Technical Readiness of HoQI for LIGO

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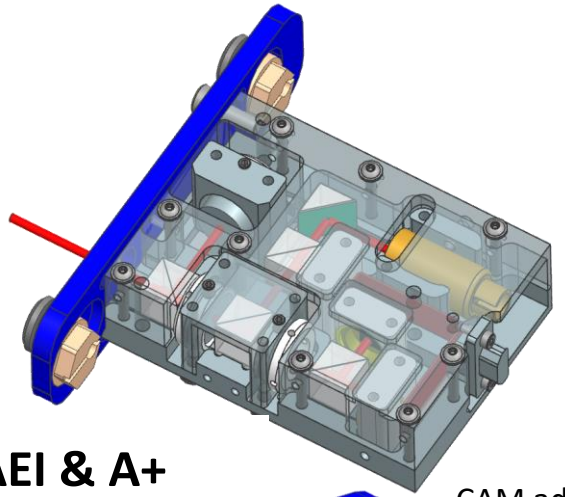
LIGO systems call

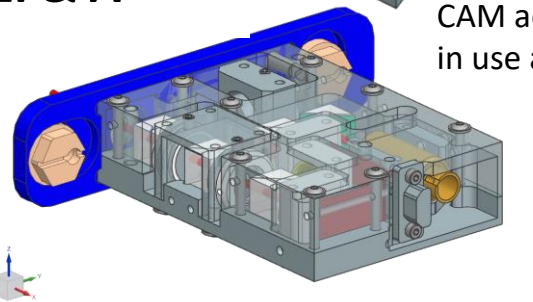
LIGO-G2201955

26th October 2022

Evolving Design

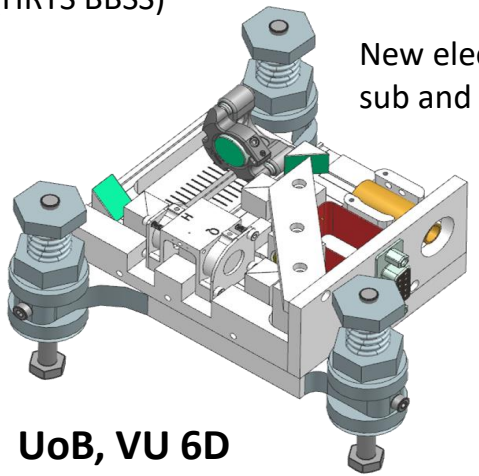


AEI & A+

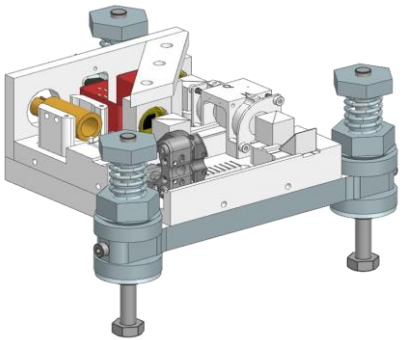


Box like cover enclosing the HoQI and containing components to set space (BBSS at M2)

CAM adjustment plates, already in use at LIGO (HRTS BBSS)

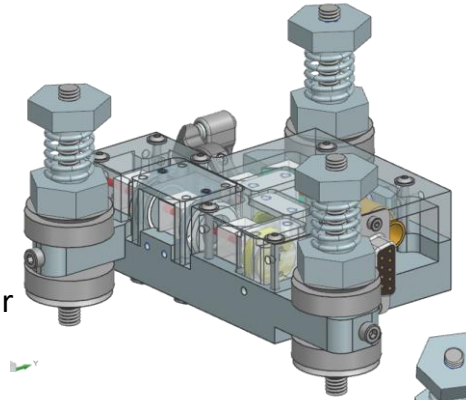


New electronics connections- D sub and micro d sub

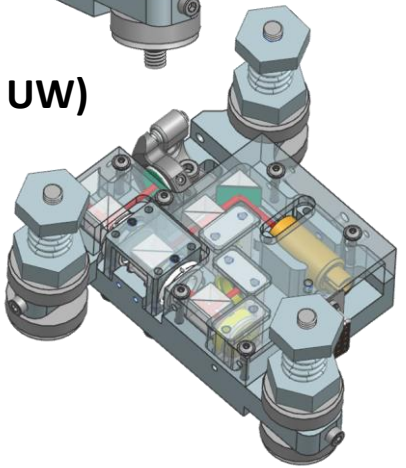


UoB, VU 6D

Mounting screws allowing for adjustment of beam angle



CRS (collaboration with UW)



Designs by Jesse Van-Dongen

What is important for HoQI?

(Practically and for good performance)

- Repeatability in units
- High quality optics chain
- Quality, frequency stabilised laser
- Vacuum compatibility
- Fringe visibility above 0.5

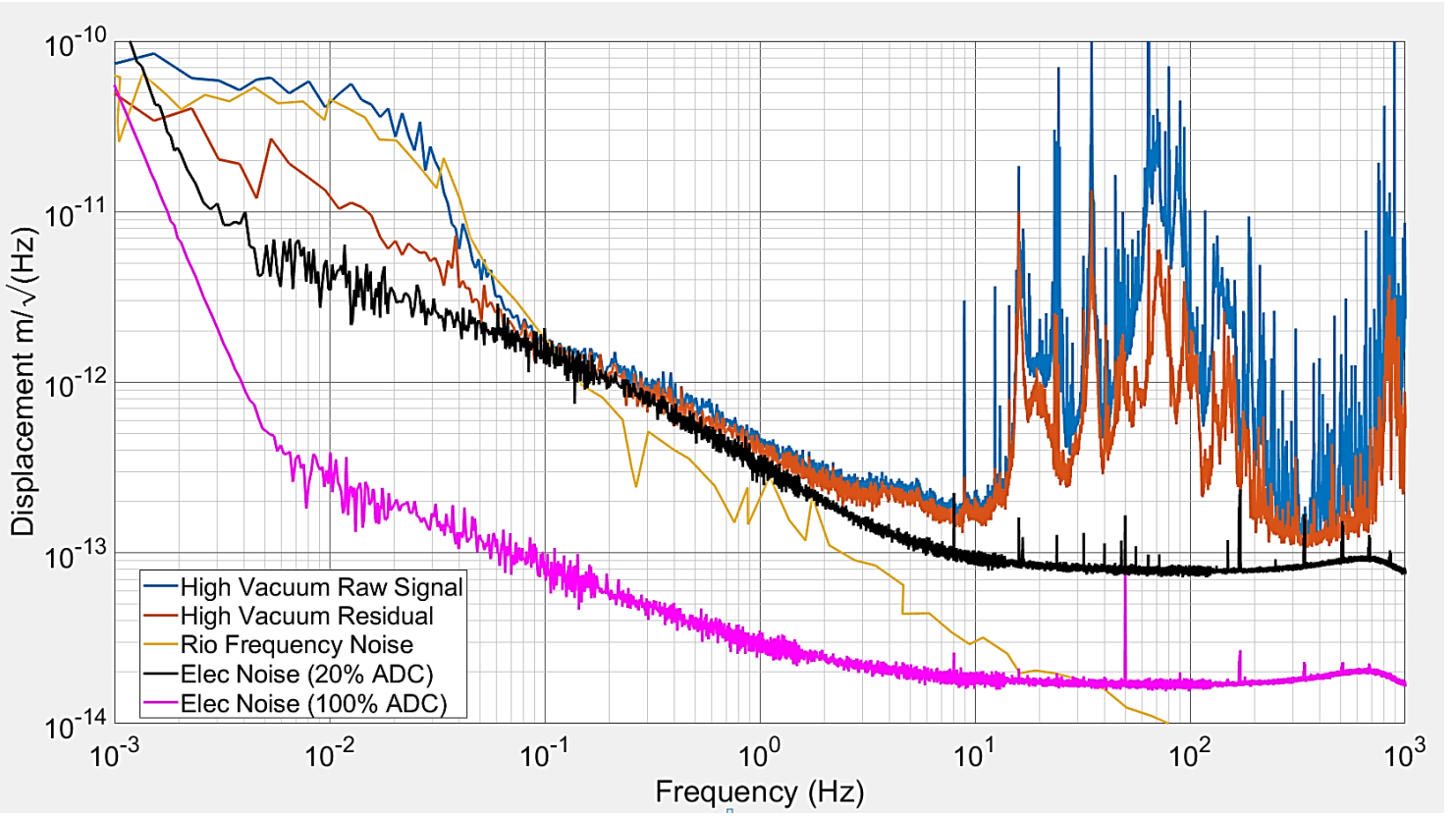
Recent results

And which aspects they demonstrate

1. **In-vacuum** measurements of multiple HoQIs
   - Signal and optics chain, repeatability in units
2. Measurements of intermediate mass on **AEI beamsplitter suspension**
   - Signal and optics chain, fringe visibility, mechanical integration, new retroreflector tests
3. **Cylindrical rotation sensor** (CRS)
   - Mechanical integration, independent optics chain

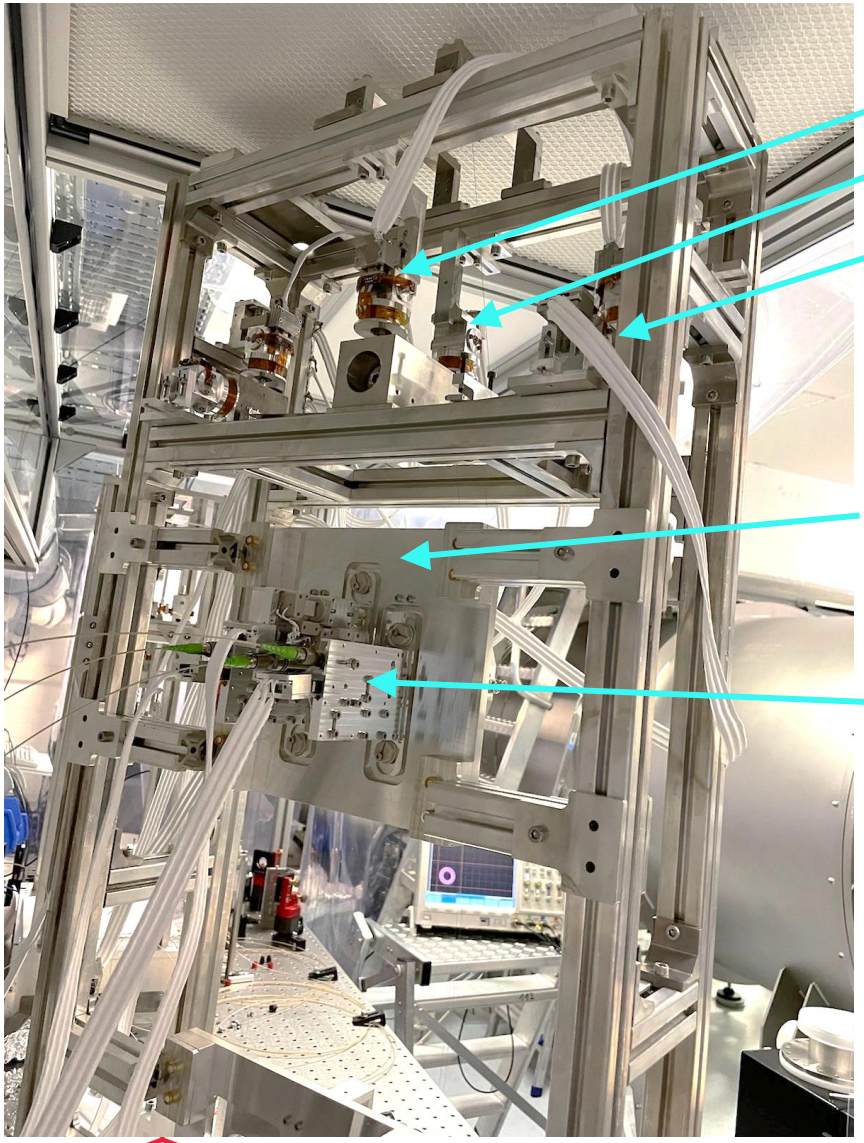
Vacuum noise measurements

- Three plane mirror HoQIs with baseplate extension for test arm, in vacuum
- ADC noise limiting across wide frequency band, need more optical gain



AEI Beamsplitter

- Triple suspension
  - BOSEMs measuring and damping top mass
  - HoQIs measuring intermediate mass
- Three corner-cube (retroreflector) HoQIs
- Measured suspension with full signal and optics chain
  - Diamond fibre vacuum feedthroughs with pigtailed PM fibre FC/APC
  - Tested cables, electronics and use of LIGO style CDS
- Tested the fringe visibility robustness



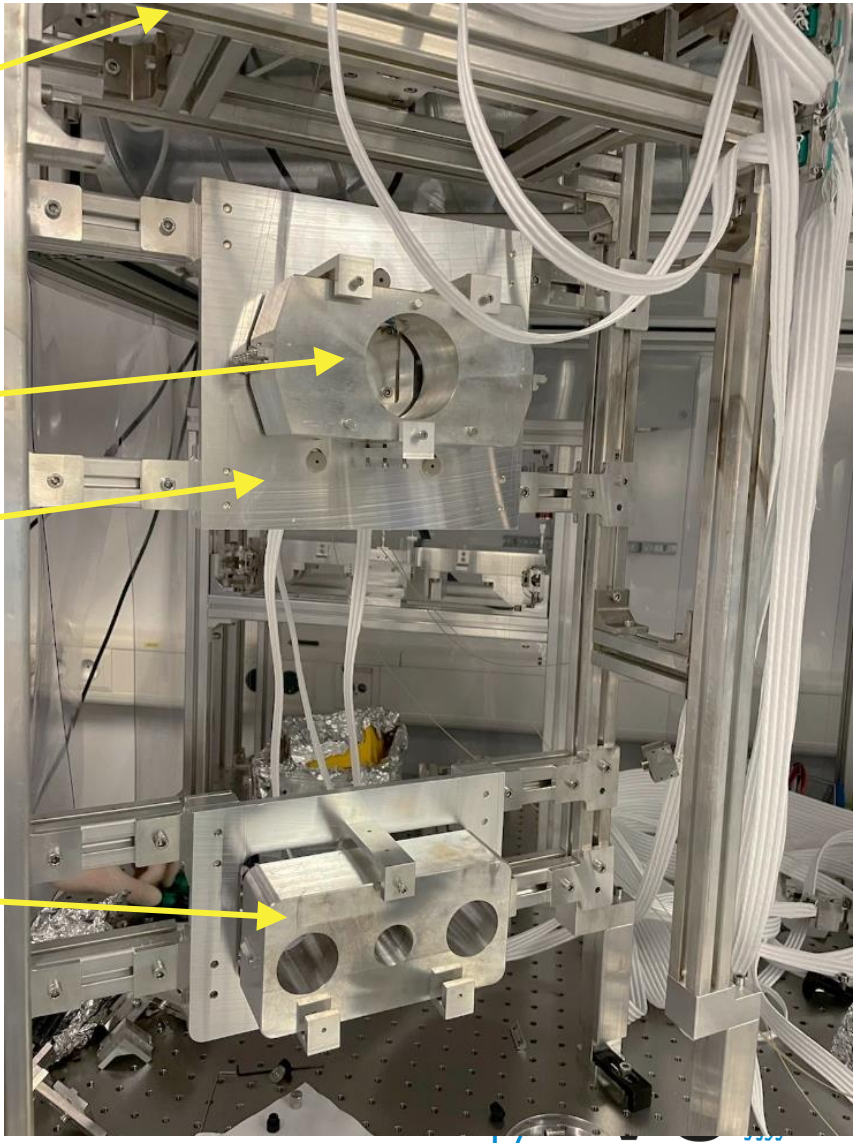
7x BOSEMS, measuring and damping top mass

IM

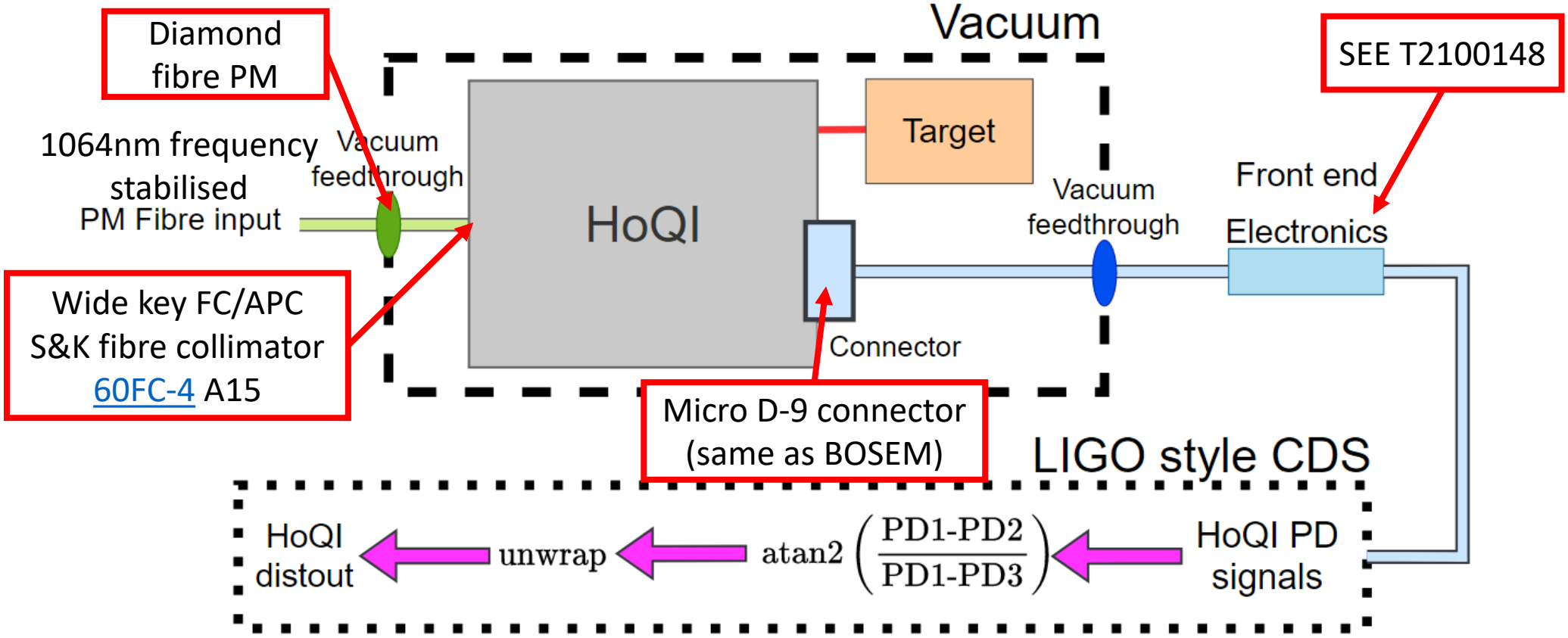
IM tablecloth

3x HoQIs, Measuring IM

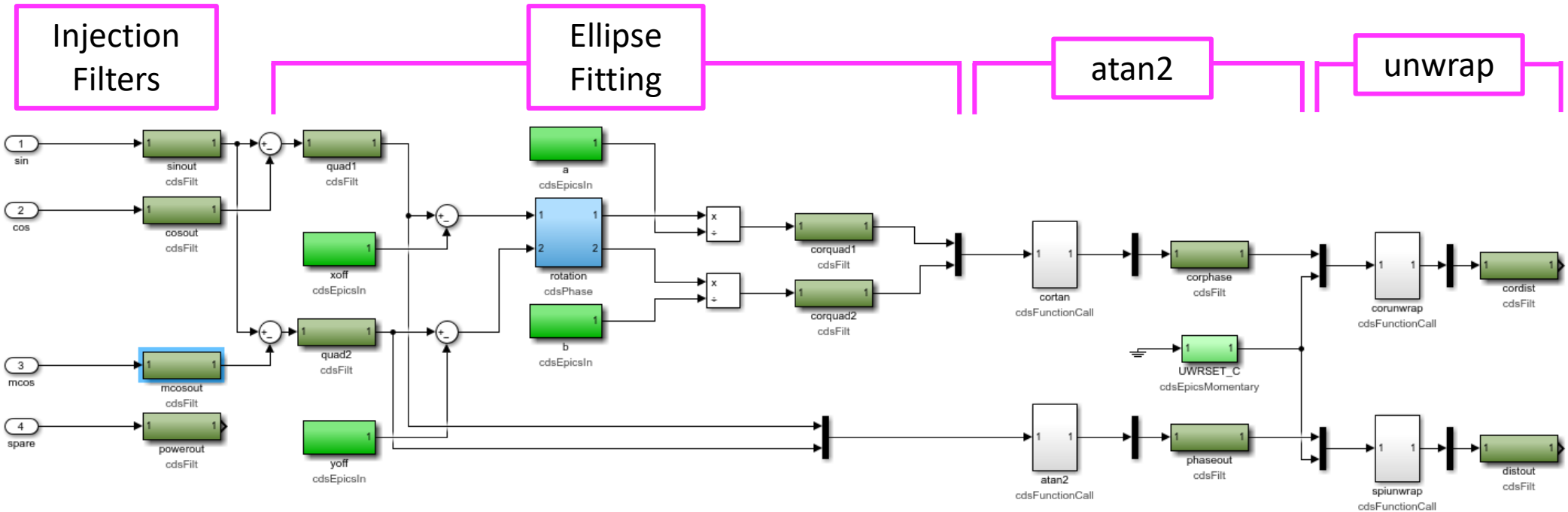
Dummy beamsplitter

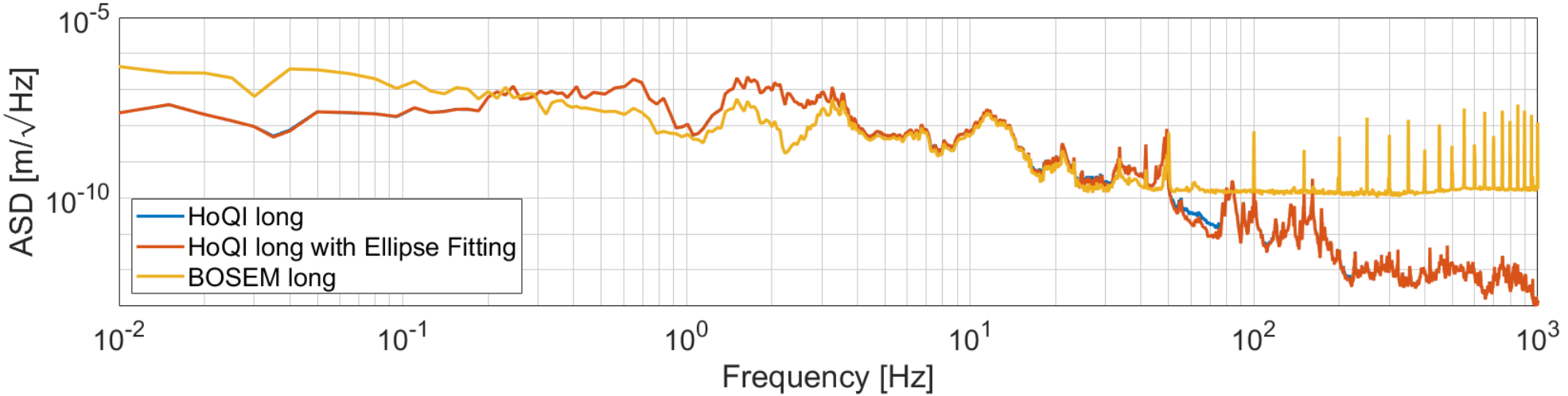


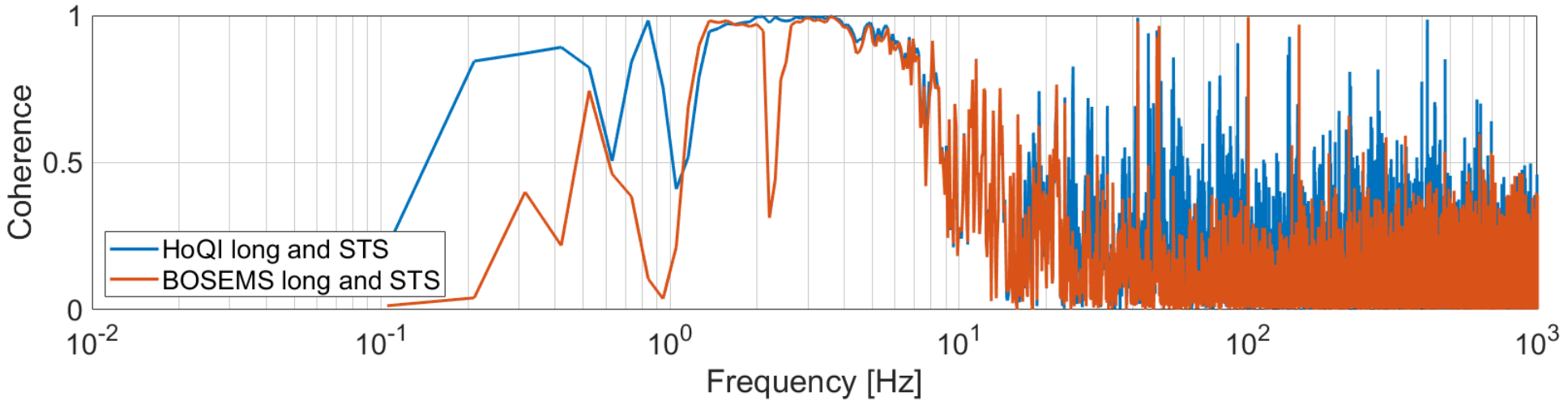
Simple signal-optics chain

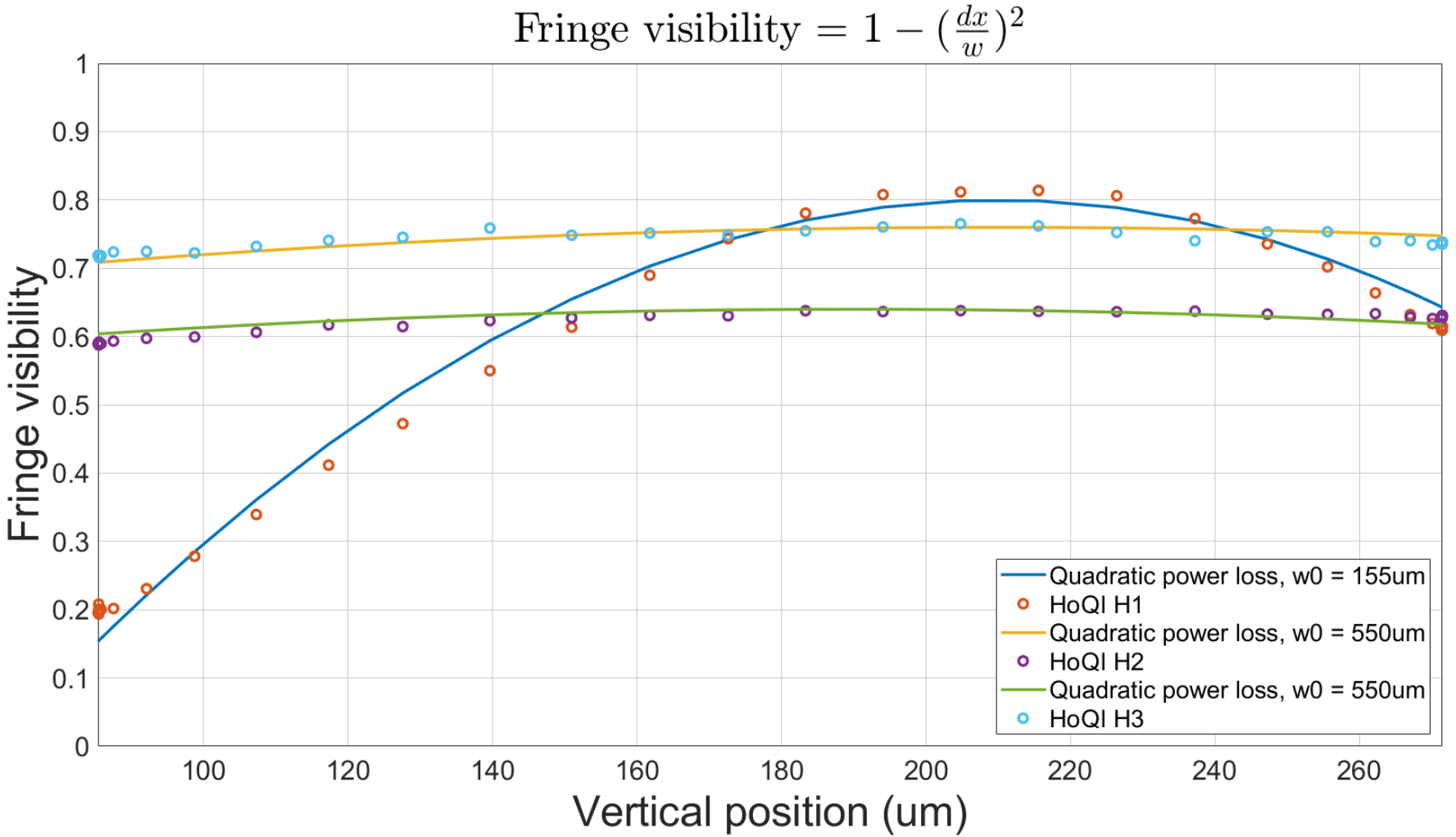


CDS model


Injection Filters
Ellipse Fitting
atan2
unwrap
1
sin
sinout
cdsFilt
2
cos
cosout
cdsFilt
3
mcos
mcosout
cdsFilt
4
spare
powerout
cdsFilt
quad1
cdsFilt
xoff
cdsEpicsIn
quad2
cdsFilt
yoff
cdsEpicsIn
a
cdsEpicsIn
rotation
cdsPhase
b
cdsEpicsIn
corquad1
cdsFilt
corquad2
cdsFilt
cortan
cdsFunctionCall
corphase
cdsFilt
UWRSET_C
cdsEpicsMomentary
corunwrap
cdsFunctionCall
cordist
cdsFilt
atan2
cdsFunctionCall
phaseout
cdsFilt
spiunwrap
cdsFunctionCall
distout
cdsFilt

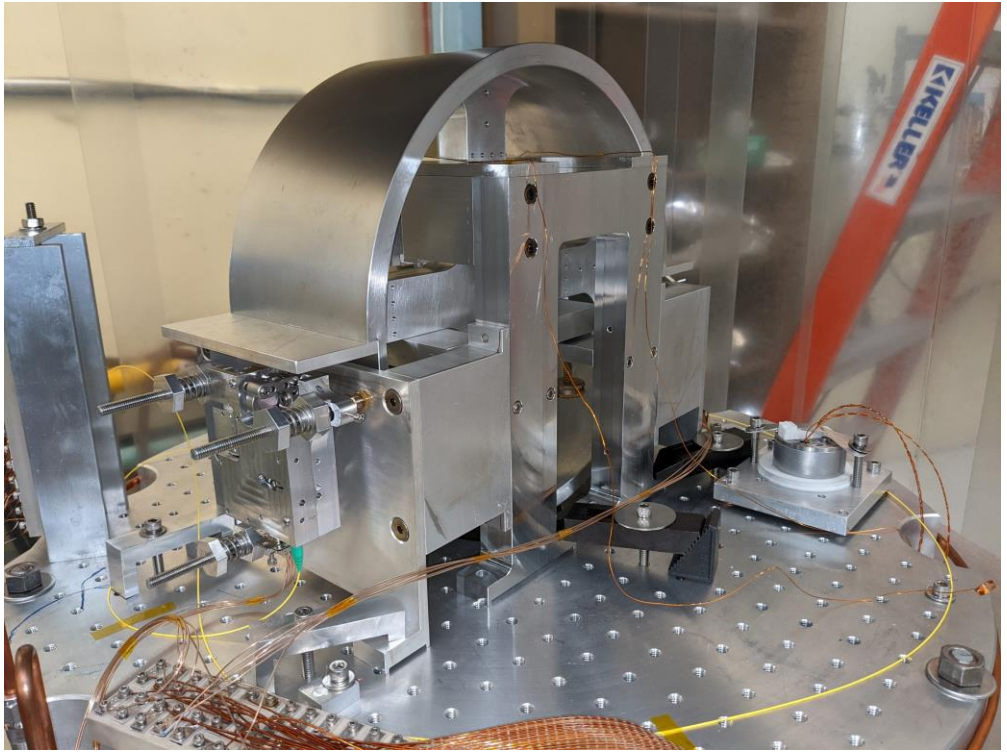

ASD [m/√Hz]
10^-5
10^-10
HoQI long
HoQI long with Ellipse Fitting
BOSEM long
10^-2
10^-1
10^0
10^1
10^2
10^3
Frequency [Hz]

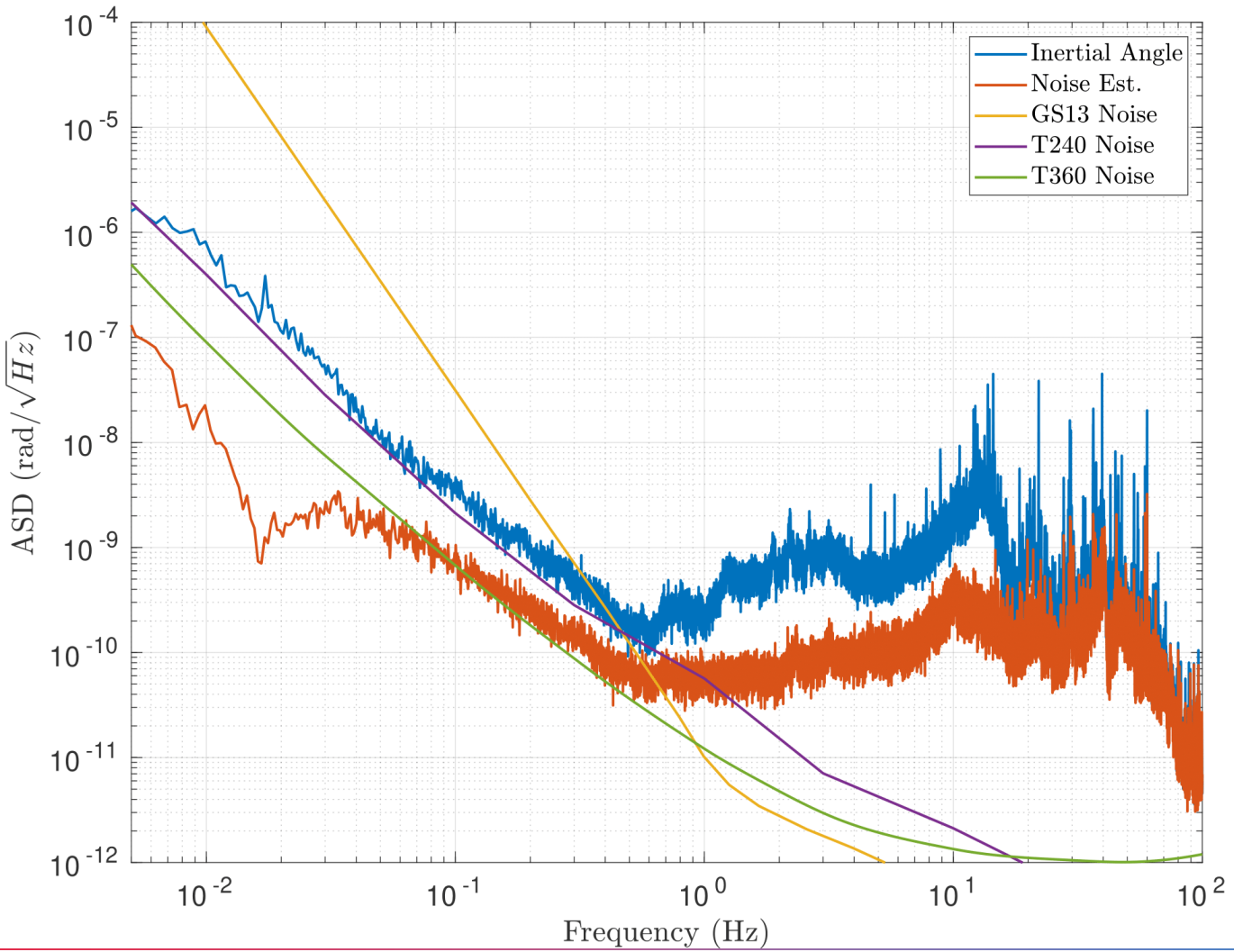

Coherence
1
0.5
0
HoQI long and STS
BOSEMS long and STS
10^-2
10^-1
10^0
10^1
10^2
10^3
Frequency [Hz]


Fringe visibility = $1 - (\frac{dx}{w})^2$
Fringe visibility
Vertical position (um)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
120
140
160
180
200
220
240
260
Quadratic power loss, w0 = 155um
HoQI H1
Quadratic power loss, w0 = 550um
HoQI H2
Quadratic power loss, w0 = 550um
HoQI H3

Cylindrical Rotation Sensor

- Constructed and tested at University of Washington
- Uses two plane mirror HoQIs to readout




Inertial Angle
Noise Est.
GS13 Noise
T240 Noise
T360 Noise
ASD (rad/√Hz)
Frequency (Hz)
10 -4
10 -5
10 -6
10 -7
10 -8
10 -9
10 -10
10 -11
10 -12
10 -2
10 -1
10 0
10 1
10 2

HoQI production

- Flexi circuits
  - Still needs work due to strain relief issues, new prototype being made for next HoQIs
- Signal chain
  - Same connector and pin configuration to BOSEMs, therefore same cables
- Plane mirrors
  - Sensitive to angular misalignment, insensitive to translation
- Corner cubes
  - Moved to hollow, gold-coated retroreflectors (from glass cubes)
  - Insensitive to angular misalignment, transverse working range dependent on the beam spot size
  - Consistent HoQI noise performance, our current baseline design
- Mounting
  - CAM adjuster and plates used in the HRTS and BBSS work for HoQI

Vacuum Compatibility

- Components have been chosen to be ‘vacuum compatible’, but not tested for LIGO requirements
- New components which may need UHV testing:
  - Collimators (Schafter and Kirchoff, titanium, 60FC-4 A3.1 or A15)
  - Photodiodes (Hammamatsu, Si, S2386-8K)
  - Adhesives (UV glue, for optics on baseplate, eg NOA61)
  - Small optics (polymer waveplates, unmounted version of Thorlabs WP and PBS & NPBS)

Useful Links

- GWADW 2022 talk HoQI construction, modelling of BBSS HoQI damping
- BBSS HoQI damping preliminary paper (P2100122)
- SWG presentation, in-vacuum measurements (G2102537)
- HoQI CDS readout board pre-amp details (T2100148)
- CAM plate for HoQI suspension in BBSS (D2100670)
- SEI logbook CRS posts
- Masters thesis containing fringe visibility modelling (T2200369)

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