Frequency drift interferometry for stray light measurement on the LISA space instrument

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On a complex optical system such as an interferometer, coherent Stray Light is a pitfall in many ways because it can affect the accuracy and resolution of the measurements, or their dynamics. This is all the more true with space interferometers as in the GRACE (Gravity Recovery And Climate Experiment) Follow-On space mission, which uses the LRI (Laser Ranging Interferometer) [1] to track the Earth's mass distribution across the planet. The GRACE-FO mission, similar to the LISA space mission project, uses laser interferometry with the highest possible accuracy and resolution. Achieving high optical phase measurement accuracy and resolution implies that coherent stray light issues are adequately dealt with and mitigated. This means that, among other aspects, a reliable and efficient measurement method is used, at system level, to check that after integration of the instrument, the allocation for stray light has not been exceeded. A measurement of the *overall* amplitude is not operative, as one needs to know what are the various stray light amplitudes, component by component, and not just the vector addition of the various amplitude, which could be anything between zero and the arithmetic sum of all the individual amplitudes. The different contributions must be identified individually, because different optical components will have different noise allocations, when expressed in optical amplitude. This is due to the fact that some components may be quite stable (for instance optics contacted to a Zerodur (R) baseplate), while others such as movable wave plates will be significantly more unstable, and hence be assigned lower acceptable stray light amplitudes.

The purpose of this work is to develop the demonstrator of an instrumentation able to measure the stray light optical amplitude, whatever its origin, in the photoreceivers of the interferometric system of the LISA space mission, the MOSA (Moving Optical SubAssembly). The instrumentation is based on the method known under the name of FMCW (Frequency Modulated Continuous Wave) but is of more general application.

We use a single-mode laser source which optical frequency is swept over time, and inject this beam in the optical system under test. During the optical frequency scan, we record all the outgoing signals (both optical and electrical). If one or more of these signals show a fringe-like behaviour, this modulation is interpreted as due to the presence of a stray light amplitude, interfering with the nominal light amplitude. The nominal/SL optical path difference (OPD) is retrieved from the frequency of these interference fringes, as in coherent reflectometry. The list [**SL amplitude** vs. **OPD**] of the different SL contributions is retrieved by spectral analysis of the recorded photo-signals.

The current demonstrator is composed of five main parts :

- **Frequency swept laser** : 1 064 nm fibered laser diode to be sweep over at least 1 nm (swept optical frequency $\Delta\nu_{opt}$= 265 GHz) allowing a resolution of 1 mm on the OPD SL/nominal
- **Frequency Ramp Control** : Offset phase-locked loop that achieves linear optical frequency drift ($\frac{d\nu_{opt}}{dt}$=Cte) using an unbalanced fibered heterodyne Mach-Zehnder interferometer.[2]
- **Frequency Scan rate measurement** : Measurement of the beat frequency between the frequency swept laser and a fixed frequency laser (method inspired by [3]).
- **Calibrator** : A fibered interferometer (ring cavity) to check the quality of the frequency ramp by doing a real time interference measurement simultaneously to the MOSA tests.
- **MOSA simulator** : Free space setup where stray light contributions with known OPD and amplitude are used to test the efficiency and accuracy of our demonstrator.

The present set up fulfills most of the requirements for MOSA stray light tests by reaching a measurement floor in fractional amplitude SL/nom under $\mathbf{10^{-5}}$ ($\mathbf{10^{-6}}$ above **10 Hz**) on the measurement range **[0–200 Hz]** and by achieving a resolution in OPD SL/nom under **1 mm**.

The set-up [4] and typical recorded spectra will be presented together with the method used to disentangle true stray light amplitude signals from perturbations that also give peaks in the Fourier Transform of the photo-signals. The accuracy and resolution will be discussed.

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References

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