The AEI 10 m Prototype

June 2014 - Sina Köhlenbeck for the 10m Prototype Team

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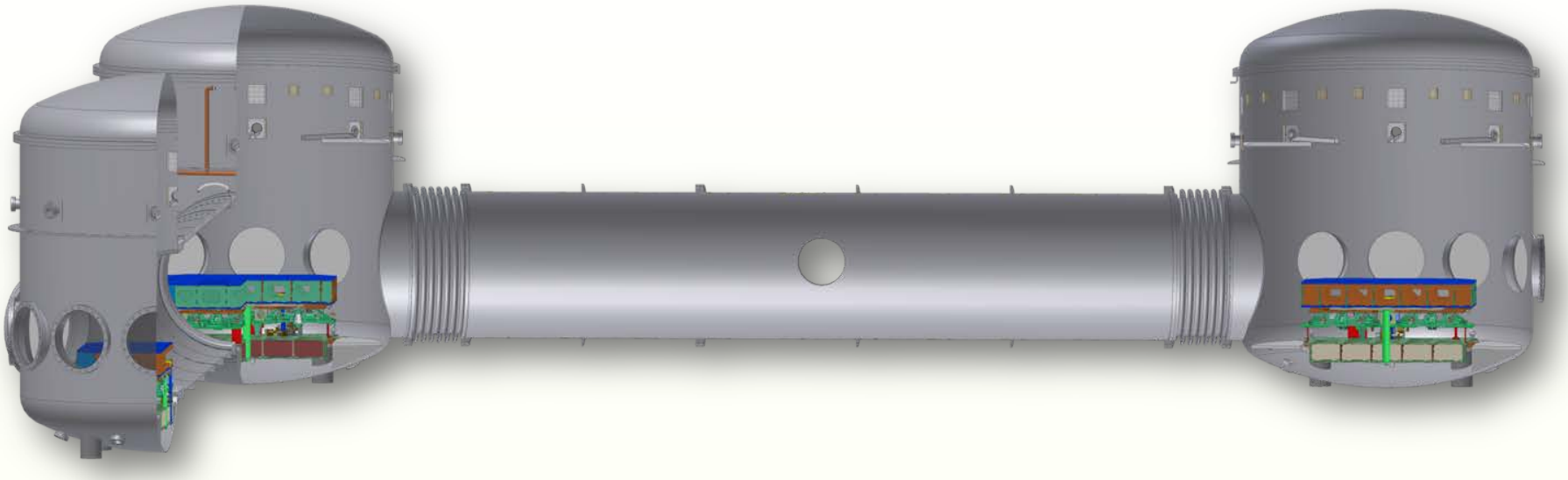
The 10m Prototype

Seismic attenuation system

Suspension Platform Inteferometer

SQL Interferometer Suspensions

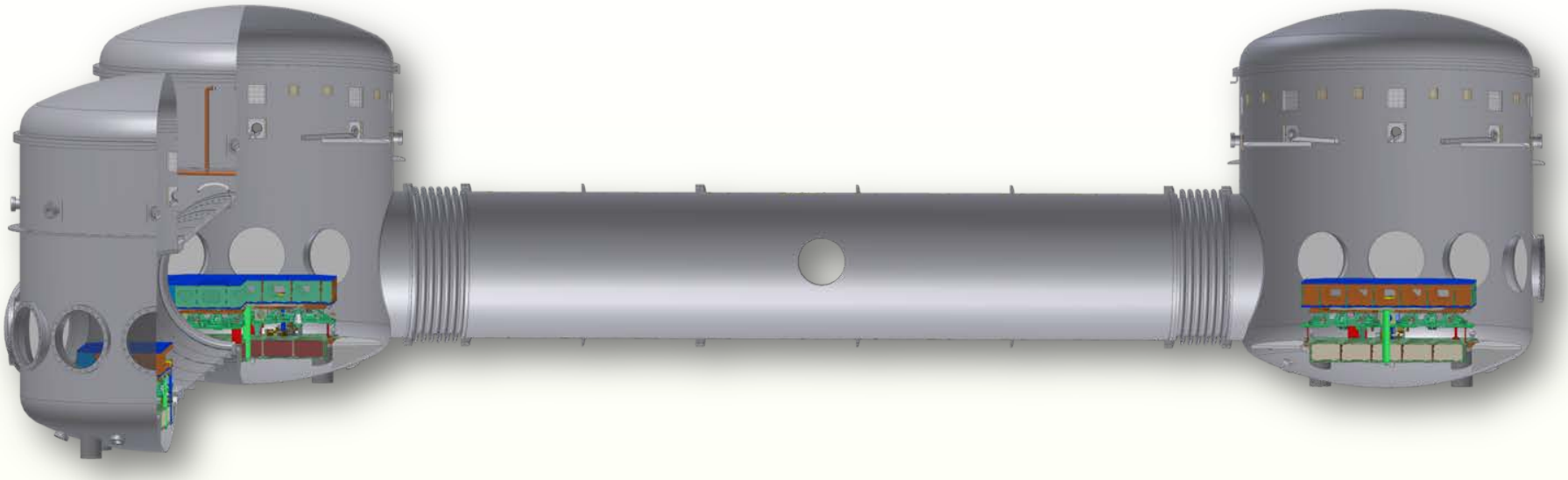
The AEI 10 m Prototype



Low noise test bed for multiple experiments

- Prototype for future gravitational wave detectors
- Measurements at and below the Standard Quantum Limit

Features of the 10 m Prototype



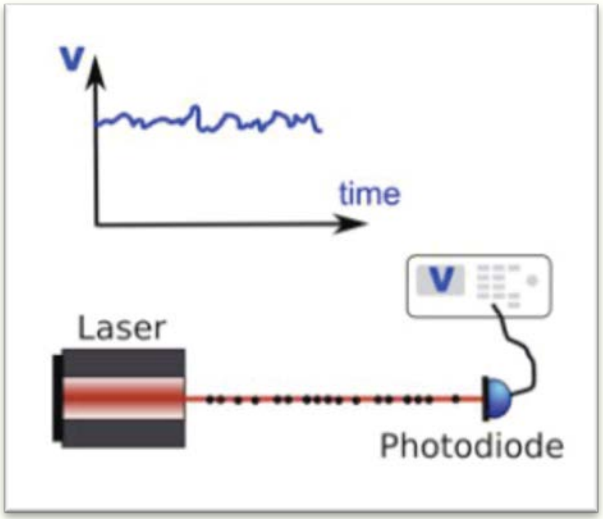
- Ultra high vacuum system
- Flexible configuration
- Seismic Attenuation System

The Standard Quantum Limit (SQL)

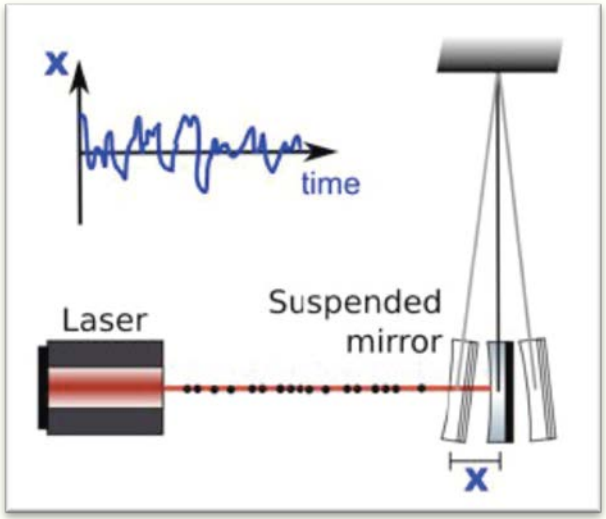
What is quantum noise?

- Photon shot noise at high frequencies
- Quantum radiation pressure noise at low frequencies

Photons in a coherent-state laser beam are not equally distributed



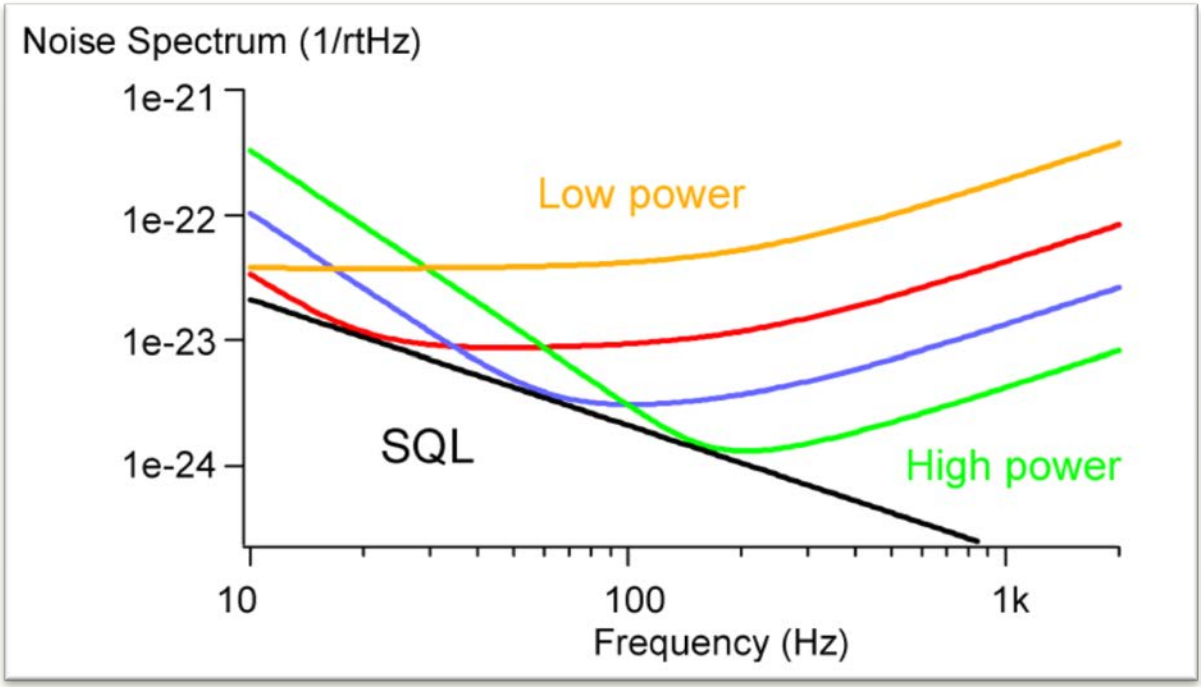
Photon shot noise



Quantum radiation pressure noise

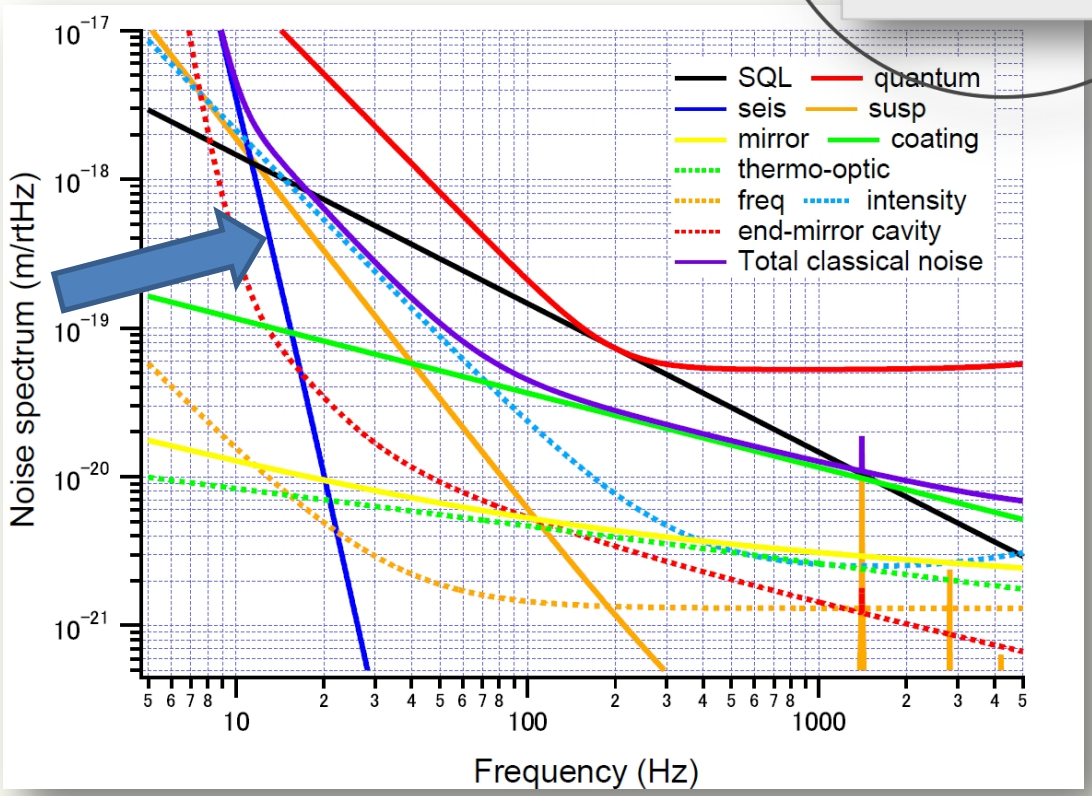
The SQL

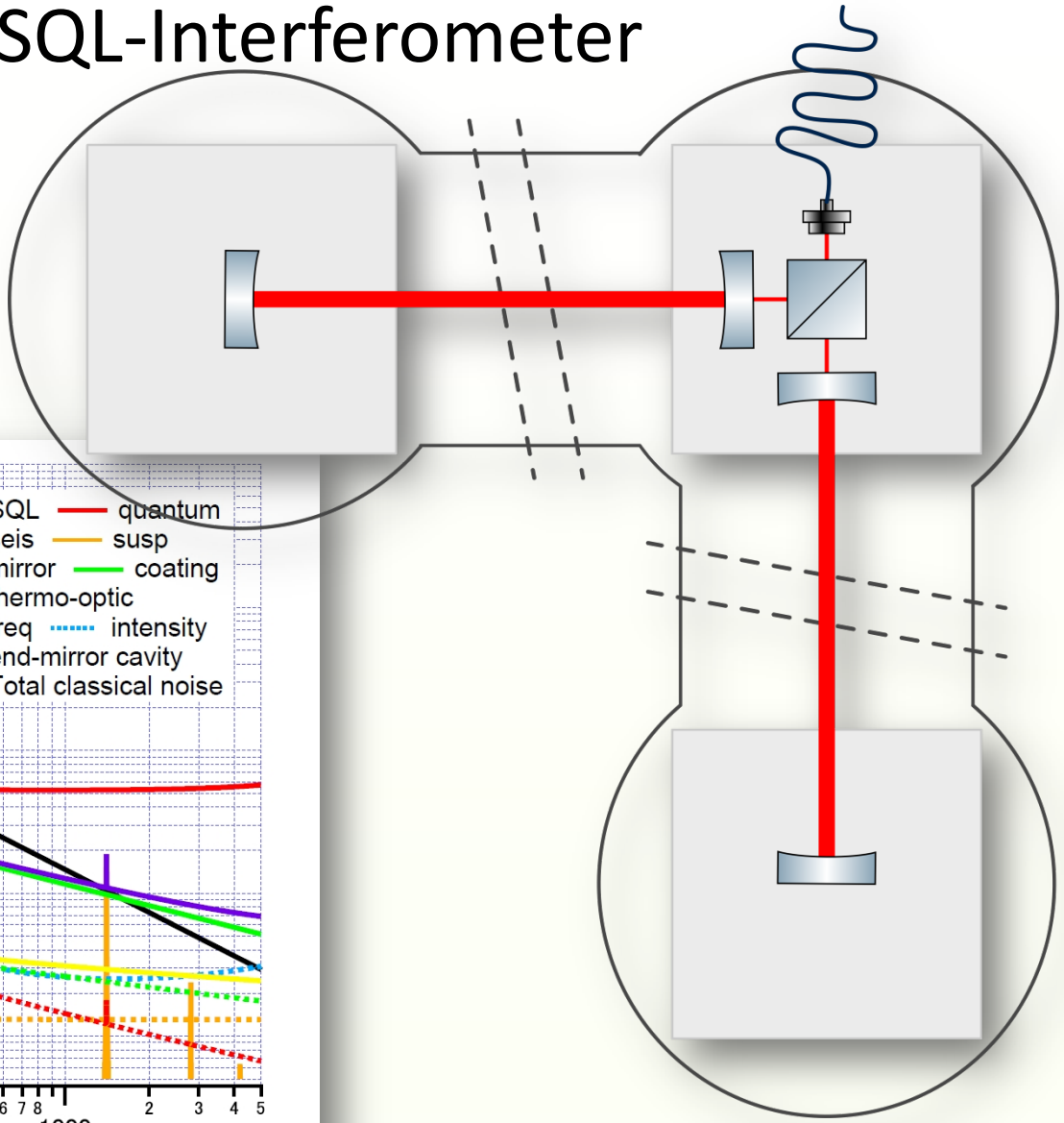
The SQL is the crossover between radiation pressure noise and shot noise



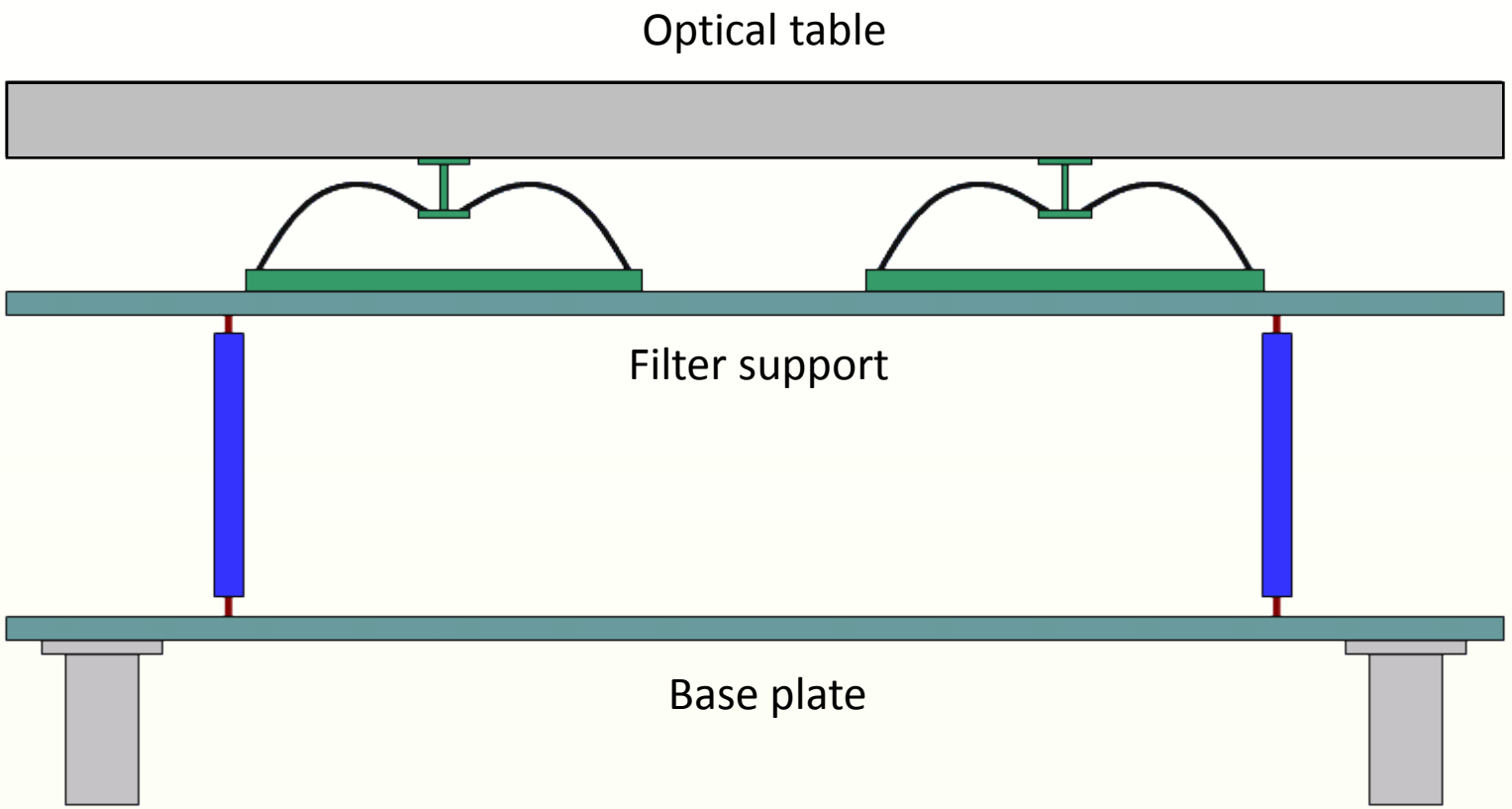
The SQL-Interferometer

Reduce all classical noise sources to be only limited by quantum noise

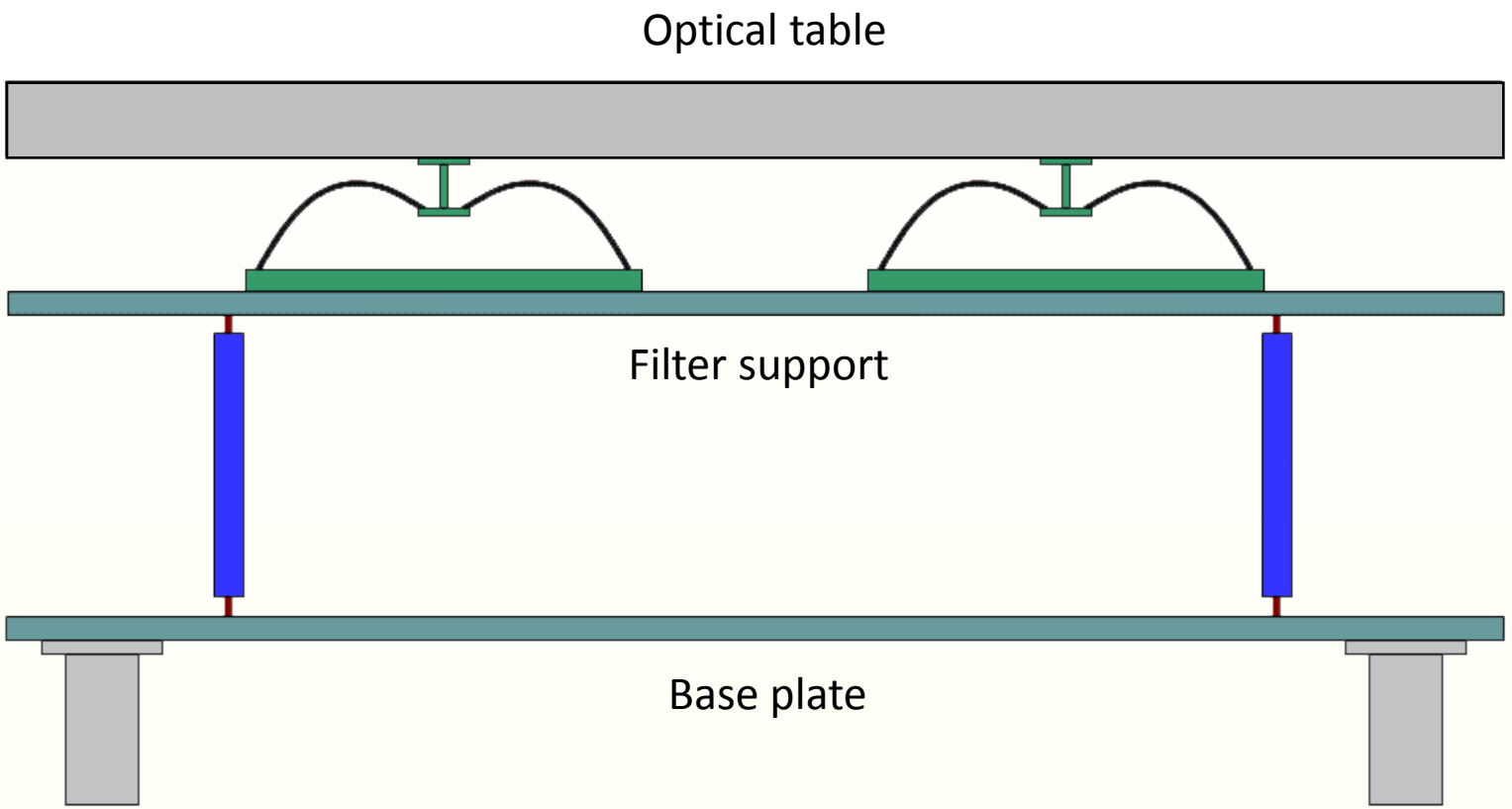




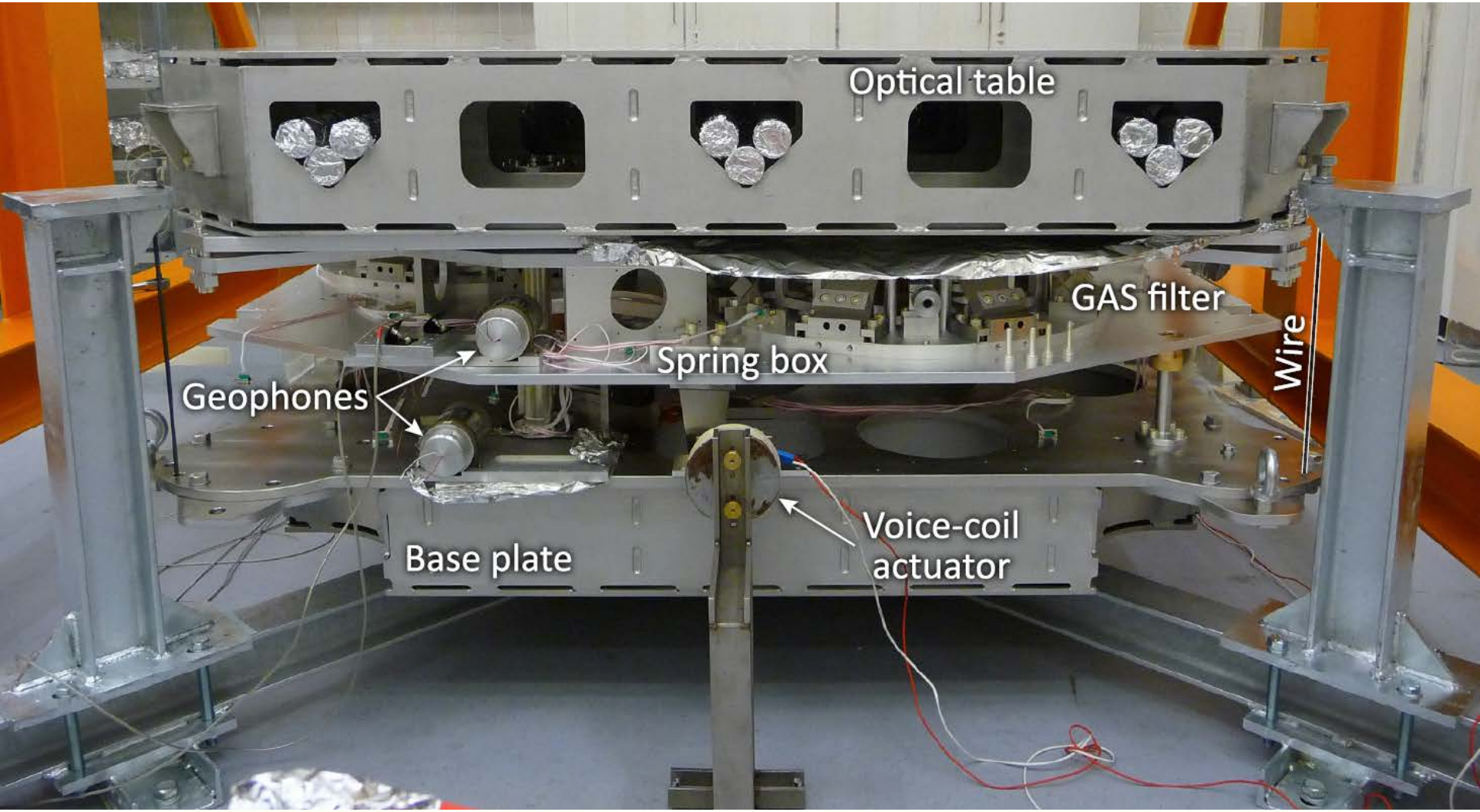
Horizontal isolation stage



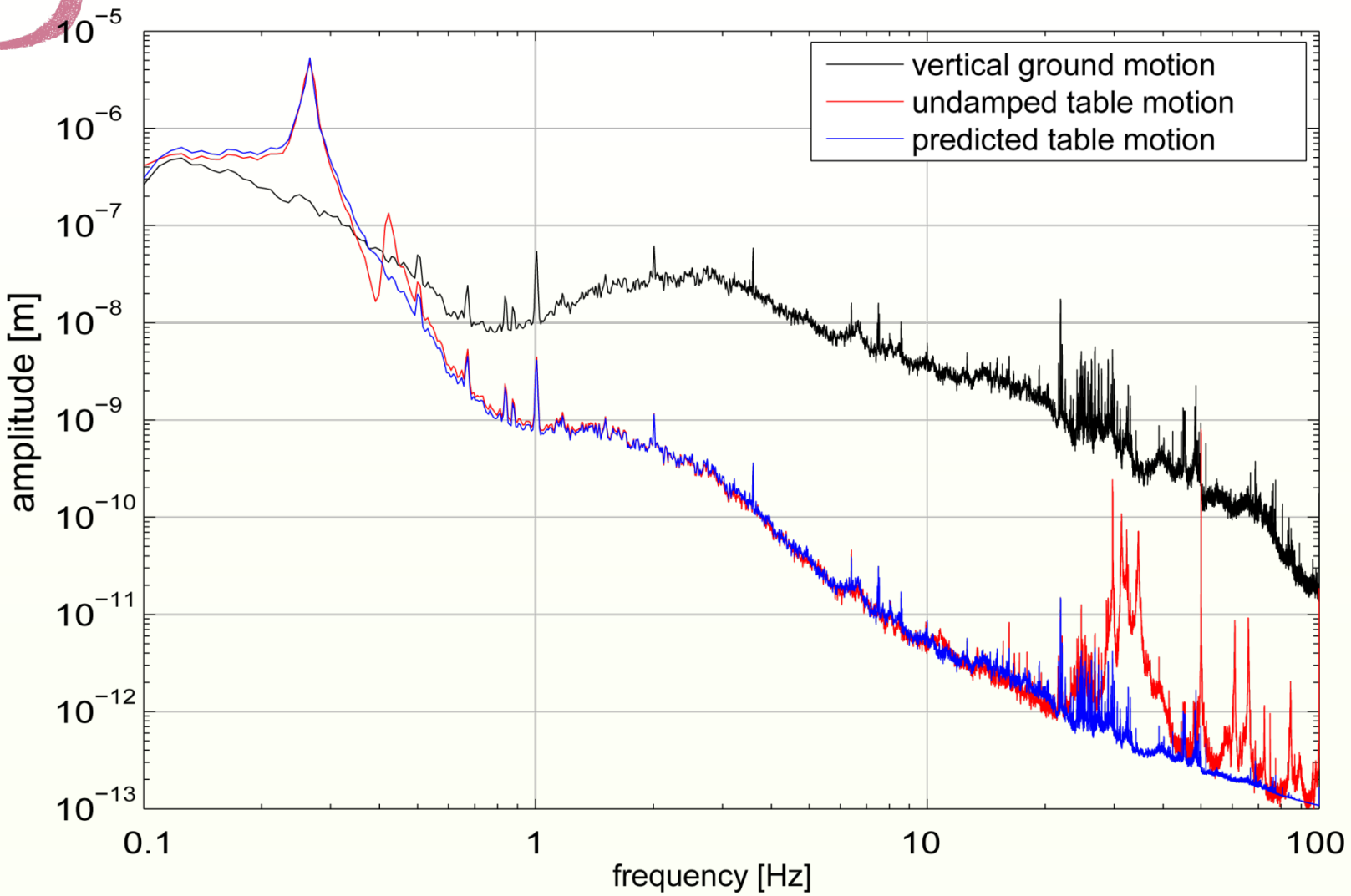
Vertical isolation stage



Seismic Attenuation System



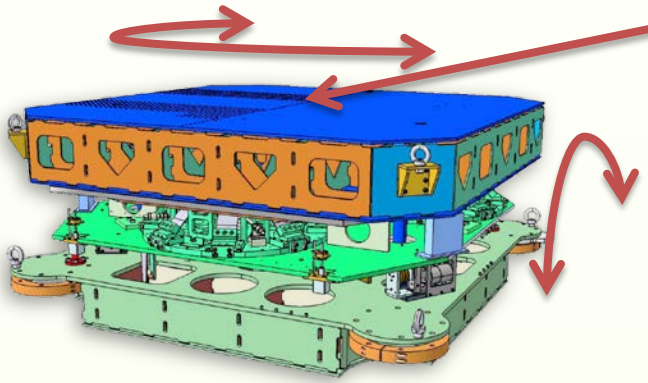
SAS vertical performance

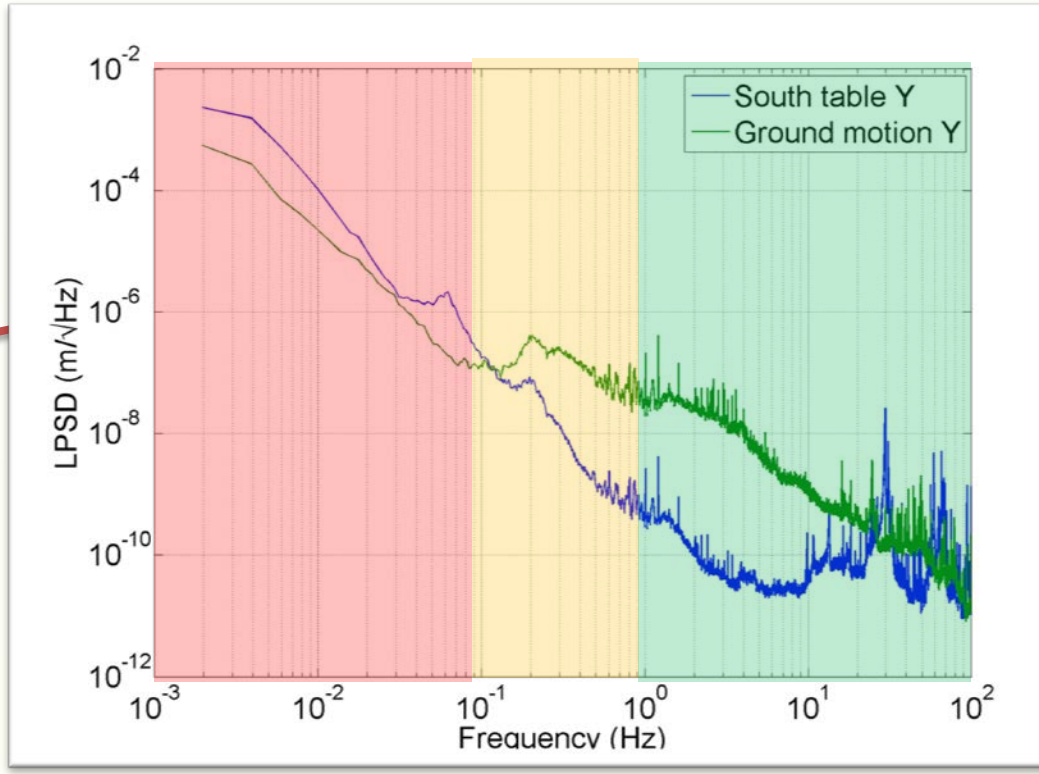


Purpose of the SPI

Control of the longitudinal and angular position of two SAS relative to each other:

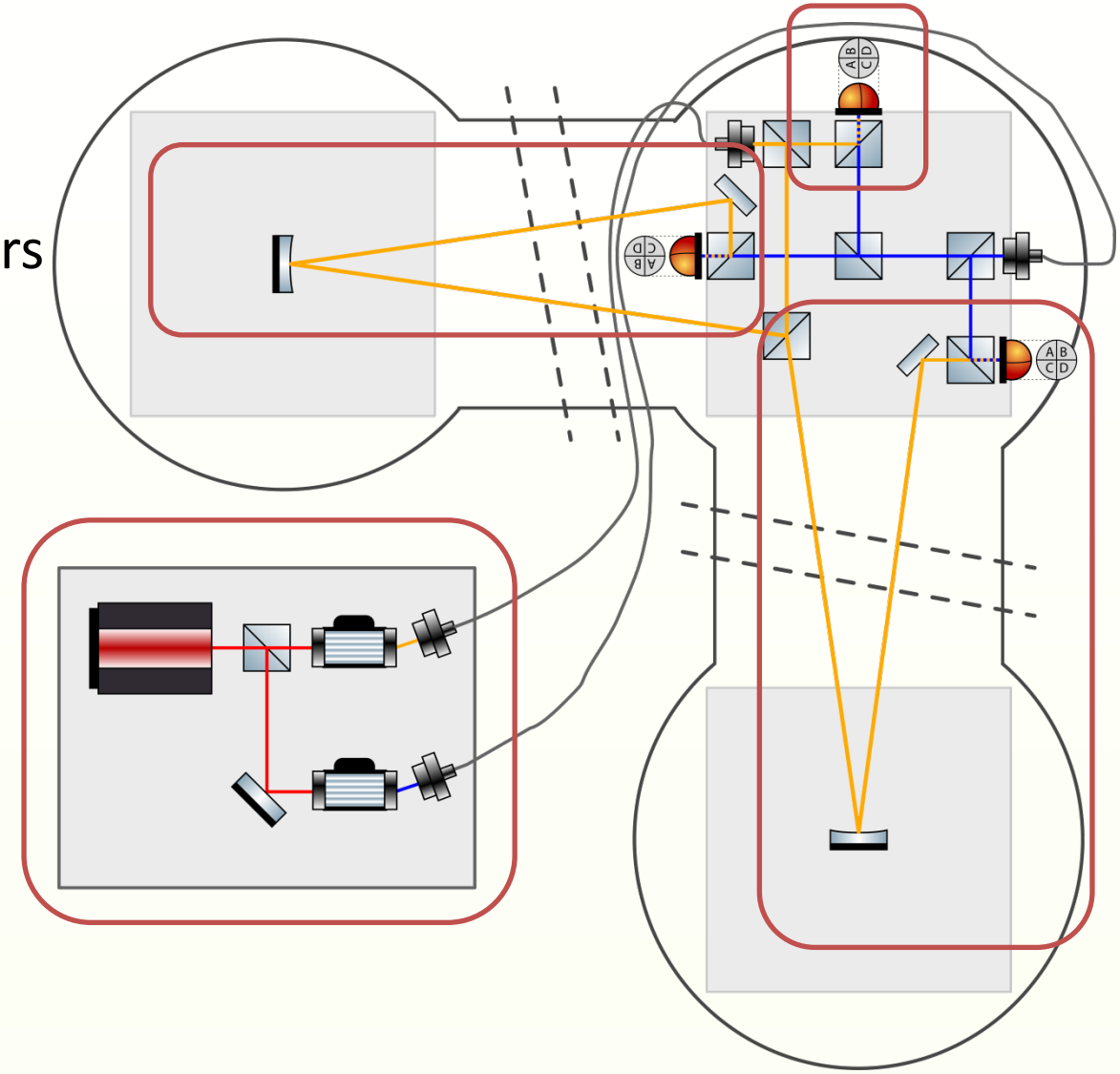
- Longitudinal:
  100 pm/√Hz @ 10 mHz
- Angular:
  10 nrad/√Hz @ 10 mHz



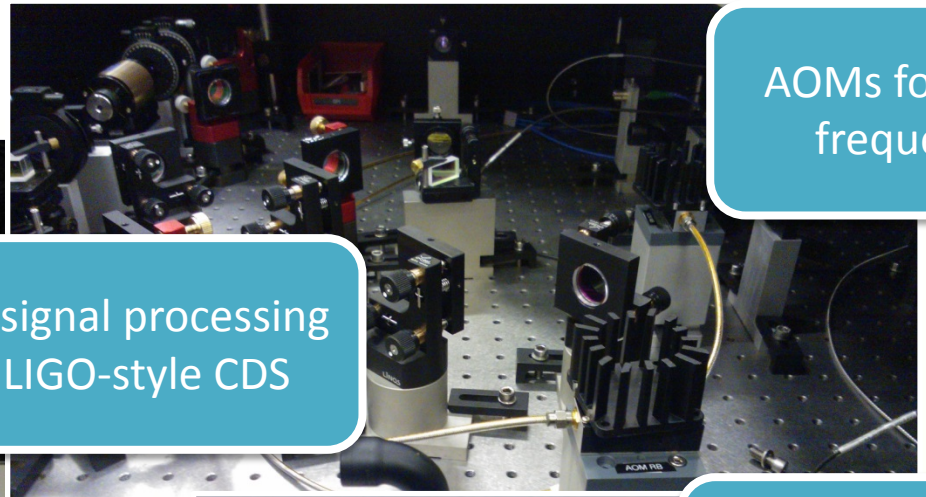


Working principle

- Heterodyne Mach-Zehnder interferometers
- Modulation bench outside the vacuum
- Two diagnostic interferometers
- Two measurement interferometers
- Phase measurement with phasemeter
- Differential wavefront-sensing (DWS)



Key features of the SPI



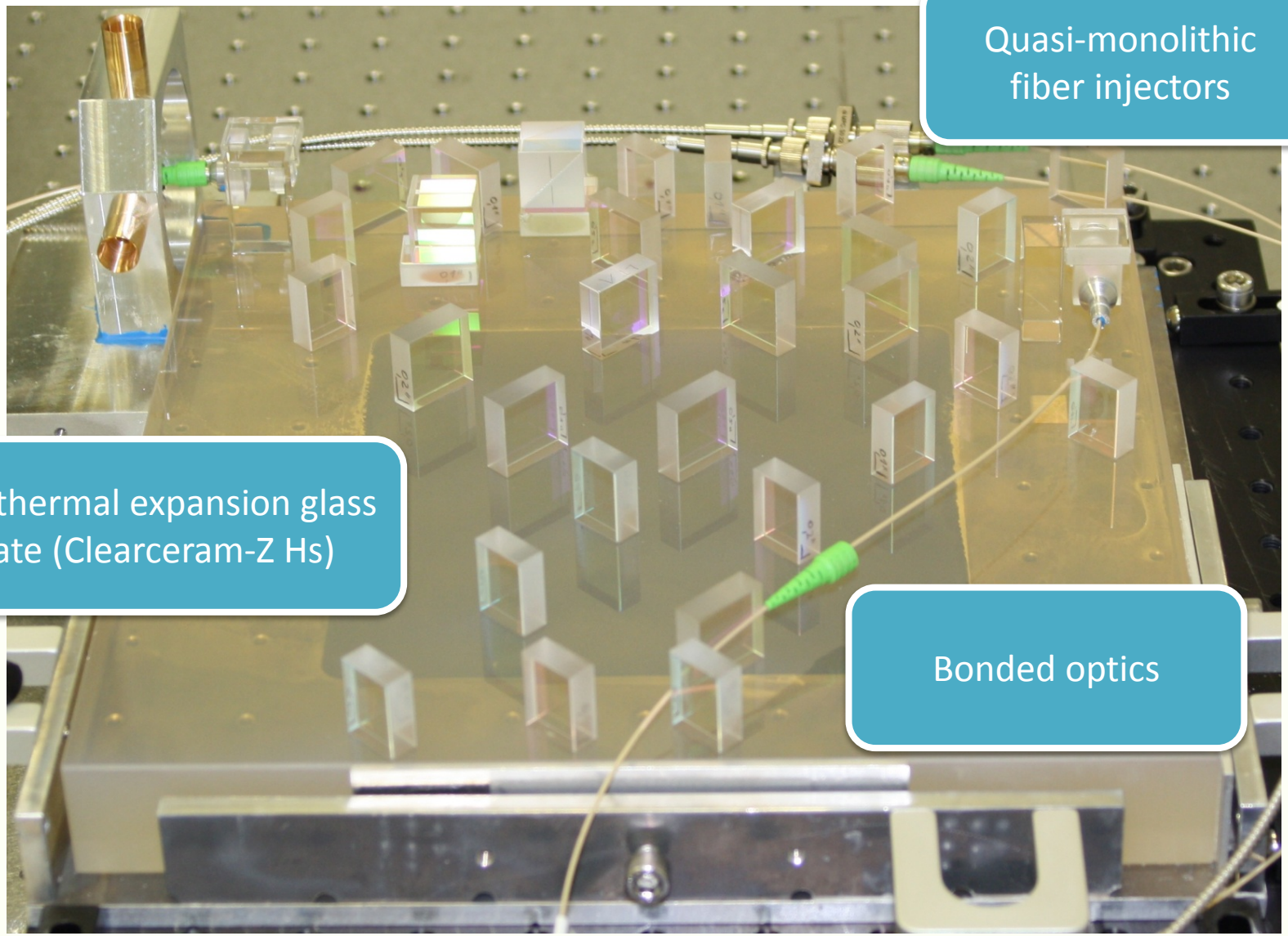
AOMs for heterodyne frequency offset

Digital signal processing with LIGO-style CDS

Phasemeter developed for LISA Pathfinder

Nd:YAG NPRO Laser stabilized to iodine reference

Key features of the SPI



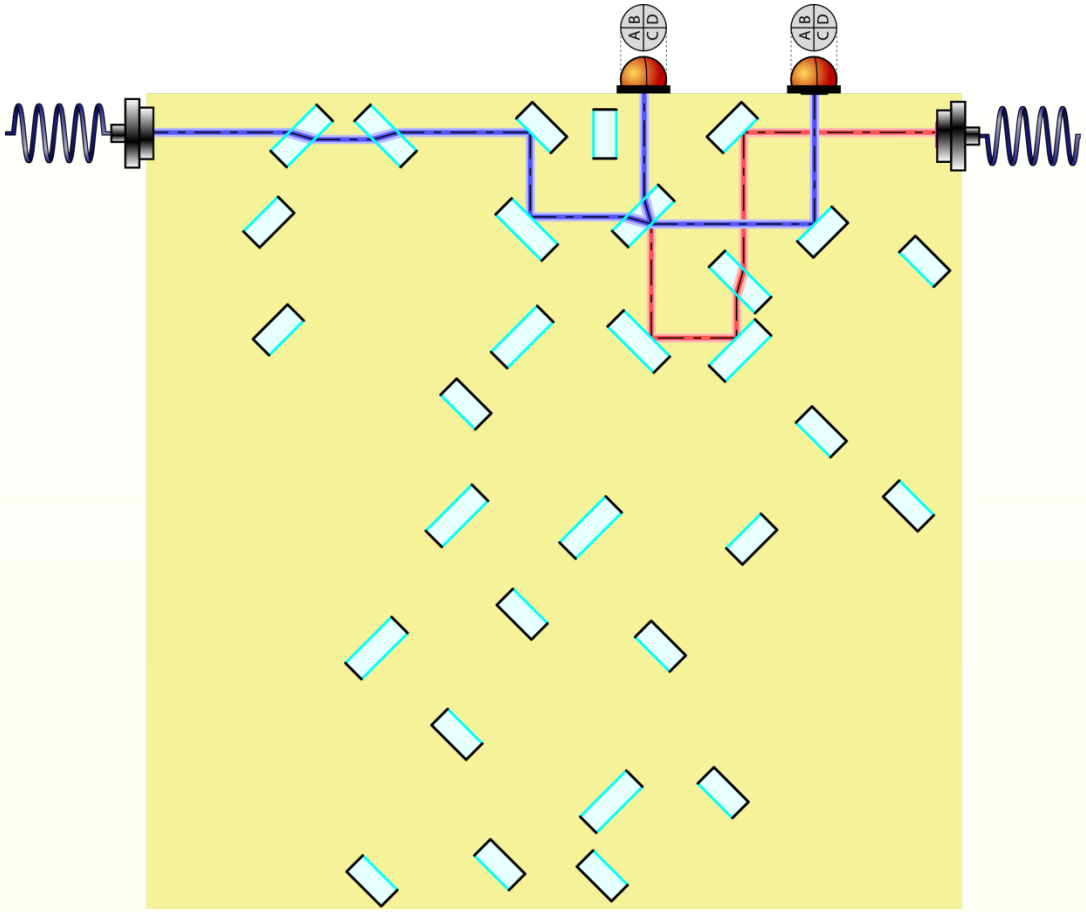
Quasi-monolithic fiber injectors

Ultra-low thermal expansion glass base plate (Clearceram-Z Hs)

Bonded optics

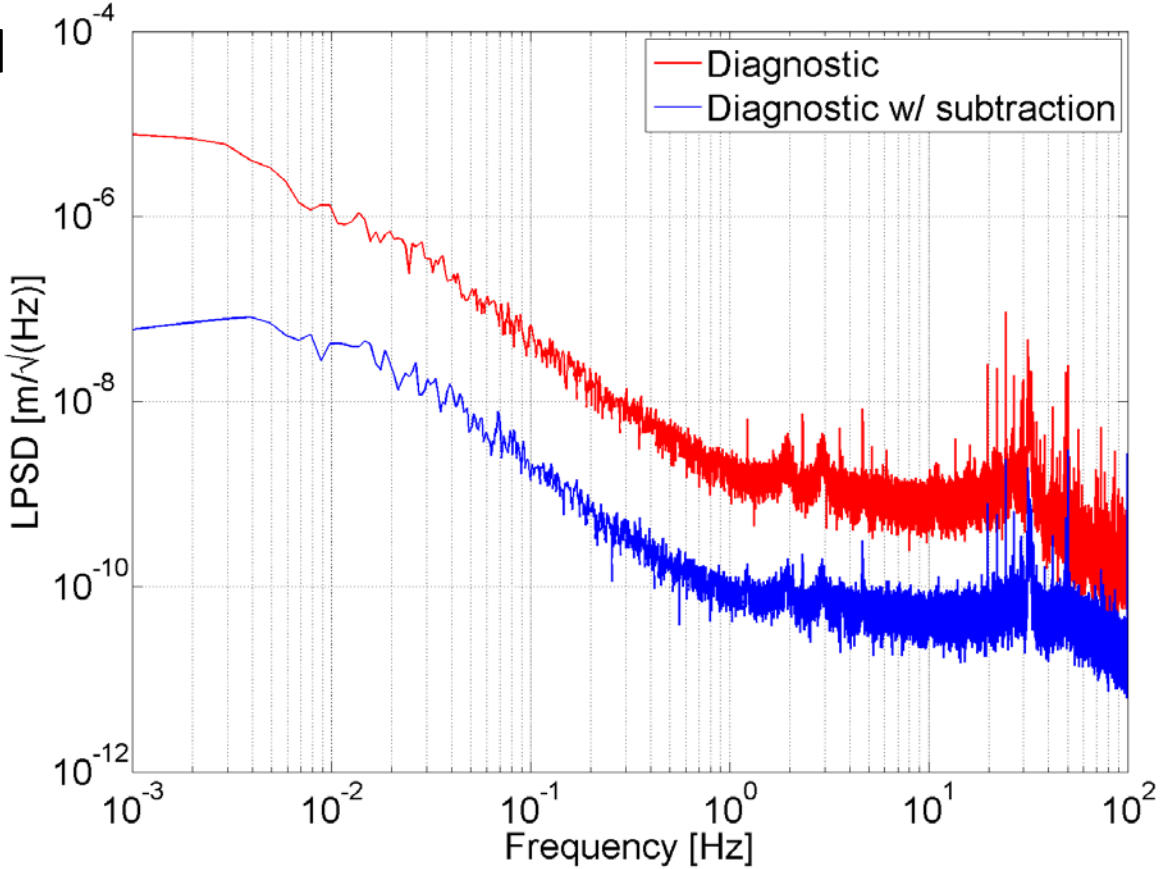
Purpose of the diagnostic interferometer

- Long optical path until the base plate
- Measures (common mode) noise
- Subtracted from measurement interferometers



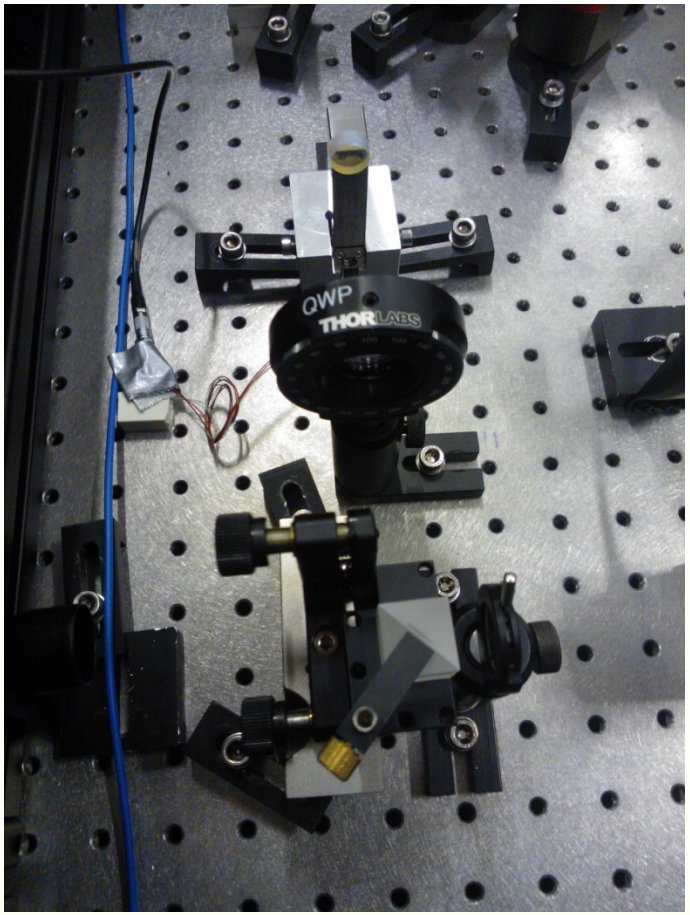
Performance of the diagnostic IFO

- Performance limited by optical path length difference noise (OPD)
- Caused by noise from the AOM drivers, stress in the fibers and on the modulation bench
- Solution: OPD stabilization

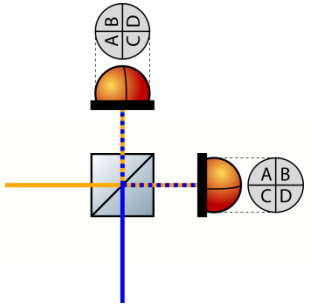


OPD stabilization

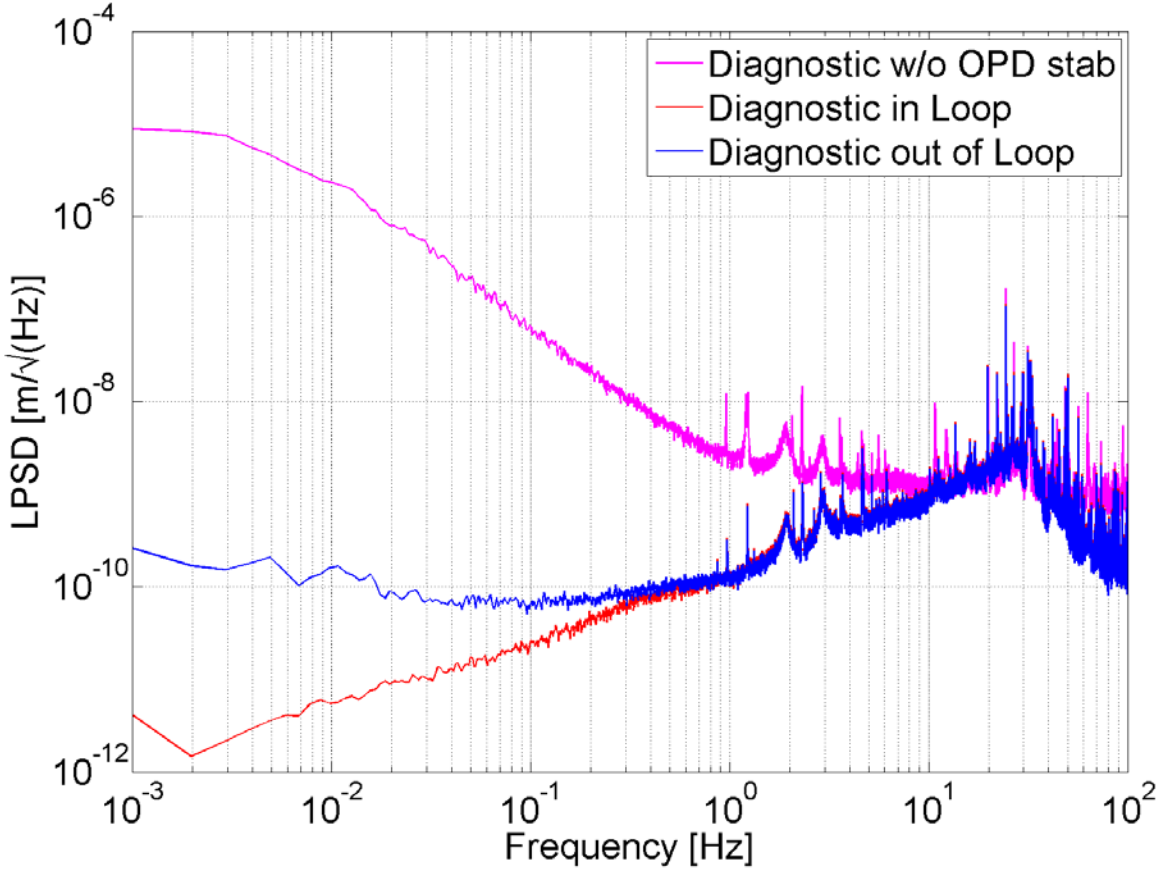
- Phase measurement of the dignostic IFO
- Digitally filtered signals
- DAC provides analog signal
- High voltage amplifier
- Analog low pass filter



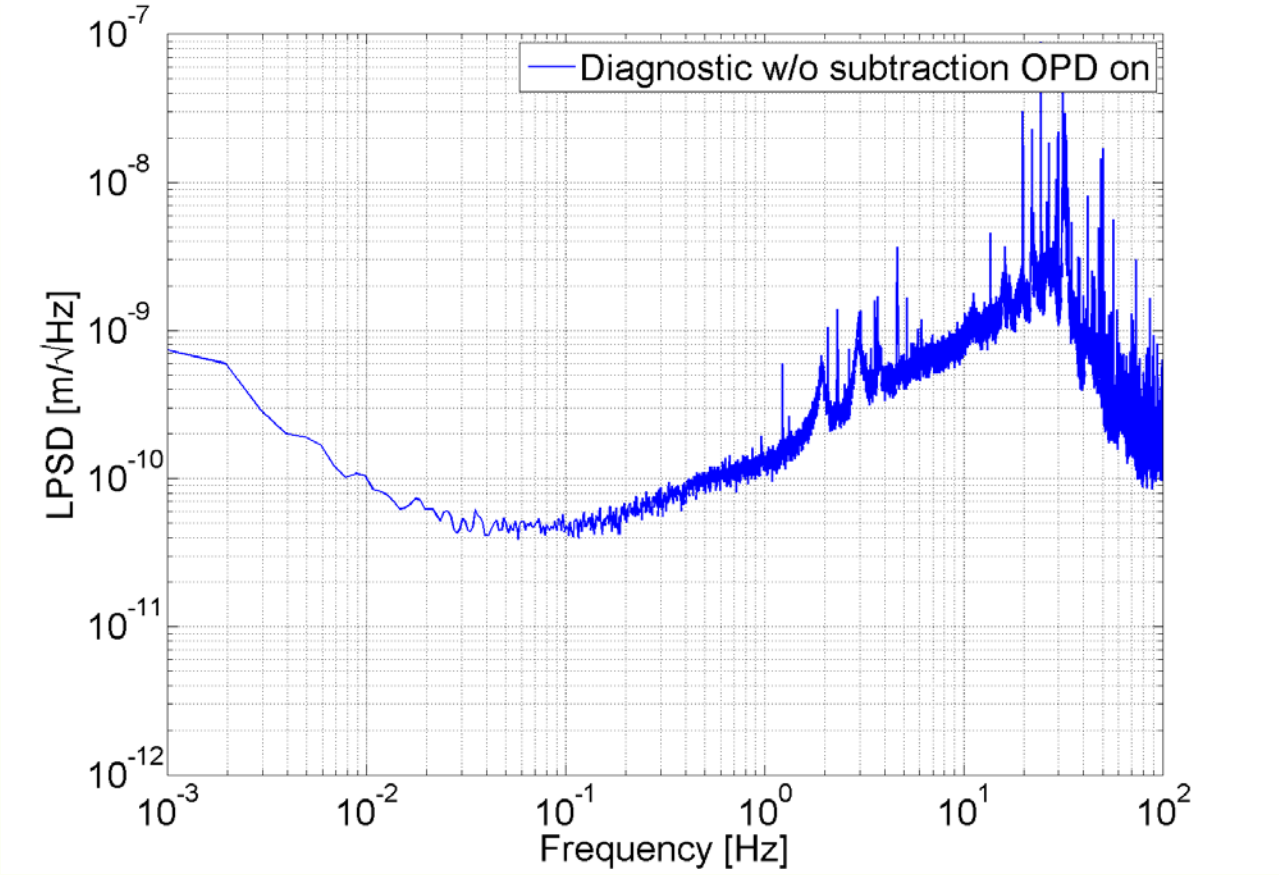
OPD stabilization



- Two PD‘s for each IFO
- First PD is an in-loop sensor
- Second PD is an out-of-loop sensor
- Residual noise from electronics and phasemeter

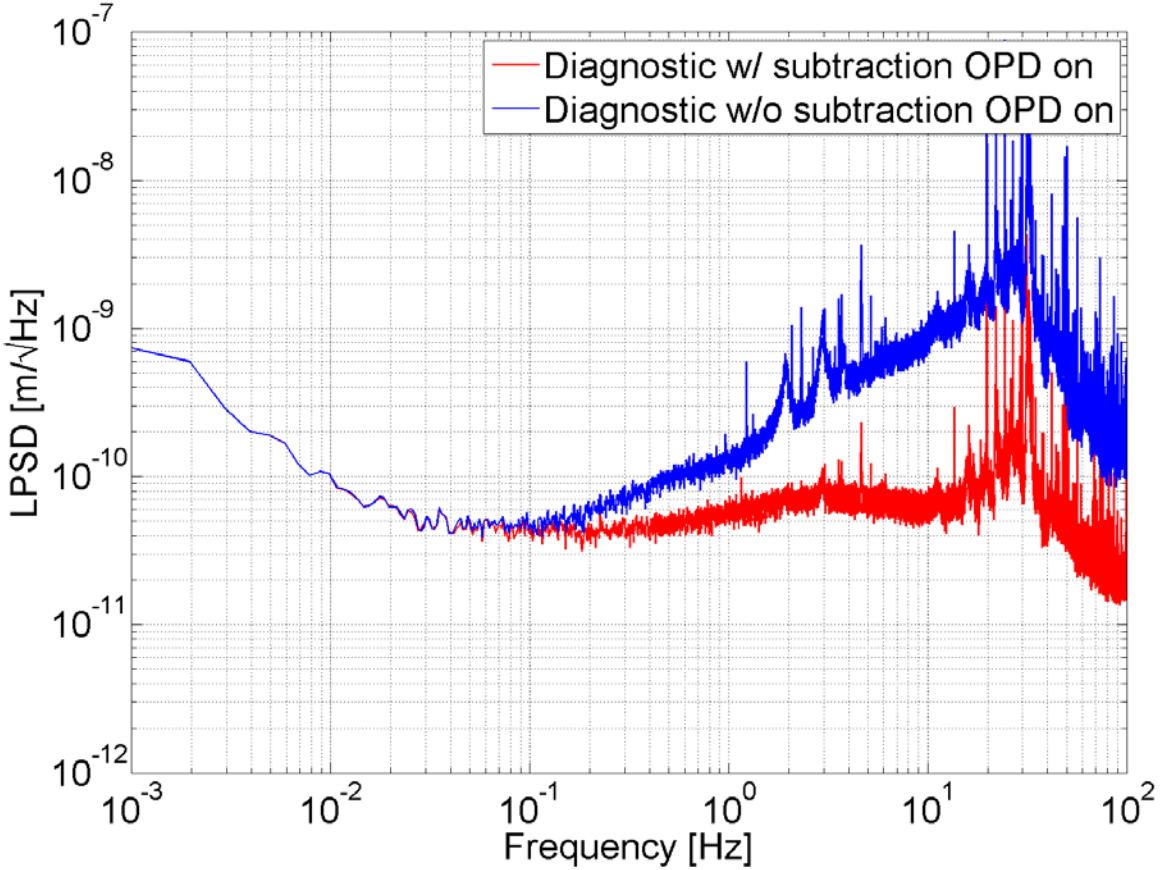


Performance of the OPD stabilization



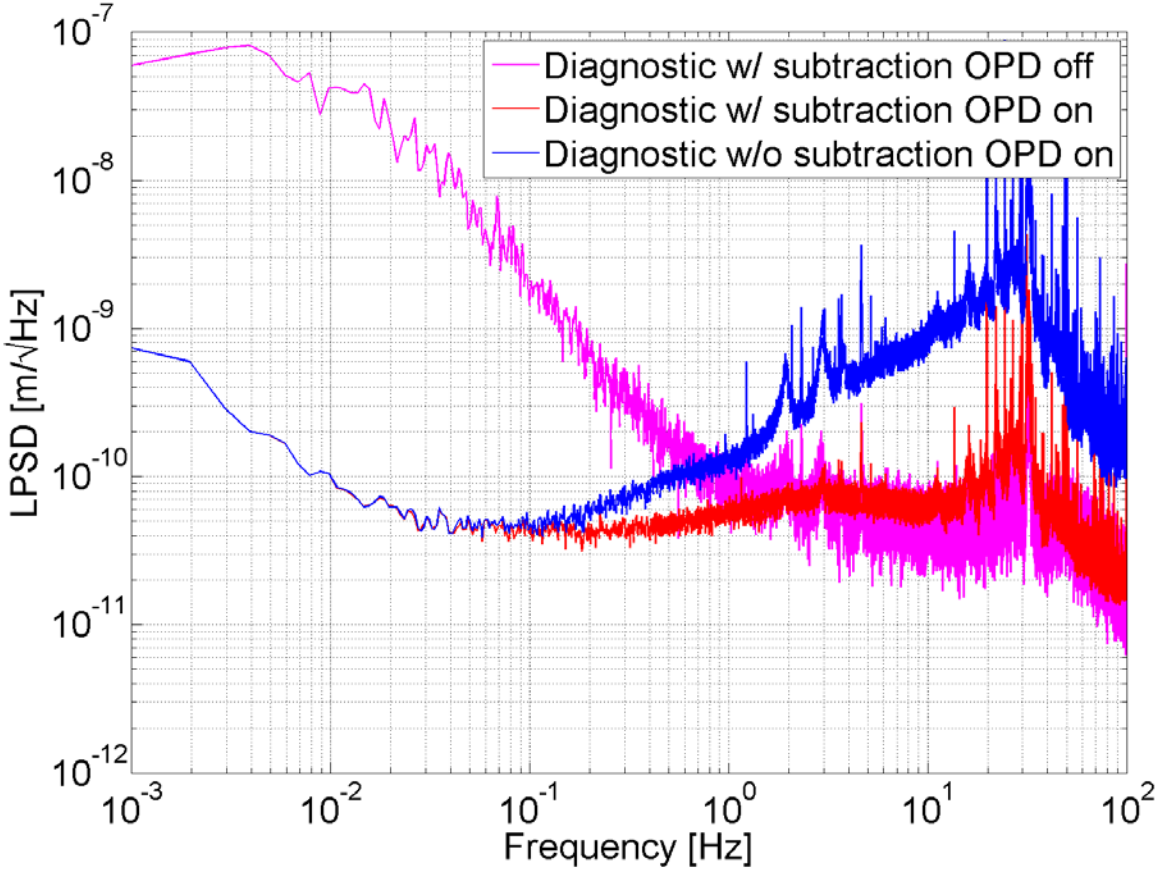
Performance of the OPD stabilization

– High frequency noise cancelled by subtraction of common mode noise



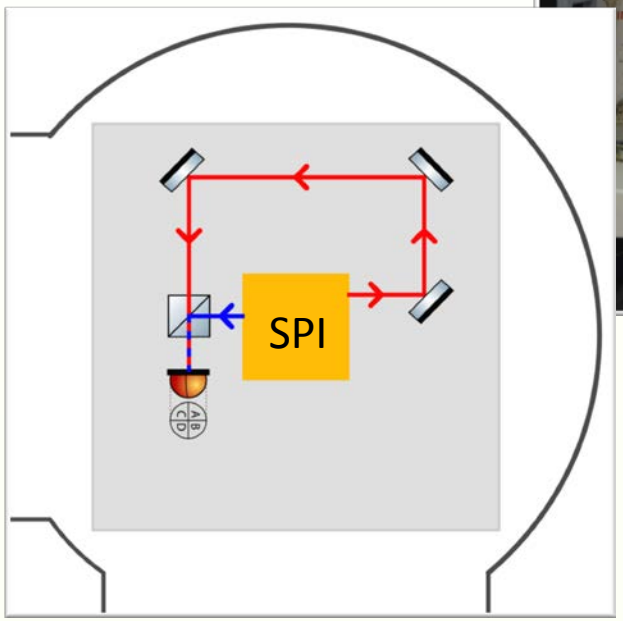
Performance of the OPD stabilization

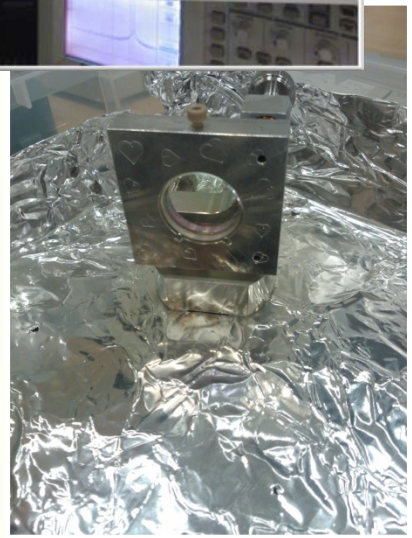
- High frequency noise cancelled by subtraction of common mode noise
- Below 1 Hz suppression by OPD stabilization



Frequency Noise Interferometer (FNI)

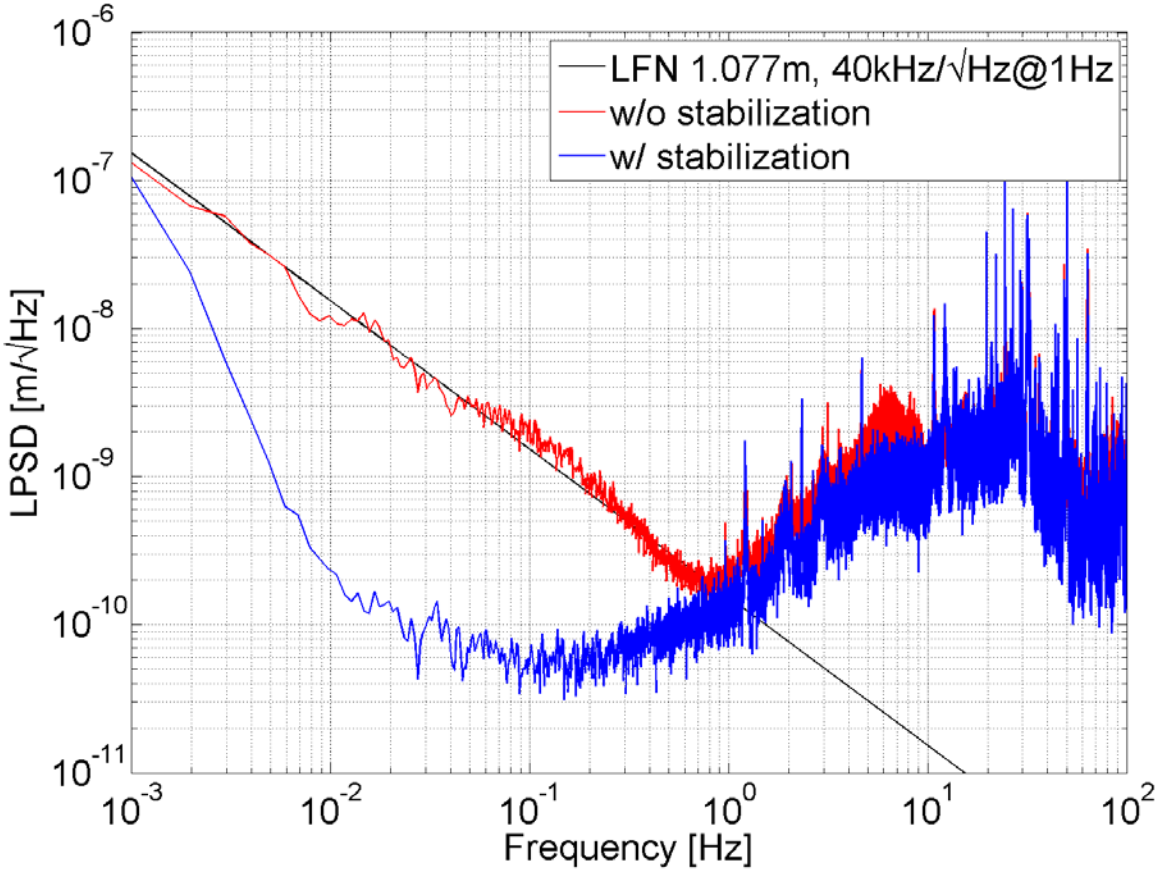
- Test for the Iodine Laser frequency stabilization
- Test for the OPD stabilization
- 1 m arm length miss match, on central table
- Built with off the shelf UHV mounts





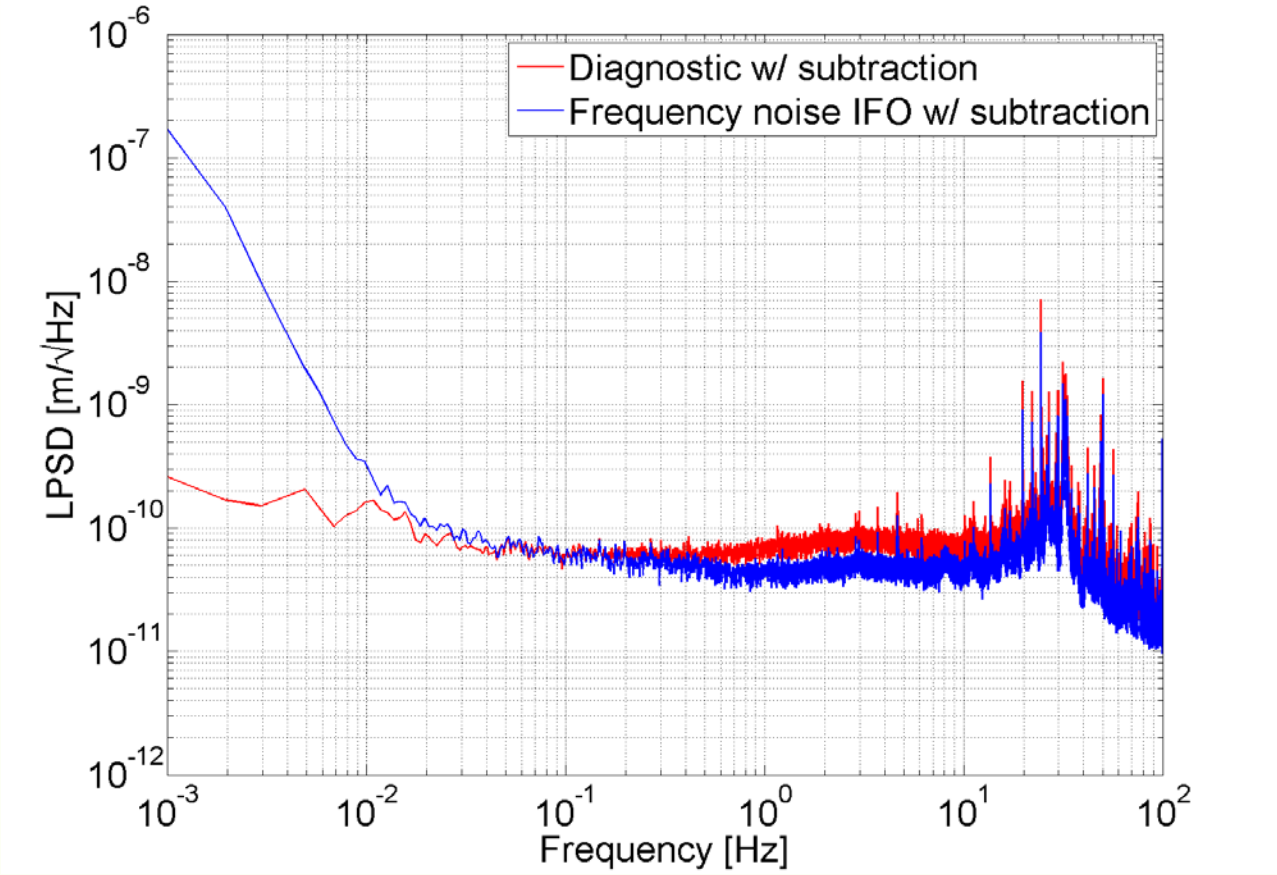
Performance of the FNI

- Measurable because of the OPD stabilization
- Frequency stabilization is working
- Modelled 1/f slope frequency noise: 40 kHz/√Hz @ 1 Hz



Comparing diagnostic and frequency noise IFO

- Subtraction reduces high frequency noise
- FNI lower noise
- Power and contrast better in FNI



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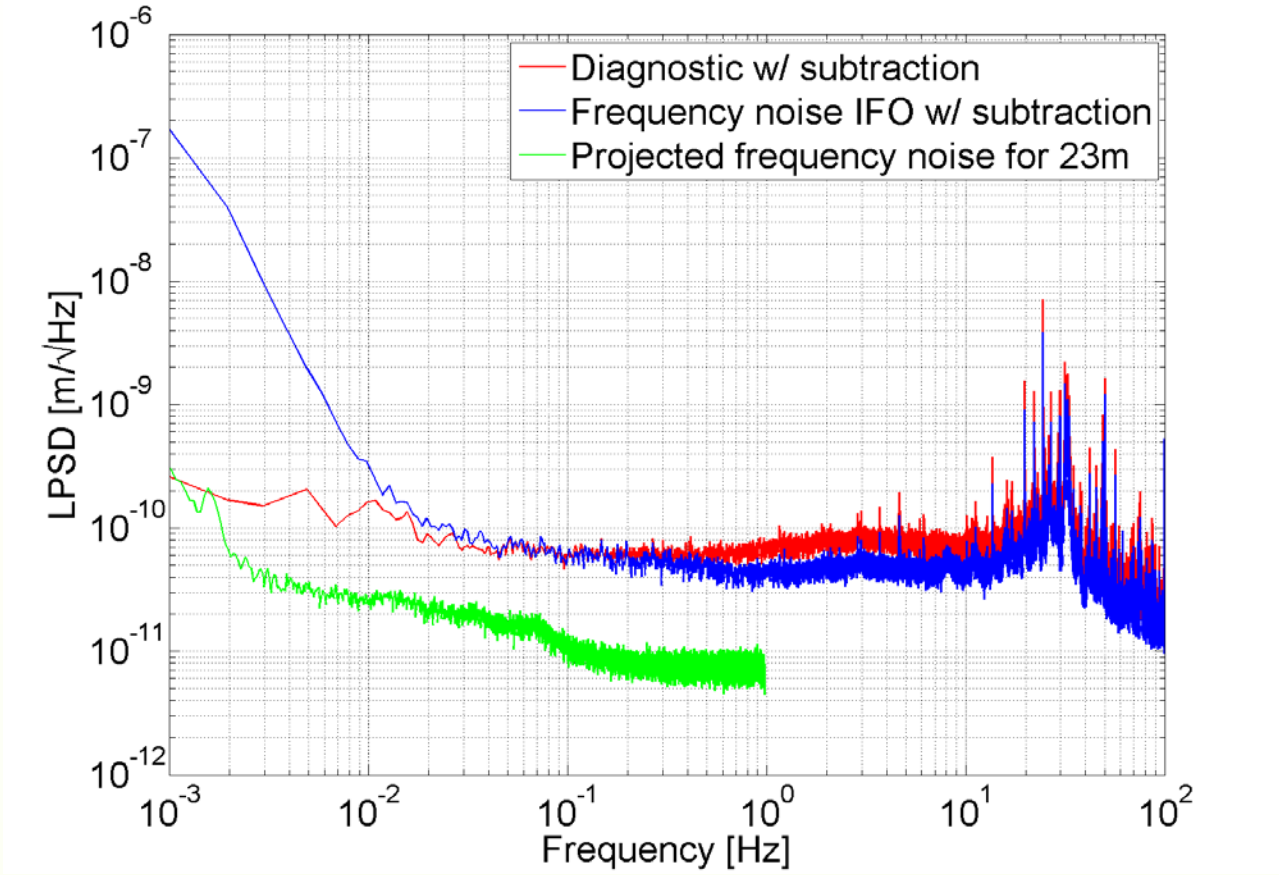
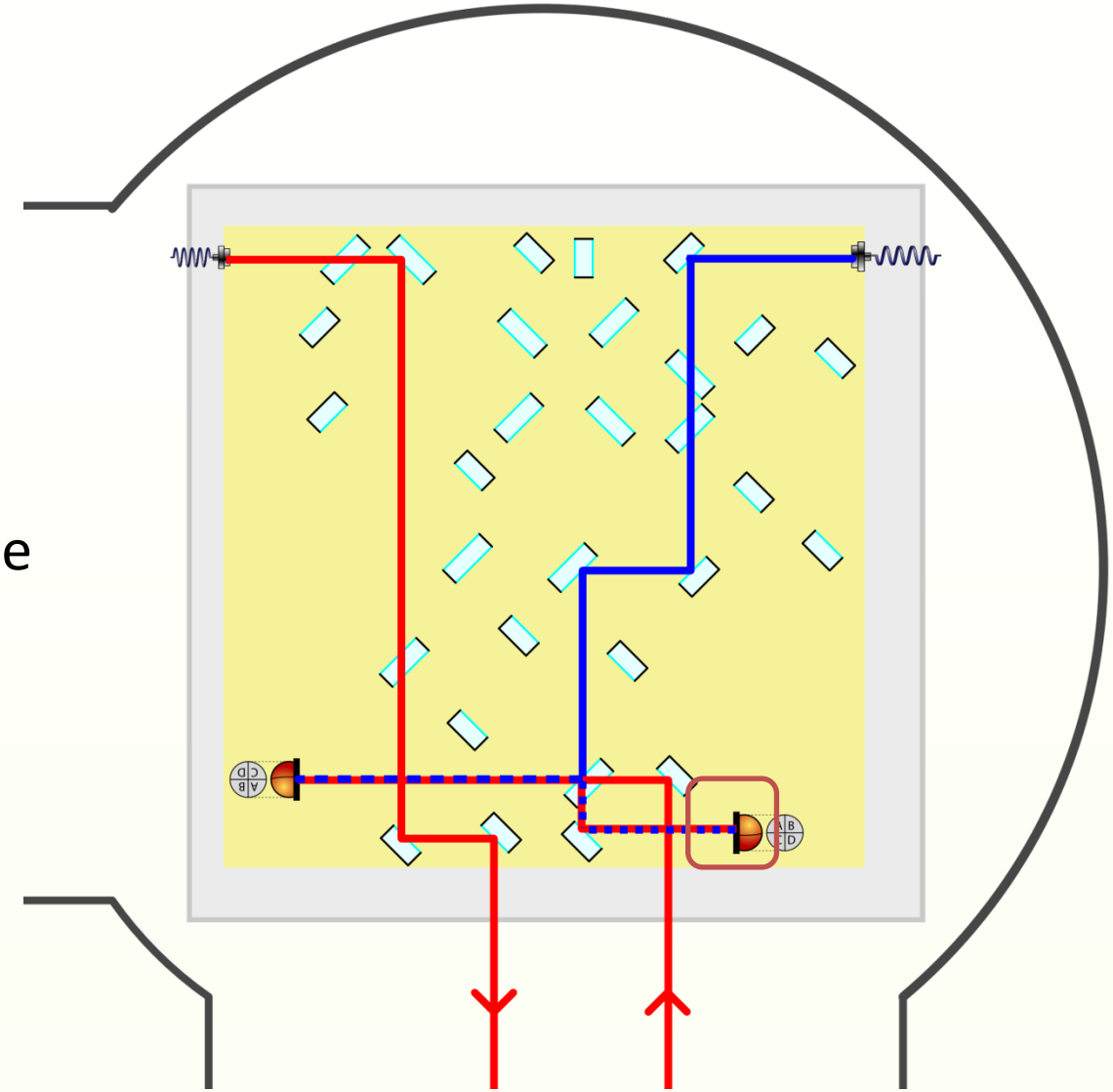
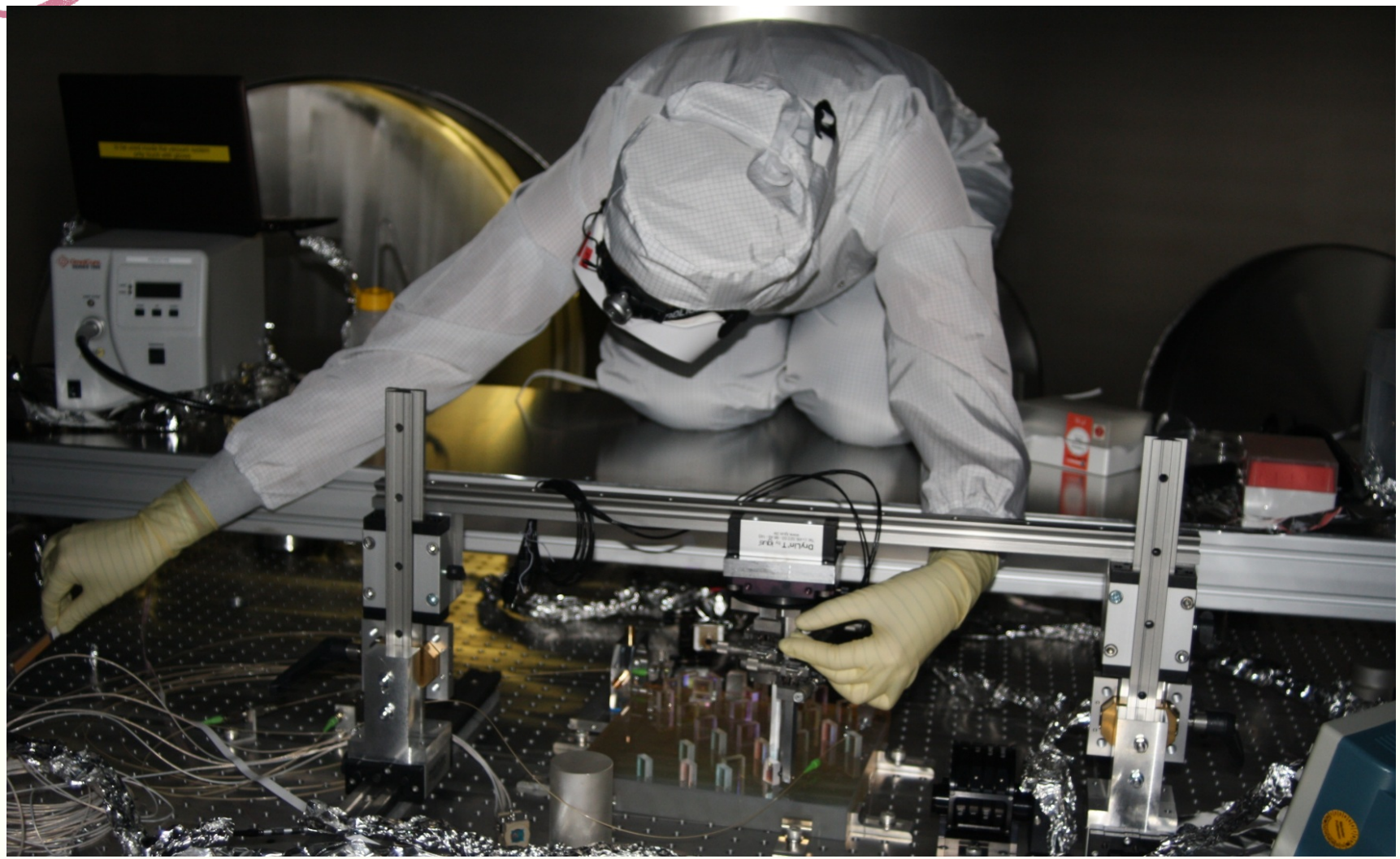


The south interferometer (SIFO)

- Measures the relative table displacement
- Last mirror had to be adjusted inside the vacuum system

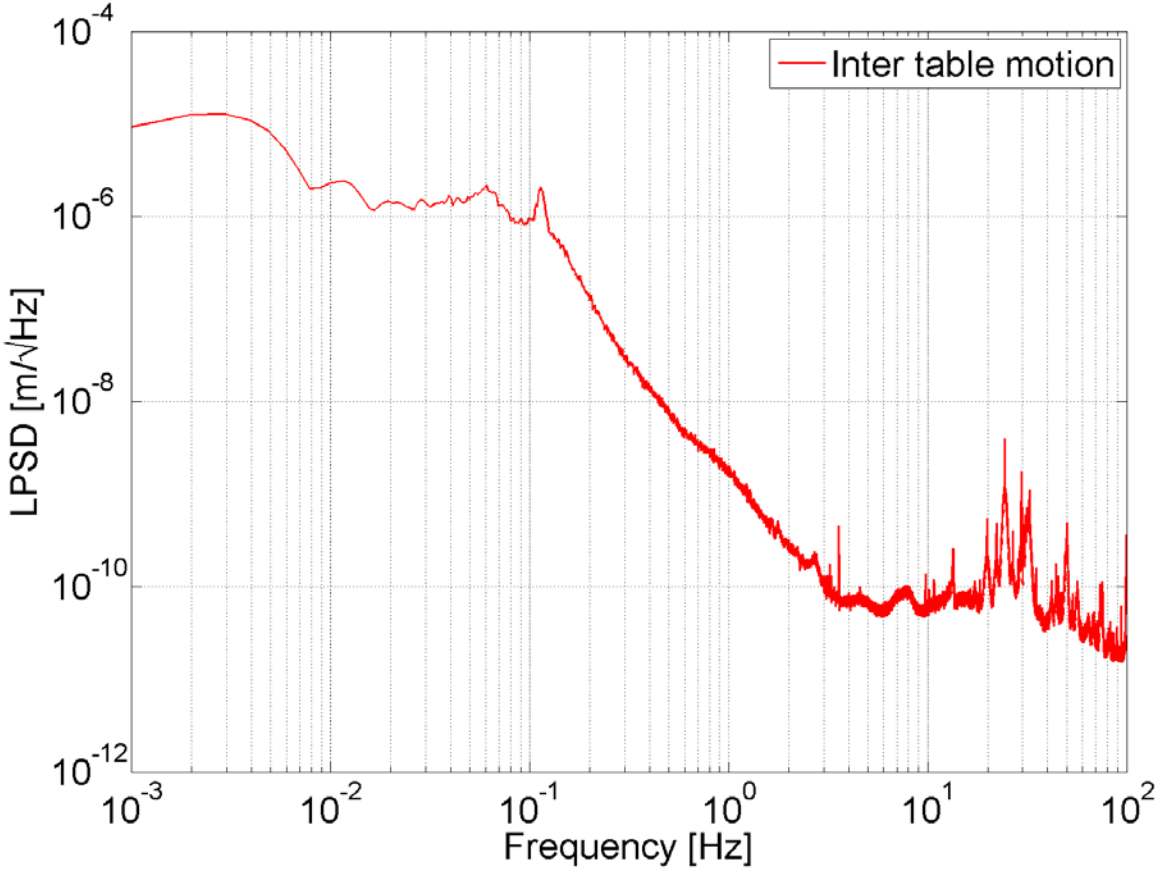


SIFO Alignment



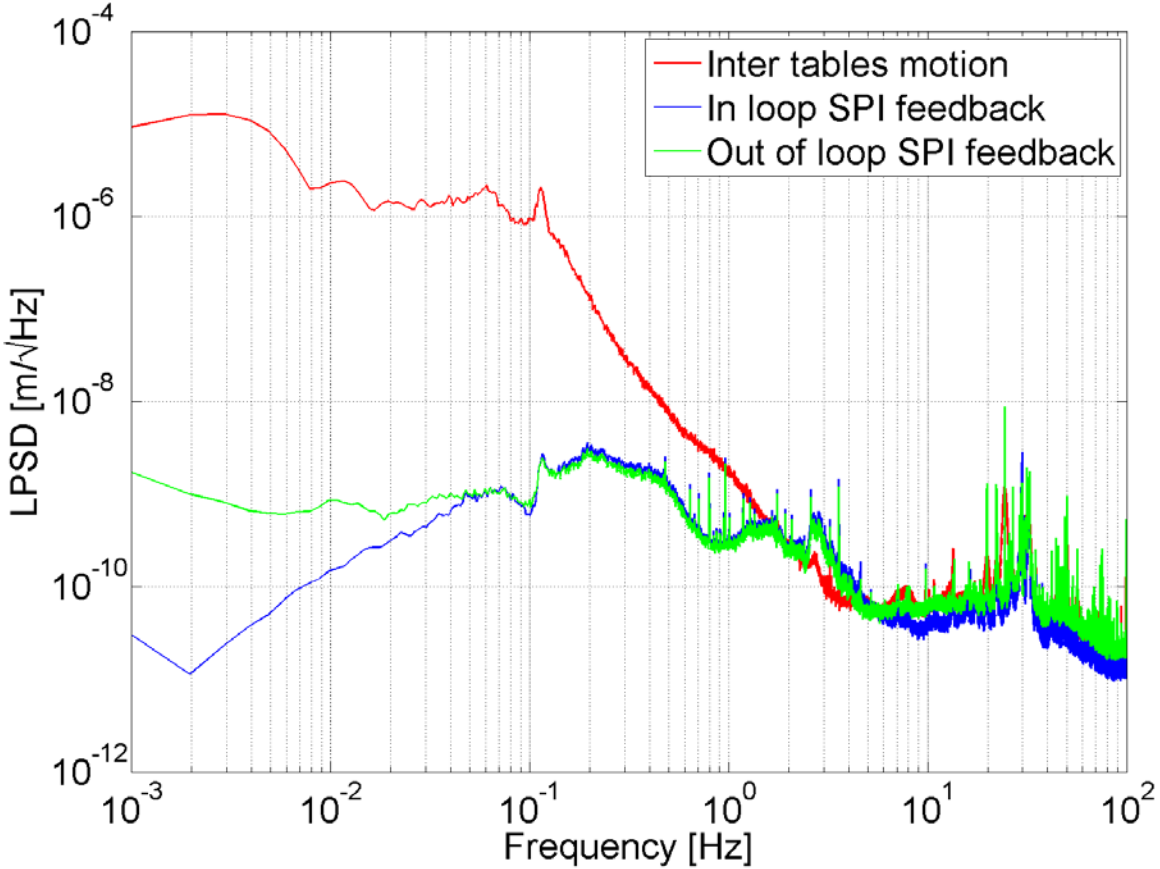
Relative table motion

- Inter table motion without any feedback from the SPI
- All degrees of freedom controlled with table signals
- Passive isolation and active control



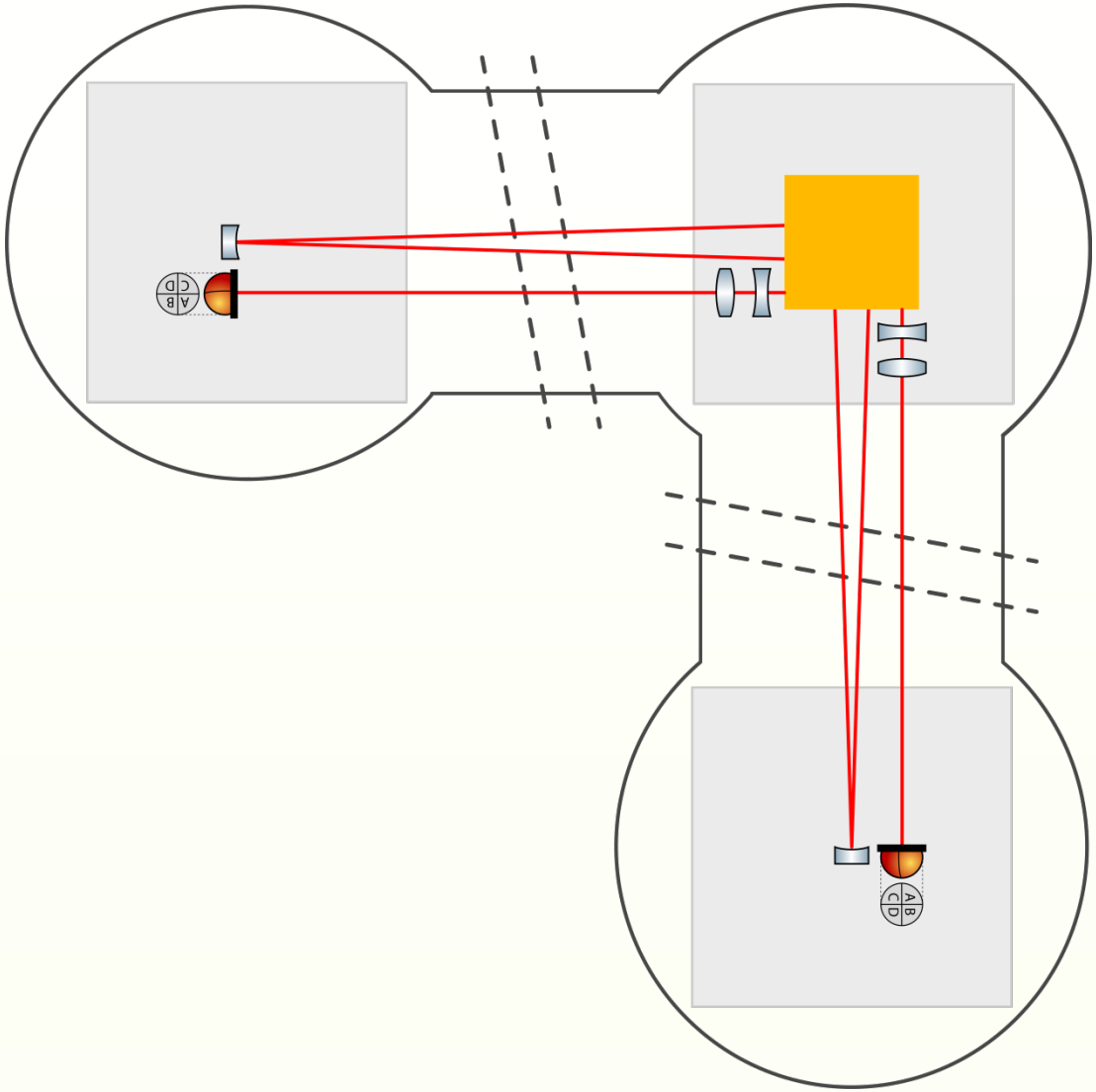
Relative table motion with SPI feedback

- Stabilized with SPI and table signals
- All degrees of freedom controlled
- Between 100 and 10 mHz suppression of 3 orders of magnitude



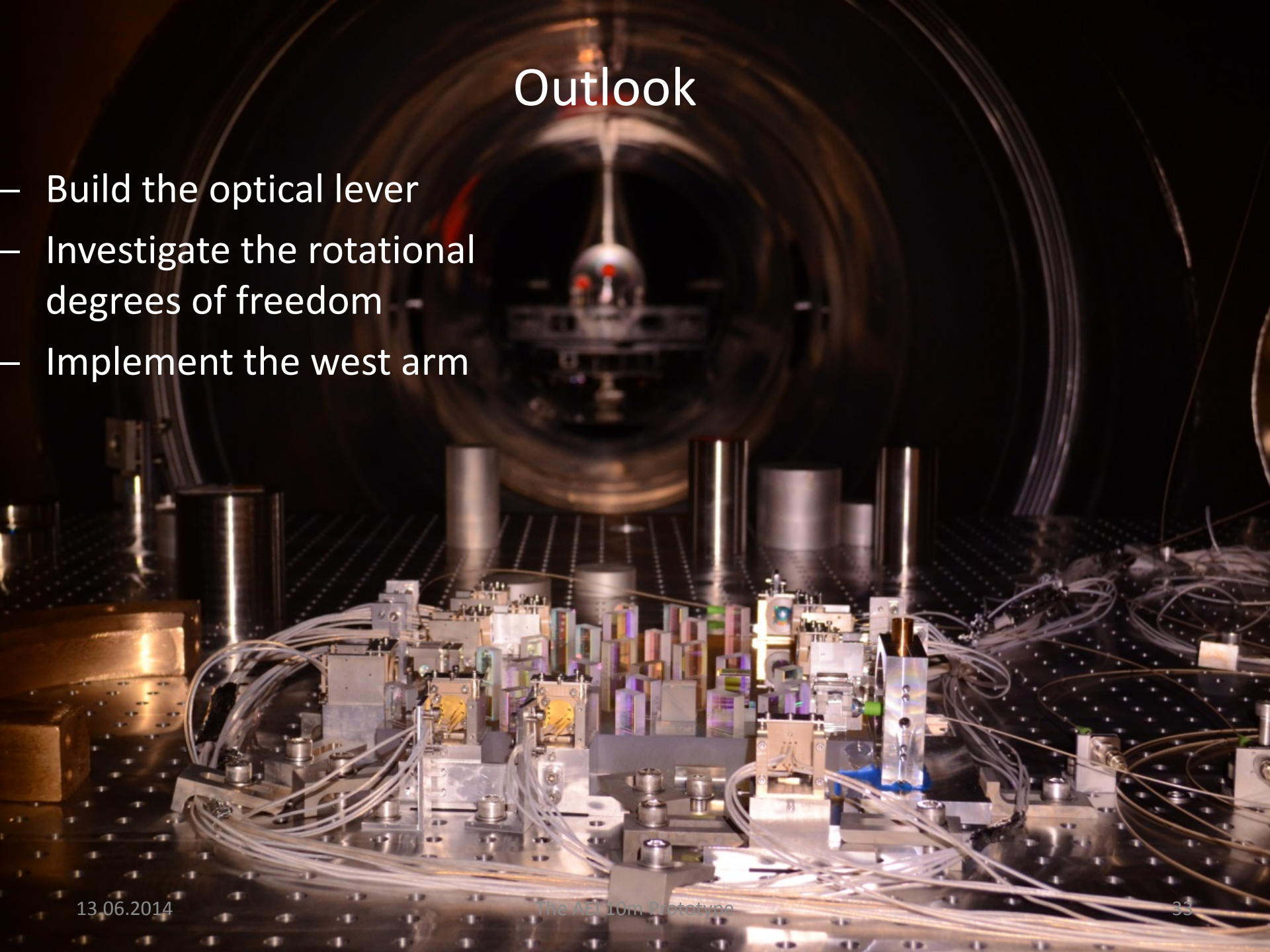
Other degrees of freedom

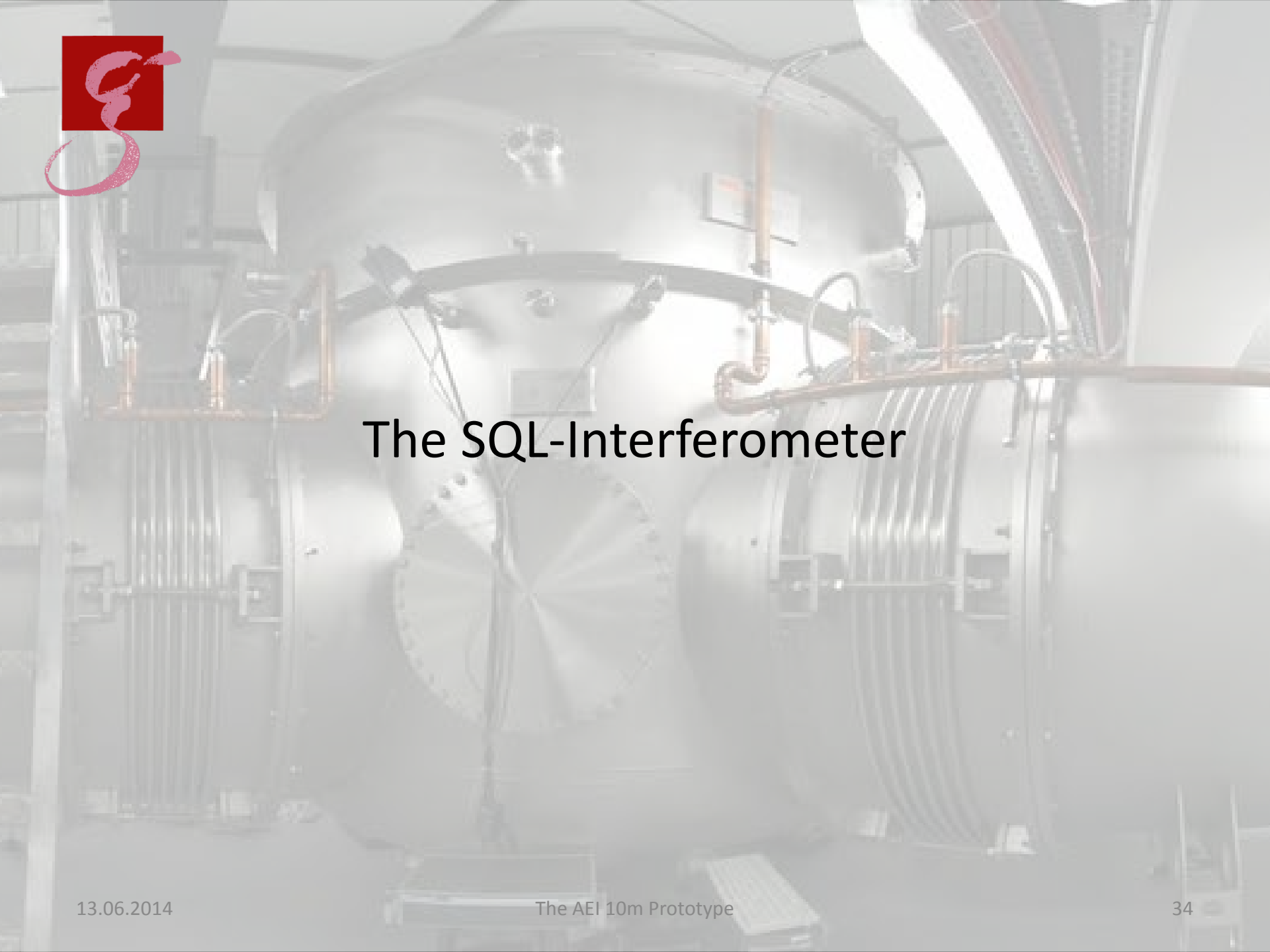
- Optical lever for central tabel pitch and yaw
- Differential wavefront sensing



Outlook

- Build the optical lever
- Investigate the rotational degrees of freedom
- Implement the west arm

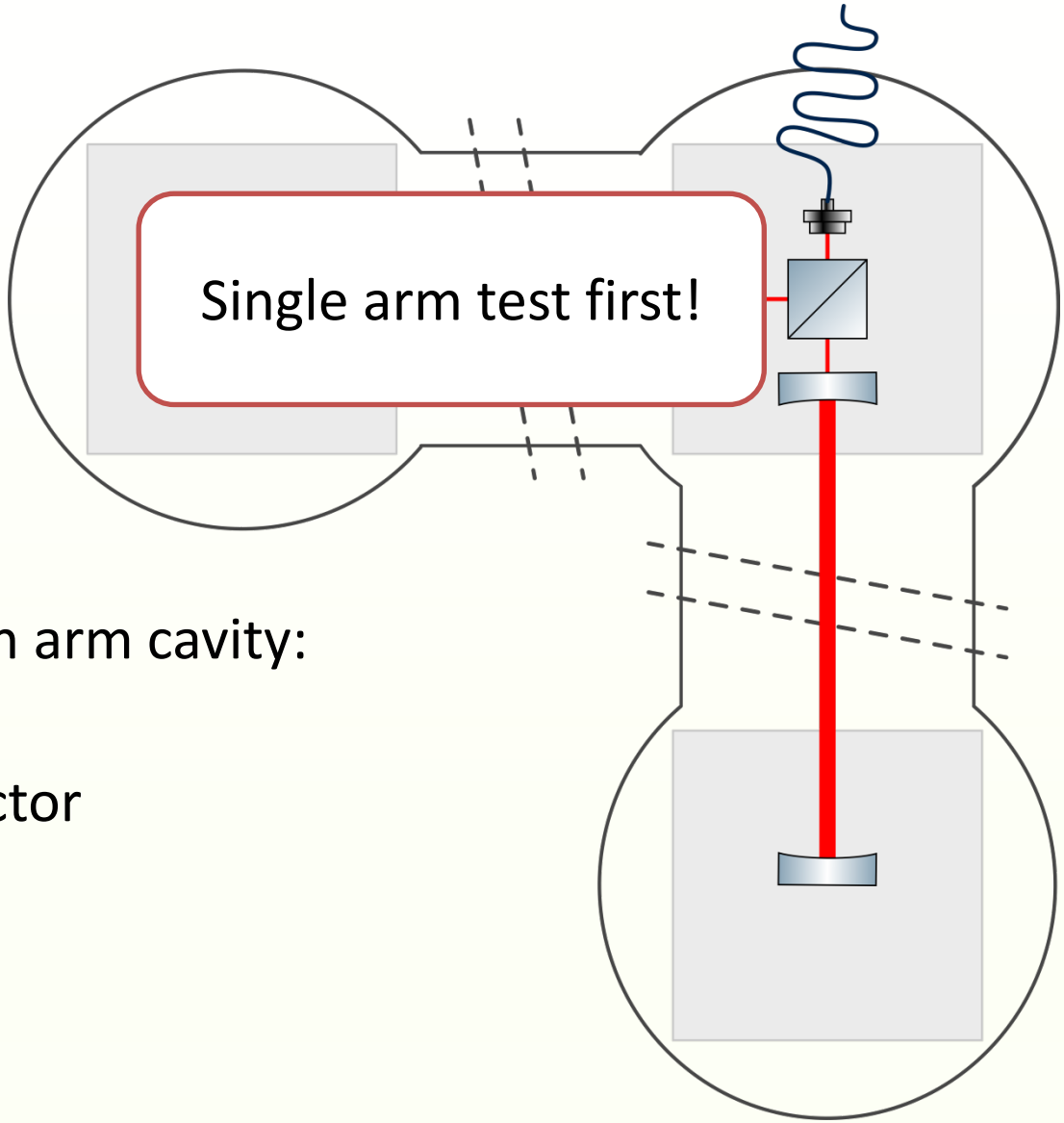




The SQL-Interferometer

Layout of the SQL Interferometer

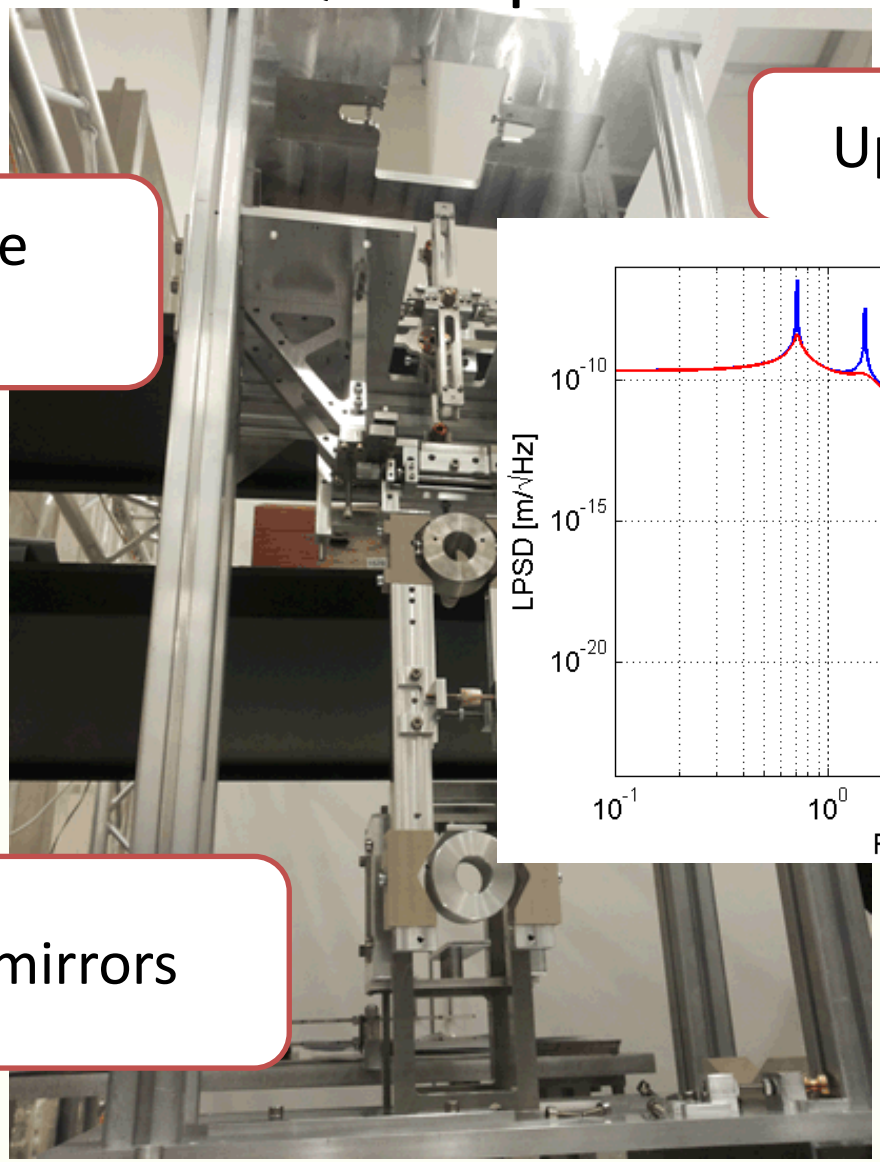
- Input power:
  5-30 W
- Finess:
  670-130
- Circulating Power in arm cavity:
  ~1 kW
- Tunable cavity g factor

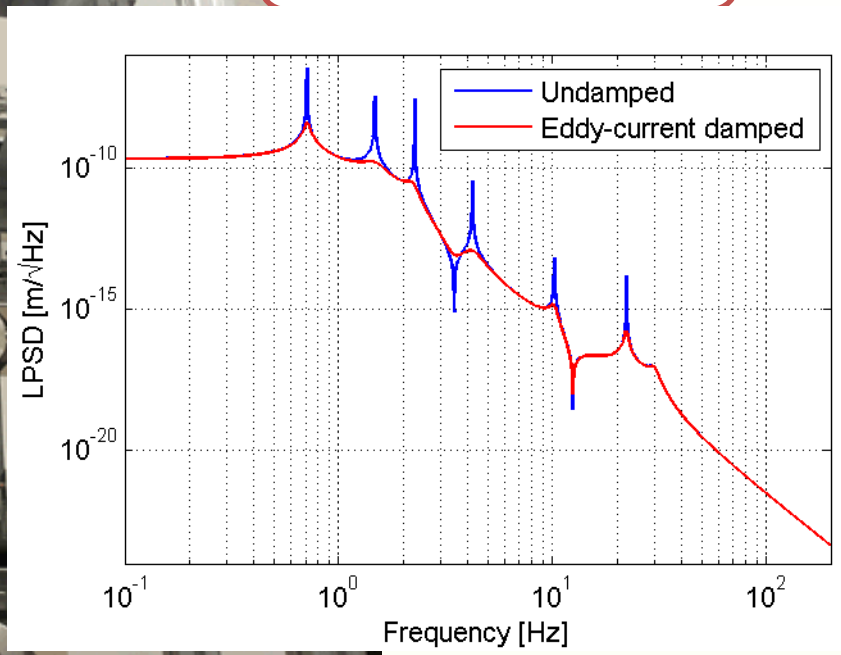


The SQL-Suspensions

Multi-stage pendula

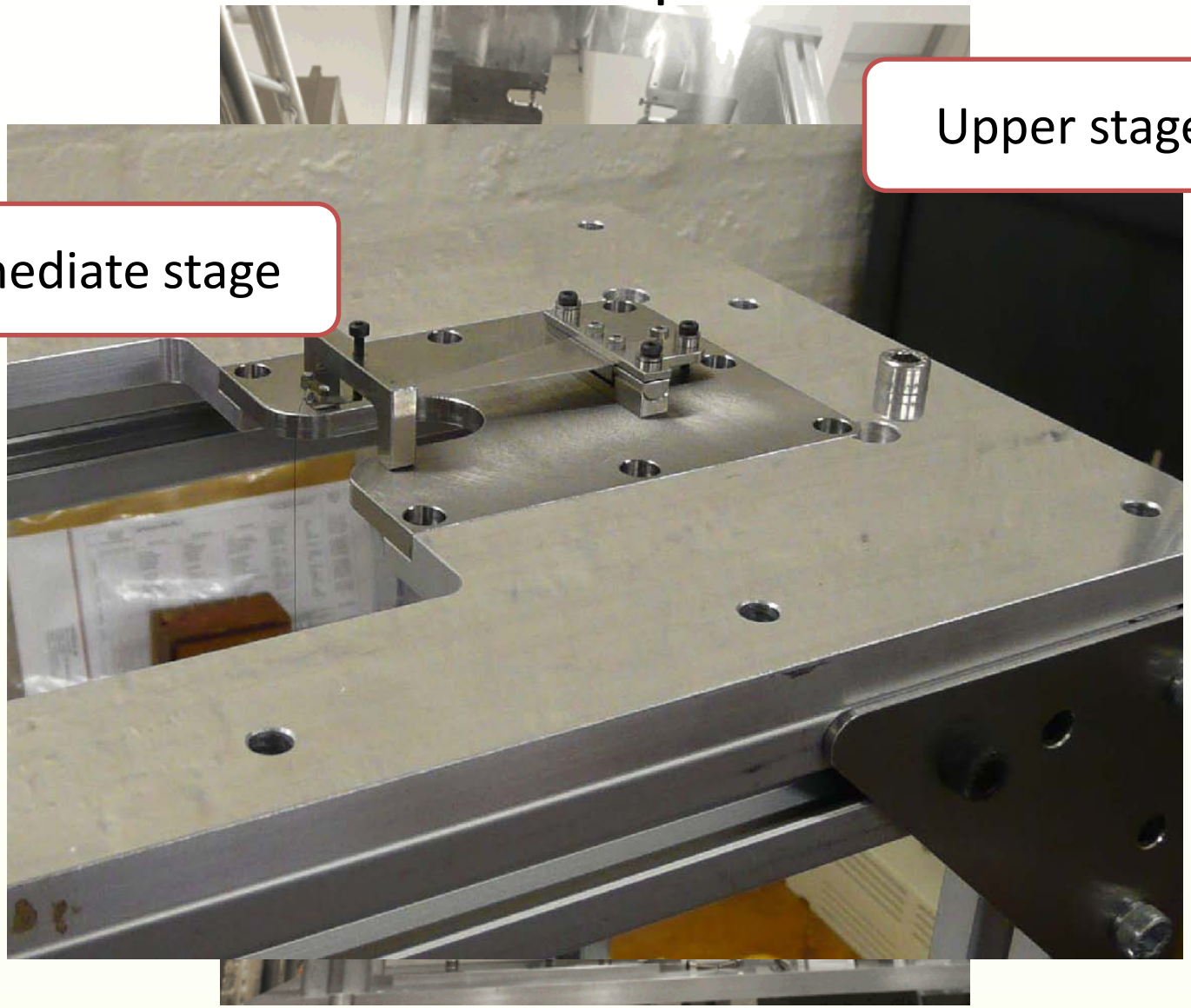
Upper stage





100 g mirrors

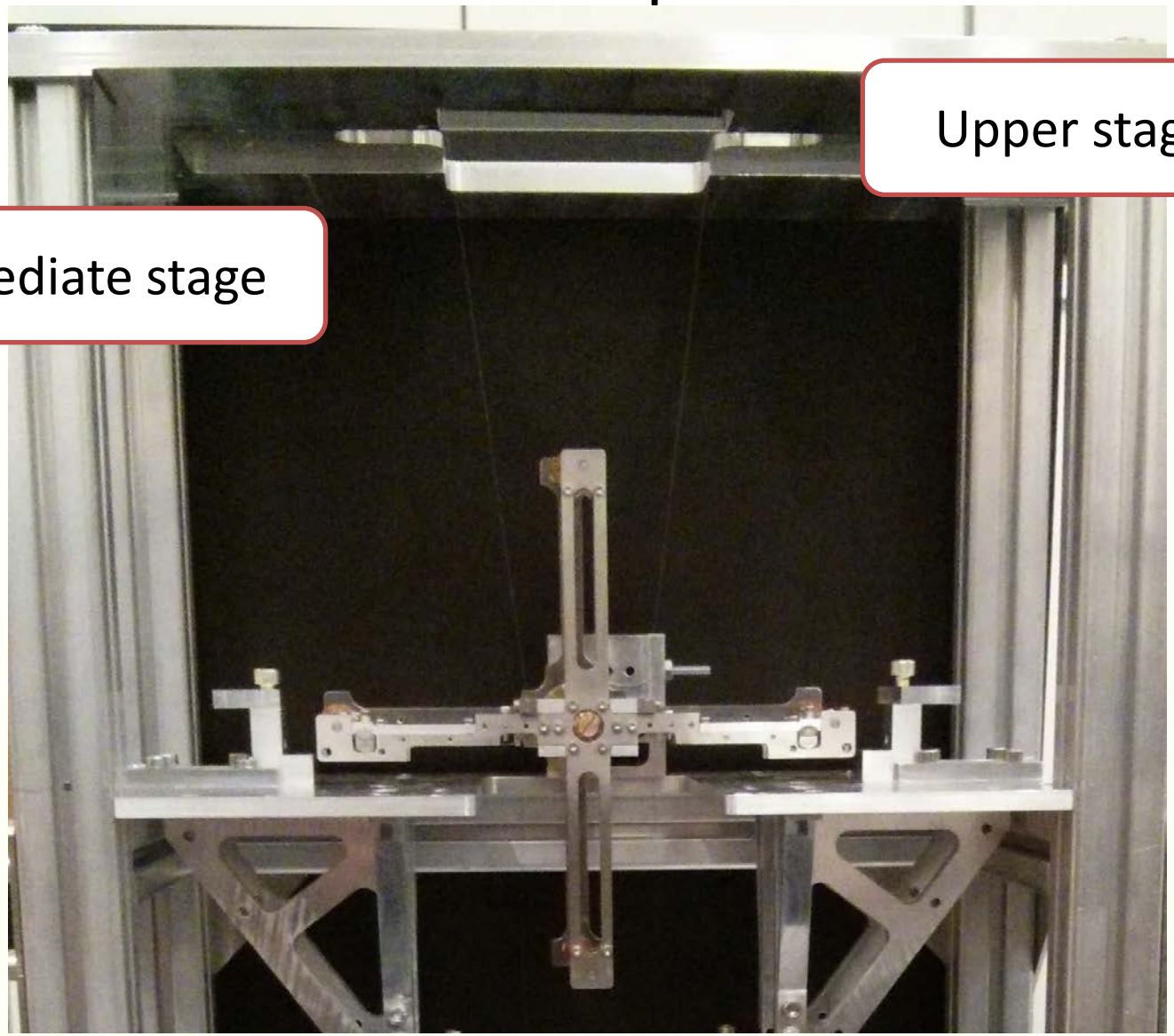
The SQL-Suspensions



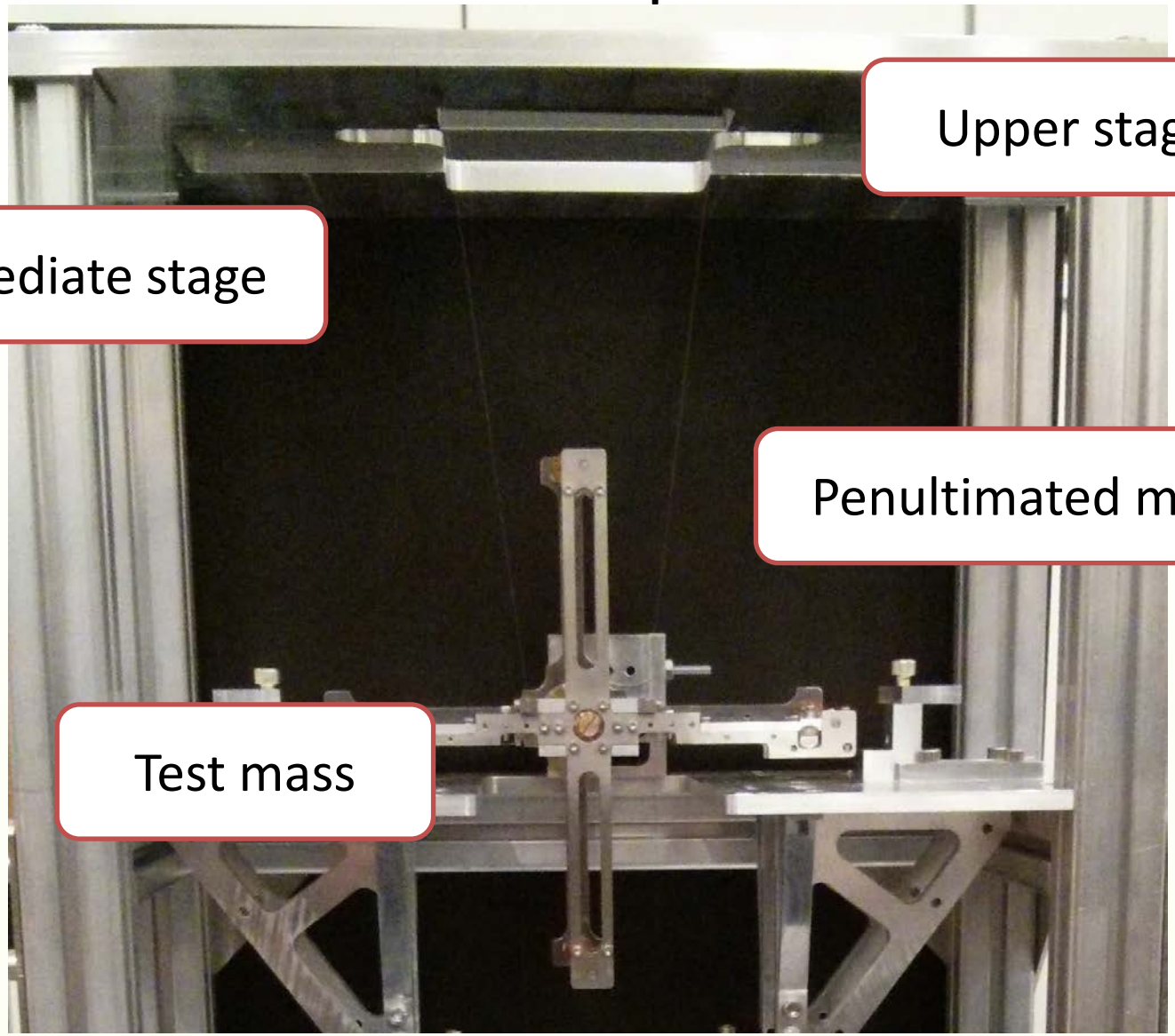
Upper stage

Intermediate stage

The SQL-Suspensions



The SQL-Suspensions



Current status and outlook

- ✓ Dirty suspension assembly
- ✓ Dummy mass hanging
- ✓ Assembly area

- ❑ Pitch alignment
- ❑ Clean suspension assembly
- ❑ Transfer to vaccum system

Thank you for your attention!