Design, construction and optical test of a laser-ranged test mass for deep space missions

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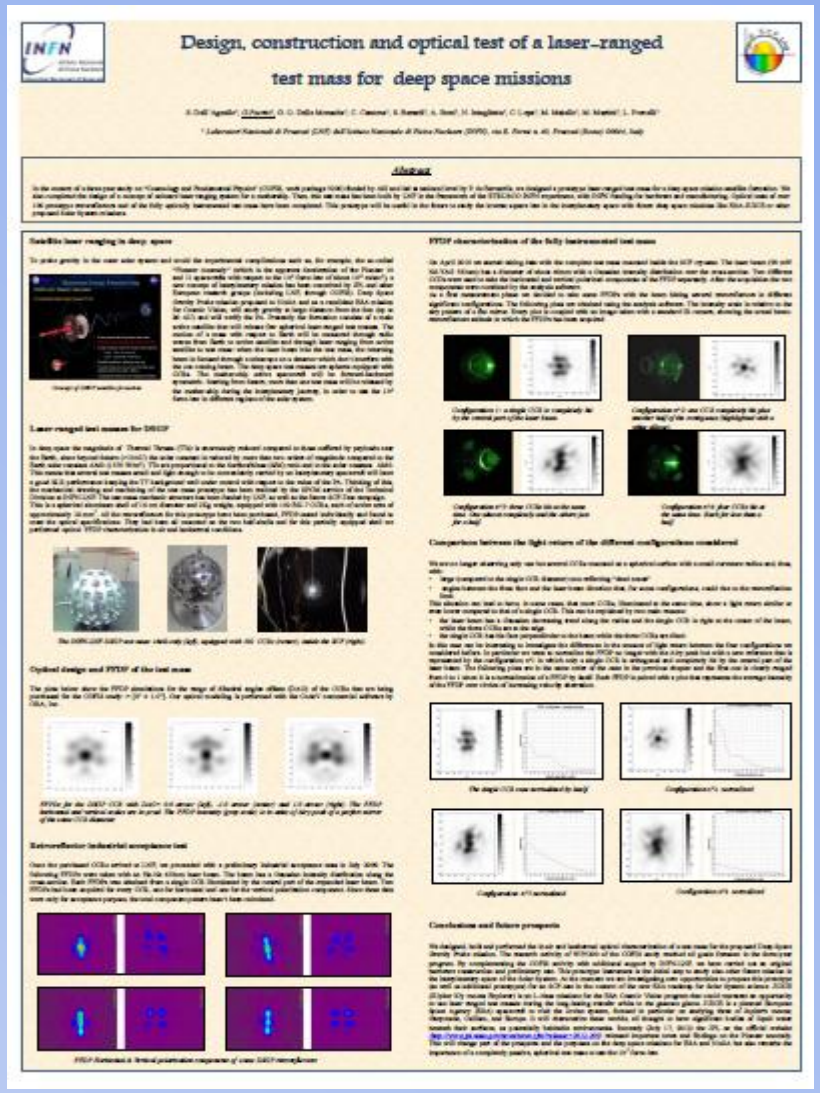
The poster



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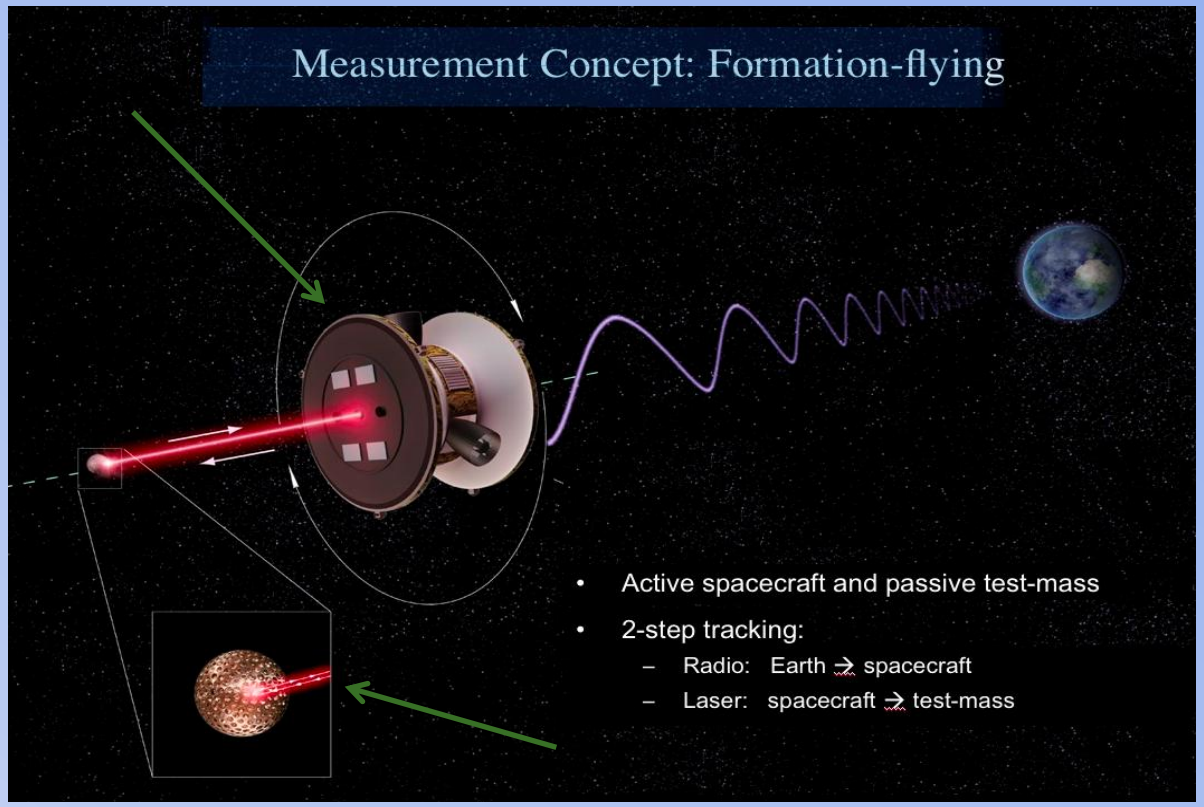
Test masses in deep space missions

- During the interplanetary journey, in order to test the $1/r^2$ force-law in different regions of the Solar System, the traveling spacecraft releases one or more spherical laser-ranged test masses (which are equipped with CCRs).



About the test mass

It should be small and light enough to be :

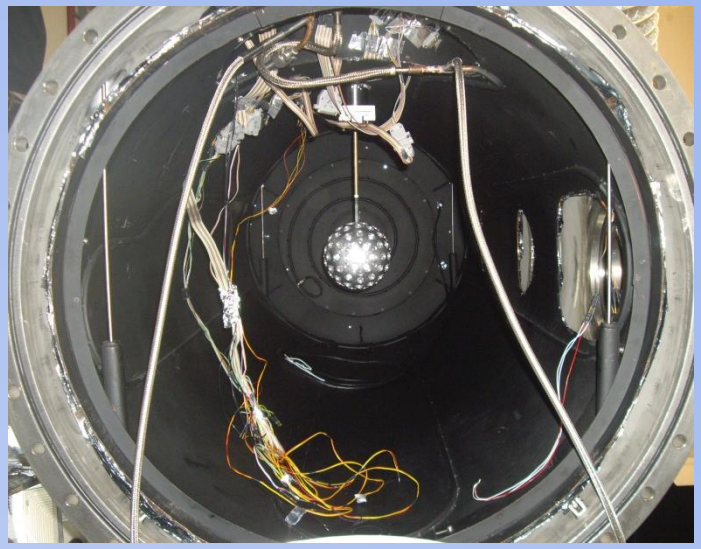
- conveniently carried by an interplanetary spacecraft
- less sensitive to the Thermal Thrusts (which are proportional to the Surface/Mass ratio and to the solar constant AM0)

Our prototype

- funded & built by LNF in the context of the 3 years COFIS program (DSGP mission)
- a 16 cm dia and 2 Kg wt aluminum sphere
- shell-only test mass
- equipped with 102 CCRs (DAO 0" ± 1")

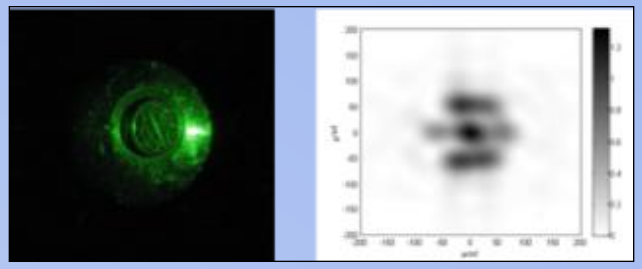
Test mass characterization

- complete test mass mounted inside the SCF cryostat
- the laser beam (532nm) has a diameter of about 40mm with a Gaussian intensity distribution over the cross-section
- two different CCDs used to take the horizontal and vertical polarized components of the FFDP separately
- after the acquisition the two components were combined by the analysis software

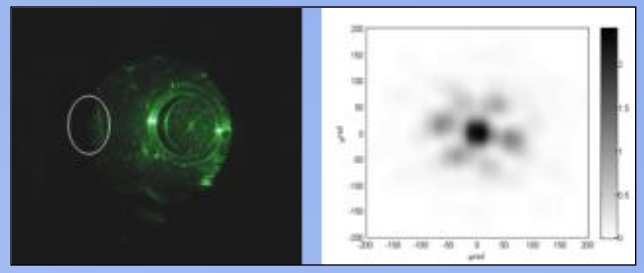


FFDP tests

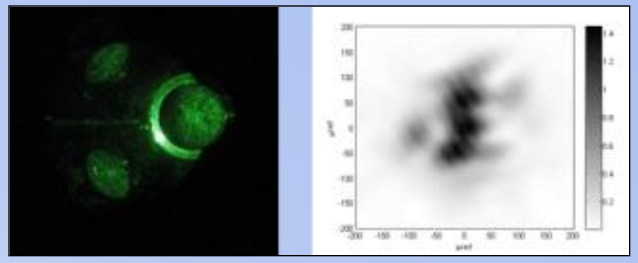
- We decided to take the FFDPs with the beam hitting several retroreflectors in different significant configurations (some of them shown below).
- For each configuration, it is reported an image taken with a standard IR camera and the relative plot obtained using the analysis software (the intensity scale is relative to the airy pattern of a flat mirror).



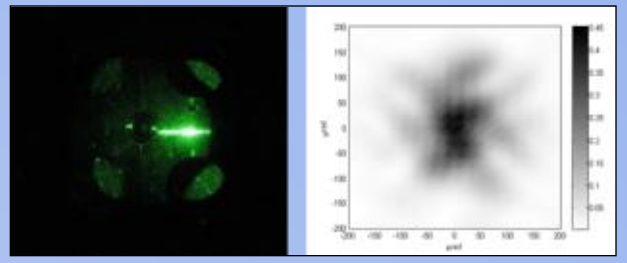
Configuration 1: a single CCR is completely hit by the central part of the laser beam.



Configuration n°2: one CCR completely hit plus another half of the contiguous (highlighted with a white ellipse).



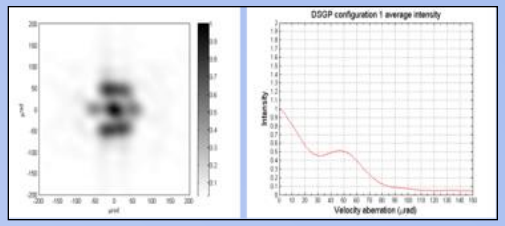
Configuration n°3: three CCRs hit at the same time. One almost completely and the others just for a half.



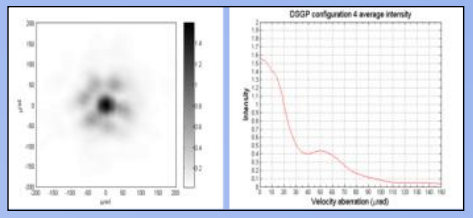
Configuration n°4: four CCRs hit at the same time. Each for less than a half.

Considerations

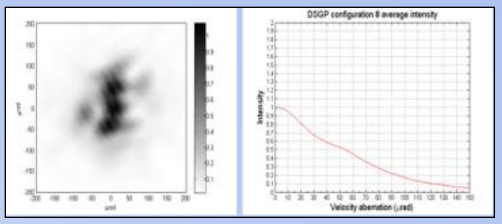
- In some configurations it has been noted that more CCRs illuminated at the same time show a light return similar or even lower compared to that of a single CCR. This can be explained by two main reasons:
  - the laser beam has a Gaussian decreasing trend along the radius and the single CCR is right at the center of the beam, while more CCRs are at the edge;
  - the single CCR has his face perpendicular to the beam while more CCRs, due to the spherical shape, are tilted.
- It can be interesting to investigate the differences in the amount of light return between the four configurations considered before:
  - So we have normalized each FFDP no longer with the Airy peak but with a new reference that is represented by the configuration n°1 in which only a single CCR is orthogonal and completely hit by the central part of the laser beam.



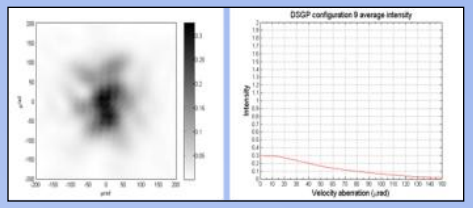
The single CCR case normalized by itself.



Configuration n°2 normalized



Configuration n°3 normalized



Configuration n°4 normalized

Conclusions and future prospects

- We designed, built and performed the in-air and isothermal optical characterization of a test mass for the proposed Deep Space Gravity Probe mission (COFIS program);

- This prototype instrument is the initial step to study also other future mission in the interplanetary space of the Solar System;

- At the moment we are investigating new opportunities to propose this prototype for an SCF-test in the context of the new ESA Cosmic Vision program.

  - JUICE (JUpiter ICy moons Explorer, which is focused on studying three of Jupiter's moons Ganymede, Callisto, and Europa) could represent an opportunity to use laser ranged test masses during the long-lasting transfer orbits to the Jovian system.

Thank you for attention!

any questions?

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