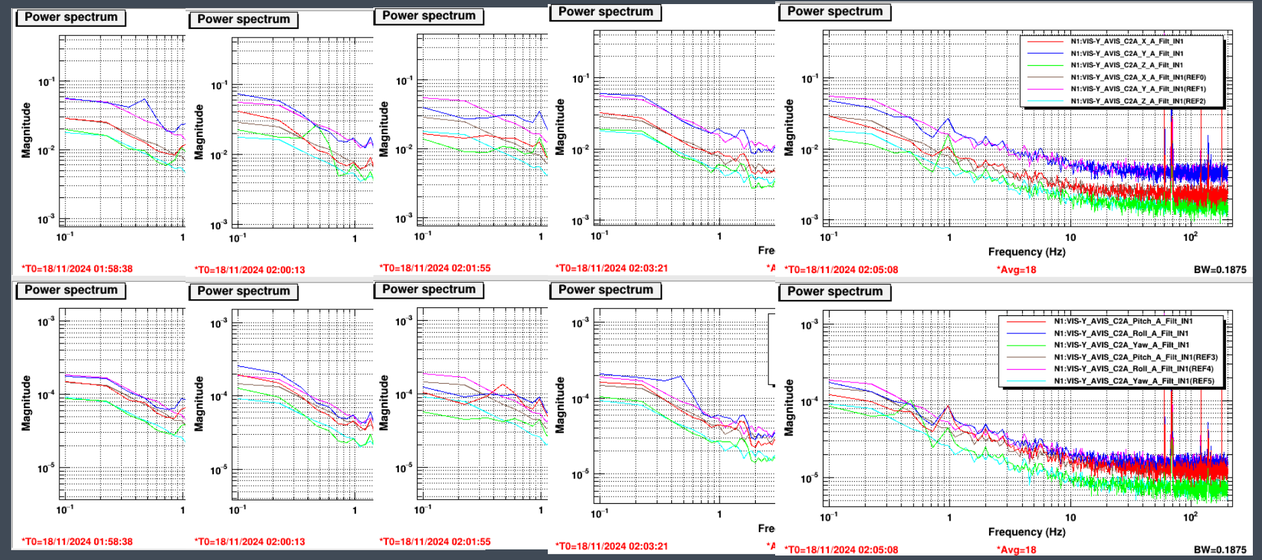
Diagonalization Result



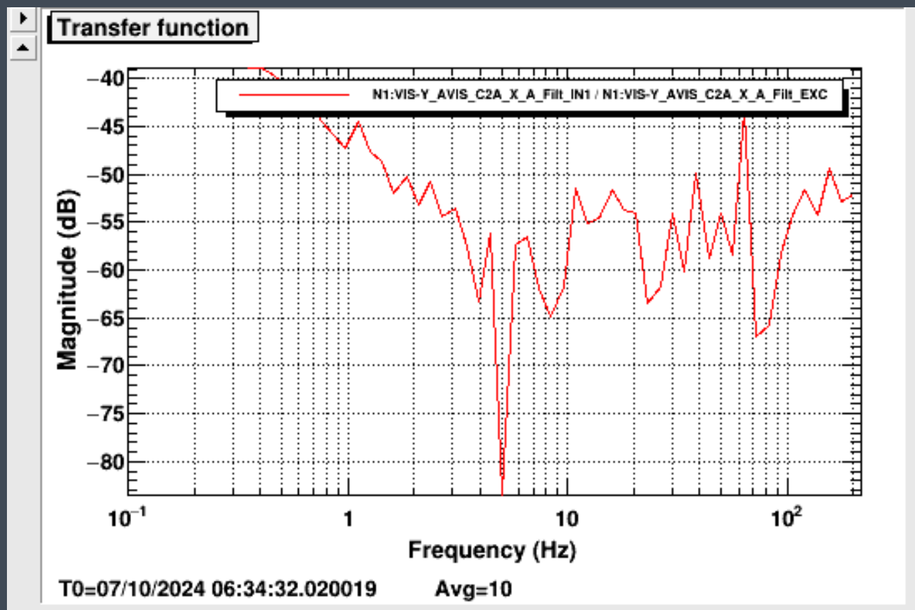


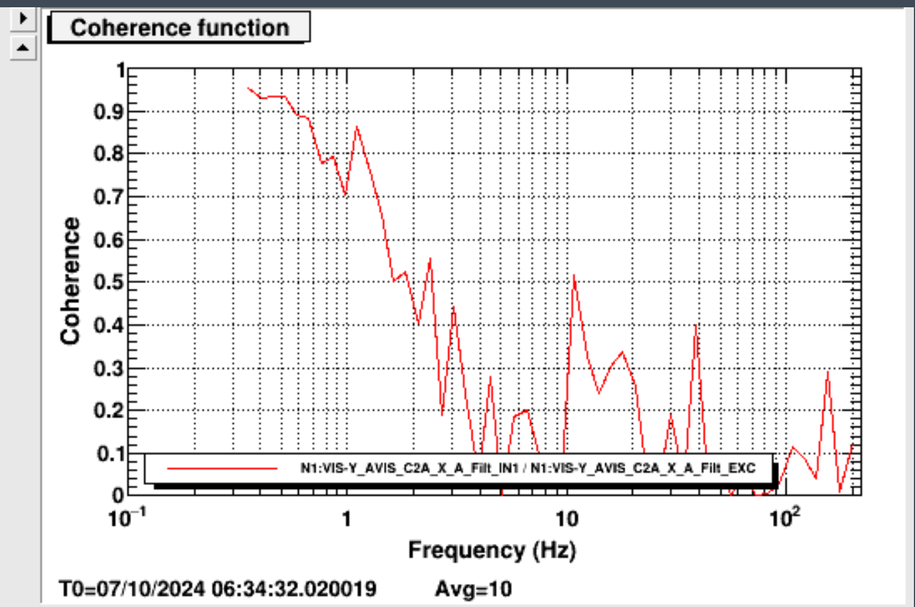
Now, only X shows the peak when we injected signal on X.

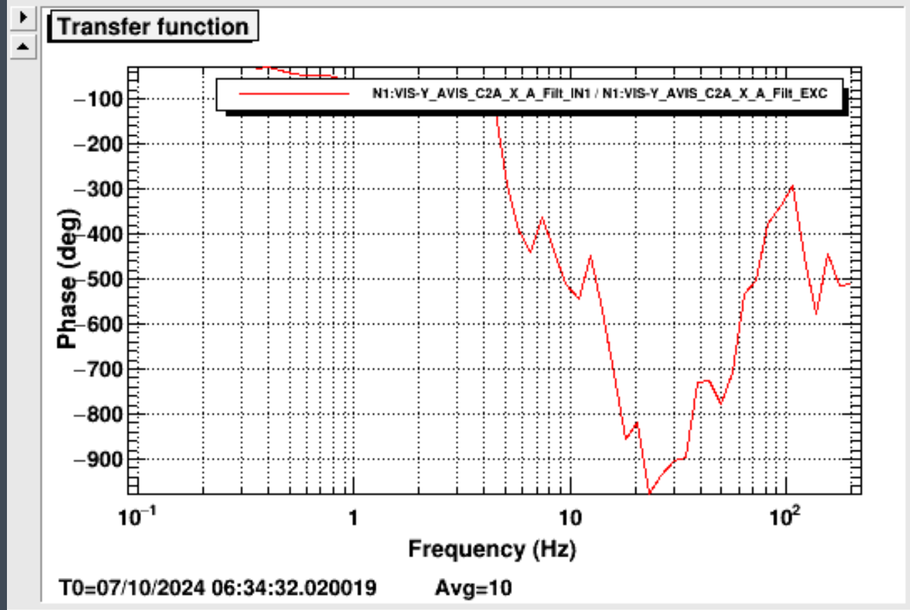
And it happens for all other DOFs

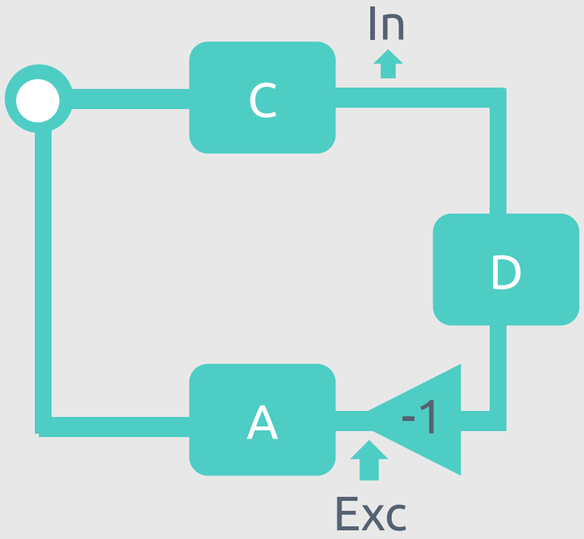


Transfer Function Measurement



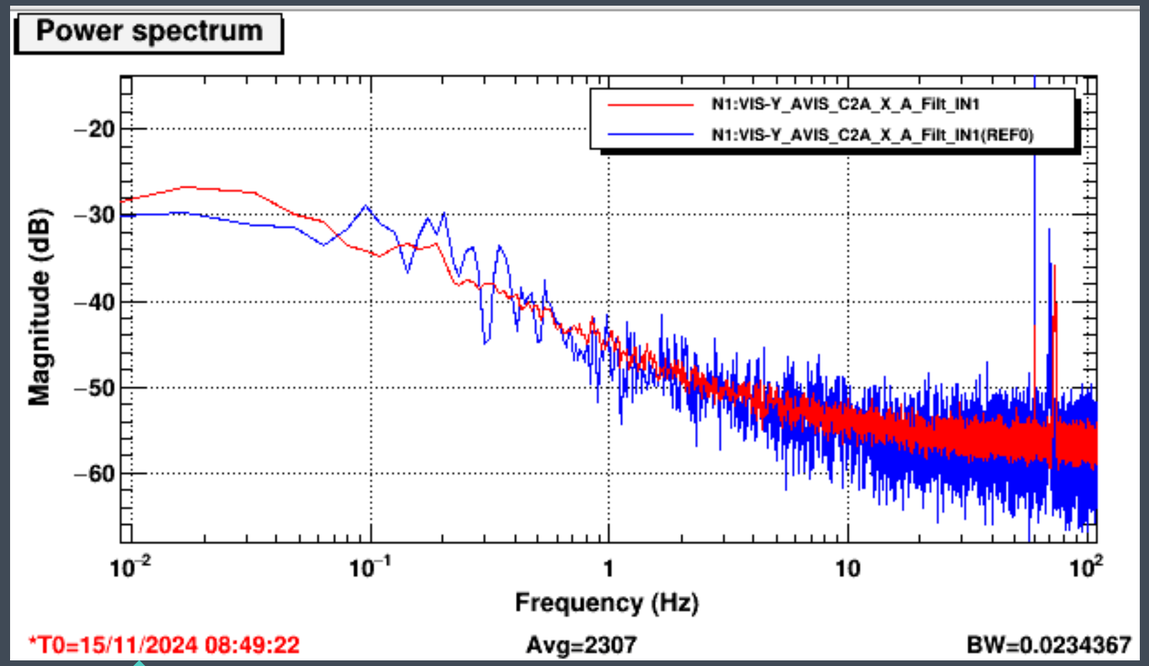


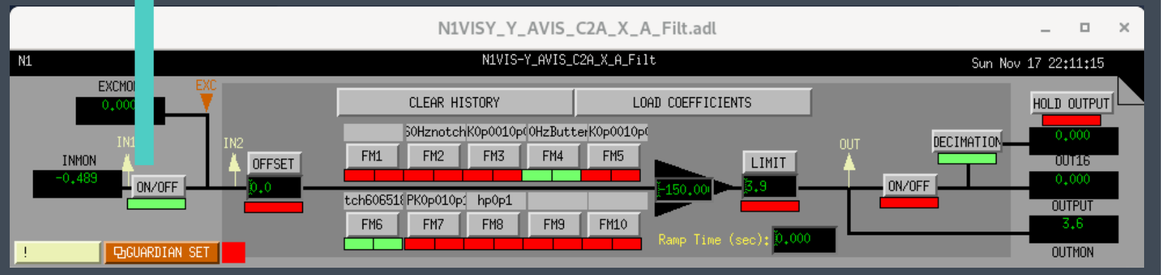




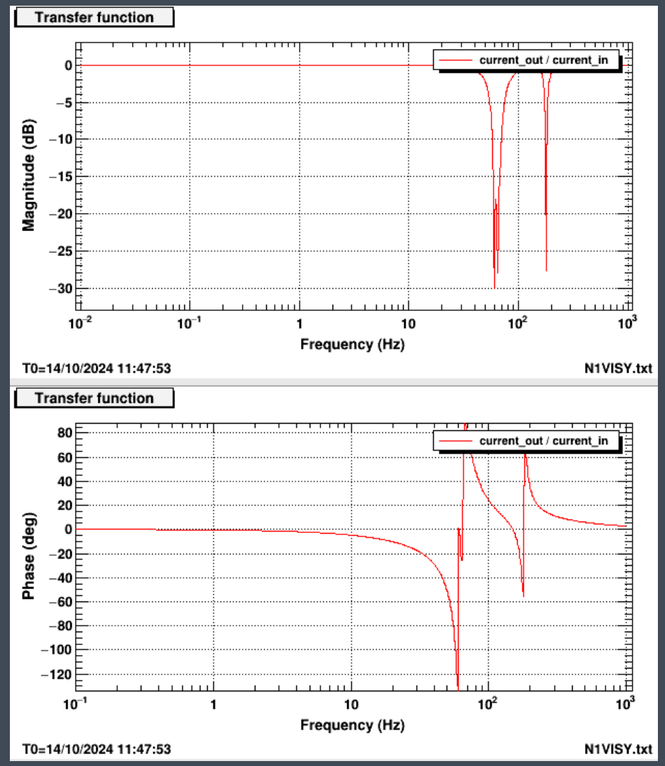
After achieving diagonalization, we measured TF for each DoF to check the coherence function.
Based on this TF, we can design digital filters to do feedback control.

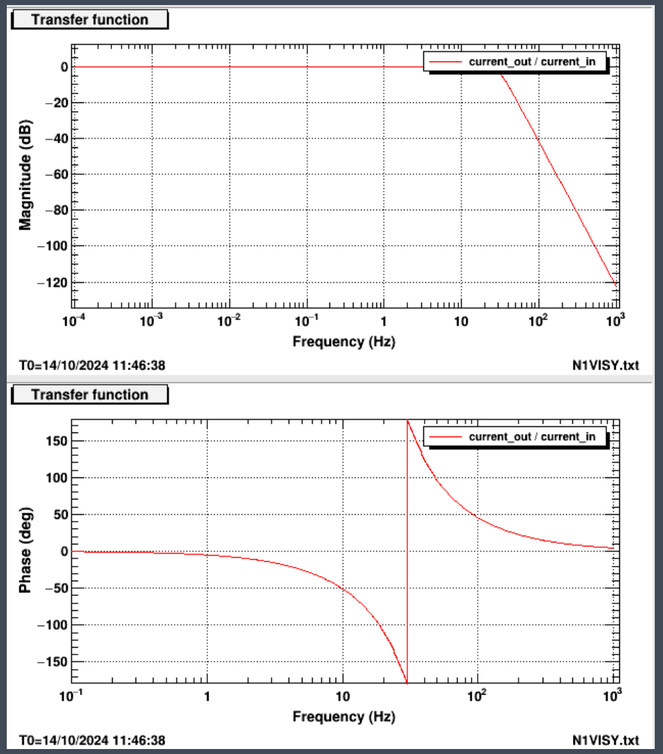
Foton Filter Design





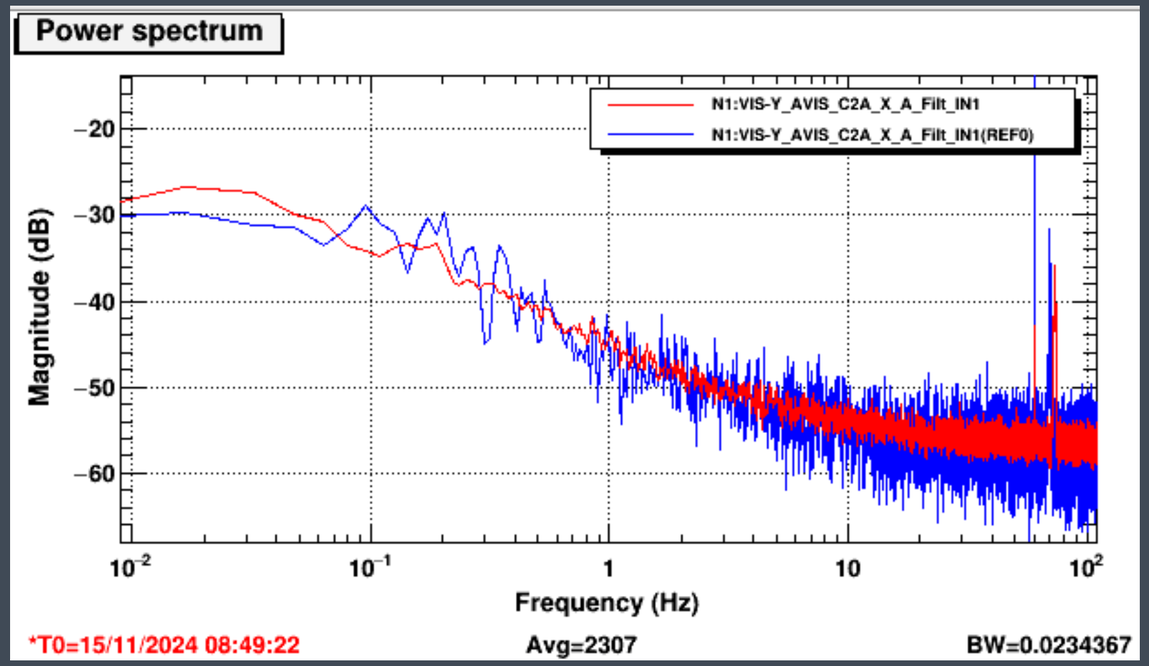
Notch filter
60 Hz, 180 Hz; Q:30

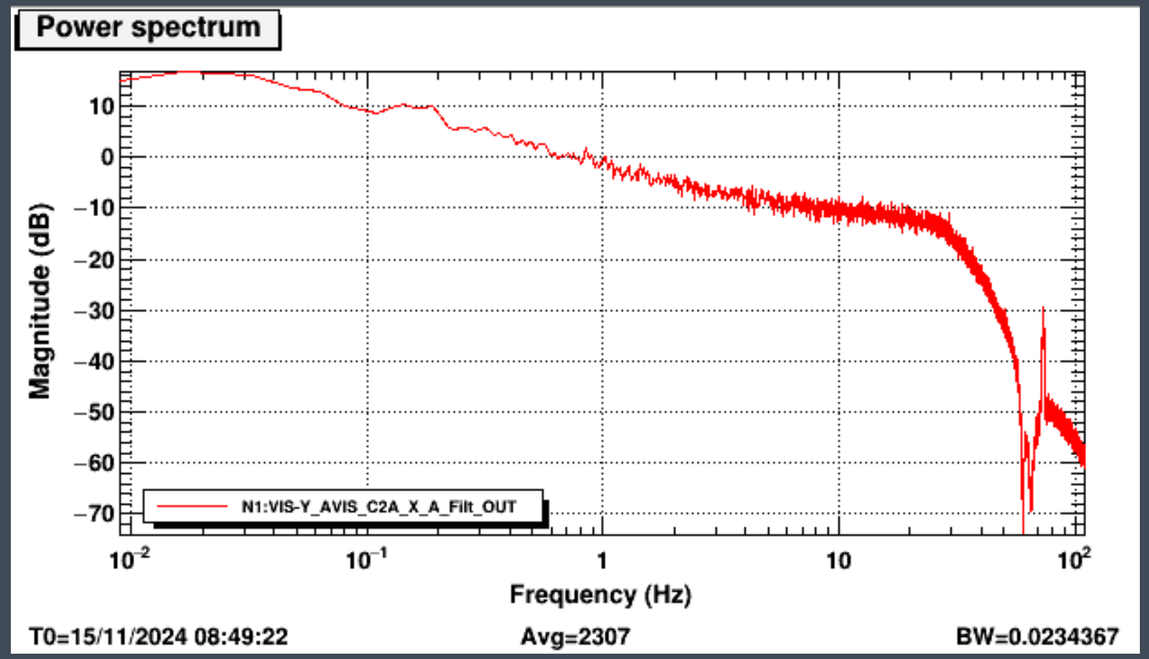




Butterworth
Low pass filter
Fcut:30 Hz 4th order

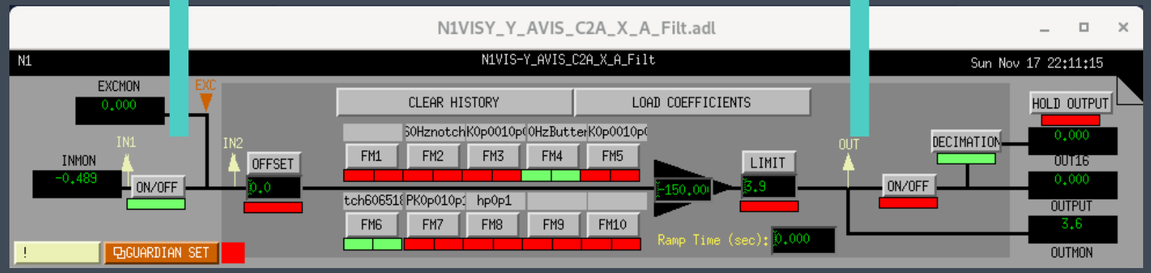
Control Signal



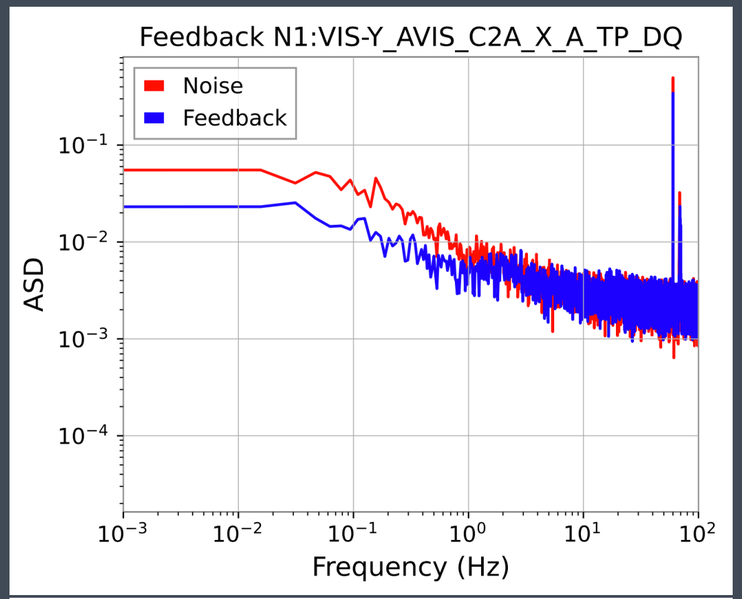


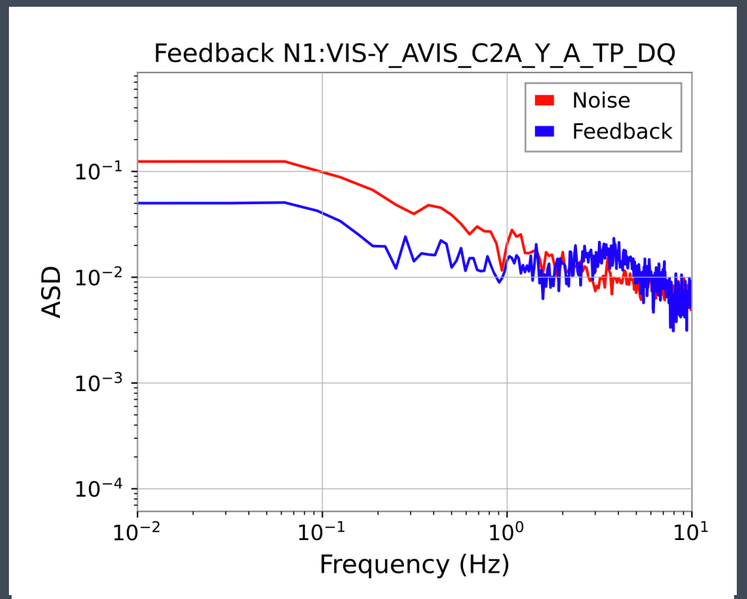
Err

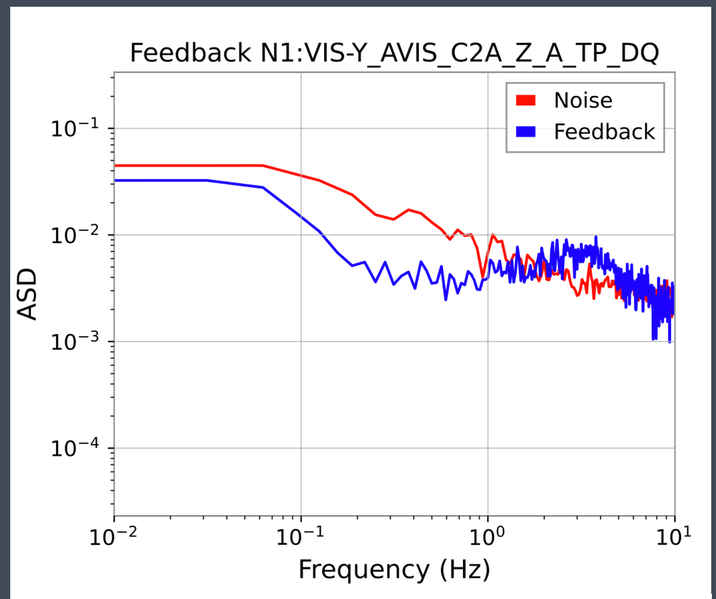
Ctrl

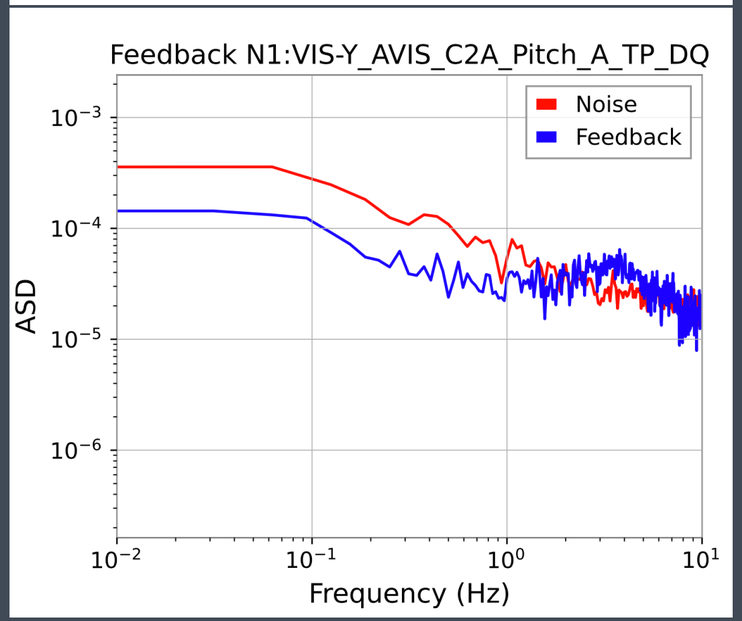


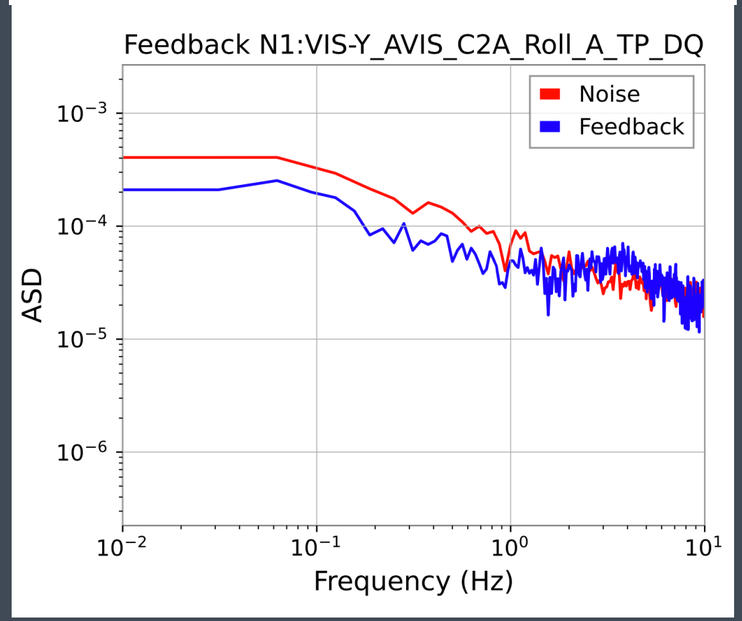
Feedback Control 6 DoF Simultaneously

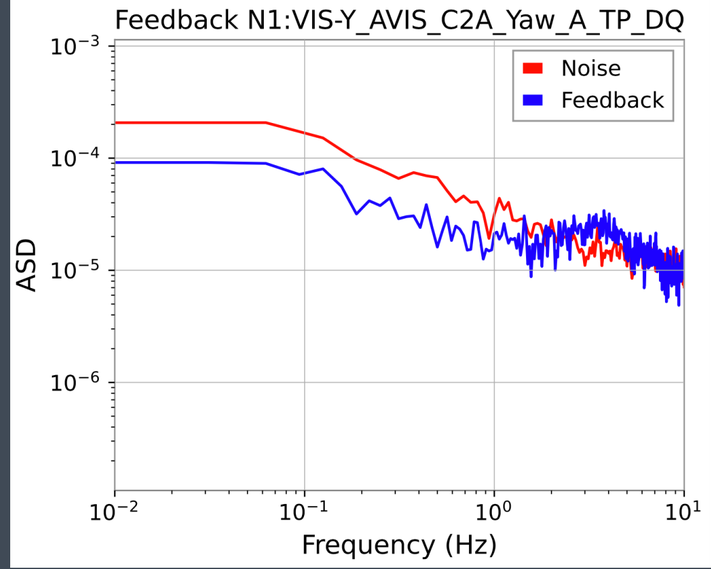












Current Status for MIF

- Xend – Diagonalization and Feedback Control for Top Stage. (Dennis, Yoyo)
- Center – Installing chasis and cables connection to DGS. (Eason Lin)
- Yend – Commisioning D Filter for Piezo stage and Diagonalization for Top Stage. (M Ma’arif)
- Input Optics – Improving PMC locking. (John Chan)

Thank you!