Design and test of photoreceivers for space-based interferometry

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Laser interferometry has been increasingly used in metrology systems over the last decades since it provides outstanding resolution and accuracy for the measurement of several dimensional quantities. The GRACE Follow-On mission (currently under development) will be the first space-based system implementing this technique, which will push its distance measurement accuracy from 10^{-6} to 10^{-7} m. The future spaceborne low-frequency gravitational wave detector eLISA will also feature laser interferometry in order to reach the picometer accuracy needed.

Requirements for the photodetection chain in space-based interferometry differ from those on Earth in terms of bandwidth, noise, topology and hardness. The relative motion between the satellites increases the needed bandwidth up to several tens of MHz and there is a tight noise budget due to the low incoming optical power, which suffers great divergence over long distances. Also the necessity of tilt measurements using differential wavefront sensing (DWS) requires quadrant photodiodes with an individual amplifier for each segment. Particle radiation and high-energy electromagnetic radiation present in outer space increase the necessity to check the photoreceiver performance under extreme conditions.

A new photoreceiver design based on a hybrid transistor-OpAmp scheme is being developed in order to meet the requirements for future interferometry systems. A bandwidth of 30 MHz and a current noise density contribution of 2 pA/√Hz are planned to be achieved with the device, with a transimpedance gain of 10^6 V/A. An optimization based on 3D planar electromagnetic analysis of the layout and circuit co-simulation is also used to bring theoretical estimations and measured prototype performance closer. Different setups and techniques for experimental noise and bandwidth characterization were also studied, and tests to verify the irradiation hardness of some components of the photoreceiver were carried out.