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LISA Pathfinder: OPD loop characterisation

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Abstract. The optical metrology system (OMS) of the LISA Pathfinder mission is measuring the distance between two free-floating test masses with unprecedented precision. One of the four OMS heterodyne interferometers reads out the phase difference between the reference and the measurement laser beam. This phase from the reference interferometer is common to all other longitudinal interferometer read outs and therefore subtracted. In addition, the phase is fed back via the digital optical pathlength difference (OPD) control loop to keep it close to zero. Here, we analyse the loop parameters and compare them to on-ground measurement results.

1. Introduction

LISA Pathfinders (LPF) main measurement [1] is the acceleration between two test masses (TM). For this purpose, the relative TM positions are determined by the optical metrology system (OMS) using heterodyne interferometry [2]. Here, the phase difference of the so-called reference and the measurement laser beam is measured at the heterodyne frequency of $f_{het} =$ 1 kHz. Both beams are generated from a single laser source (Nd:YAG, λ=1064 nm) at the laser modulator unit (LMU). They are transmitted via fibres onto the optical bench which houses 4 ultra-stable bonded interferometers. The optical properties of fibres are sensitive to thermal and mechanical stress. This results in a variation of the optical pathlength difference (OPD) between the reference and the measurement beam. The varying phase (Ψ_r) between the beams is measured in the reference interferometer. As this phase is common to the other 3 interferometers, it is always subtracted from their longitudinal read out.

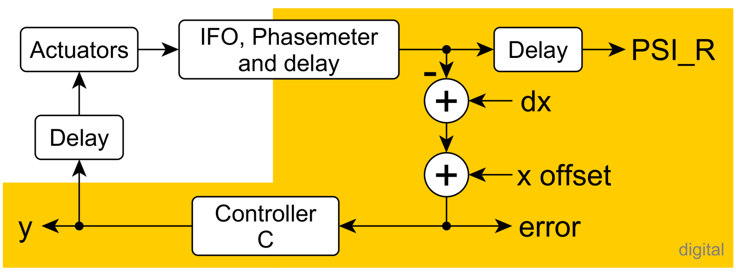

Figure 1. Schematic of the OPD control loop. The reference interferometer (IFO) measures the optical pathlength difference PSI_R(Ψ_r). Arrows (dx, ...) pointing towards the loop show injection and offset points. Arrows (y, ...) pointing away from the loop symbolise parameters that can be accessed.

In addition, there is a digital control loop using the phase $-\Psi_r$ as the error point (see Figure 1). The response of the digital controller is fed back to 2 piezo actuators in the LMU. Here, a push-pull configuration allows to double the actuation range and provides redundancy in case of a piezo failure. The reference interferometer then measures the changed OPD and the loop is closed.

2. OPD noise performance

Spectra of the longitudinal signal Ψ_r are shown in Figure 2. The data from the on-station thermal tests (OSTT) in 2011 shows the best performance that was measured on ground [3]. As the LPF spacecraft at the Lagrange point L1 provides a thermally and mechanically stable environment for the OMS, the OPD noise can be expected to be lower. First data looks promising but needs to be further analysed.

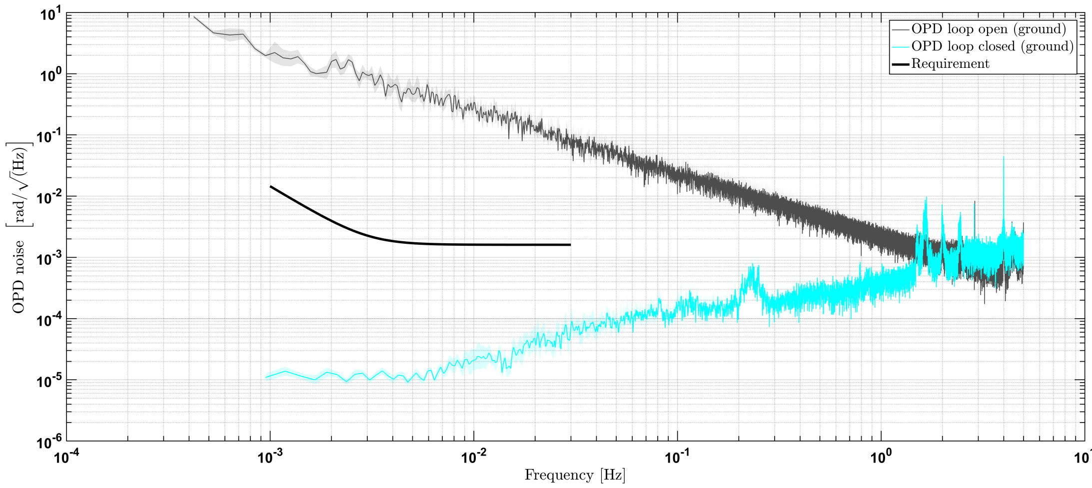

Figure 2. OPD noise spectra measured during OSTT campaign on-ground.

3. OPD system identification

The OPD system identification is done by measuring transfer functions (TF) of sinusoidal guidance injections (Figure 3). The 8 sine waves (f=[0.011 .. 1.123] Hz) are injected into the closed loop at dx in Figure 1. During the injections PSI_R is available at a sample rate of 10 Hz. The other parameters have only a 1 Hz rate and are so-called housekeeping data (HK). Therefore, only the 6 injections below the Nyquist frequency of 0.5 Hz can be analysed. The other 2 signals require the use of IDL data which has the full 100 Hz rate that is used by the digital system. The 100 Hz data requires special commanding and is only available for a limited time because of memory constraints. One of the challenges of the ongoing analysis is the timing correlation between the different clocks of the 10 Hz and the HK parameters.
Furthermore, the long-term stability of the piezo actuator gain will be investigated.

4. Conclusion

The OPD noise data looks very promising. With the digital OPD control loop working as expected the noise is further reduced. As the main mission goal is already achieved [1], further investigations of the very good OMS performance are being done. For the OPD analysis, a stable timing correlation between the involved parameters needs to be achieved for precise phase values in the transfer function measurements. After the end of the extended mission, final results and an analysis of the long term performance of the OPD loop will be published.

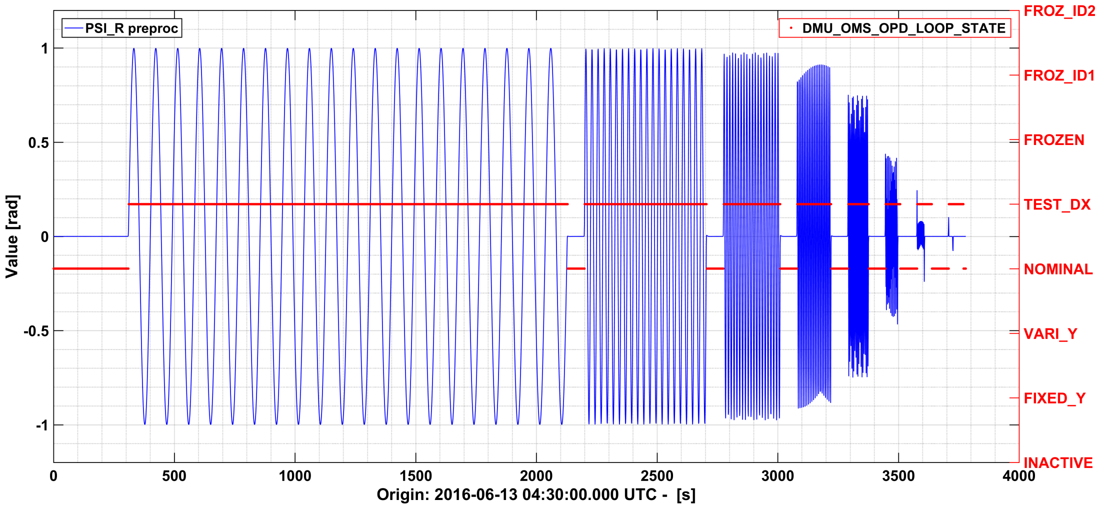

Figure 3. The 8 guidance injections into the OPD loop are seen in PSI_R. For each injection the control loop is switched to the 'TEST_DX' state.

5. Acknowledgements
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References
[1] Armano M *et al.* 2016 *Phys. Rev. Lett.* **116**(23) 231101
[2] Audley H 2017 *Journal of Physics: Conference Series to be published in this issue*
[3] Audley H 2014 Preparing for LISA pathfinder operations : characterisation of the optical metrology system