The Italian Ministry of Research's Project 'Laser Ranging to Galileo'

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Abstract

We shall present the activities that are being performed in the framework of the joint ASI-INFN 'Premiale' Project '**Laser Ranging to Galileo (LR2G)**', which is funded by the Italian Ministry of Research. Thanks to LR2G, ASI-CGS and INFN-LNF are implementing important upgrades of their respective equipments and infrastructures, and, subsequently, they will carry on their peculiar tasks for the completion of the project. Namely, ASI-CGS will laser range to LRAs (Laser Retroreflector Arrays) on board Galileo IOV (In-Orbit Validation) vehicles and to LAGEOS satellites; whereas, INFN-LNF's SCF_Lab will complete full laboratory thermo-vacuum-optical characterisations of the 5th spare flight Galileo IOV LRA (on loan to LNF from ESA) and of the LAGEOS Engineering Model (also known as LAGEOS Sector, on loan to LNF from NASA). Besides the technical challenges related to equipment/infrastructure upgrades (which will be commented), the objective of the present project is to compare Galileo IOV retroreflectors against LAGEOS retroreflectors, both in the laser ranging station and on the laboratory optical bench. Following results will help optimizing GRA (GNSS Retroreflector Array) design and manufacturing. The project has started in 2016 and, during its first year, has envisaged tests on LAGEOS only; we shall then present the rationale of the activities and some already obtained results.

1. Project Overview

LR2G is a joint ASI-INFN project performed in the framework of the ASI-INFN Agreement N. 2015-048-R.0 for 'Adeguamento SCF_Lab' [1]. The project as a whole was granted through Italian Ministry of Research Decree 25 November 2013 Nr. 973 [2].

LR2G is building on previous experiences and direct involvement of ASI-INFN in cutting-edge laser ranging activities; namely:

- ASI, through MLRO (Matera Laser Ranging Observatory), is one of the core stations of the ILRS (International Laser Ranging Service) [3] and is deeply involved in the daily generation of geodetic products thanks to laser ranging measurements [4].
- INFN-LNF's SCF_Lab (Satellite/lunar/GNSS laser ranging/altimetry and cube/microsat Characterization Facilities Laboratory) is a space infrastructure, devoted to space R&D and located inside an ISO 7 clean room; the experimental innovation of the SCF_Lab is the concurrent measurement and modelling of the optical FFDP (Far Field Diffraction Pattern) and the temperature distribution of SLR (Satellite Laser Ranging) payloads under realistically simulated space conditions, with respect to temperature, pressure and solar constant load [5, 6]. Recently, the SCF_Lab has already been involved in thermo-vacuum-optical tests of spare and loose Galileo CCRs (Cube Corner Retroreflectors) [7, 8, 9, 10].

LR2G foresees equipment and infrastructure upgrades both at ASI-MLRO and SCF_Lab. ASI-MLRO will then laser range to LRAs on board Galileo IOV vehicles and to LAGEOS satellites; whereas, SCF_Lab will complete full laboratory thermo-vacuum-optical characterisations of the 5th spare flight Galileo IOV LRA and of the LAGEOS Engineering Model.

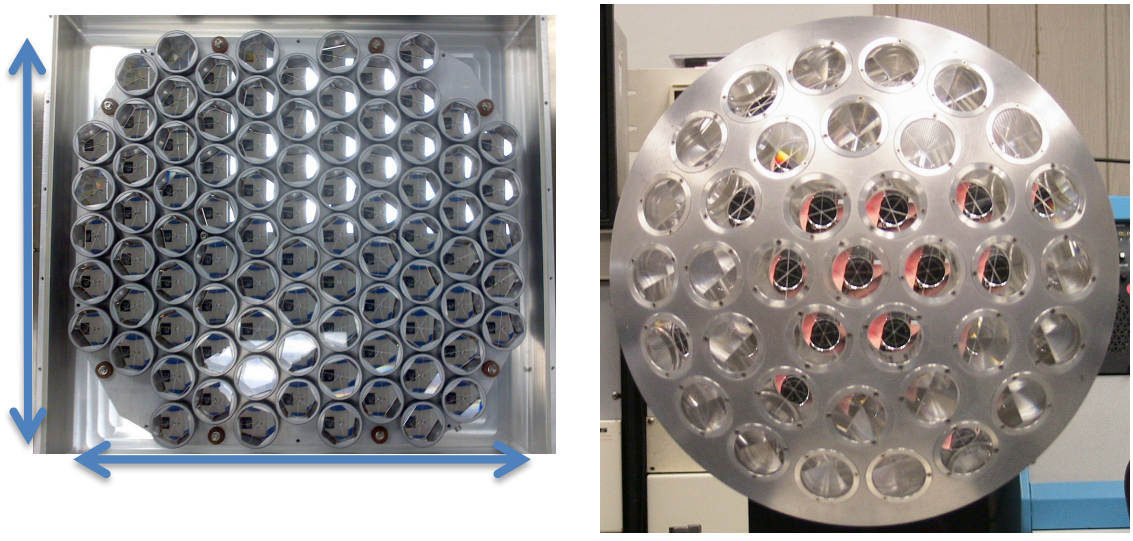

Figure 1 - Left: 5th spare flight Galileo IOV LRA (ESA courtesy); dimensions are approximately 430 mm x 470 mm. Right: LAGEOS Engineering Model (NASA courtesy).

2. Equipment and Infrastructure Upgrades

2.1 ASI Upgrades

The upgrades to the ASI-MLRO system are beyond the scope of this paper. The 1.5-meter telescope primary mirror was recently recoated [11]; other upgrades, such as the procurement of new up-to-date real time computers and the switch to kHz regime, are currently under study.

2.2 INFN Upgrades

SCF_Lab has been undergoing, so far, several upgrades; namely:

- Optical window replacement, in order to match with the maximum available optical tunnel dimension (Fig. 2):
  - Diameter = 230 mm.
  - Thickness = 50.8 mm (2 in).
  - OCA (Optical Clear Aperture) = 200 mm.
- Beam expander replacement, in order to perform multiple-CCR FFPD investigations of the Galileo IOV tray (Fig. 3):
  - Overall dimensions of about 500 mm x 250 mm x 250 mm (to replace current hardware).
  - Match with the maximum available optical tunnel dimension.

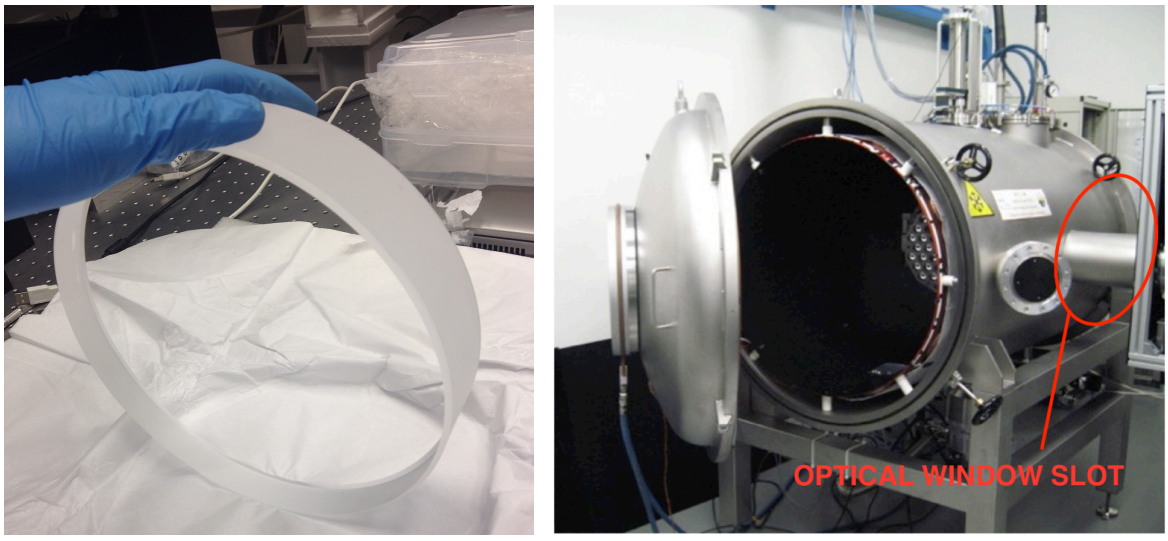

Figure 2 - Left: New optical window. Right: Optical window slot in the tunnel of the cryostat.

Figure 3 - Sketch of the intended multiple-CCR FFDP investigations of the Galileo IOV tray: the green areas are parts of the LRA lit with the expanded laser beam at 532 nm.

3. Early Results

As already commented, the measurements performed in 2016 concerned the LAGEOS Sector; we report here some early results of the SCF-Test of LAGEOS Sector performed at about 300 K [12]. The Sector was set in a thermo-vacuum environment and controlled in temperature at about 300 K; during the heating phase, it was directed towards the incoming solar beam for about 3 hours, it was then moved towards the optical window for continuous laser interrogation during the cooling phase for about 3 more hours. Reference FFDPs were recorded before the heating phase; continuous thermometry acquisition takes place during the whole test. The maximum estimated error for all the optical cross sections presented in this document is 15%; tests were performed on polar CCR.

Since LAGEOS VA (Velocity Aberration) is about 35 μrad, we plotted the time series of the average intensity at this specific VA (azimuthally averaged over the full FFDP) during the whole SCF-Test (Fig. 4).

Figure 4 shows that during the whole SCF-Test, the optical performances of the polar CCR of the LAGEOS Sector are not degraded; VA at 35 μrad keeps constant, before and after the solar load. The ILRS requirement for average intensity at LAGEOS altitude is of the order 1.0×10^6 m^2 per single CCR, and, as expected by simulation and ILRS modelling, should be constant in every thermal condition; details can be found in [13].

Extended optical and thermal analyses of SCF-Tests and Orbit Tests, both for LAGEOS Sector and Galileo IOV LRA, are intended for publishing during 2017, following the already ongoing activity.

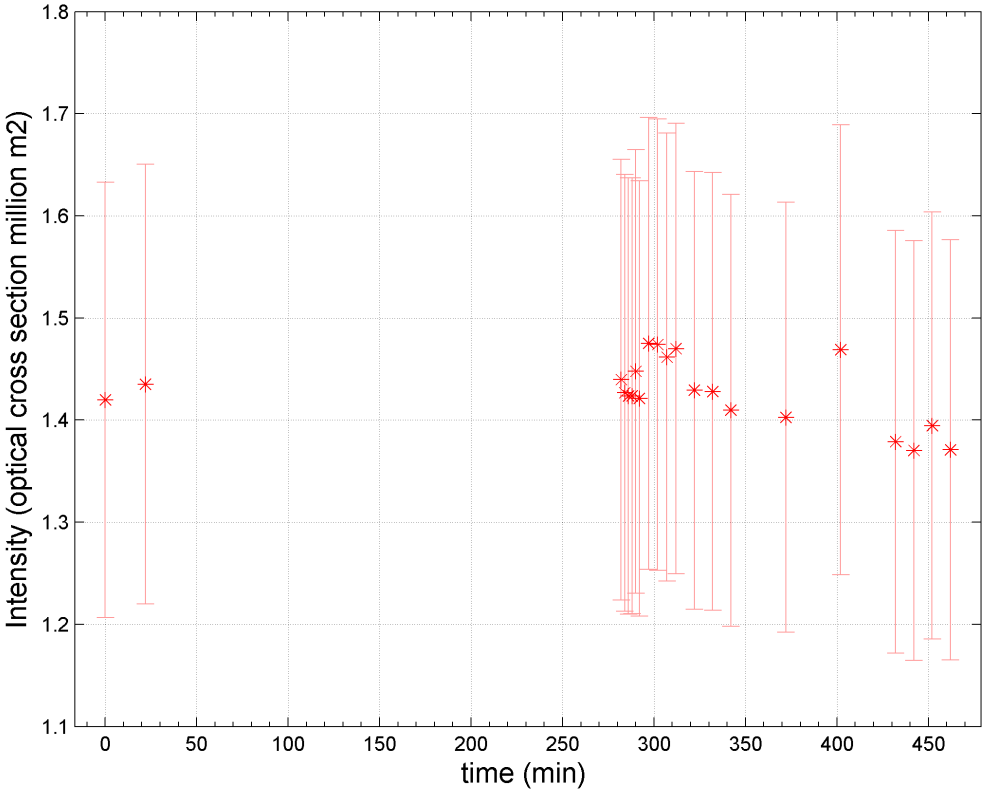

Figure 4 - 35 µrad intensity variation during SCF-Test for LAGEOS Sector polar CCR @ T ~ 300 K.

Acknowledgments

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