Comprehensive Experimental Study of the Elements in the LISA Interferometric Noise Chain

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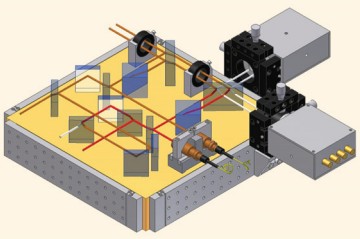
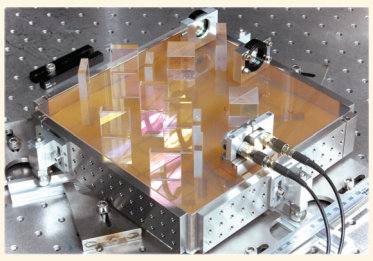
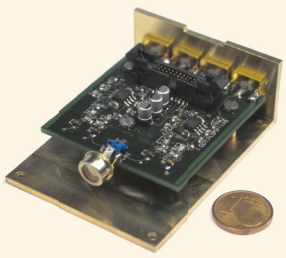
Picometer Metrology Using Laser Interferometry

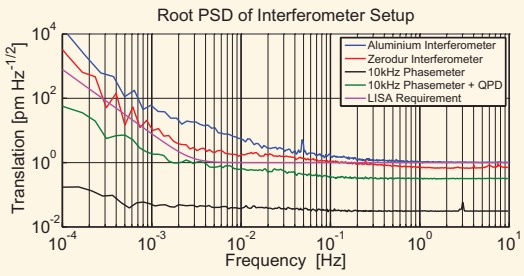
Astrium had developed a heterodyne laser interferometer as possible concept for the optical readout of the LISA proofmass. Its highly symmetrical design with only 20 mm beam height was mounted on an aluminium breadboard. This first generation heterodyne interferometer enabled measurements within an accuracy of a few picometer (translation) and a few nanoradian (tilt) in the LISA measurement band. In the last two years an advanced, second generation was integrated and tested which incorporates some major improvements:





- compact setup on a Zerodur baseplate for optimal thermo-mechanical stability
- optical components integrated with Astriums' adhesive bonding technology
- achieved contrast > 90 % on the QPDs
- all new QPD design, using stabilised bias voltage of 5 V, developed to enable detection at LISA beat frequencies
  - DC channels for frequencies up to 10 kHz
  - AC channels for frequencies 2 – 20 MHz



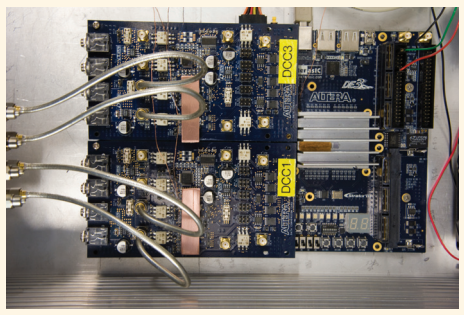


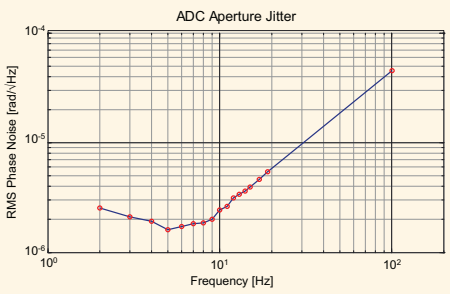
no post-correction (e.g. with DWS or temperature) on the measurement signals applied

Phasemeter Development

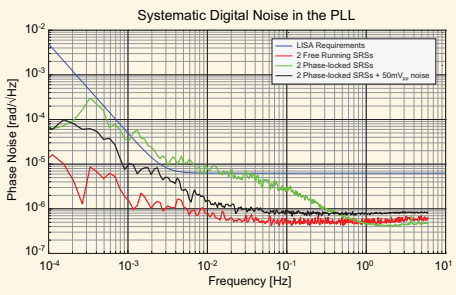
A phasemeter was realised in VHDL working with PLLs for multi tone tracking at LISA beat frequencies. As ADC timing jitter reduces the performance, an aliased pilot-tone correction at 100.3 MHz was implemented.

FPGA	DE3 Stratix III
Logic Elements	254400
Used Cycle Rate	100 MHz
ADC	AD9254
Used Sampling Rate	100 MSPS
Aperture Uncertainty	0.1 ps rms

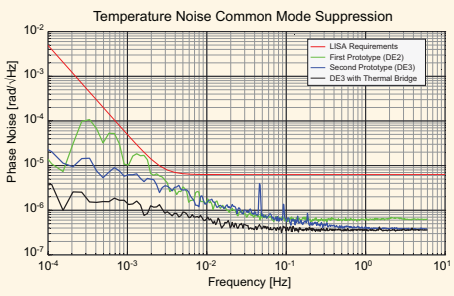




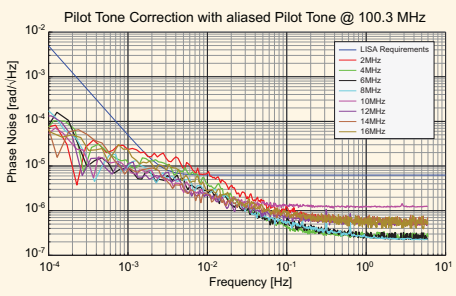
The linear trend in the observed rms phase noise indicates that the underlaying sources acts in the time domain. The noise increase with frequency is attributed to the aperture jitter of the ADC.



If the phase noise of signal and pilot tone are correlated, systematic errors within the PLL can be increased. Adding additional white noise eliminates the correlation effects.



Differential temperature fluctuations are a notable source of noise. These were mitigated by installing a thermal bridge between the ADCs and a heat sink on the FPGA.



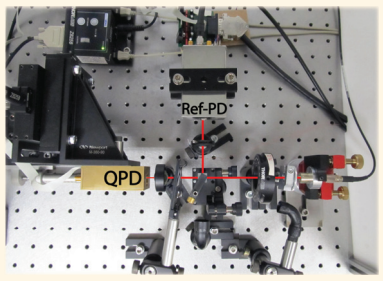
Characterisation of Quadrant Photo Diodes

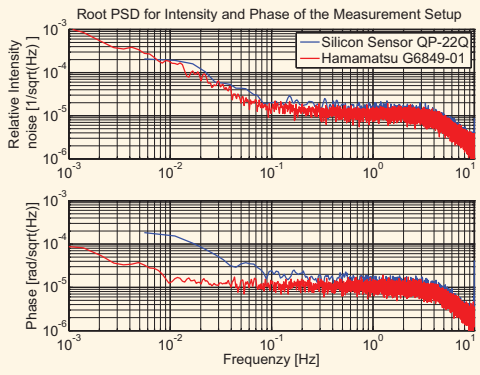
Two possible diodes for the required QPDs of the LISA/LTP space mission were selected, the enhanced silicon (Si) diode Silicon Sensor QP-22Q and the indium gallium arsenide (InGaAs) diode Hamamatsu G6849-01. Both diodes were spatially resolved characterised to check their applicability, as deviations result in phase center offset effects which could cause detrimental coupling to pointing jitter.

Diode	Silicon Sensor QP-22Q	Hamamatsu G6849-01
Material	Si (enhanced)	InGaAs
Diameter [mm]	5.3	1.0
Responsivity [A/W]	0.55	0.68
Capacitance [pF]	2 @150V_{bias}	20 @1V_{bias}

Measurement Setup

- 1064 nm laser wavelength
- laser beam diameter ≈ 40 µm
- InGaAs single element reference diode (OSI FCI-InGaAs 1000)
- QPD moved by motorized translation stages
- scanning stepsize 20 µm (QP-22Q) and 10 µm (G6849-01)
- phase measurement using FPGA based phasemeter at 10 kHz
- diodes connected to LET QPD front-end with stabilised bias voltage of 5 V
- front window of diode removed
- measuring noise reduction by averaging 5 values per position

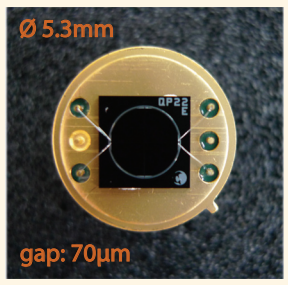


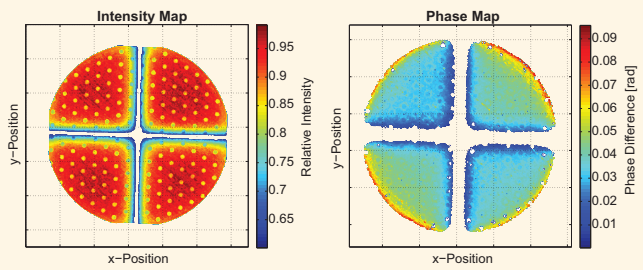


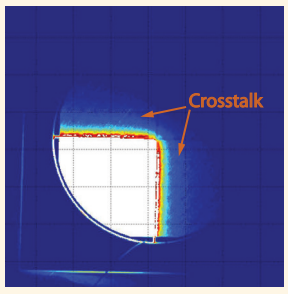
Measurement Results

Silicon Sensor QP22-Q:

- measurement duration ≈ 12 h per scan
- the spot pattern over the whole active area results from interruptions of the isolating reflection layer on the backside, required to connect the diode to the electrode, which locally reduces the responsivity.
- the diode shows major crosstalk between its quadrants during measurement, caused by the diffuse back-reflections of the intensionally roghed reflection layer.

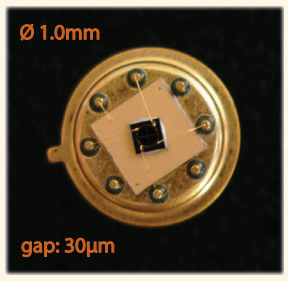


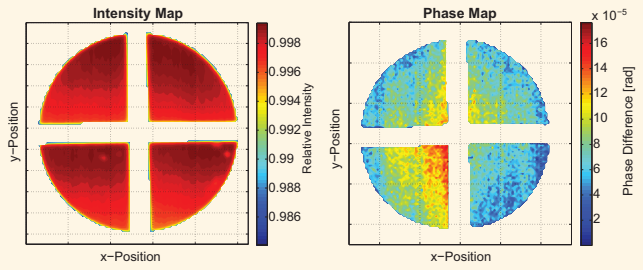


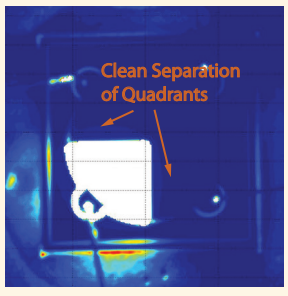


Hamamatsu InGaAs G6849-01:

- measurement duration ≈ 4 h per scan
- the spots in the intensity map are most likely contaminations on the active area
- the spatial deviations in phase are near the resolution limit of the measurement setup and are interpreted as measurement noise
- during measurement no significant crosstalk between the quadrants was noticable







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