Seismic measurements with optical sensors

A Seismic Platform Interferometer in the aLIGO infrastructure?

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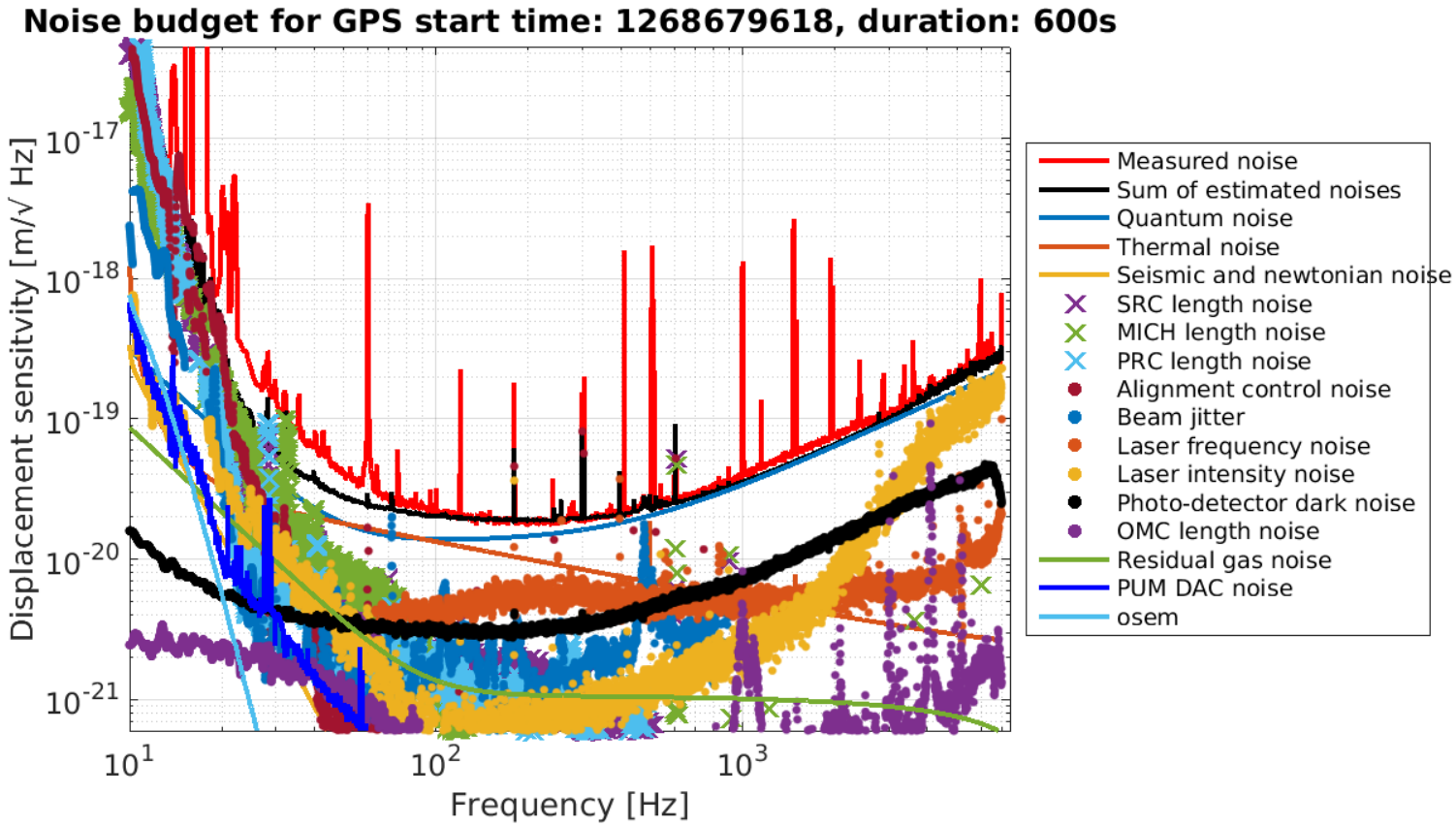
Why do we want more sensors?

- Seismic noise is very well attenuated in DARM
- But: Auxiliary control loops contaminate gravitational wave band
- Stray light
- Excess noise below 30 Hz

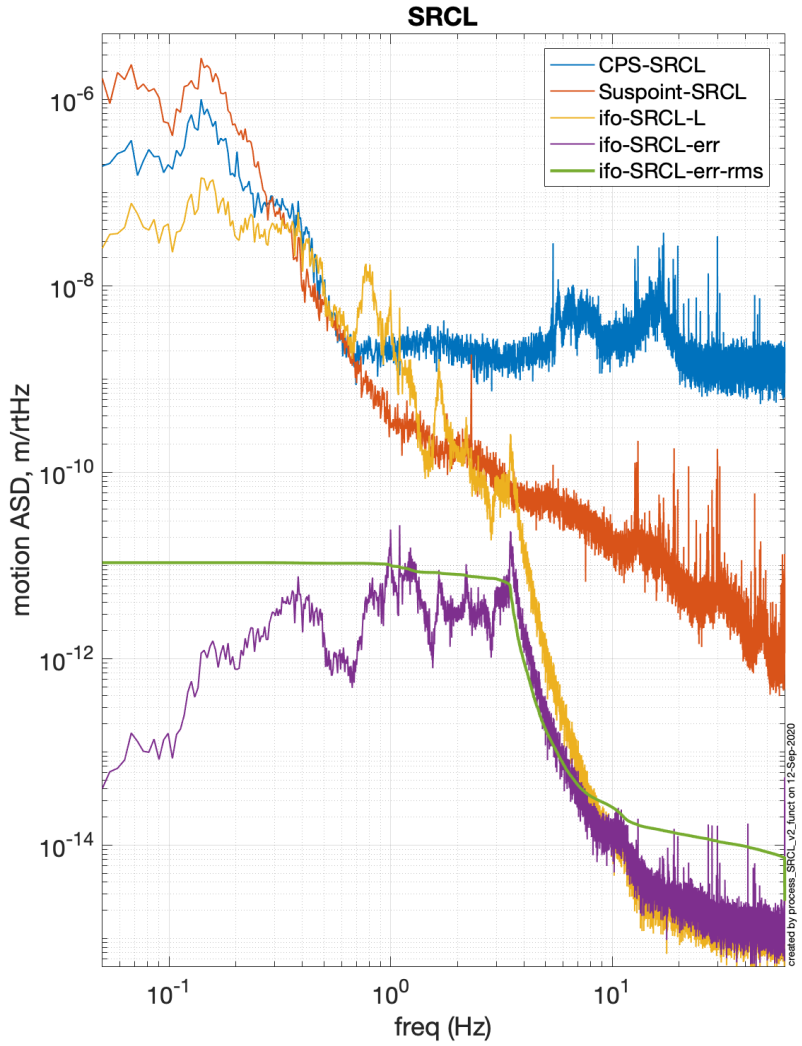


Source Brian's talk: Sep. 2020 G2001539
And LHO O3 noise budget, S. Dwyer LHO log 55755

Why can more seismic isolation help?

Input noise reduction allows change in auxiliary control loop bandwidth:

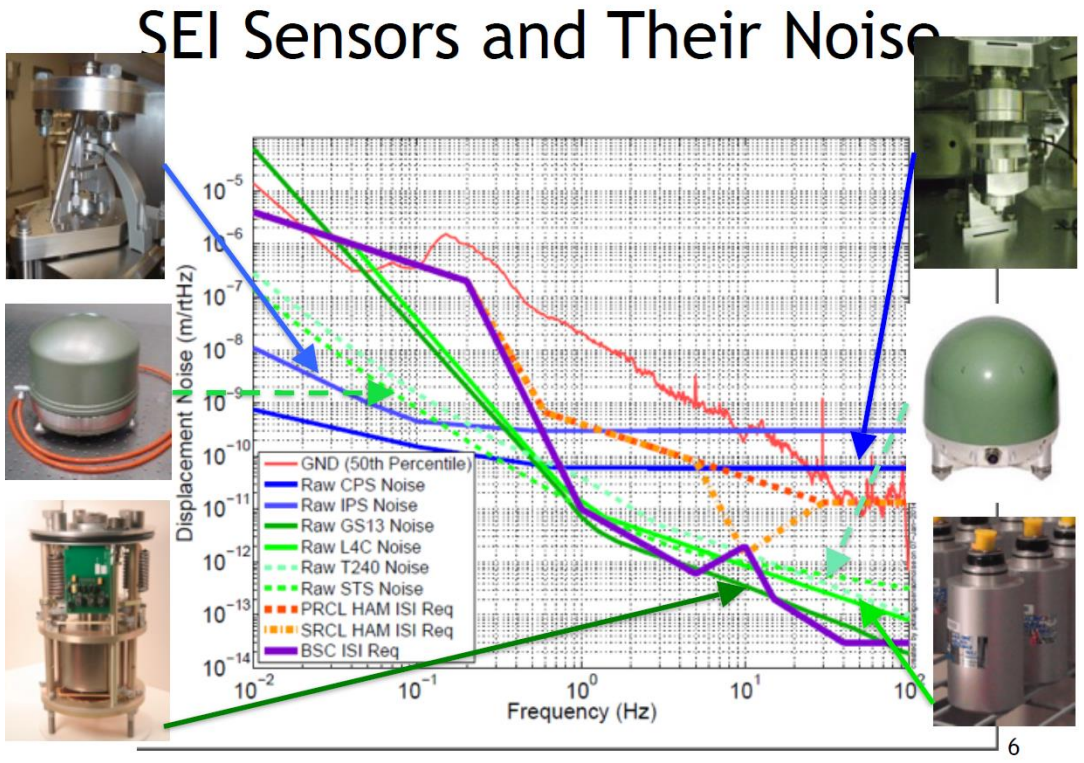
- Noise out-side control bandwidth from sensor
- Bandwidth set by residual rms motion
- Filter cannot be more aggressive
- Solution: Reduce input motion



Source Brian's talk: Sep. 2020 G2001539

Why not more inertial isolation?

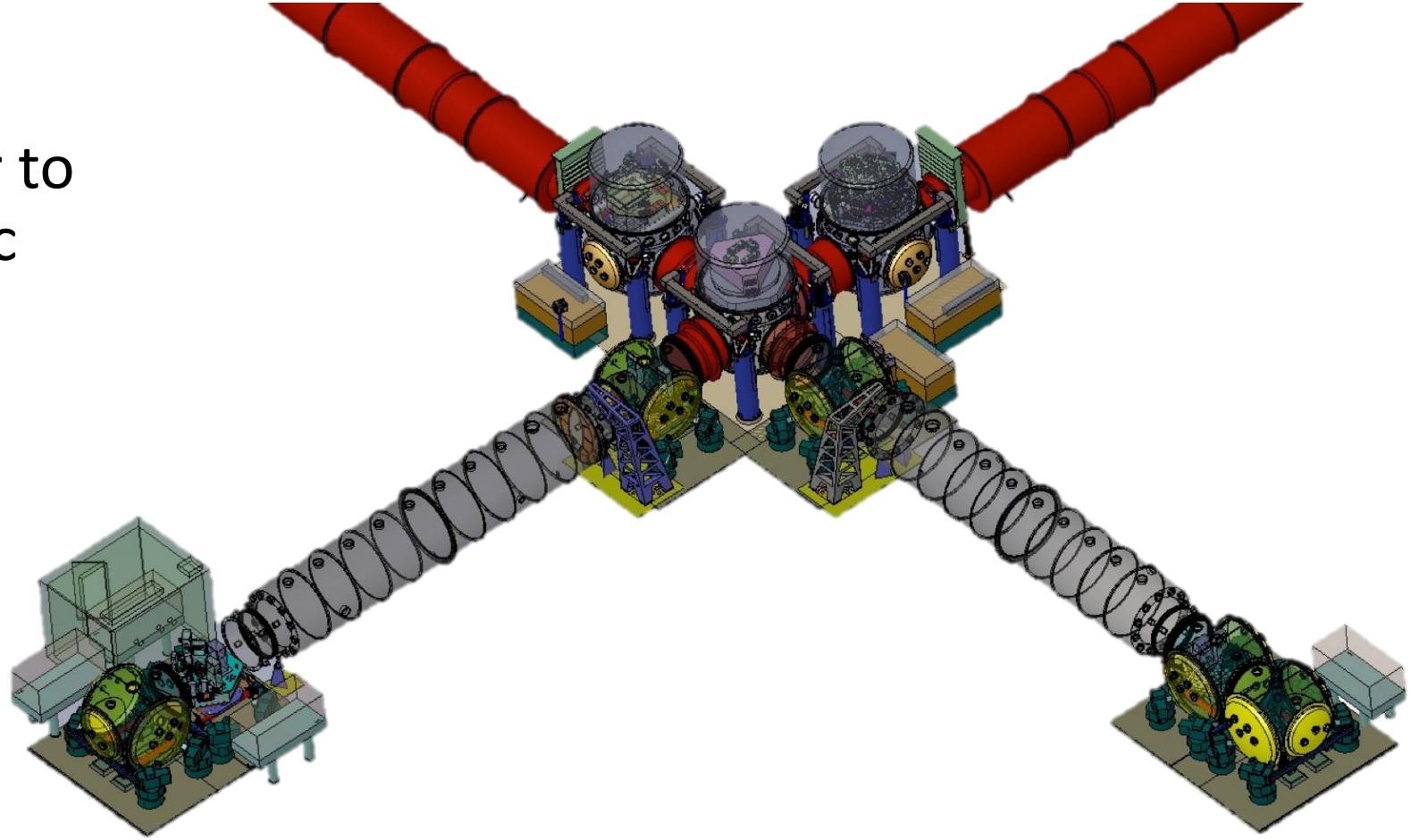
- We would if we could
- Feedback cavity length to ISI?
- Okay, but only when at operation point
- Mirror suspension allows feedback only below suspension resonances



Source: LIGO-T1300929-v5

Why not use the best tool at our hand?

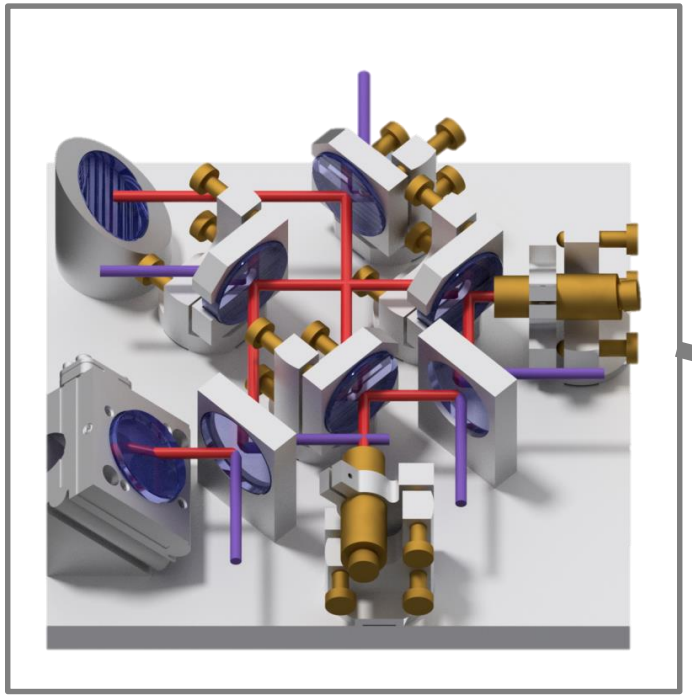
- Interferometer!
- Auxiliary interferometer to measure relative seismic platform displacement.

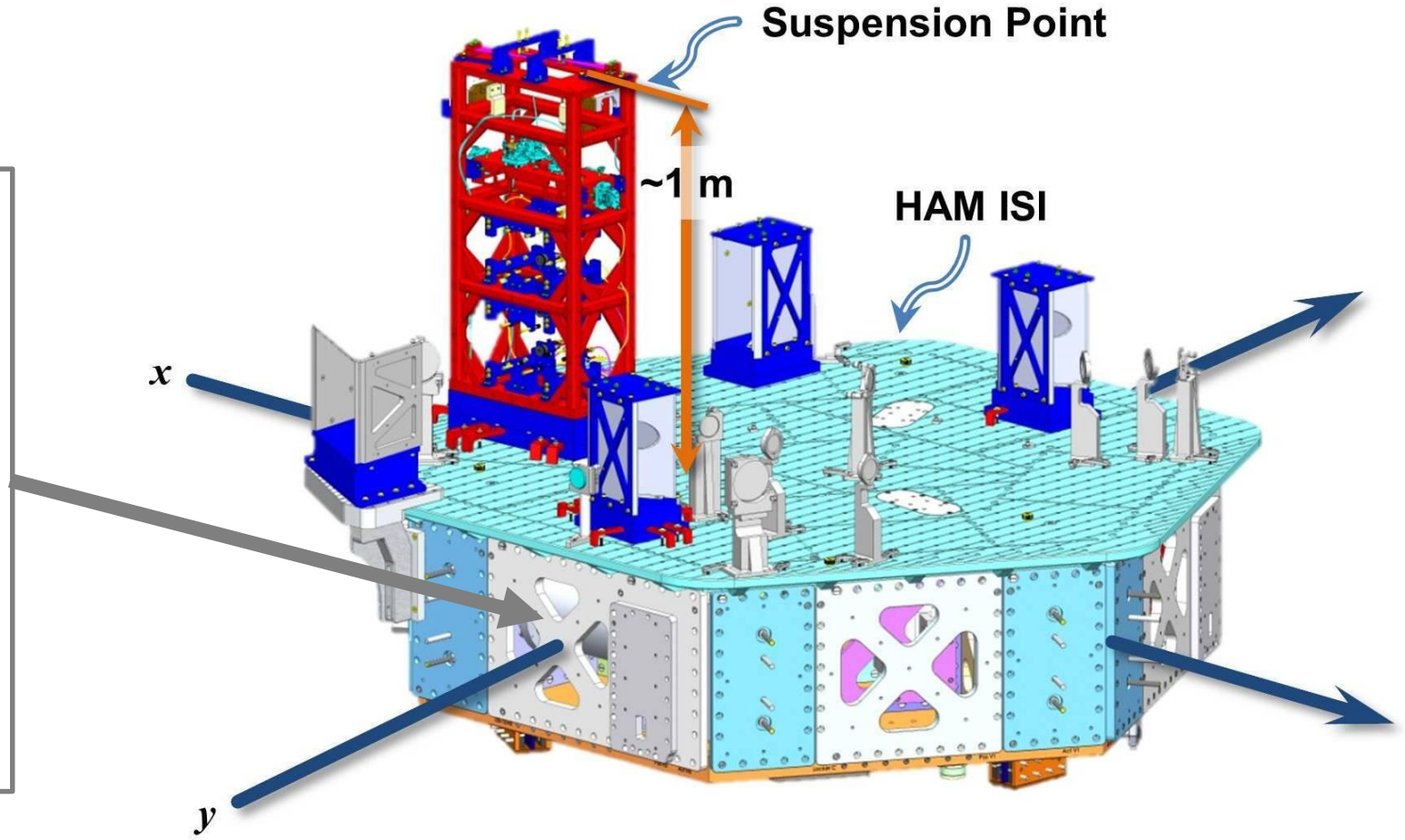


Source Brian‘s talk: Sep. 2020 G2001539

Where could we put it?

- Table tops are crowded but sides are blank

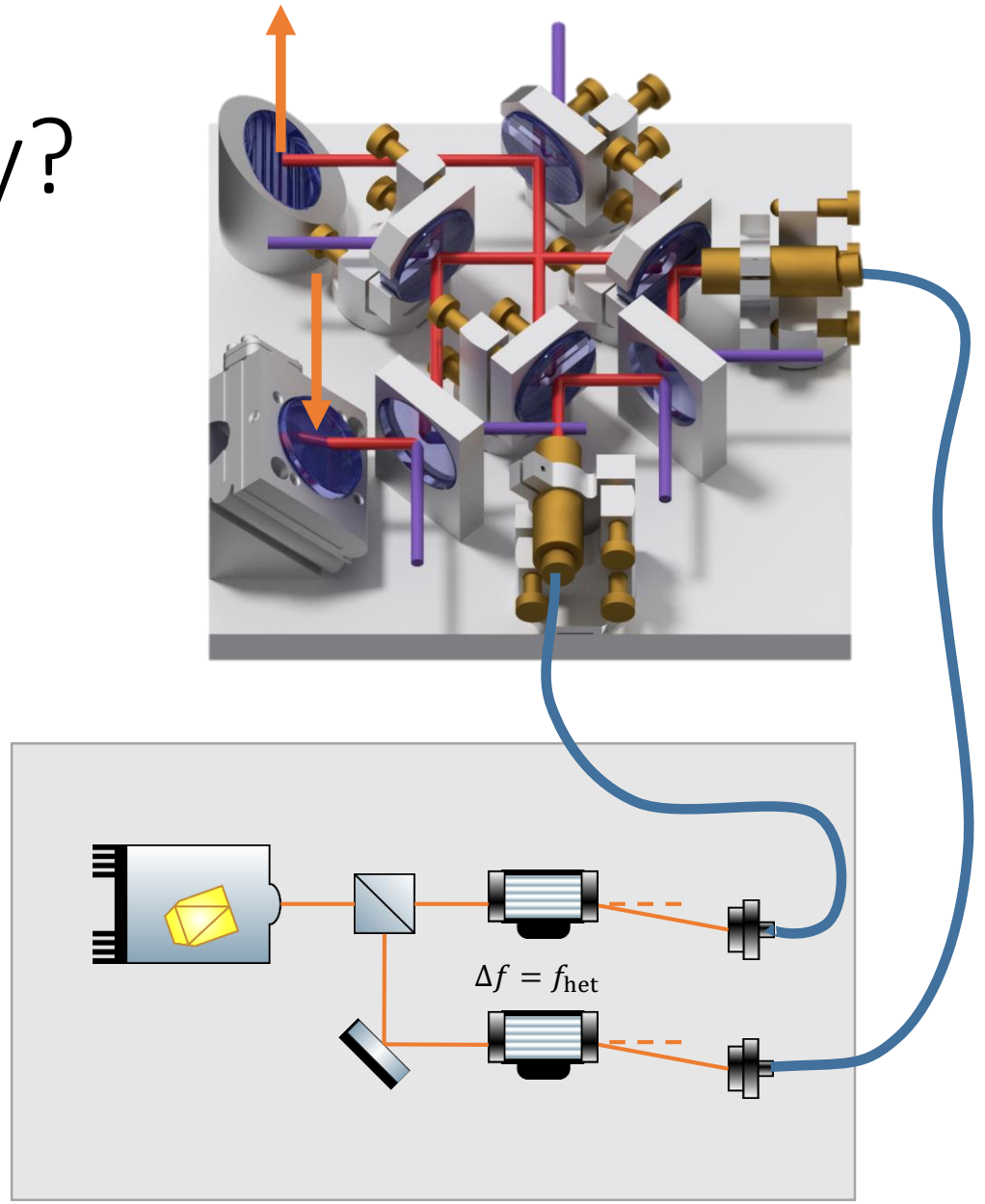




Source Brian's talk: Sep. 2020 G2001539

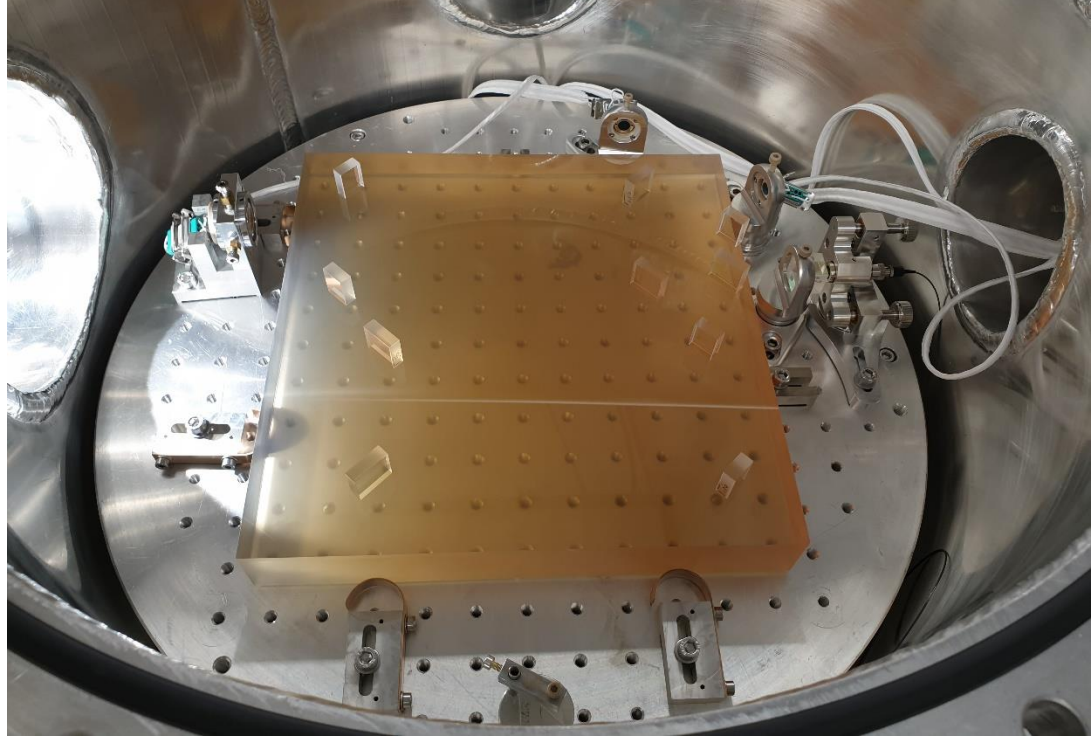
What kind of interferometry?

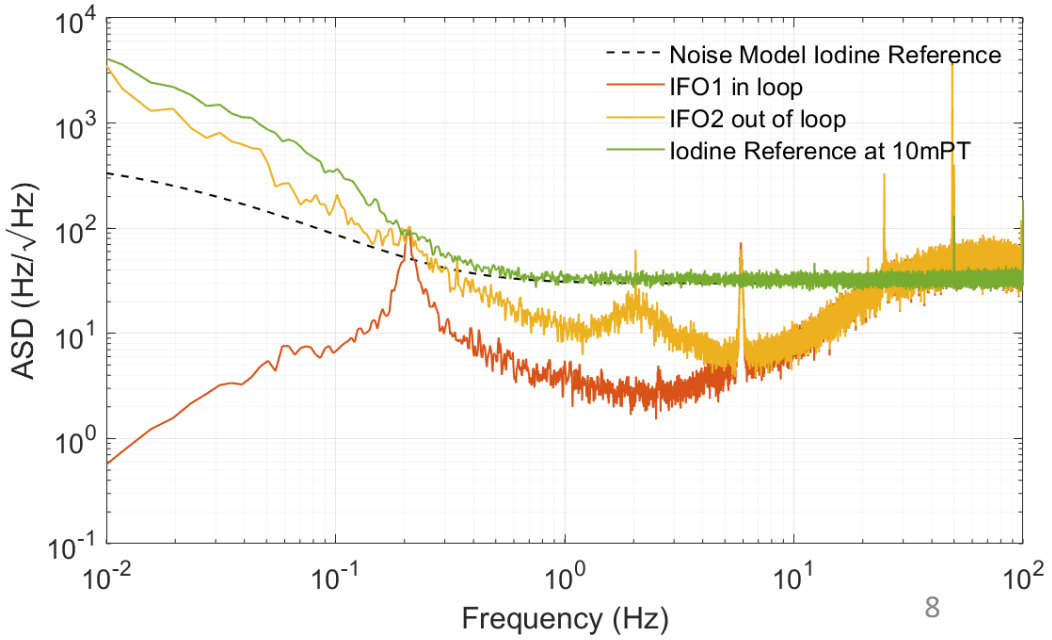
- Multi-fringe readout for out of loop characterization
- Heterodyne interferometry
  - Well known
  - Tested at the AEI 10m-Prototype
- Inherent large arm-length difference



Laser frequency noise

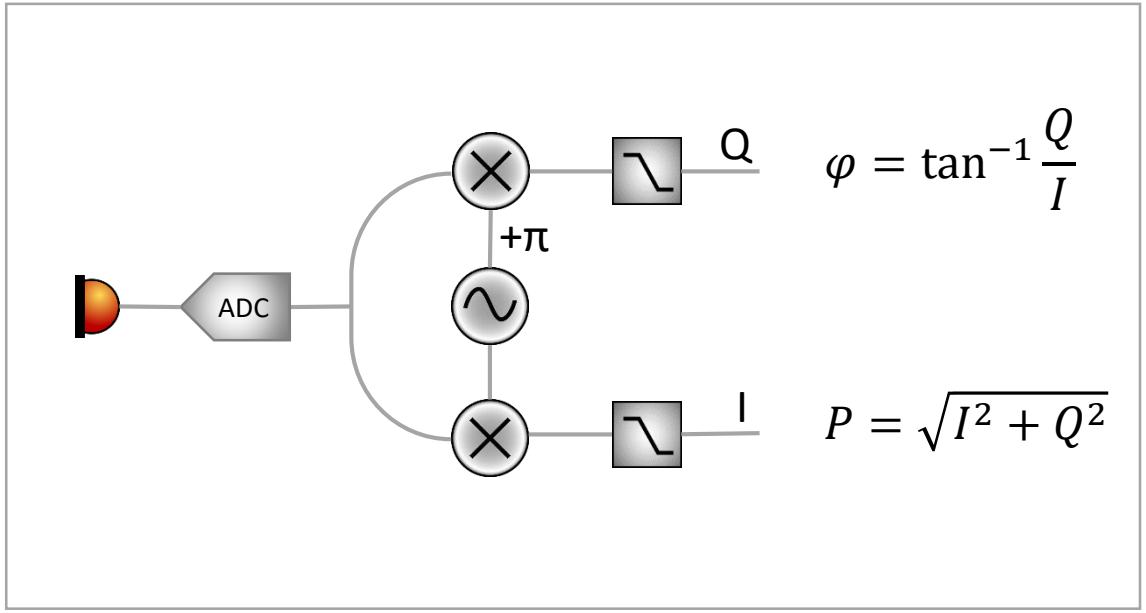
- Main laser should have low frequency noise
- Offset by defined frequency
  - AOM
  - Auxiliary laser lock
- External reference
  - Molecular reference system
  - Self-made interferometric reference





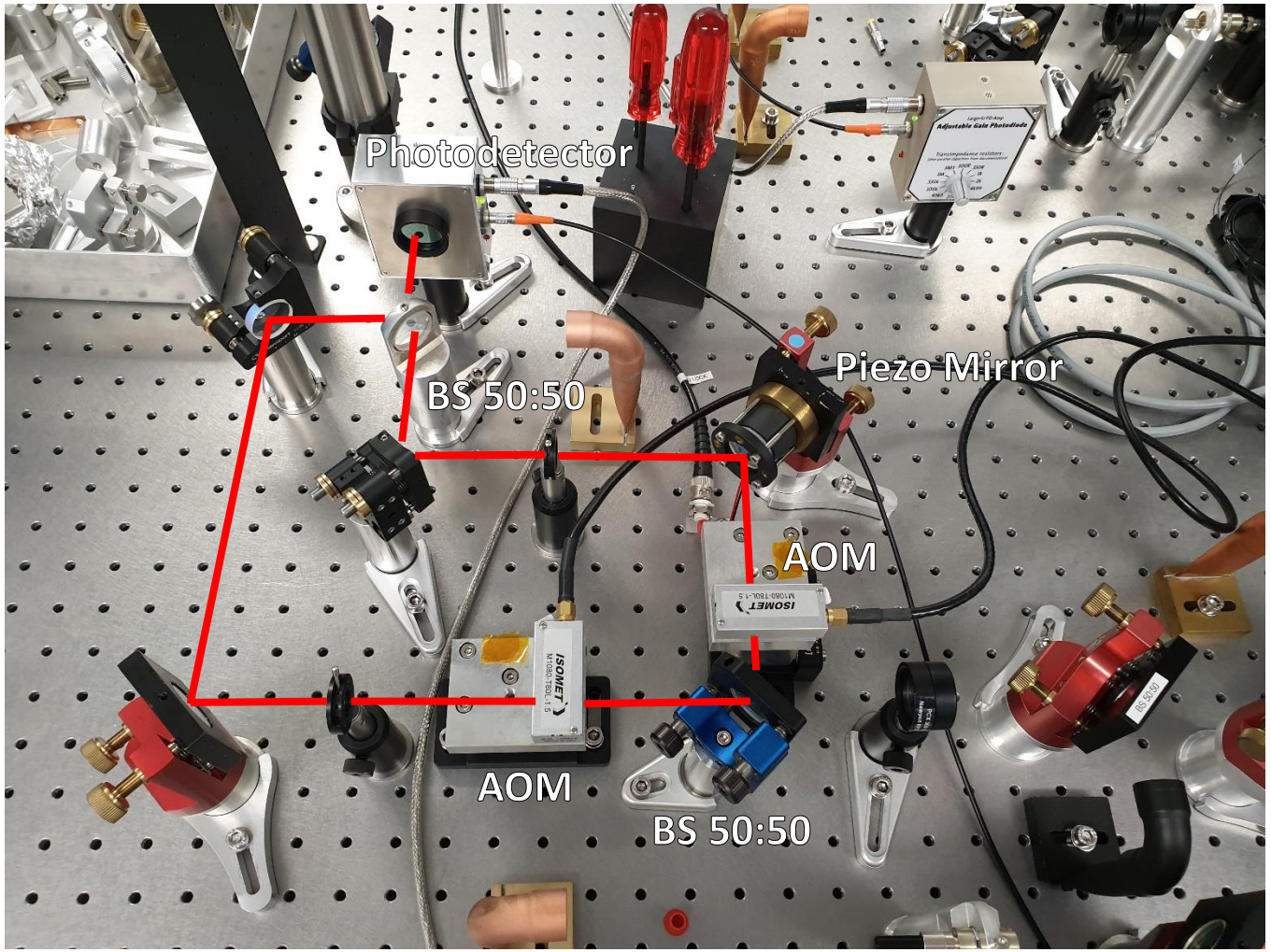
Phase read out

- Compute interferometer length from IQ demodulation at specific heterodyne frequency
- Utilize existing hardware
- CDS based phasemeter



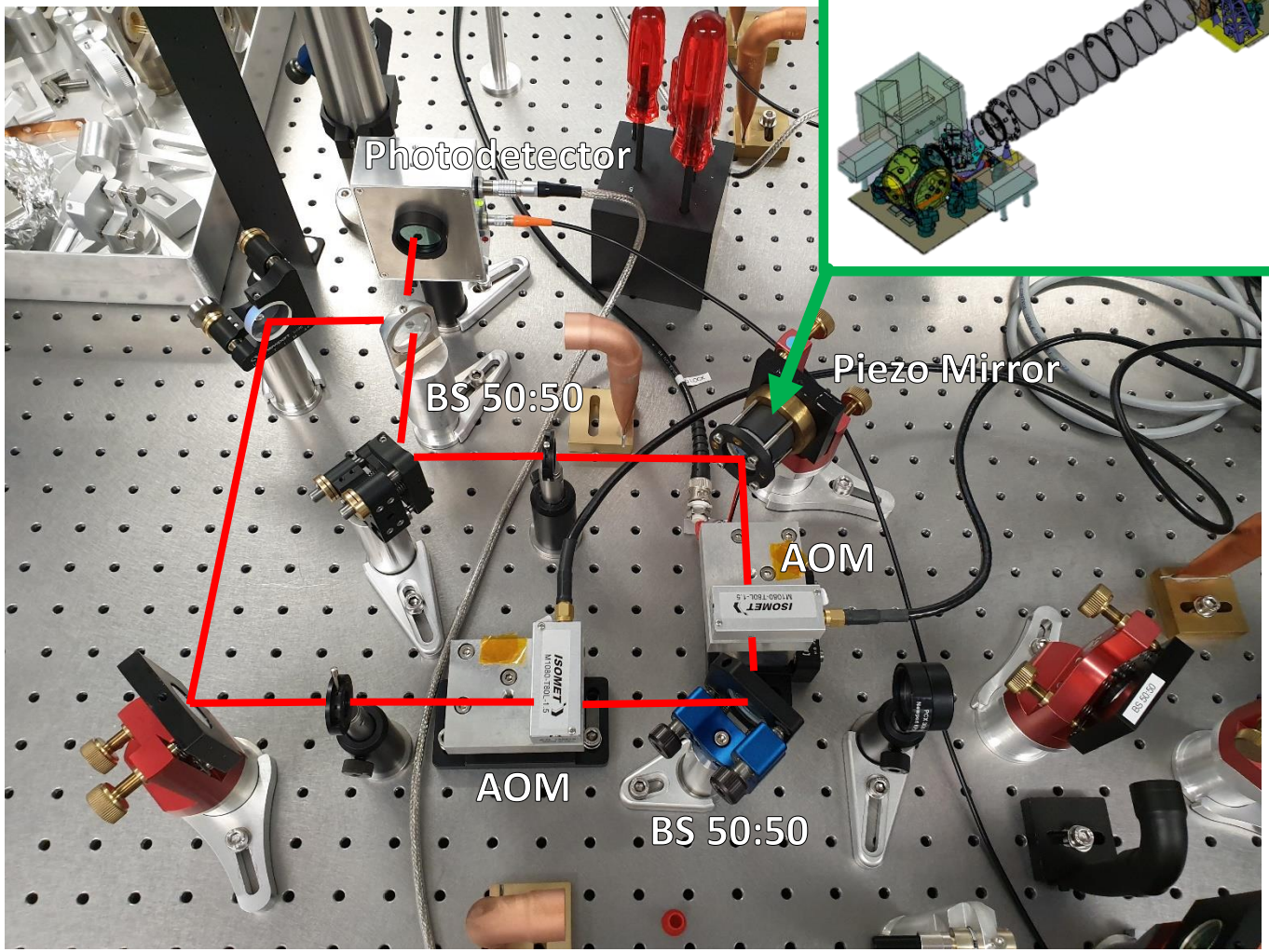
Testing the CDS Readout

- Real signal from photodetector
- Heterodyne Interferometer
- Two AOM for kHz frequency offset



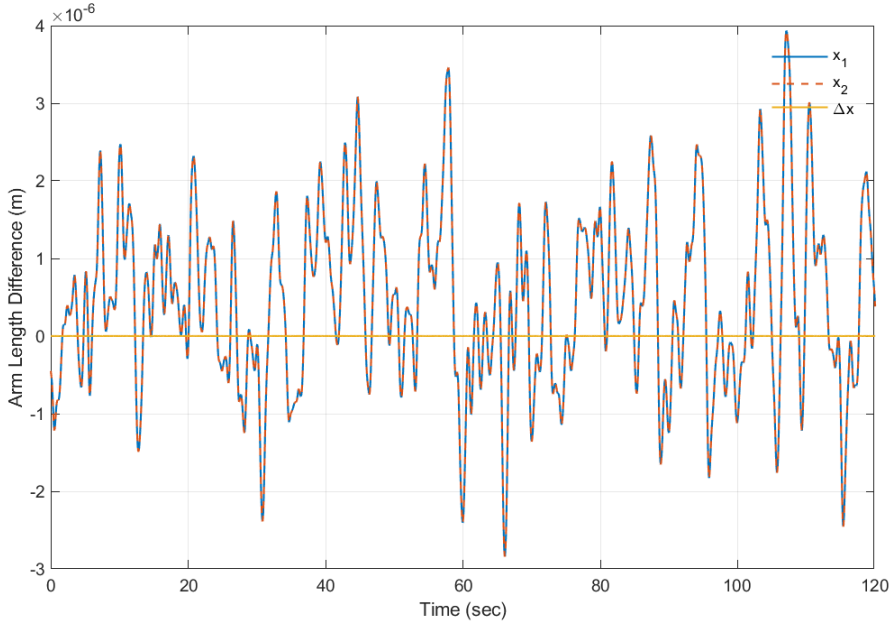
Testing the CDS Readout

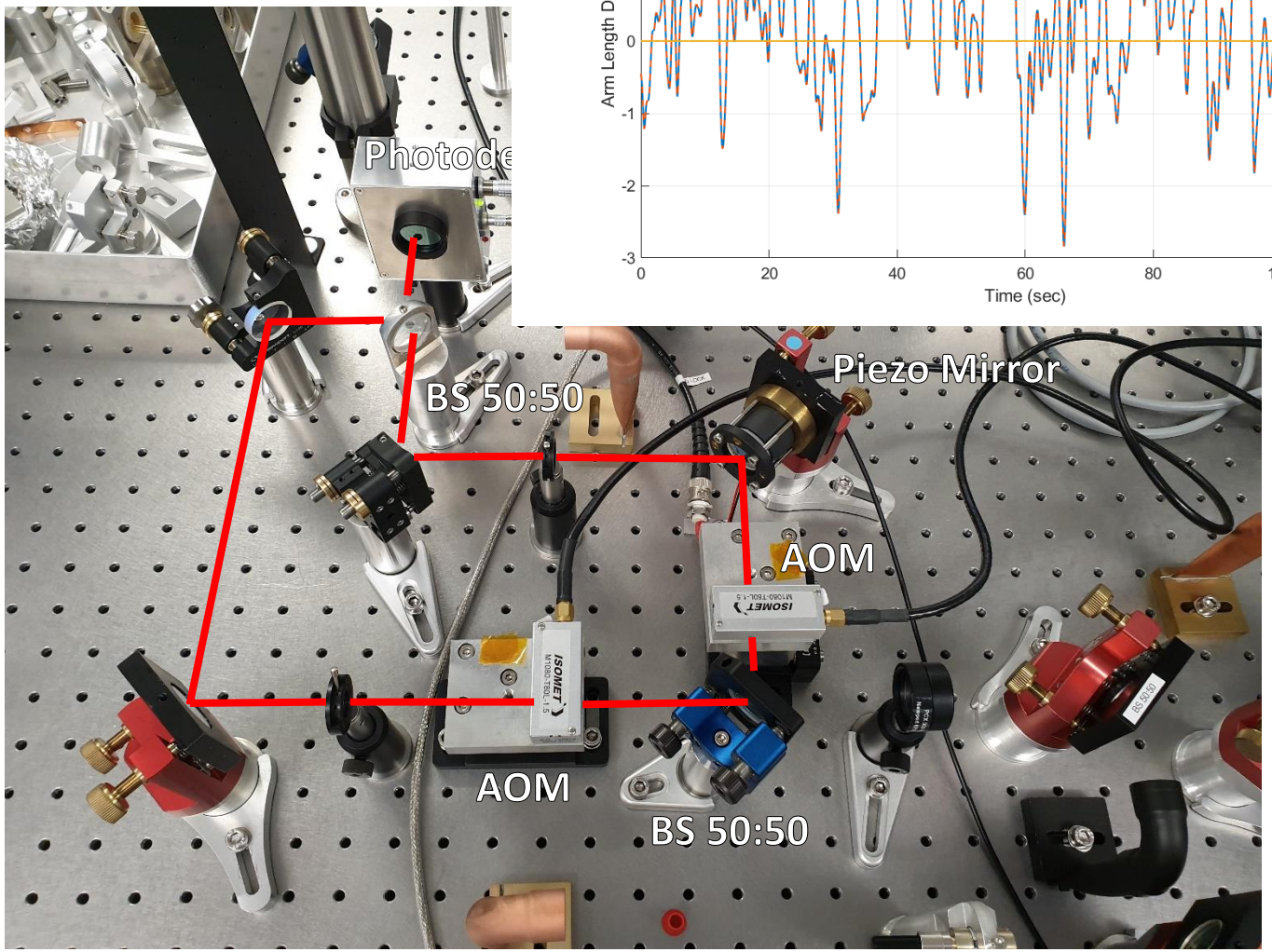
- Interferometer with piezo actuator in one arm
- Simulate seismic displacement
- Drive piezo element with HV amplifier to create large displacements



Testing the CDS Readout

- Apply filtered Gaussian noise to piezo
- Measure interferometer output with a photodiode
- Photodetector signal digitized by CDS

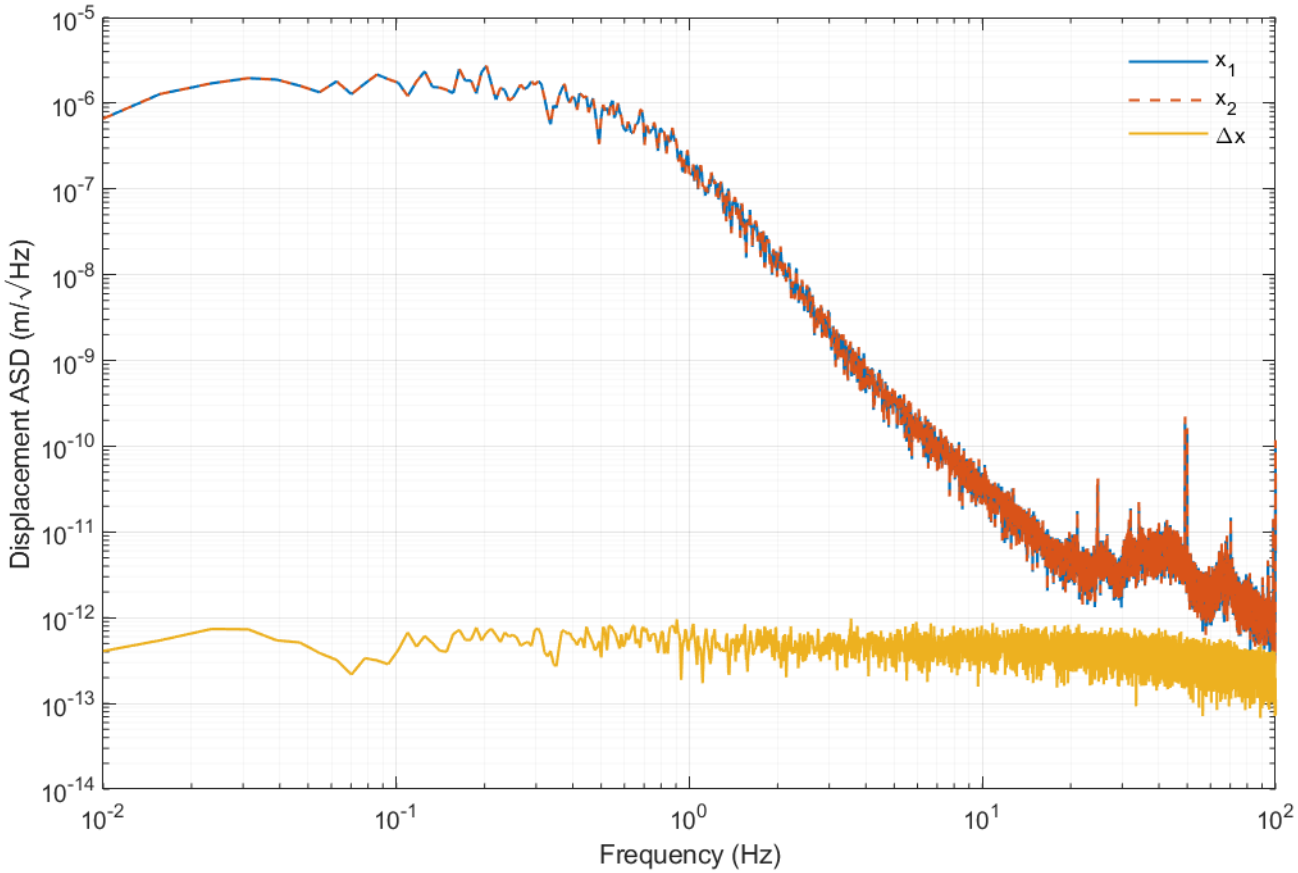




Testing the phasemeter readout

Split signal test:

- Split the photodetector signal in two parts
- Two individual phasemeters
- Subtract signal to determine noise floor



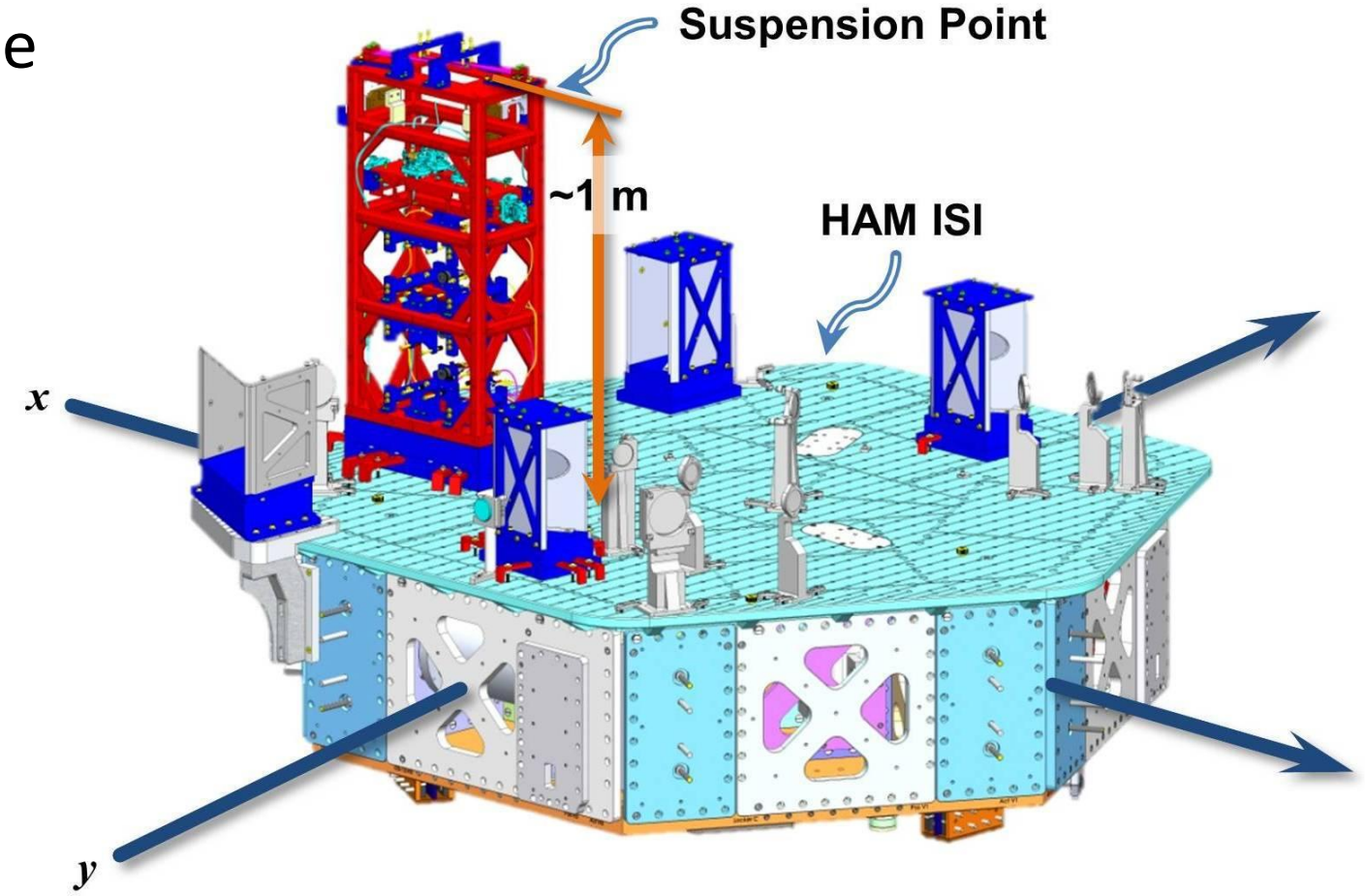
What now?

The platform motion is not the suspension point motion!

Luckily only three degrees of freedom are of importance:

- Differential length
- Pitch
- Yaw

Multiple interferometers or optical levers

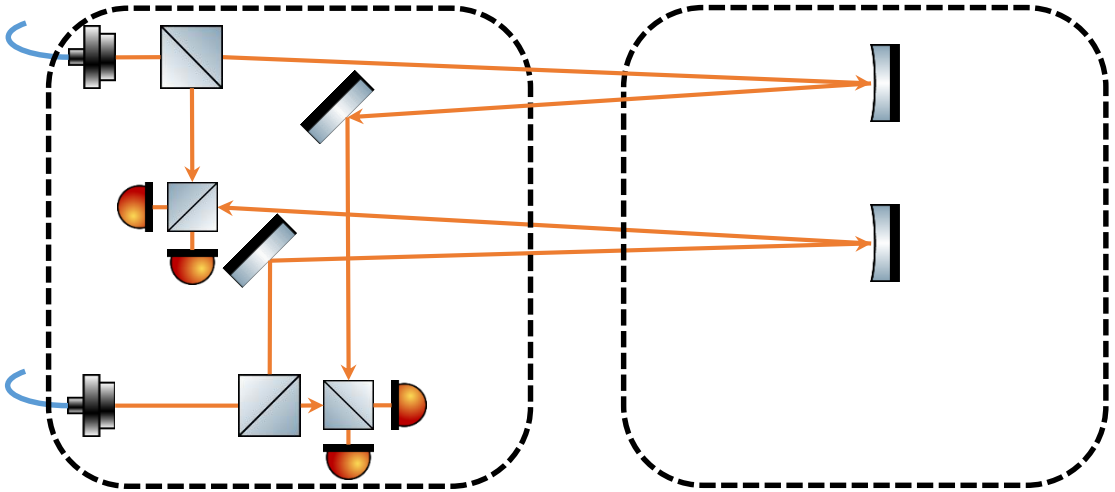


Source Brian‘s talk: Sep. 2020 G2001539

What geometry could we choose?

Three point interferometer

- High signal-to-noise ratio
- Coupling of length to angle
- Differential rotation



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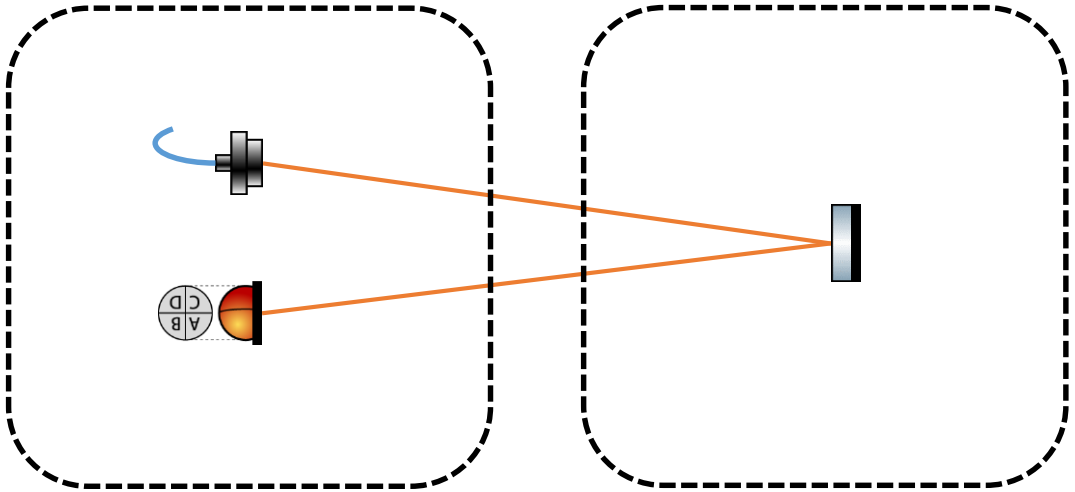
Optical lever with sending and detection on the same isolation system

- Decoupled from translations
- Coupling of thee rotations of the two isolation systems



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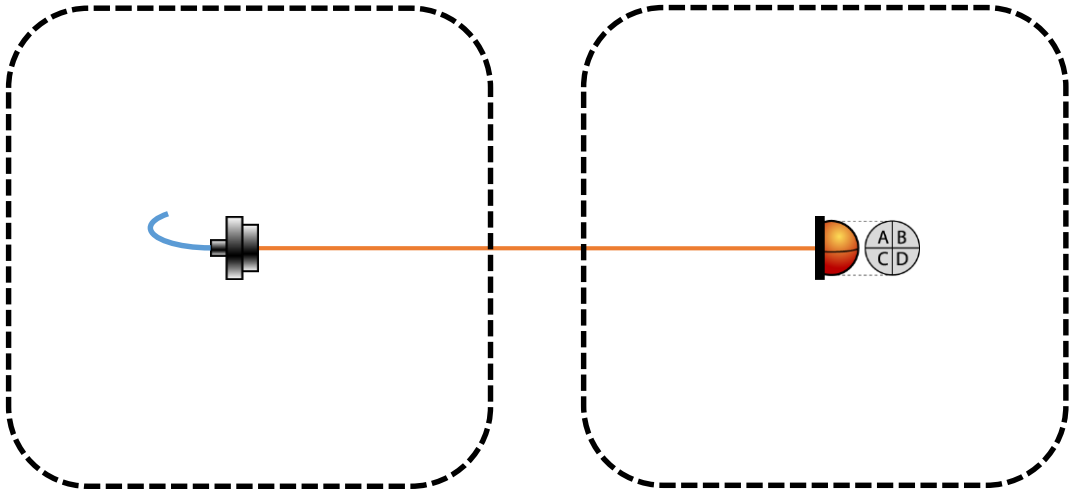
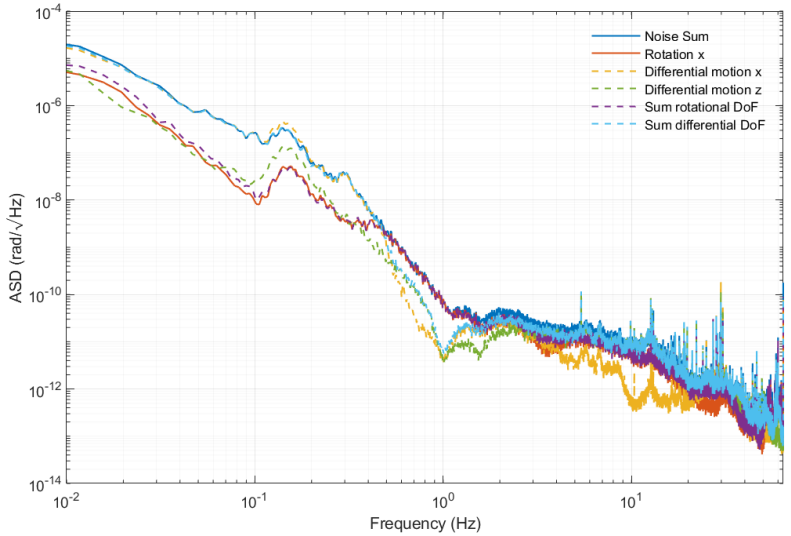
- Rotation sensing for individual isolation systems
- Coupling to translation degrees of freedom





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Let’s meet at the low frequency workshop!