The AEI 10 m Prototype

June 2014 - Sina Köhlenbeck for the 10m Prototype Team
The 10m Prototype

- Seismic attenuation system
- Suspension Platform Interferometer
- 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
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

Optical table

Filter support

Base plate
Vertical isolation stage

Optical table

Filter support

Base plate
Seismic Attenuation System

- Optical table
- GAS filter
- Geophones
- Spring box
- Base plate
- Voice-coil actuator
- Wire
SAS vertical performance

The AEI 10m Prototype
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

- Nd:YAG NPRO Laser stabilized to iodine reference
- Digital signal processing with LIGO-style CDS
- AOMs for heterodyne frequency offset
- Phasemeter developed for LISA Pathfinder

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Key features of the SPI

- Ultra-low thermal expansion glass base plate (Clearceram-Z Hs)
- Quasi-monolithic fiber injectors
- 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 diagnostic 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
Comparing diagnostic and frequency noise IFO

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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 table 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

Single arm test first!
The SQL-Suspensions

- Multi-stage pendula
- 100g mirrors

Upper stage

Graph: LPDSD [m/\sqrt{Hz}] versus Frequency [Hz]

- Blue: Undamped
- Red: Eddy-current damped
The SQL-Suspensions

Intermediate stage

Upper stage
The SQL-Suspensions

Intermediate stage

Upper stage
The SQL-Suspensions

Intermediate stage

Upper stage

Penultimated mass

Test mass
Current status and outlook

- Dirty suspension assembly
- Dummy mass hanging
- Assembly area

- Pitch alignment
- Clean suspension assembly
- Transfer to vacuum system
Thank you for your attention!