LARES SATELLITE

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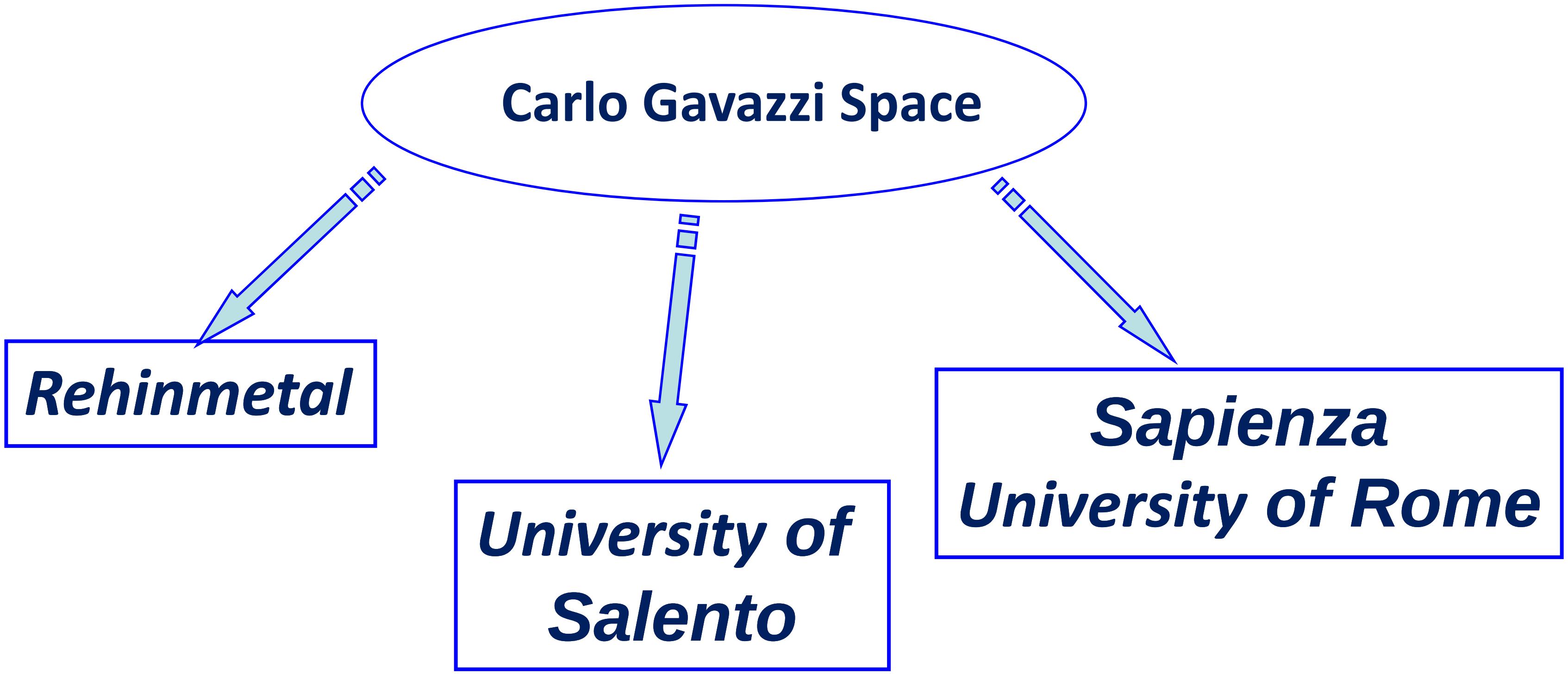
The LARES program

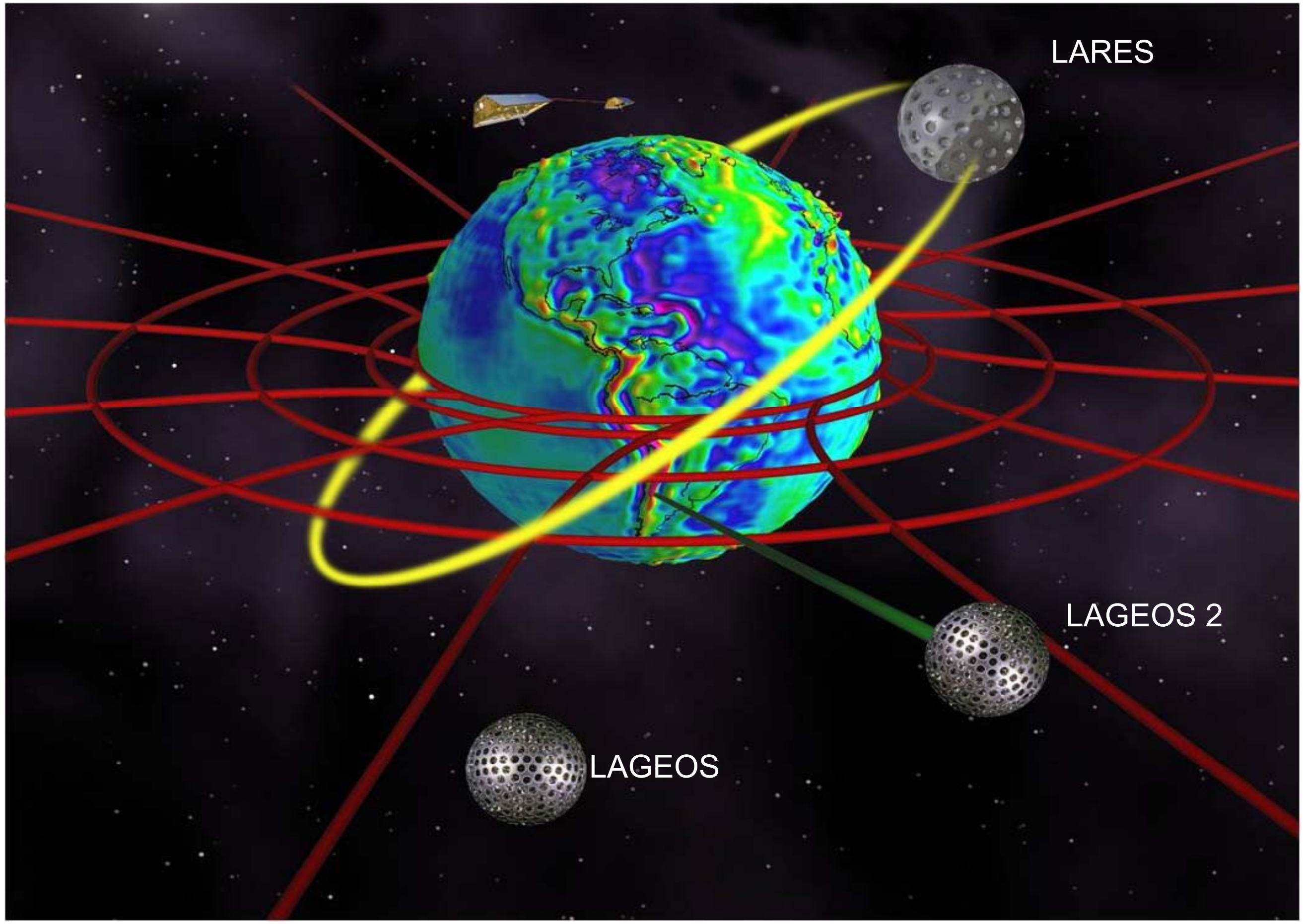
Officially started on February 2008

Main contract to



LARES- Laser Relativity Satellite

- Measure the twist of spacetime induced by the Earth Rotation (Lense-Thirring effect).
- The node of LARES orbit will be dragged by the Earth rotation by a small but measurable amount.
- The challenge is to eliminate, or very accurately estimate, the effect of classical perturbations on the node motion of the satellite.



LARES

Laser Relativity Satellite

- To minimize the non gravitational perturbations LARES satellite will be made of high density material.
- Once in orbit LARES will be the known object with the highest mean density in the Solar System.
- The surface of the satellite will be covered with Cube Corner Reflectors (CCR) for Laser Ranging.
- LARES will be launched with the VEGA maiden flight.

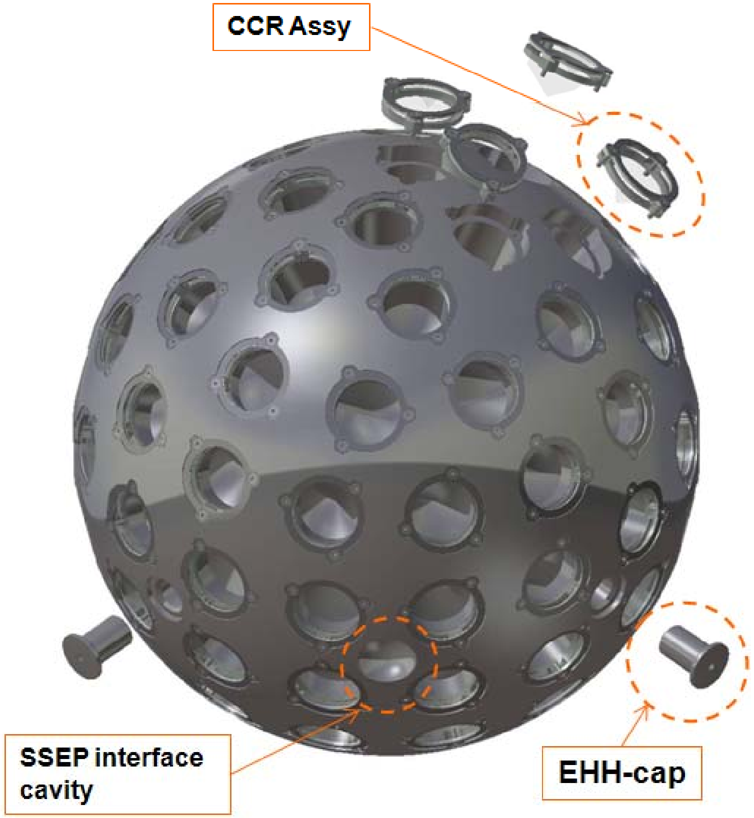
LARES

Laser Relativity Satellite

- **Completely passive satellite.**
  Made of solid metal
  (Tungsten Alloy).
- **Radius:** 182 mm
- **Mass:** 387 Kg.
- **Orbit Altitude:** 1450 Km.

SATELLITE BODY

LARES is a passive laser ranged satellite designed to minimize the non gravitational perturbations such as particle drag and thermal thrust. Thermal thrust is induced by thermal gradients on the satellite surface. The satellite is a massive sphere with Cube Corner Reflectors (CCRs) mounted on its surface. CCRs are made of glass and designed to guarantee that a laser pulse sent from a ground station will be reflected back to the same station in order to measure the total travel time and consequently the distance.



The satellite needs to be interfaced with the separation system and with the Ground Support Equipments (GSE). For this purpose some additional cavities have been designed on the satellite surface. Particular attention has been devoted to the CCR mounting system. This last one has been derived from the LAGEOS design. However, since the used metal is completely different, the design of the retainer ring needed to be changed with the constraint of avoiding any increase in thermal thrust

LARES MATERIAL

To minimize the interaction with the Earth magnetic field it has been used a non-magnetic alloy with a low electrical conductivity. Furthermore to maximize the mass-to-surface ratio a tungsten alloy with a nominal density of 18,000 kg/m^3 has been chosen, namely a THA-18N tungsten alloy that fulfill the SAE AMS-T-21014D Class 3

Semifinished parts in tungsten alloy

LARES MATERIAL

Acceptance of flight material at OMPM Srl, located in Angri (SA), Italy.

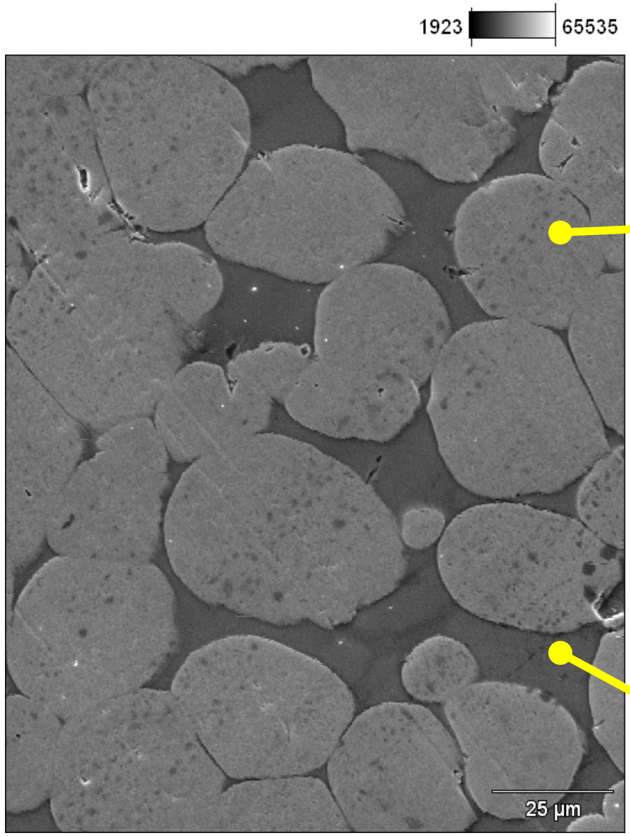
OMPM s.r.l.

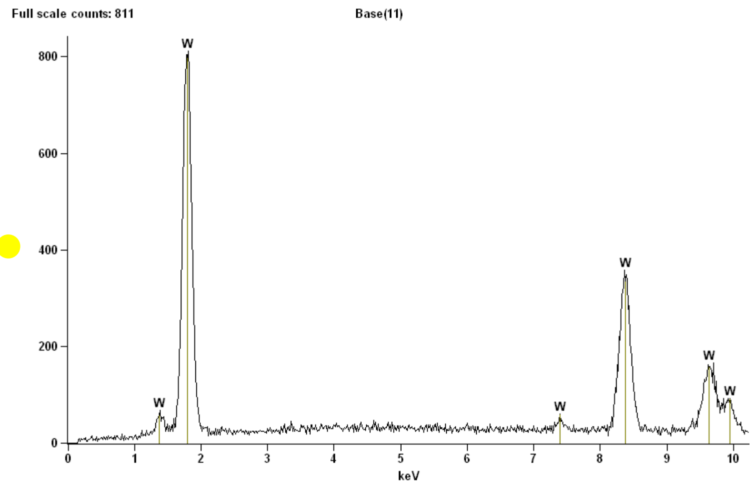
Lenght

Mass

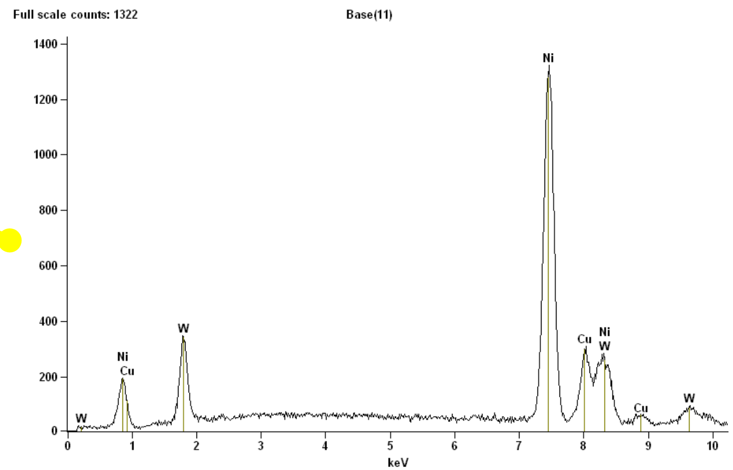
Rockwell Hardness.

LARES MATERIAL





grain composition , 100% W



Composition of low melting phase.

SEM micrograph polished with alumina 0.1 μm)
Alloy cpmposition.
≈ 95% W
≈ 3 - 4 % Cu
≈ 1 - 2 % Ni

SATELLITE MASS BUDGET

In table is reported a summary of the mass budget calculation.

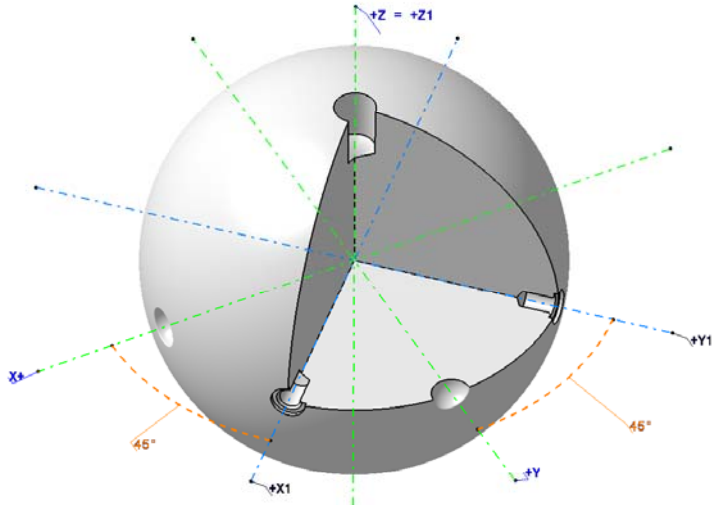
FM Mass Budget				
	Material	x1 Item [kg]	Q.ty	Whole System [kg]
SB	THA-18N	380.757	1	380.757
CCR	Suprasil 311	0.0333	92	3.063
RR	THA-18N	0.0120	92	1.107
UR	PCTFE	0.00237	92	0.218
LR	PCTFE	0.00691	92	0.636
SCREW	THA-18N	0.00204	276	0.563
EHH cap	THA-18N	0.167	4	0.669
Total Mass				387.01312 kg

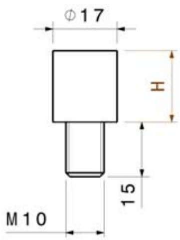
Mass Budget

LARES Balancing masses

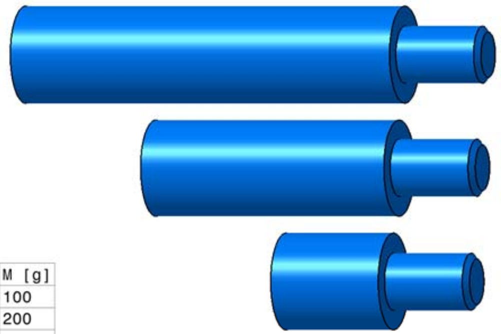
Balancing Masses

In order to make a “fine balancing” small calibrated masses will be used. The fine balancing will be performed controlling the CoG position using the small balancing masses along the 3 coordinate axis X_1, Y_1, Z_1, which are represented on the right.





Dash #	Ø [mm]	H [mm]	M [g]
BallMass.00	17	19.35	100
BallMass.01	17	43.8	200
BallMass.02	17	68.3	300

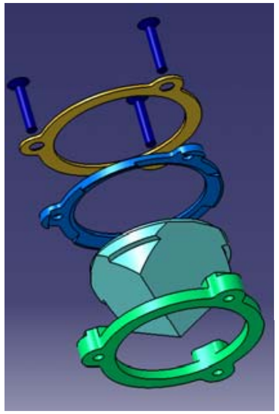


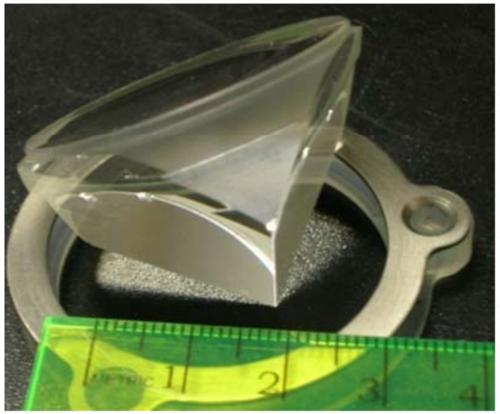
The small balancing masses are cylinders, made by the same SB tungsten alloy (THA-18N) which have one threaded end M10, 15 mm threaded length, while the other end has a variable length which depends on the mass, as shown in the figure on the left.

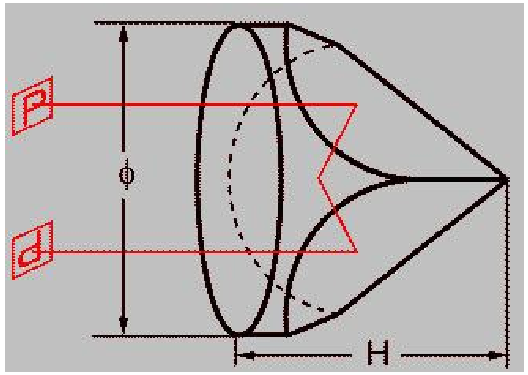
The axis X_1 and Y_1 are positioned in correspondence to the EHHs, with 45 degrees angle from the principal axis; the axis Z_1 overlaps with the polar axis Z .The balancing masses will be screwed on the back side of the EHH cap, where there is a threaded hole Y and on the bottom of the polar cavities which are deeper than the other cavities because of the required difference in moment of inertia.

Cube Corner Reflectors CCR

3D prism that reflects spotlight back to its source

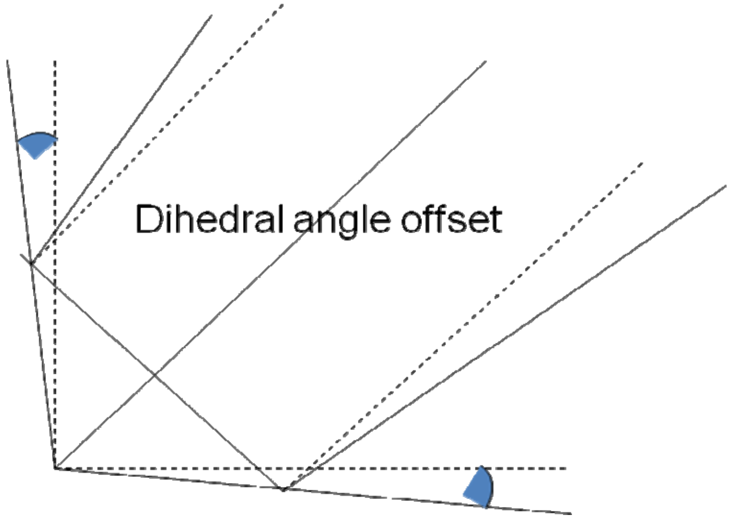




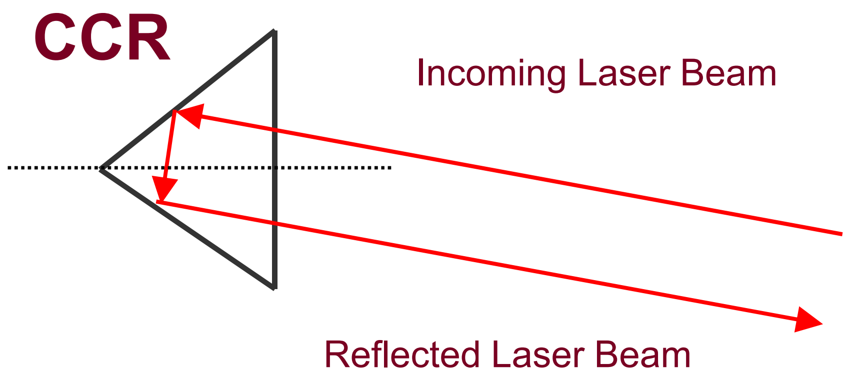


The uncoated CCR operates by total internal reflection

- **Diffraction effect due to finite aperture of the CCR**
- **If the dihedral angle is increased by a small quantity the energy will be spread over a bigger area**

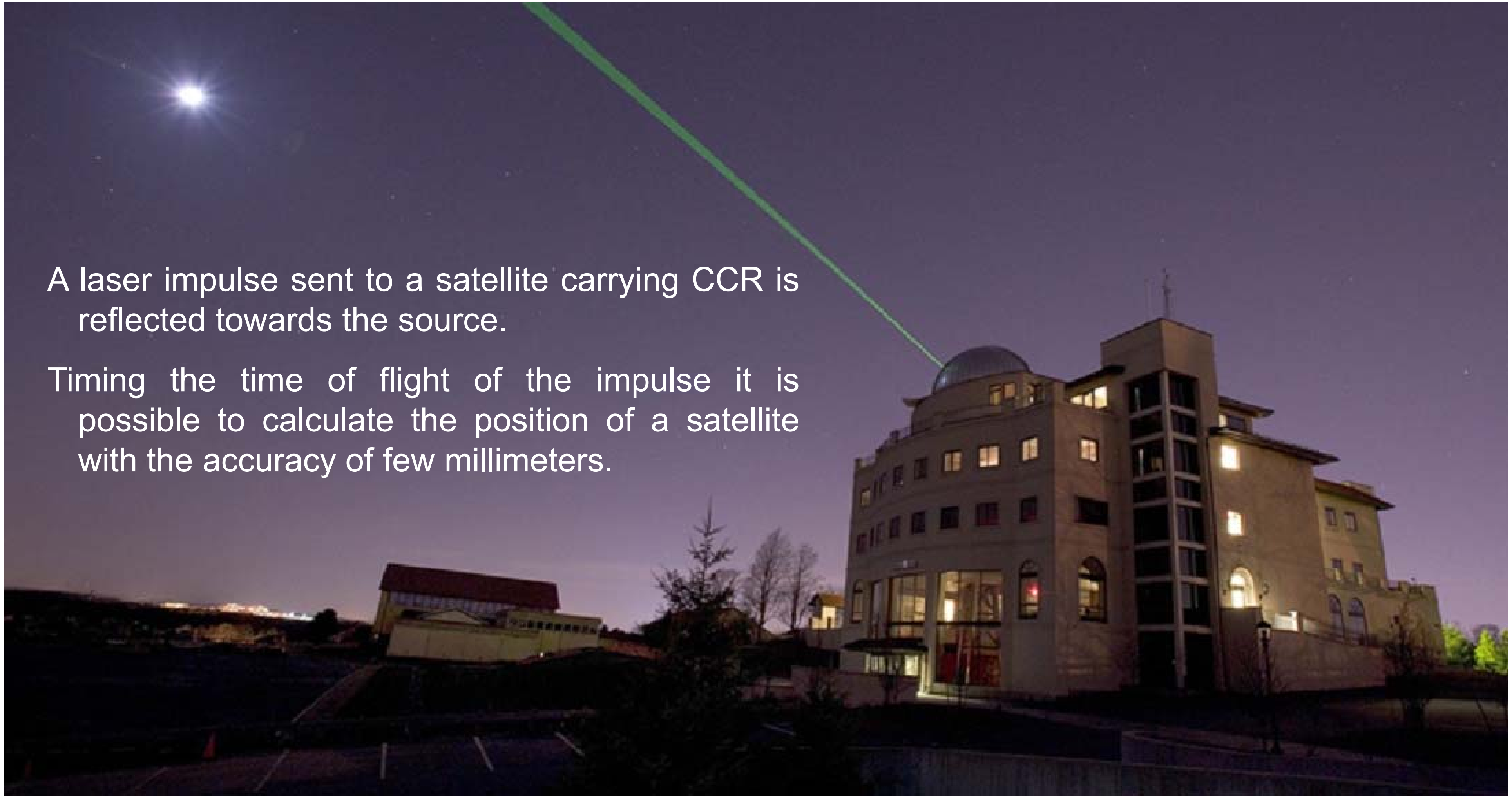


Laser Ranging Technology



A beam entering the Corner Cube Retroreflector (**CCR**) is reflected by the three surfaces (total internal reflection) and emerges from the entrance / exit surface parallel to itself.

Laser Ranging Technology

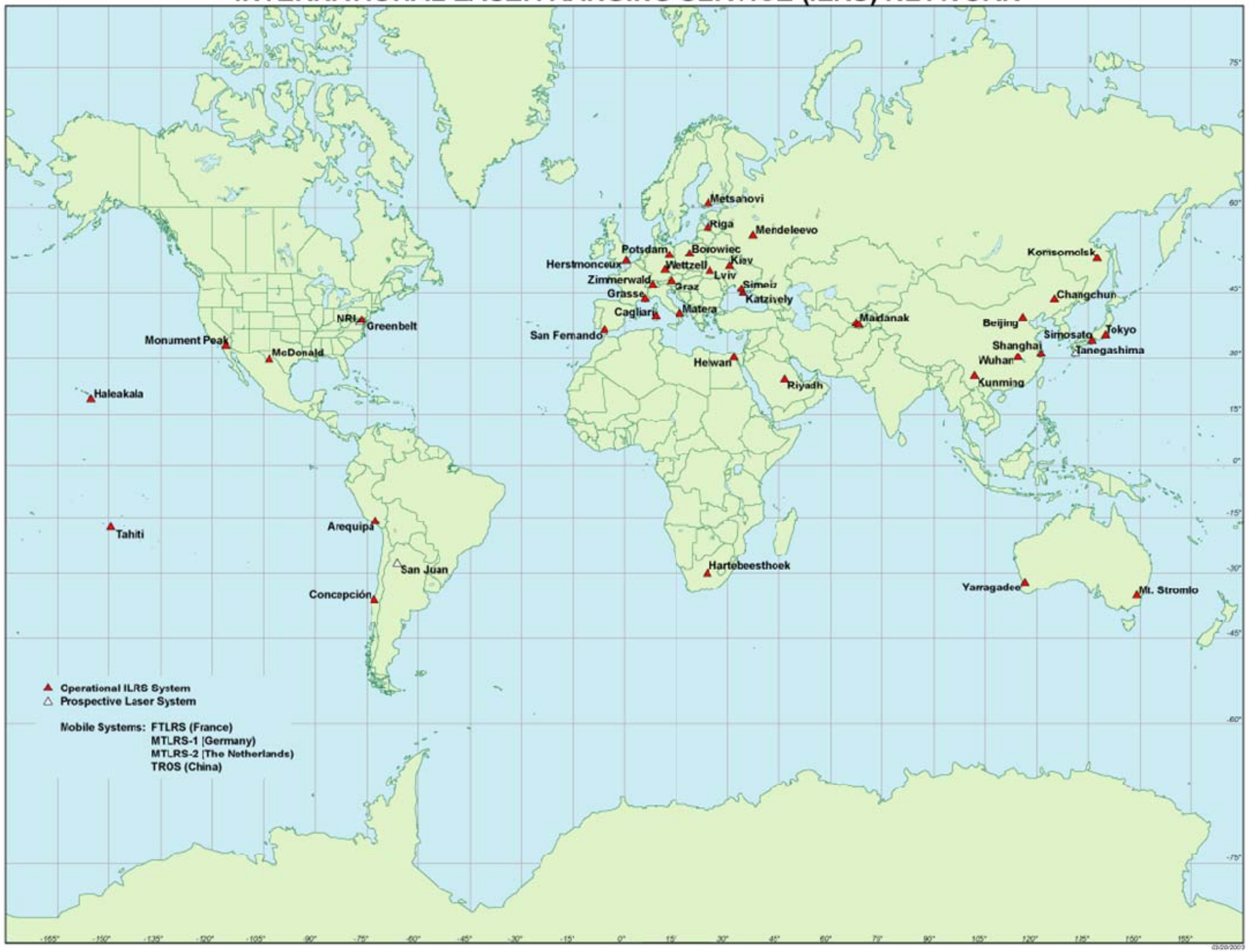


A laser impulse sent to a satellite carrying CCR is reflected towards the source.

Timing the time of flight of the impulse it is possible to calculate the position of a satellite with the accuracy of few millimeters.

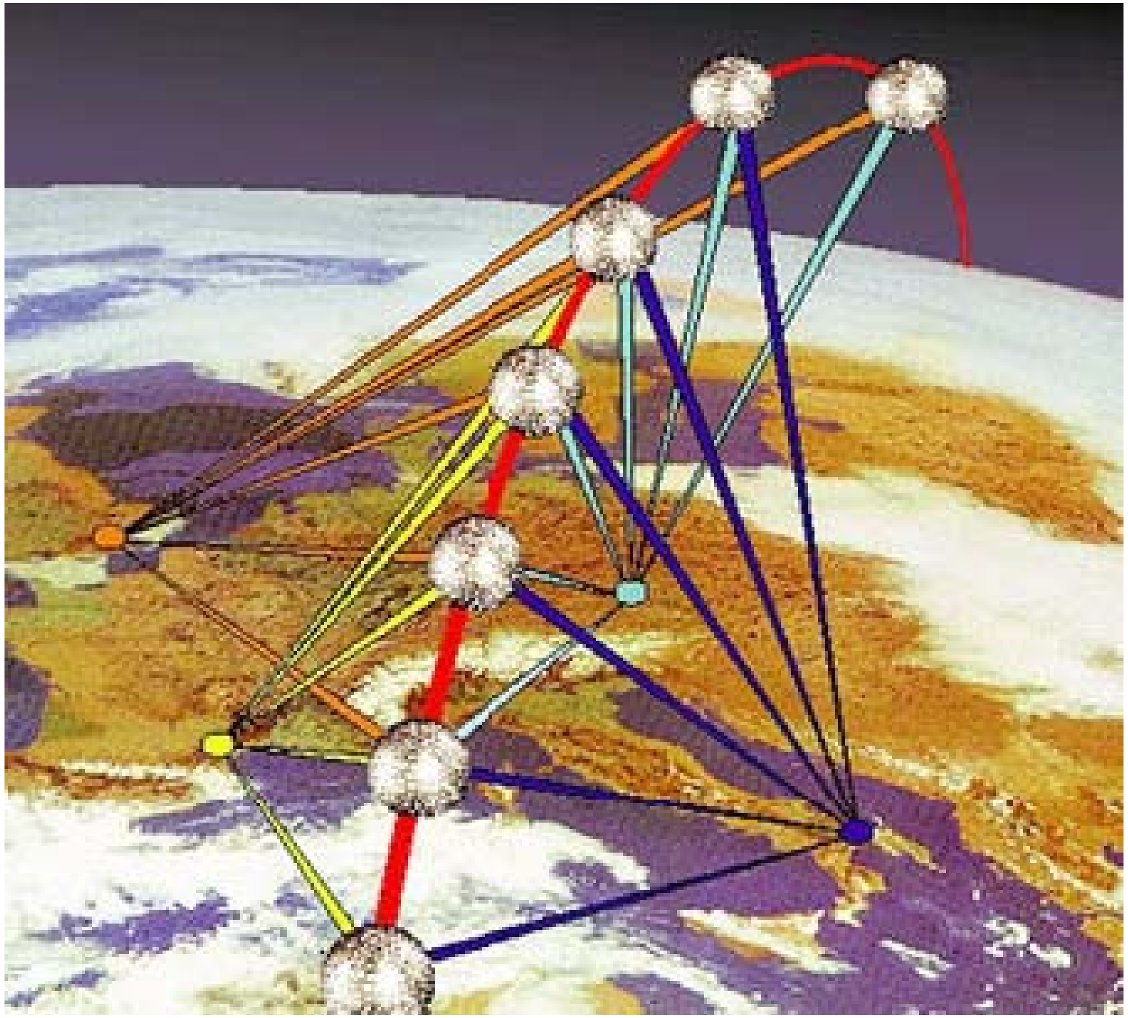
International Laser Ranging Stations

INTERNATIONAL LASER RANGING SERVICE (ILRS) NETWORK



Laser Ranging Technology

Positioning using Laser Ranging

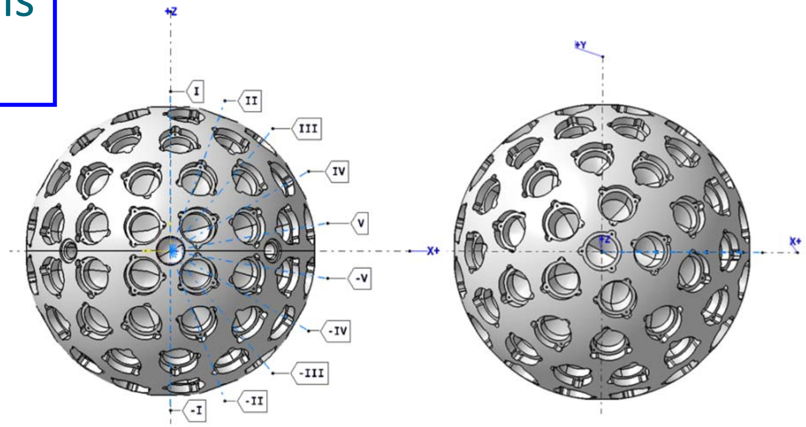


International Laser Ranging Service (**ILRS**) stations allows precise satellite positioning.

OPTICAL DESIGN OF LARES

It has been chosen a distribution that privileged
the *uniformity* with respect to the *number of CCR* per unit surface

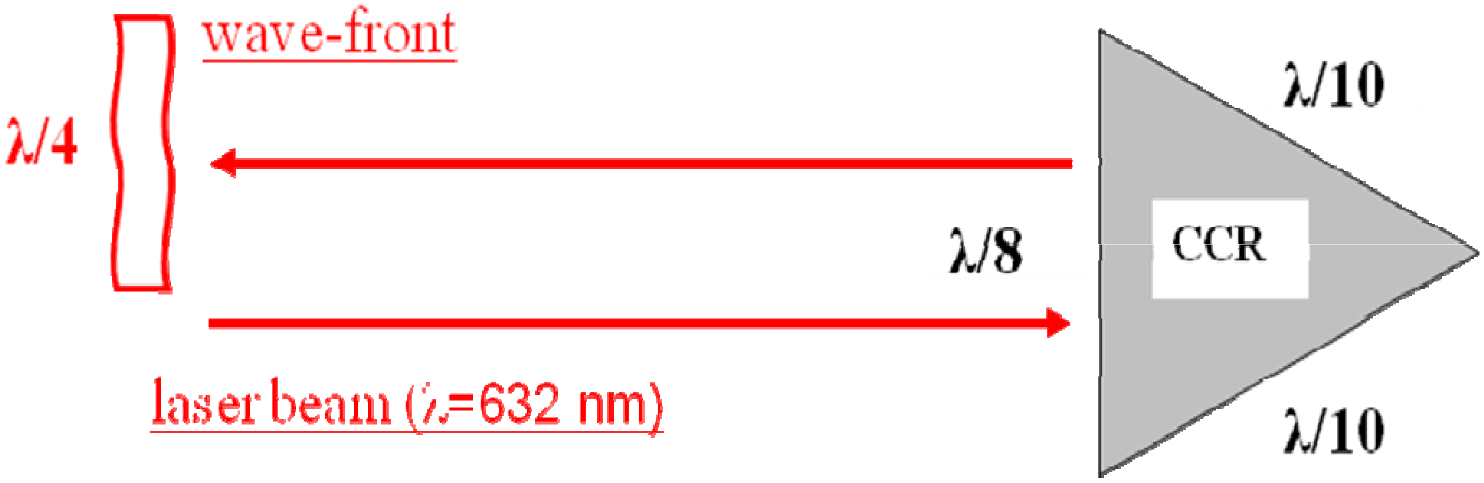
the cross section of the satellite is very high considering that the orbit is relatively low



Laser return that is more independent on satellite attitude

The chosen distribution reduced the ranging error,
due to unknown satellite orientation, at about 1.5 mm

CCR REQUIREMENTS



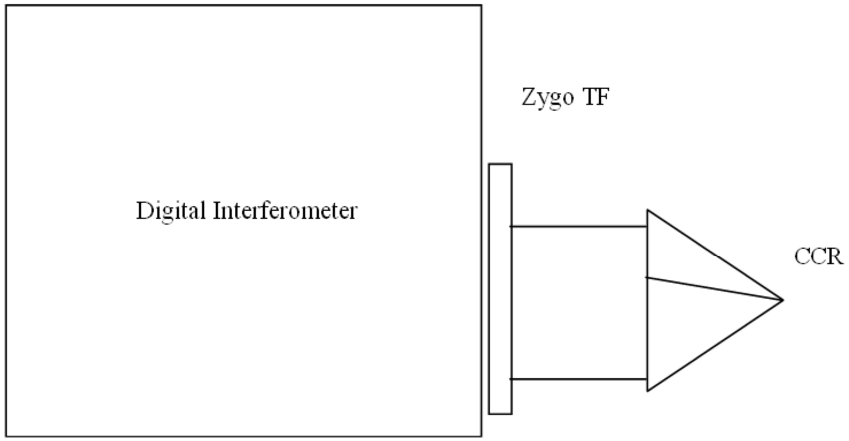
Fused Silica Suprasil 311

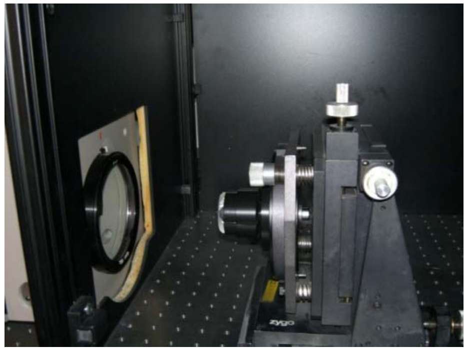
MANUFATURING AND TEST OF CCRs

110 manufactured by Carl Zeiss using
a measuring-correction technique (*Ion Beam Milling*)
for surface flatness and Dihedral Angle Offset (DAO)

Surface flatness ⟷ *DAO*

Measurements with interferometric tecnique





FRONT FACE MEASURAMENTS

The first evaluation of front face flatness
was perform by Zeiss operator observing fringes
with analogue interferometer (no documentation was provided)
In order to have a more objective evaluation
two different measurement campaigns
have been performed

(1) Introducing a misalignment by tilting the CCR

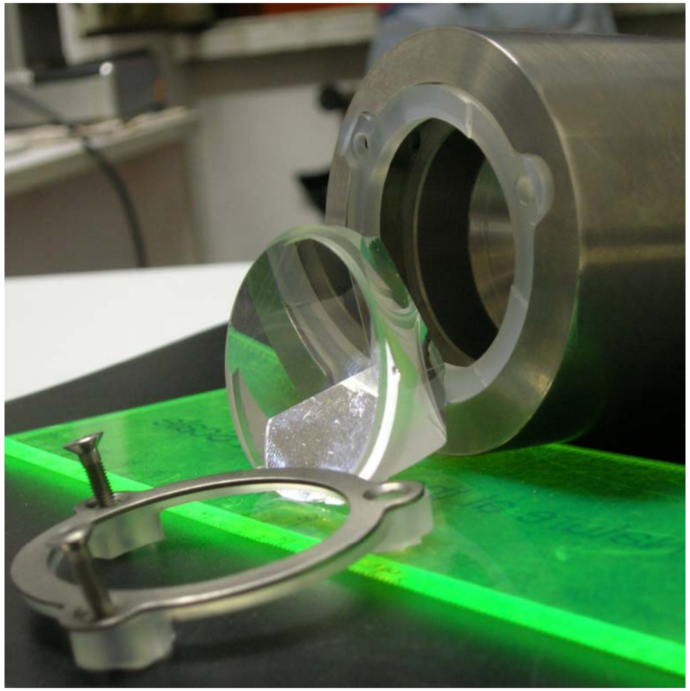
(2) Painting the three back faces

FRONT FACE MEASURAMENTS

The measurement of the front face is typically done before polishing the back faces of the CCRs or even before manufacturing the edges of the back faces.

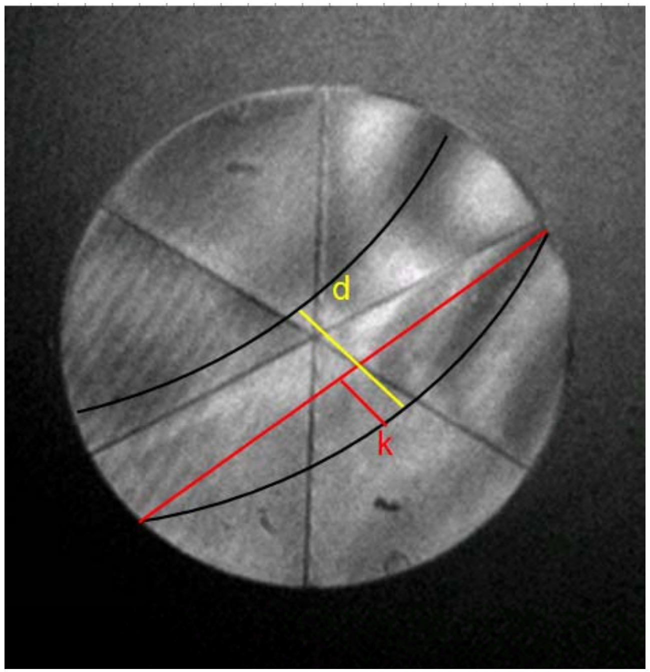
In fact in this case it is possible to study the wavefront reflected by the CCR front face without having a superposition with wavefronts produced by the back faces.

However this procedure it has been performed without producing any written documentation but was the experience of the operator that evaluated, looking at the fringes, when to stop the polishing of the front surface of the CCRs.

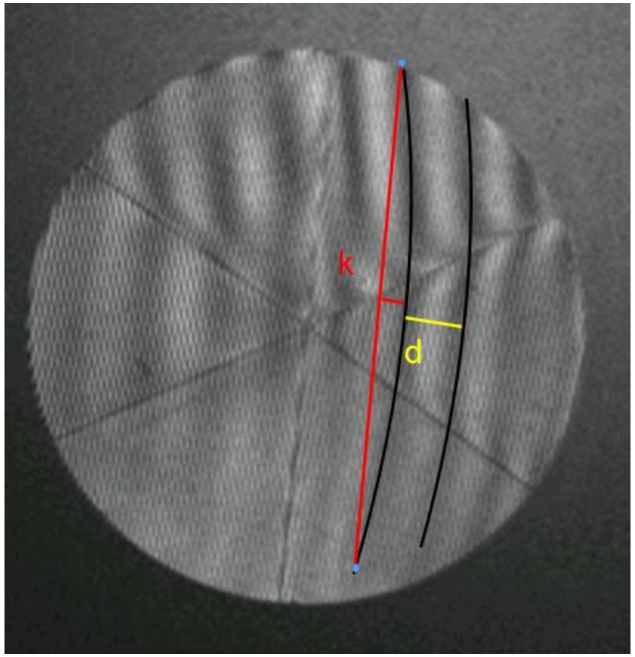


Due to the great importance of the quality of the CCR it has been decided to have a more objective evaluation of the CCR front face. Two different measurement campaigns have been performed: in the first one we used 15 CCRs of the first lot that were already delivered to us and performed, autonomously a test. In this case the problem was the above mentioned superposition of the wavefronts. This has been attenuated by introducing a misalignment by tilting the CCR. However the retroreflected wavefront introduced a noise in the interferogram.

(1) Introducing a misalignment by tilting the CCR



CCR n°22 - k/d = 0,40 planarity ≈ λ/5



CCR n°36 - k/d = 0,43 planarity ≈ λ/5

The relation between the interference fringes and the flatness of the surface is given by the following formula $(k/d)\cdot(\lambda/2)$

(2) Painting the three back faces

Red paint removed with ultrasonic waves and special bath

The measurements confirmed the nominal value of (λ/8).

Conclusions

•The cube corner reflectors passed all the testes and are ready for integration.

•LARES Demonstration model is ready to be shipped for integration with the separation system

• Qualification foreseen at end of August 2009