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An optical read-out system for the LISA gravitational reference sensor: present status and perspectives.

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Abstract.

Since a few years, the LISA-PF group in Napoli has been working to the development of an optical read-out system, based on optical levers and position sensitive detectors, for the LISA Gravitational Reference Sensor (GRS). This is intended as a more sensitive extra sensing device, in addition to capacitive readout that is the reference solution already tested on flight by the LISA-Pathfinder mission. The reliability of the proposed ORO device and the fulfillment of the sensitivity goals have been already demonstrated in bench-top measurements and tested with torsion pendulum facilities. In this paper we report on the present status of this activity, presenting the results obtained so-far and the perspectives for the future LISA mission.

1. Introduction

We report on the status of the development of an Optical Read-Out (ORO) [1] system for the LISA [2] inertial sensor. The present design of the Gravitational Reference Sensor (GRS) [3] is based on capacitive sensor; our goal is to integrate the ORO in the capacitive one without changing the present set-up and electrode design. The motivation is twofold: a) risk mitigation and b) to improve the sensitivity. For the first aspect the ORO could be a back-up sensor in case the capacitive sensor fails after the launch. For the second aspect we should note that any reduction of the noise of the sensor used for Drag Free and Attitude Control System (DFACS) would relax specifications on cross couplings (CC). Present requirement on CC is 0.1 % that is a very strong specification. In the following sections we will describe the proposed ORO set-up, we report on sensitivity for tests on bench top and on a two stages torsion pendulum facility [4] and we describe possible layouts for the implementation in LISA. First results and next steps for space qualification are finally discussed.

2. Sensor Set-up

Figure 1 shows the schematic drawing of the ORO sensor. A light beam is sent through a single mode optical fibre to the test mass and the position of the reflected beam is measured with a Quadrant Photo-Diode (QPD) or (Position Sensing Device (PSD)). The sensitivity depends on input power, measurement range (beam size for QPD or detector size for PSD) and geometry.



With a suitable combination of beams and sensors we can recover the six degree of freedom (DOF) of the test mass.

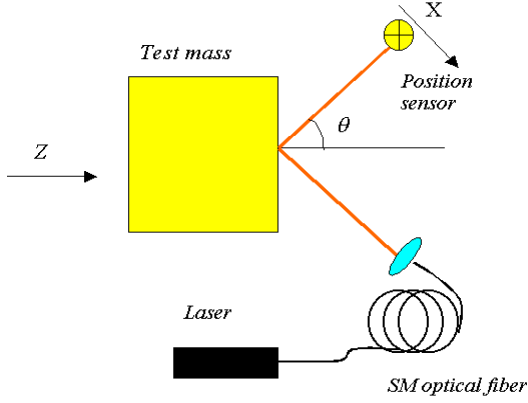


Figure 1. Schematic of the ORO sensor.

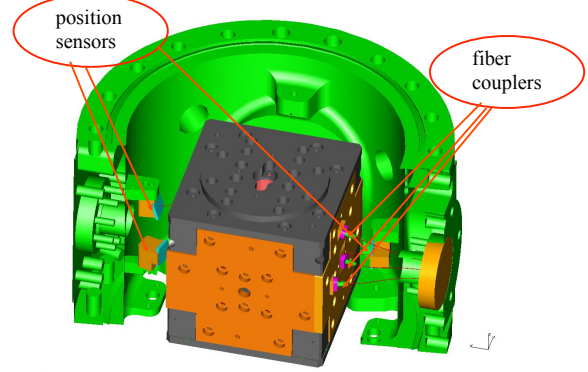


Figure 2. Possible implementation in the GRS.

3. Sensitivity

The figure 3 shows the ORO sensitivity for the two types of photodetectors PSD (upper curve) and QPD (lower curve) measured in a bench-top setup. The measurement ranges are 0.4 mm for QPD and 4.7 mm for PSD. In both cases the ORO sensitivity is limited by the input trans-impedance amplifier current noise. For comparison also the sensitivity of the capacitive sensor is reported.

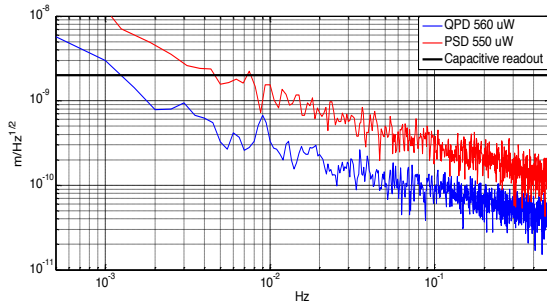


Figure 3. ORO sensitivity with different photodetectors. The black line shows the capacitive readout sensitivity

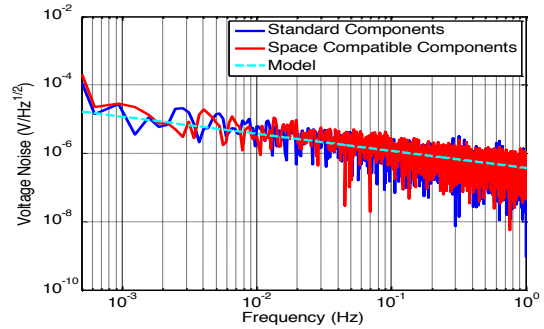


Figure 4. Comparison between standard and space qualified front end electronics.

4. Space qualified front-end electronics

We have verified the noise characteristics of Space Qualified (SQ) front-end electronics (see figure 4). The electronic used for processing QPD signals is based on OP27EP operational amplifier. There is a SQ equivalent component OP27AJ/QMLR. The noise performance is exactly the same as for the standard components.

5. Possible implementation in LISA

The idea is to use the electrodes as mirrors for directing the beams to the test mass surface and to the sensors. We tested the 3 beams configuration with a prototype (figures 5, 6). We used a two degrees of freedom angular piezoelectric (PZT) stage and a 3 axial linear PZT stage to check 5 DOFs out of 6 (Z , Y , α , η , θ). The analytical model was validated moving the dummy test mass with PZT actuators equipped with calibrated capacitive readout. The measured matrix elements coincide, within a few percent, with the analytical model (compatibly with the prototype machining and assembling tolerances). Figure 2 shows a possible implementation of the ORO in the GRS used for LISA-PF.

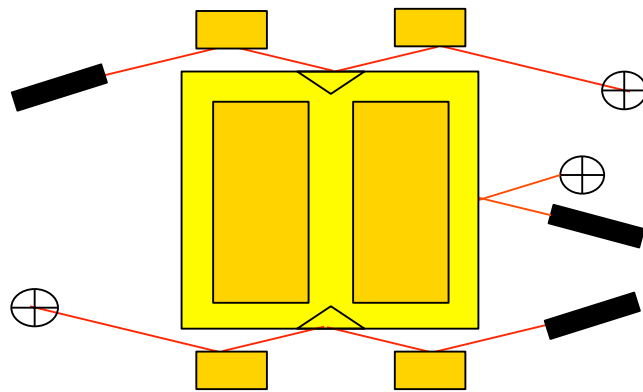


Figure 5. Schematics of 5 DOF (Z , Y , α , η , θ) readout system using 3 beams. Front view.

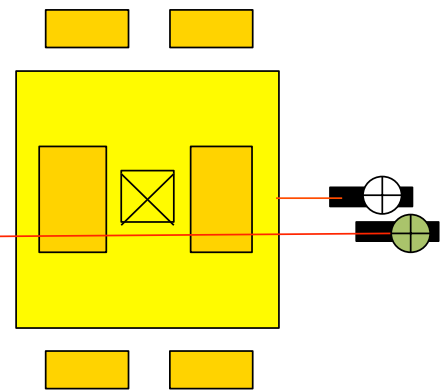


Figure 6. Schematics of 5 DOF (Z , Y , α , η , θ) readout system using 3 beams. Top view.

6. Conclusion

Both tests on bench top and on engineering model suspended to a torsion pendulum confirm that the ORO sensitivity can be better than the capacitive sensor, above 1 mHz. The noise level is well characterised and allows to make predictions and trade-off between sensitivity and measurement range. It has been identified a possible layouts for the integration, with minimal impact on the present design, into the GRS. Study of space compatible parts is just started: read-out electronics is not a problem. Next step would be the search for space qualified optical components. The ORO has been developed up to TRL 4 and is a good candidate as a back-up sensor for the LISA inertial sensors, with possible sensitivity improvement.

References

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