Thermal-Optical design and simulation of the ETRUSCO2 GNSS Retroreflector Array (GRA)

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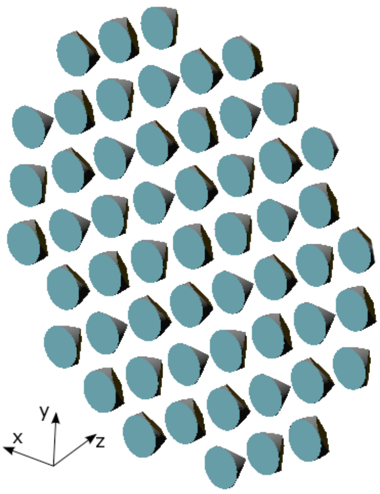
Measurements performed at the SCF_Lab (Satellite/lunar/GNSS Characterization Facilities Laboratory) for the ETRUSCO projects, along with others, were a useful background to the following ETRUSCO-2 ASI-INFN R&D project, whose goals include the development and measurement of a full size array of retroreflectors to be used on GNSS constellations and the construction of a new characterization facility, the SCF-G, optimized for the test of a GRA (GNSS Retroreflector Array). GRA design is intended to enhance performance in orbit of retroreflector arrays in three critical aspects:

- Low thermal exchange between the retroreflectors and the array base
- Array signature identical for all the laser inclinations
- Contained optical performance degradation

Here we report preliminary concurrent thermal and optical simulations of the array performed for the *ThermaOptiSim* work package with two different softwares: Thermal Desktop and CODEV. Optical simulations with CODEV were essential to determine the basic characteristics of the GRA to be realized for the project. To minimize as much as possible thermal exchange between the CCR and the rest of the satellite we inherited LAGEOS mounting rationale. Each CCR is a solid uncoated retroreflector , made of Suprasil 1, with a circular front face of 33 mm diameter. Angles between the faces the reflecting faces are 90°, with a manufacturing tolerance of ±0.5 arcsec. In order to respect ILRS standards the number of CCRs necessary on the array would 88. To control target signature effects caused by the variation of the relative inclination between the satellite and laser ranging station, we decided to design a quasi-circular shaped array. To meet this requirement it would be possible to design an array of 84 CCRs, but, following the decision made by ESA to design LRAs of reduced dimensions for budget and weight reasons, we designed an array of 55 retroreflectors. In Fig. 1 there is the GRA model used in CODEV along with the design FFDP of the array.



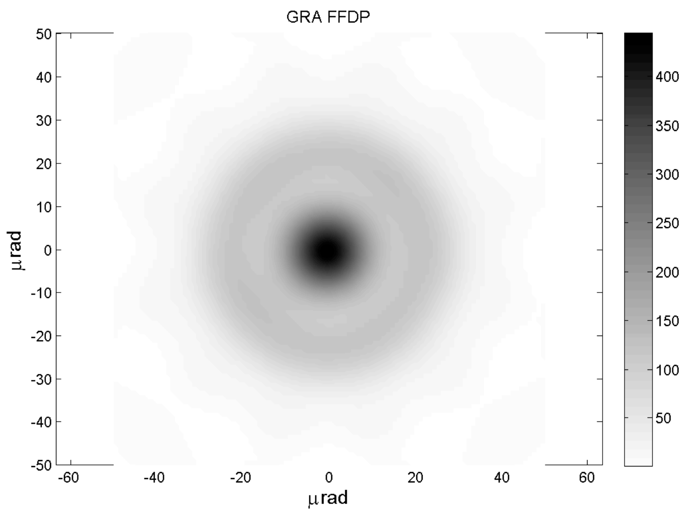


figure1 - (left) GRA model in CODEV used for optical simulations. (right) GRA FFDP for a = 532 nm laser beam.

In order to get an axial symmetric FFDP with a constant intensity values at Galileo velocity aberration (~ 24 µrad) CCR were arranged in four orientation groups. The final array FFDP has an intensity at Galileo VA of $113 \cdot 10^6$ m^2. In Thermal Desktop a finite element model of a single retroreflector was defined; then the whole GRA array was simulated in a critical orbit of Galileo, GNSS Critical half-Orbit (GCO), which is the one whose angular momentum is orthogonal the Sun-Earth direction. The output was the temperature distribution inside all of the CCRs at each time step of the orbit, which was eventually converted into an axial-radial gradient of temperature inside the CCRs. Those thermal gradients were input to the CODEV optical model of the array to plot the resulting FFDP at each time step. Intensity variation at the VA of 24 μrad was then plotted for the entire orbit.

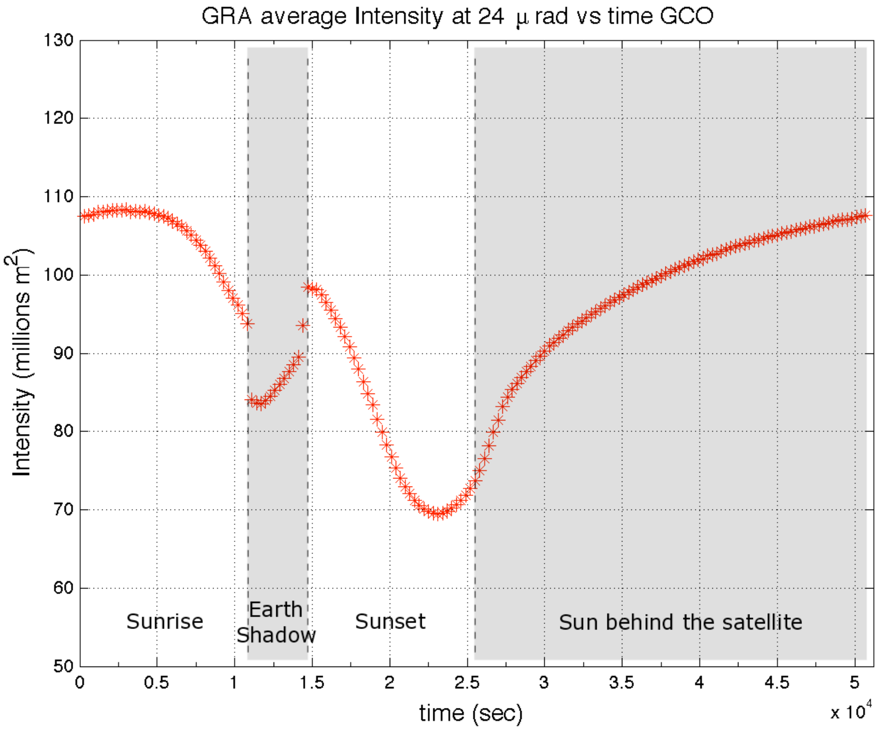


figure2 - GRA average intensity variation at 24 μrad during the simulated GCO.

Results showed some distinct differences from the real Galileo CCR, thanks to the thermally optimized mounting scheme implemented in Thermal Desktop, inherited from the LAGEOS satellite CCRs. These simulations, along with SCF measurements, will help the optimization of the GRA (one of the main products of ETRUSCO-2) to reduce the thermal degradation of the optical response (FFDP) in orbit. A good optimization process for these payloads is fundamental in order to deeply exploit the contribution of SLR tracking of GNSS satellites: increased satellite positioning accuracy, absolute positioning of GNSS satellites with respect to the ITRF (International Terrestrial Reference Frame), better orbital modeling and more accurate time transfer.

Conclusions

ThermaOptiSim simulations procedure is fundamental to test GRA in other conditions which is not possible to simulate at the SCF_Lab. It needs however laboratory measurements on a GCO to be validated. The model will be in future enhanced and completed in order to completely fulfill ETRUSCO-2 objectives.