Preliminary LISA Telescope Spacer Design

J. Livas, P. Arsenovic, K. Castelliucci, J. Generie, J. Howard, R.T. Stebbins
NASA/Goddard Space Flight Center, USA
J. Sanjuan, A. Preston, L. Williams, G. Mueller
University of Florida, Gainesville, USA

Abstract
The Laser Interferometric Space Antenna (LISA) mission observes gravitational waves by measuring the separations between freely floating proof masses located 5 kilometer apart with an accuracy of ~10 picometers. The separations are measured interferometrically. The telescope is an alloform Cassegrain style design with a magnification of 80x. The entrance pupil has a 40 cm diameter and will either be stabilized on-axis or centered on-axis to avoid obscurations. The two main purposes are to transform the small diameter beam used on the optical bench to a diffraction limited collimated beam to efficiently transfer the metrology laser between spacecraft, and to receive the incoming light from the far spacecraft. It transmits and receives simultaneously. The basic optical design and requirements are well understood for a conventional telescope design for imaging applications, but the LISA design is complicated by the additional requirement that the total optical path through the telescope must remain stable during the measurement of the telescope thermal distribution. This poster describes the requirements for the telescope and the preliminary work that has been done to understand the materials and mechanical issues associated with the design of a passive metering structure to support the telescope and to maintain the spacing between the primary and secondary mirrors in the LISA on-orbit environment. It includes the requirements flowdown from the science goals, thermal modeling of the spacecraft and telescope to determine the expected temperature distribution, layout options for the telescope including an on- and off-axis design, and plans for fabrication and testing.

Objective
- Develop and test a mechanical design for the main spacer element between primary and secondary mirrors
- Establish tolerance analysis
- Establish design interface requirements

Overview of the Mission
The LISA mission studies gravitational waves by detecting the strain they produce with a laser interferometer that measures the distance between pairs of freely floating proof masses arranged in a 5 x 10^9 km equilateral triangle constellation that orbits the sun at 60° with respect to the ecliptic. Each of the three spacecraft is 20° behind Earth's orbit. The plane of the triangle is angled 30° with respect to the ecliptic. Each of the three spacecraft are in an independent orbit around the sun, so no station-keeping is required to keep the constellation together. The proof masses are isolated from disturbances using drag-free slewing technology that keeps a spacecraft centered around the proof mass on its own.

Telescope Stability Requirements
- The LISA telescope is for metrology not imaging; pathlength stability is key
- Two main requirements
  1) Wavefront error < 20 - driven by the spacecraft's orbit requirements
  2) Length stability < 0.1 pm/mHz
- On-axis design used initially because a tolerance analysis was available; off-axis design has tighter requirements
- Main emphasis in this work is on a demonstration of the length stability requirement

Materials and Design
- Basic spacer design is a cylinder for both on- and off-axis telescopes. Fabrication limitations forced a quadpod design, but matches the symmetry of the quad cell main detector
- Materials properties typically vary vendor and process dependent

Thermal Modeling
- No New Model

Results
- Observed Michelson Fringe displacements agree with expected values
- Fringes move slowly, so stability is acceptable
- Visibility is ~95%
- Coefficient of Thermal Expansion (CTE) slightly less than vendor's reported numbers
- Encouraging; no unusual effects from joints or bonding
- Next step is to construct a Fabry-Perot cavity and lock a laser for stability measurement by comparison to a conventional cavity-stabilized laser

Summary and Conclusions
- Silicon Carbide is a viable candidate for a LISA telescope metering structure
- Care must be taken when choosing a vendor

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