Isothermal FFDP-Test and SCF-Test of Flight-quality Uncoated Cube Corner Laser Retroreflectors

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ABSTRACT

Using dedicated facilities of INFN-LNF in Frascati, Italy, including the "Satellite/lunar laser ranging Characterization Facility" (SCF,[1]), we characterized the detailed thermal behaviour and/or the optical performance of many flight units of coated and uncoated cube corner laser retroreflectors (CCRs). As a reference for the ILRS community, with this article we provide a compilation of the many tests carried out in the last years on uncoated CCRs (tests on coated CCRs are reported in detail in [1]).

1. Industrial optical acceptance test of 110 LARES Flight CCRs (ASI reference document: DC-OSU-2009-012)

The work reported in this section has performed by INFN-LNF authors only. At the end of 2008 INFN-LNF was requested by ASI[1] to perform an industrial acceptance test of all of the 110 CCRs of the LARES satellite. LARES is a tungsten sphere passive satellite of about 18 cm radius, covered with 92 CCRs made of fused silica. It will orbit at a nearly circular orbit with semi-major axis of about 7900 Km. The CCRs used for the satellite were manufactured by ZEISS, but in order to asses the compliance with their specification ASI requested INFN-LNF to do FFDP (Far Field Diffraction Pattern) measurements of those CCRs. Specifications of LARES CCRs were:front face aperture of 1.5", DAOs[2] = 1.5±0.5 arcsec. We performed FFDP measurements at the SCF, in air at room temperature, in 3 working weeks before Christmas 2008, on a red laser optical table (He-Ne, λ=632.8 nm) [2], since CCRs were designed by ZEISS at this wavelength. In Fig. 1 we can see one of the measured CCRs. In order to define a criterium of acceptance for the CCRs, we referred to the shape of the FFDP of an uncoated CCR with front face aperture of 1.5" and DAOs as specified before, oriented with a physical edge vertical and an horizontally polarized beam.

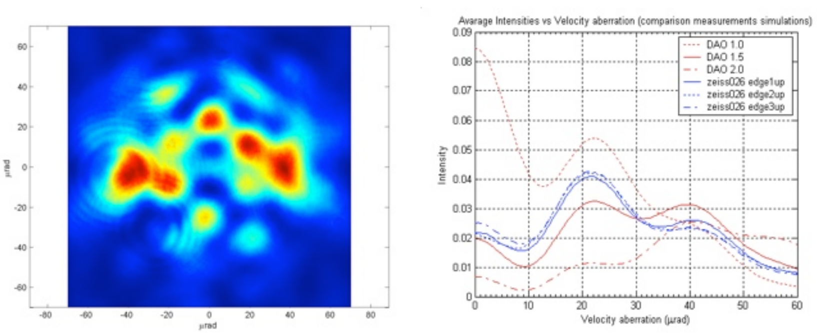
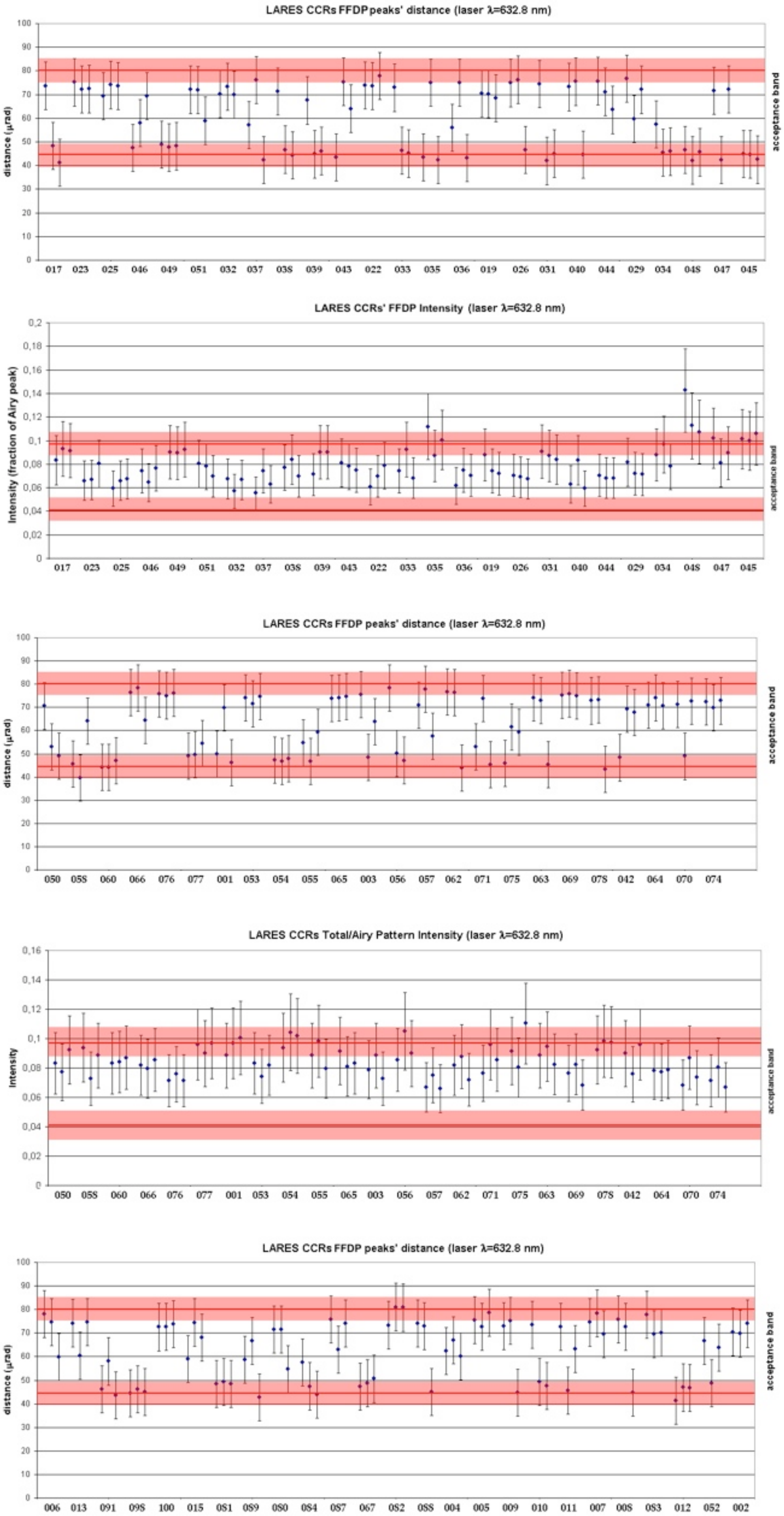


Figure 1 (left) Measured FFDP of one of LARES CCRs. (right) Average intensity vs velocity aberration, comparison measurements simulations. Measured intensity has ±25% relative intensity error not shown

[1] Italian Space Agency

[2] Dihedral Angle Offset

The FFDP has a very distinctive shape with two peaks distributed horizontally, symmetric with respect to the center. We therefore compared the distances between those peaks and their intensities with measurements. Simulations (peaks distances and intensities), defined a band, in red in Fig. 2, in which measured values should be delimited. In Fig. 2 we present the results of the tests on all of the 4 lots in which were divided the 110 CCRs.



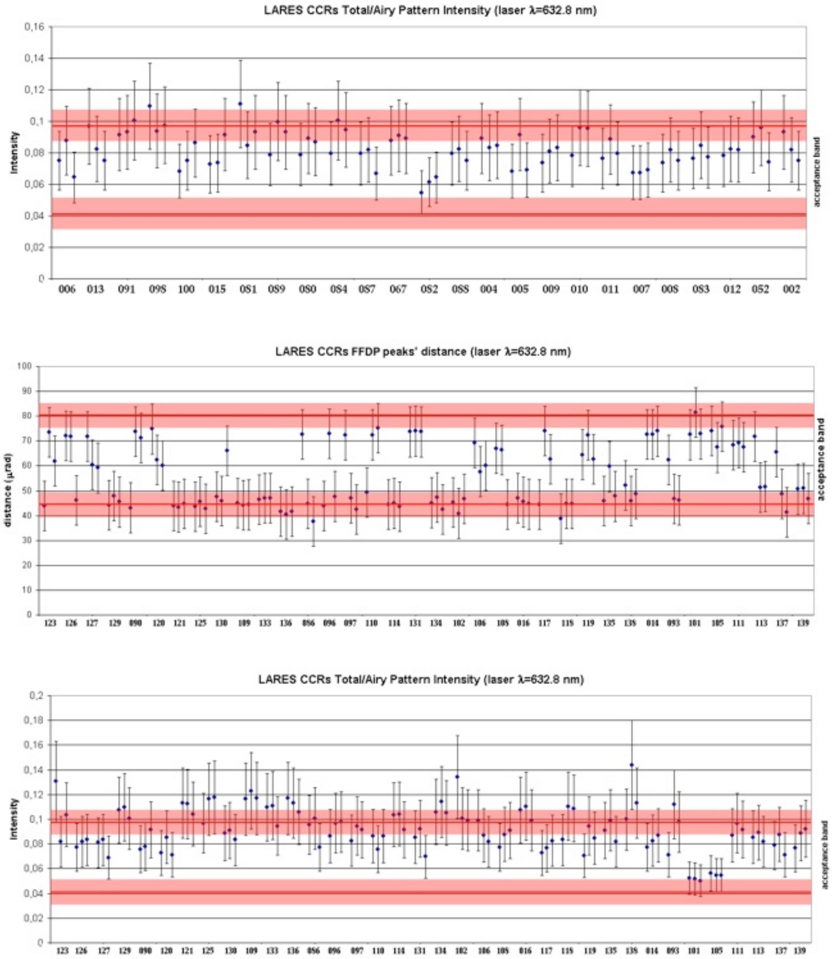


Figure 2 Industrial acceptance test performed on all of the LARES flight CCRs, by INFN-LNF authors only, at a red optical table. Error on measured peaks distance is ±10 µrad. Error on measured intensity is ±25% relative

This work was completely successful and approved by ASI with ASI reference document: DC-OSU-2009-012. Right plot of Fig. 1 shows another analysis we started to perform, involving the evaluation of the average intensity of the FFDP vs. the velocity aberration. This is a better way to compare measurements with simulations as we will explain in section 3. Figure one shows, for example, that the CCR, within errors, is in very good accordance with DAO specs. Results of this analysis will be subject of a future work.

2. LLRRA-21[3]/MoonLIGHT[4] an uncoated lunar CCR

Here we present the SCF-Test performed on a 100 mm front face aperture uncoated CCR, LLRRA-21, for the next generation of lunar laser ranging. Full description of CCR characteristics can be found in [3]. The CCR was installed with its housing inside the SCF, on the rotation positioning system, see Fig. 3. The housing was controlled in temperature with tape heaters. An IR (InfraRed) camera measured CCRs' front face temperature. Platinum RTD sensors recorded housing and gold cans temperatures while two precise diode sensors recorded the temperature of one of the faces of the CCR, in order to have a third dimension on the thermal gradient of the CCR. These last one were put one on the center of this face and one close to the front face.

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[3] Lunar Laser Ranging Retroreflector Array for the 21st century, funded by NASA with Contract NASA NNX07AV62G for the LSSO (Lunar Sortie Scientific Opportunities) and by the LUNAR (LUnar Network for Astrophysics Research) via Cooperative Agreement NNA09DB30A.

[4] Moon Laser Instrumentation for General relativity Hugh-accuracy Tests (an INFN R&D experiment).

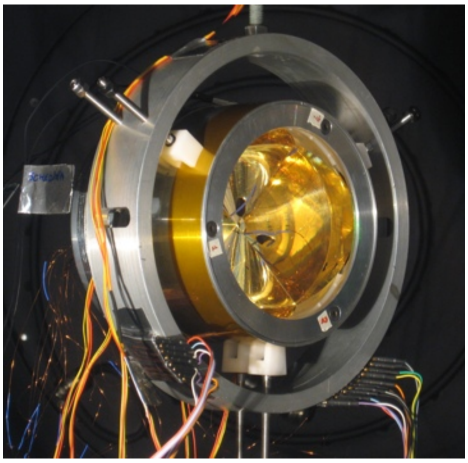

Figure 3 MoonLIGHT/LLRRA-21 flight CCR hold inside the SCF, ready for the test

The CCR had an orientation inside the housing such that one physical edge was horizontal. The procedure of the SCF-Test was the same as described in [1]. Created the simulated space environment we heated the CCR with the Solar Simulator (SS), with the beam orthogonal to the CCR. After this condition, which, thermally, is the best for an uncoated CCR, we simulated also an illumination of the Sun at lower elevations. In order to do this the CCR was rotated of 30º clockwise and 30º counterclockwise with respect to the SS. In one direction we had a Total Internal Reflection breakthrough situation, in the other not. Temperature variation with time of various prototype's parts is in Fig 4.

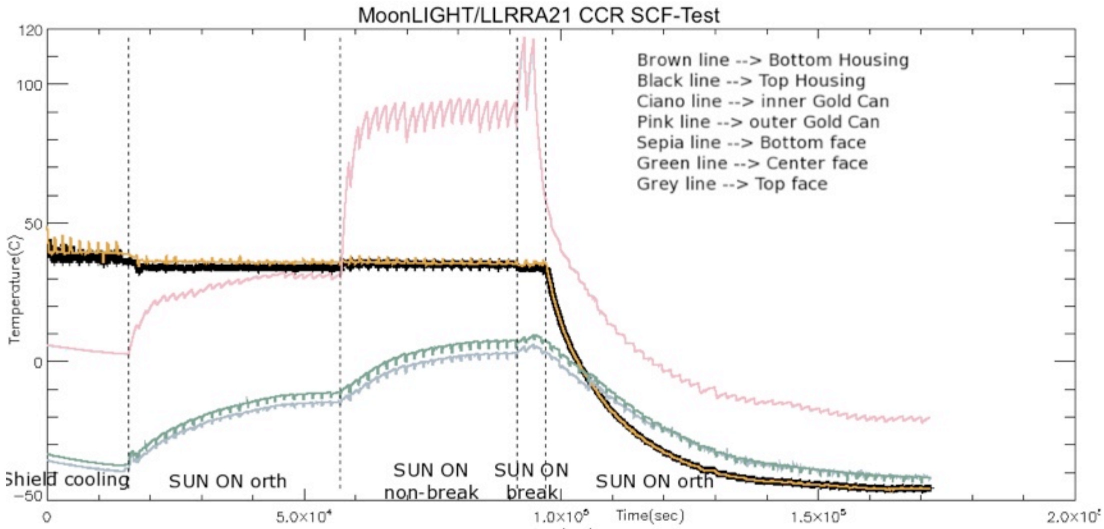

Figure 4 MoonLIGHT/LLRRA-21 flight CCR temperature variations of various housing parts and of CCR

As expected, going from an orthogonal SS beam to non-breakthrough position to a breakthrough position increased the temperature of the CCR and most of all the temperature of the gold cans. In particular we noticed an increasing temperature gradient on the CCR face. Until the "SUN ON break" phase the housing was controlled, while on the last phase the housing was left floating. The FFDP measurements reflected this behaviour (see Fig. 5). FFDP measurements were performed with a green laser (λ= 532 nm), but the diameter of the beam hitting the CCR was only 38 mm, not 100 mm as the front face of the CCR. Future upgrades of the optical table will allow that. As mentioned above, the temperature difference between the two sensors on a reflecting face of the CCR (green and grey lines of Fig. 4) increased; the intensity of the FFDP at Moon velocity aberration decreased until the breakthrough phase. Instead during the last phase the intensity increased, as the temperature difference of temperature sensors on the CCR reduced.

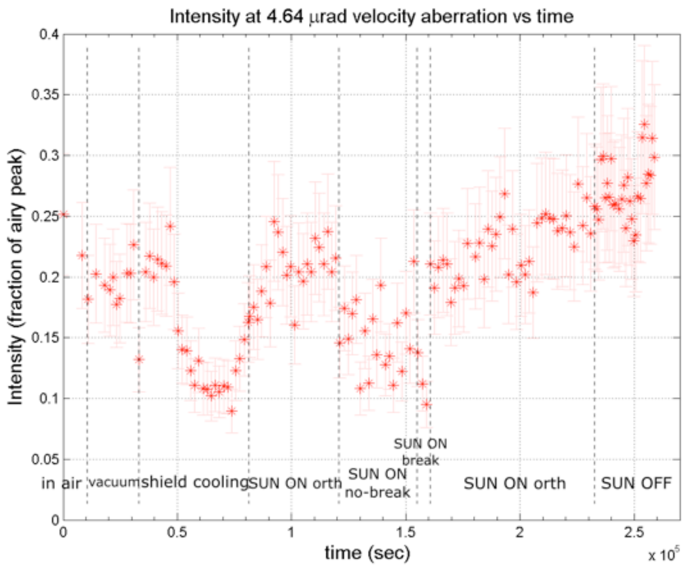

Figure 5 MoonLIGHT/LLRRA-21 flight CCR average FFDP intensity variation at Moon velocity aberration (2V/c) during tests. Error on intensity is ± 20% relative.

3. Conclusions

The SCF has proven to be the right facility for the test of flight quality uncoated CCRs in an accurate laboratory-simulated space environment and in air for FFDP acceptance tests. In particular LARES flight CCRs FFDP acceptance tests represent a big milestone for our facility, because proved our equipment to be appropriate for such aim. These tests were a good occasion to start thinking on a new approach on FFDP analysis. Future publications will describe in detail such analysis on LARES flight CCRs. Finally we report a complete SCF-Test of a new concept of lunar LRA (described in [3]), which proved useful for the design progress of LLRRA-21. Refinements on hardware is mandatory for an exhaustive test.

References

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