Characterization of the optical performance of COTS laser retroreflectors for ASI-INFN Joint Projects

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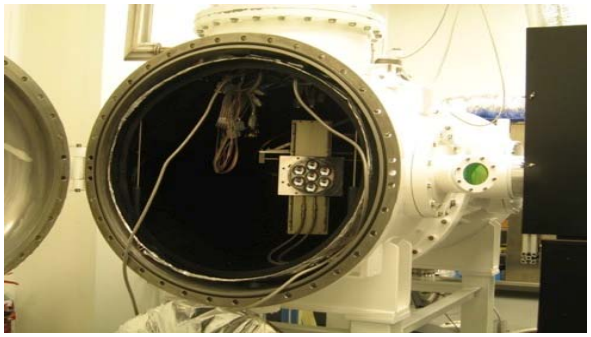
21st International Workshop on Laser Ranging 2018

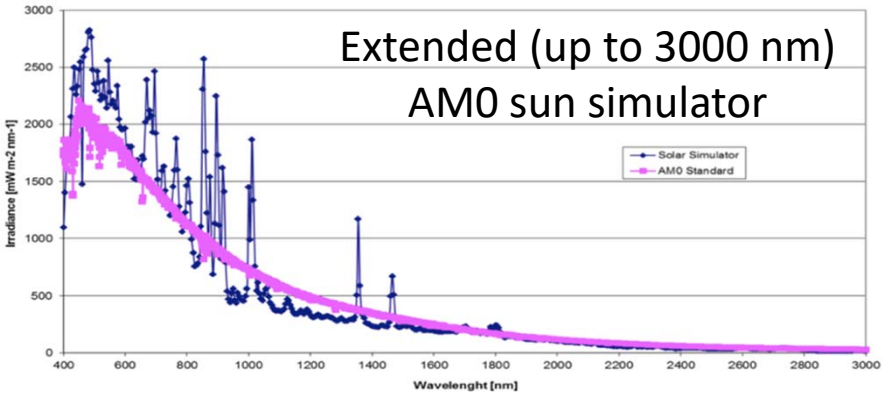
Outline

- Joint Lab: INFN-SCF_Lab & ASI-MLRO
- COTS for space applications
- COTS characterization at INFN
- Summary

INFN-ASI Joint Lab on laser retroreflectors & ranging

- Two Optical Ground Support Equipment (OGSE) to establish TRL ~ 6-7 for retroreflector performance
- SCF (top right) & SCF-G (bottom right, especially dedicated to Galileo, other GNSS).
- **SCF-Test**: detailed solar-orbital-thermal-vacuum-optical testing (Reference paper: Adv. Space Res. 47 (2011) 822-842)

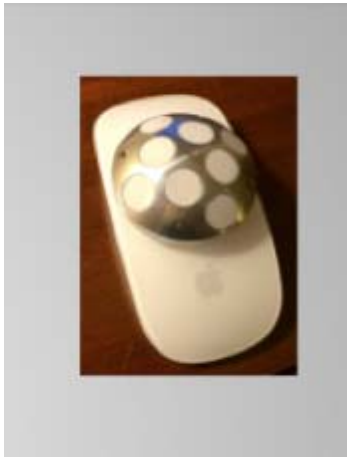


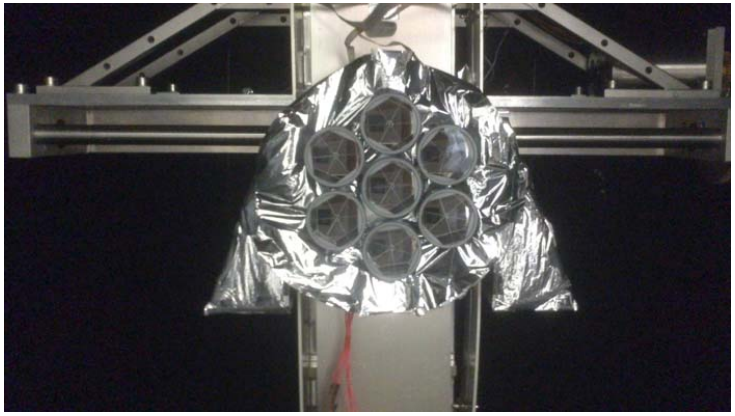


Joint Lab on laser retroreflectors & ranging

Recent achievements (amongst the others):

- INRRI-EDM/2016 - qualification for space flight:
  - First laser retroreflector on the surface of Mars (sigh!).
    - Adv. Space Res. 59 (2017) 645-655.
  - **InSight Mars Lander (landing: Nov 26, 2018)**
    - **See Marco Muccino's talk**
- Galileo IOV CCRs thermo-optical vacuum testing:
  - Adv. Space Res. 57 (2016) 2347-2358.
- IRNSS flight LRA thermo-optical vacuum testing:
  - Adv. Space Res. 60 (2017) 1054-1061.
- Moon CCR thermo-optical vacuum testing:
  - Adv. Space Res. 60 (2017) 1300-1306.
    - **See Luca Porcelli's talk**





Satellite/GNSS and Lunar LASER RANGING

Matera Laser
Ranging Observatory
1.5 m telescope
@ASI - CGS

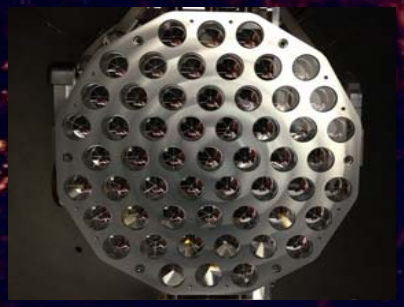
LEO

Mars
μ–reflector

Moon

LAGEOS

GNSS



COTS laser retroreflectors

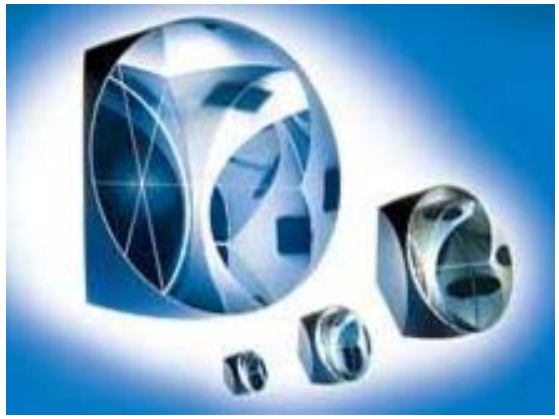
COTS: commercial off-the-shelf products ready-made and available

<u>Lower cost, shorter procurement time, rad-resistant fused silica</u>

Commercially available technologies, with specific limitations (for ex. less accurate **DAO** = dihedral angle offsets) to be adapted to traditionally *customized* applications (like LAGEOS reflectors with its three mounting "tabs")

However, they have well understood advantageous properties (for ex. for radiation resistance), are listed in online catalogues and can perform different functions

Easily available in the commercial marketplace and can be bought and used under government contract.

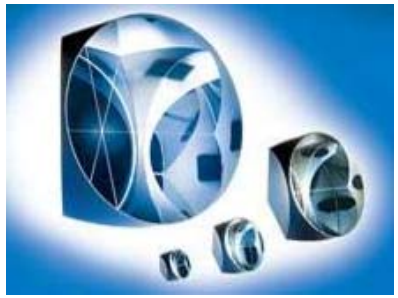


Characterization of 1 inch COTS Retroreflectors

Presented today: measurements by INFN-LNF of 50 COTS CCR, acquired exclusively with INFN own funds prior to any ASI-INFN Agreement.

Work being repeated for the delivery of the LARES-2 satellite to ASI, under a specific and public ASI-INFN Agreement signed between public entities governed by the Italian Ministry of Research

- Incoming / visual inspection
- In-air **FFDP** test (Far Field Diffraction Pattern)
- Measurements of reflector DAOs with Fizeau interferometer
- Measurement of vertex-front face distance
- Mounting first CCR in prototype metal cavity/cavities



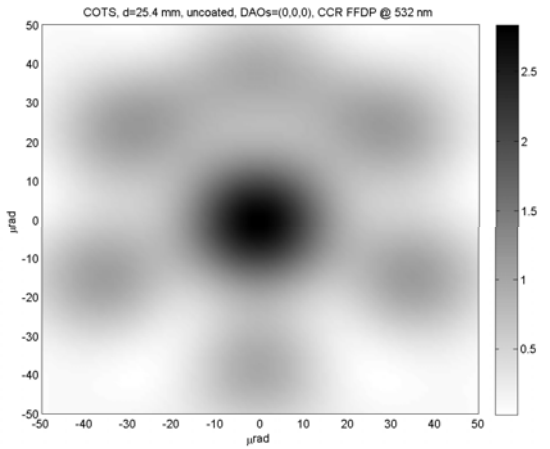
Next:

1. SCF-Test (Adv. Space Res. 47 (2011) 822-842) of the reflectors at 300 K (& hi-lo T)
2. Solar load for 3 hours, radiative cooling for 3 more hours
3. Reference FFDP/thermogram before heating
4. FFDP and IR thermograms during the test.

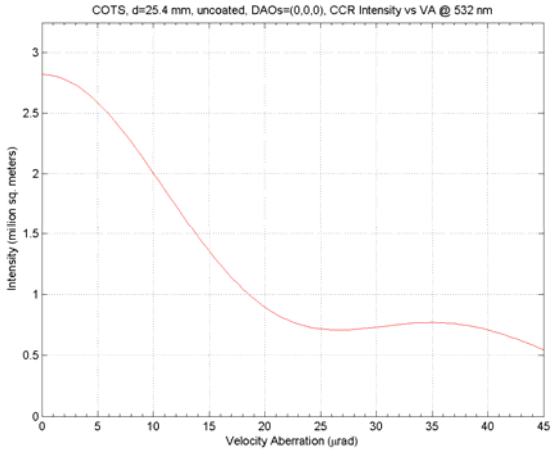
CODE V Simulations of Optical Cross Section (OCS) 'intensity'

CODE V is a comprehensive program for optical design, analysis, model and fabrication support for the development of optical systems for diverse applications.

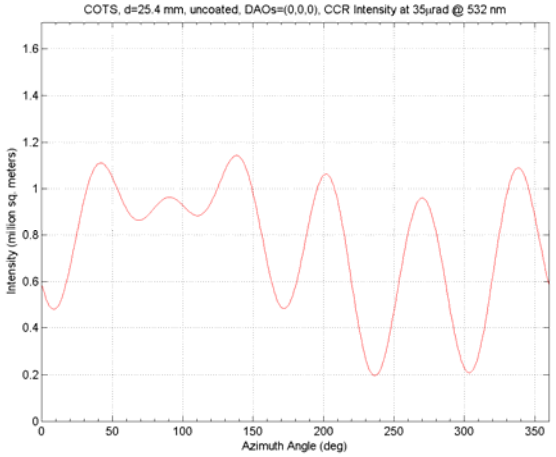
Simulations for nominal COTS DAO centered around 0.0 arcsec



Simulated FFDP of a COTS CCR



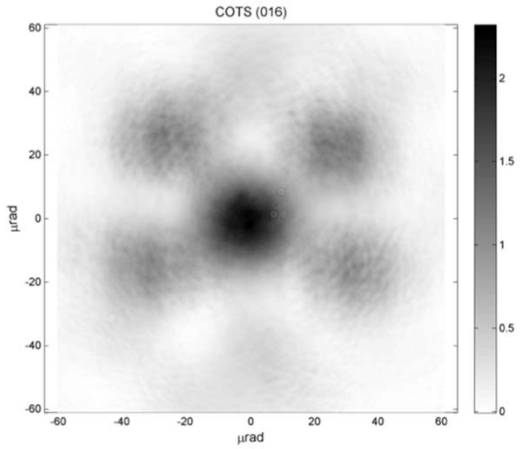
Simulated OCS intensity (averaged over the azimuth in the FFDP plane) vs. VA (Velocity Aberration) of a COTS CCR



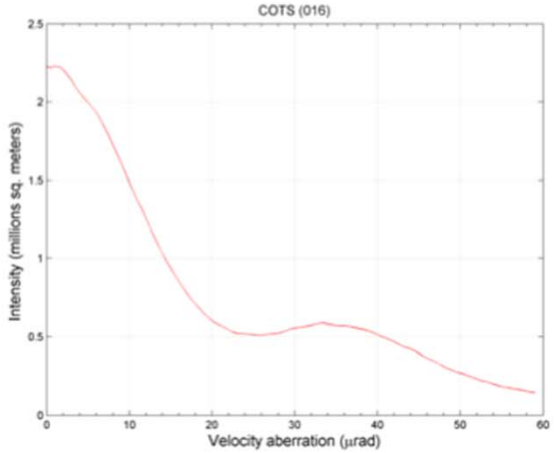
Simulated OCS intensity at a specific
VA = 35 µrad, relevant for the LAGEOS altitude

1-inch COTS in-air early results

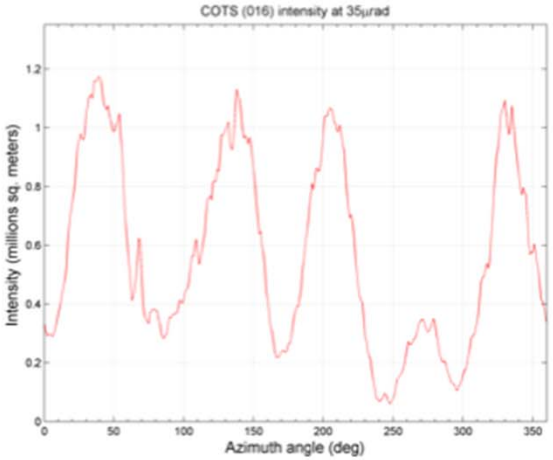
Measurement for nominal COTS DAO centered around 0.0 arcsec:



FFDP of a COTS CCR



OCS intensity (averaged over the azimuth in the FFDP plane) vs. VA of a COTS CCR

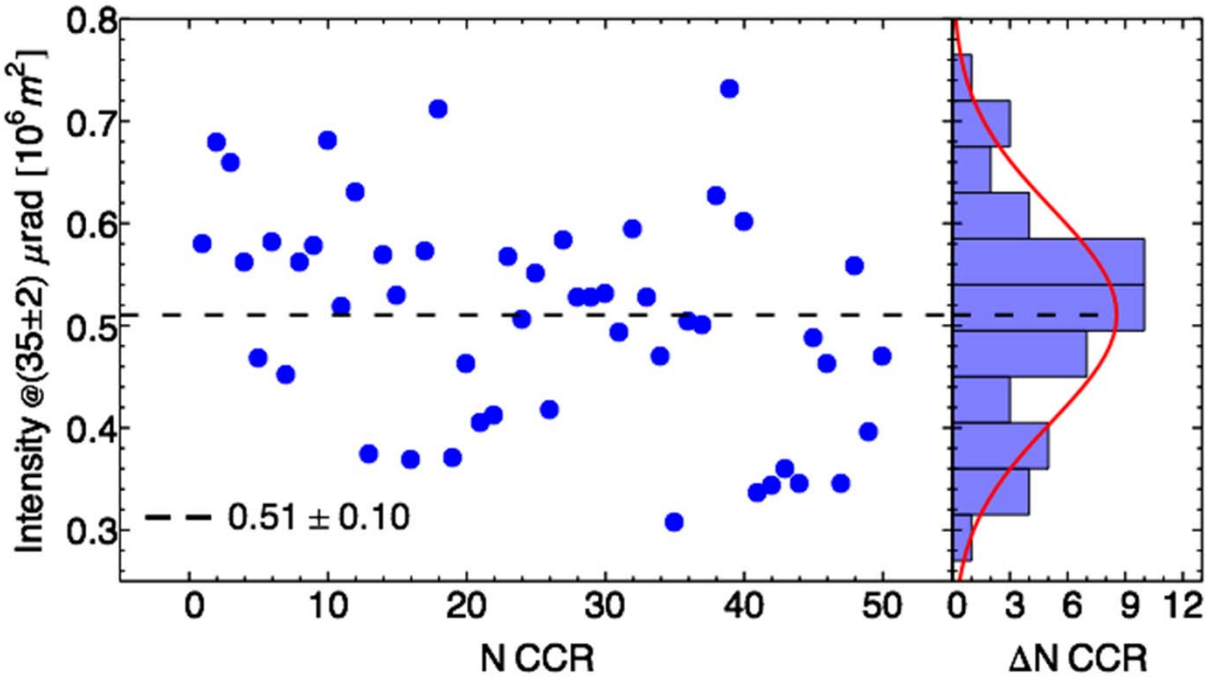


OCS intensity at a specific VA

➔ These COTS reflectors are uncoated and, as such, they have a field of view up to ~20 degrees

➔Effective space thermal environment may have detrimental effect on the FFDP (SCF-Test to be done)

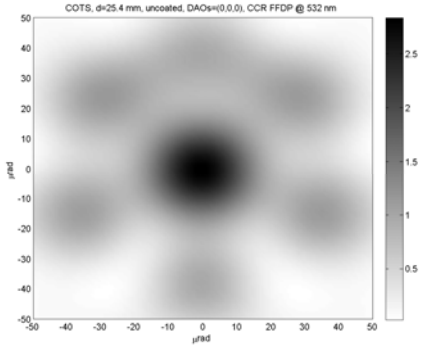
50 1-inch COTS: FFDP test results

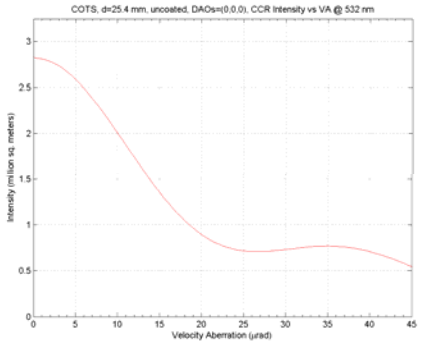


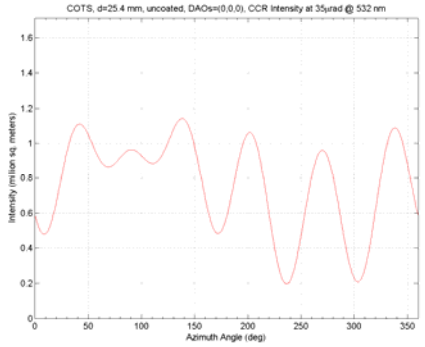
- Nominal COTS DAO centered around 0.0 arcsec
- The average OCS intensity at 35 μrad is 0.51 msqm vs. the nominal OCS one foreseen by CODEV (0.75 msqm)
- For this batch of COTS ➔ OCS is 33% lower than nominal

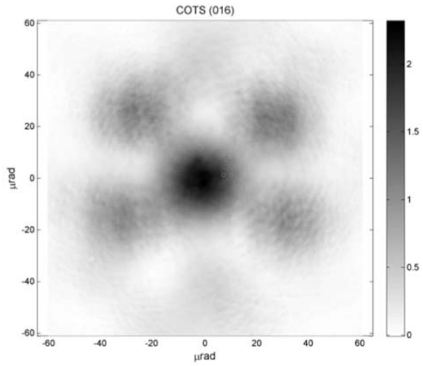
1 inch COTS Retroreflectors

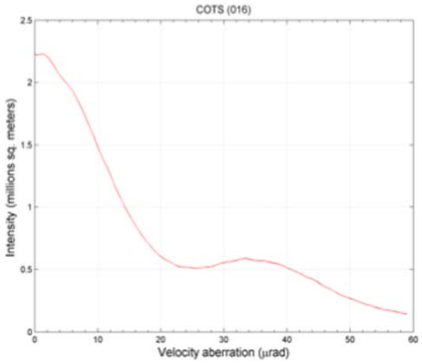
Comparison with Simulations

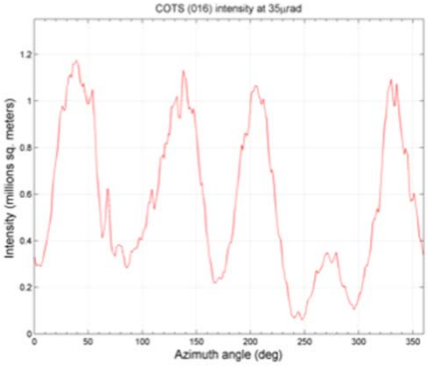












Simulations

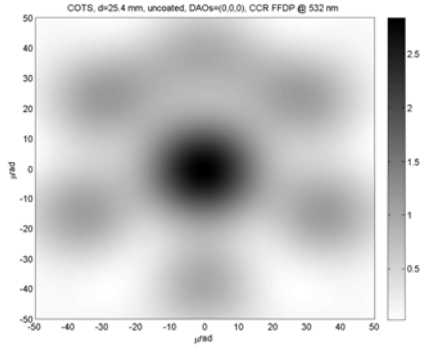
Right plots: **VA = 35 µrad, relevant for the LAGEOS altitude**

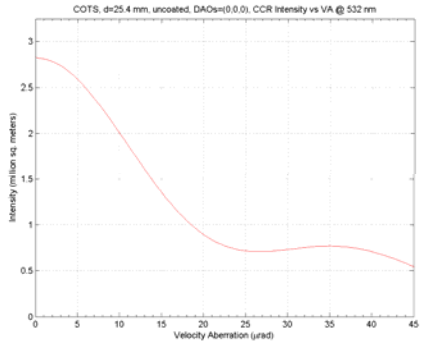
Measurements:

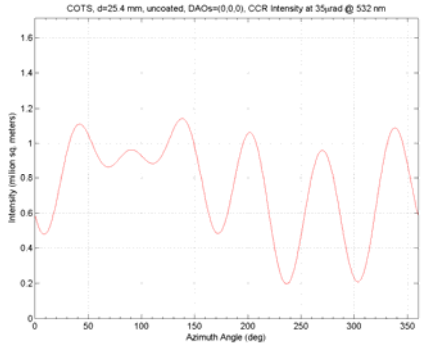
Consistent with nominal DAO (0.0 arcsec)

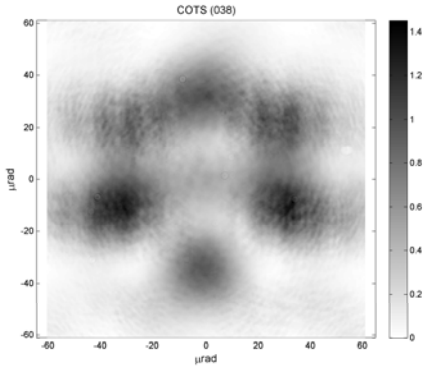
1 inch COTS Retroreflectors

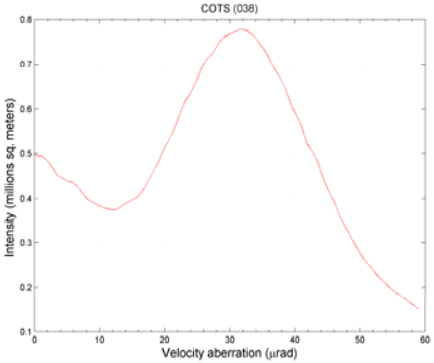
Comparison with Simulations

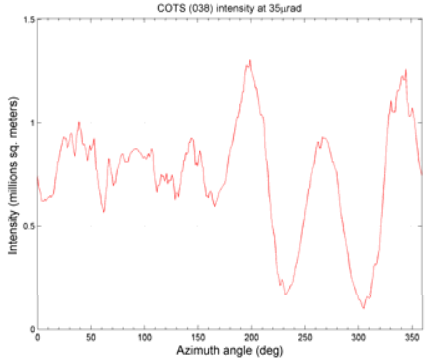












Simulations

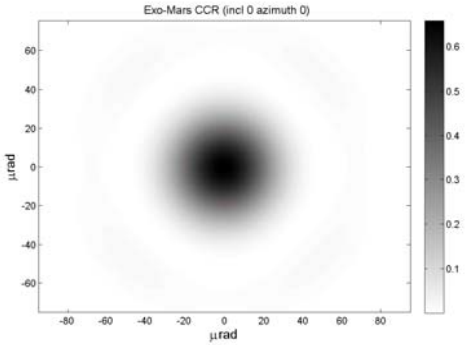
Right plots: **VA = 35 mrad, relevant for the LAGEOS altitude**

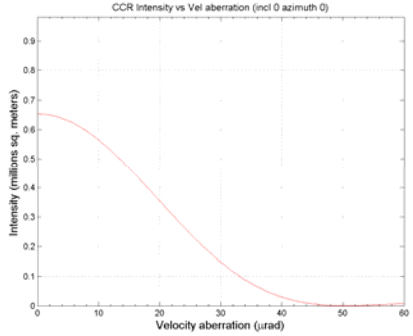
Measurements:

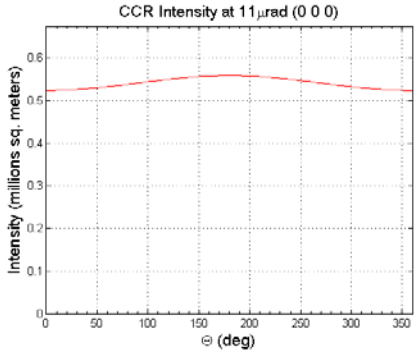
DAOs not consistent with 0.0 arcsec. But OCS value @ 35 μrad is at the level of reflectors with nominal DAOs (0.0 arcsec)

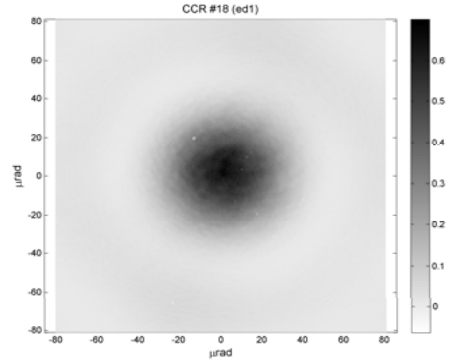
1/2 inch COTS Retroreflectors

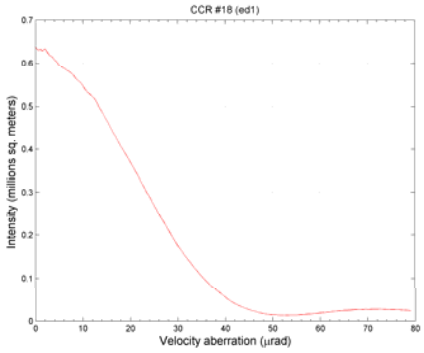
Comparison with Simulations

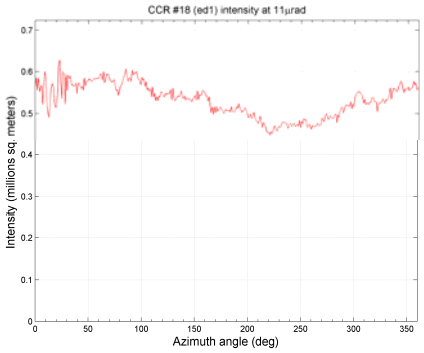












Simulations

Right plots: **VA = 11 mrad, relevant for the few hundred km *lunar* altitude**

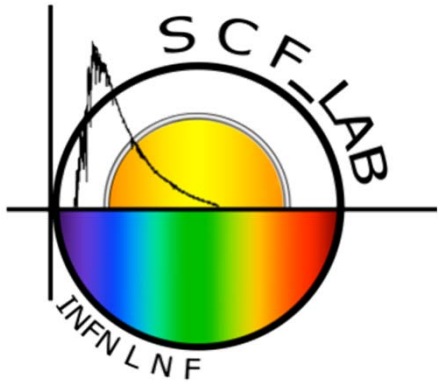
Measurements:

Consistent with nominal DAO (0.0 arcsec)

Summary

- ASI-CGS: planning to laser range to new satellites for space geodesy and gravitational physics studies.
- INFN-LNF's SCF_Lab: working on laboratory solar-orbital-thermo-vacuum-optical characterisation ("SCF-Test") of COTS retroreflectors for future missions
  - Results to come starting from early 2019.
- Results will help to optimize retroreflector arrays design and manufacturing reducing the costs
- SCF_Lab is a space R&D infrastructure open to further collaboration.

Thank you for your attention!



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