Mirrors for GRANIT, production, characterization

The LMA in the project

LMA : Laboratoire des Matériaux Avancés (Lyon)

❑ Features : Optical coatings

Main projects

✓ Mirrors for gravitational waves antennas : VIRGO – LIGO

✓ Astrophysics telescope : LSST

✓ GRANIT

Our role in GRANIT (ANR project)

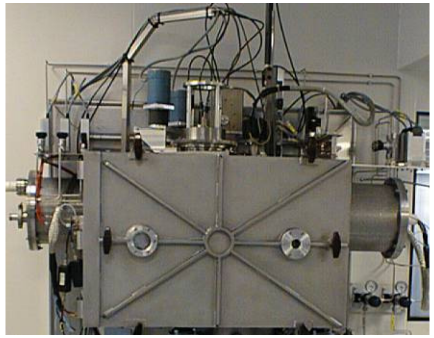
- ✓ **Expert and advice for the construction of the GRANIT cleanroom**
- ✓ **Expert and metrology of the different mirrors in GRANIT**
- ✓ **Coating of the trap, transportation and extraction optical pieces**

LMA IBS (Ion Beam Sputtering) deposition Facilities

IBS technique is the deposition process to obtain optical stacks with the lower optical losses on large surface

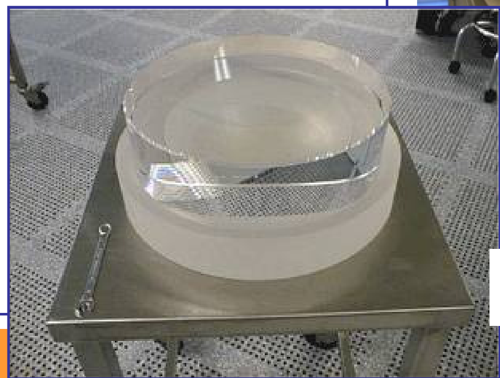
- Small IBS coater : DIBS
  - Able to coat homogeneously up to 3“ substrates
    - ✓ Continual upgrades since 1990 : now equipped with an RF ion source (filament ion source before) like in the large coater
  - Very flexible machine ⇒ ideal for prototyping

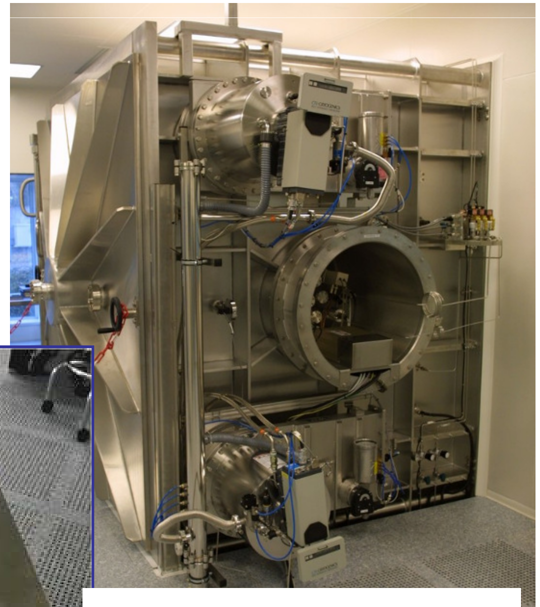
Small IBS coater



- Large IBS coater : GC
  - ✓ 2,2 m X 2,2 m X 2,0 m inner deposition chamber
  - ✓ Designed to coat substrates up to 1 meter diameter
  - ✓ Used for VIRGO large mirrors since 2001
    - ❖ Periodic quarter wave doublet stacks (Ta_2O_5 and SiO_2)
    - ❖ Between 130 and 180 nm layer thickness

350 mm diameter VIRGO mirrors





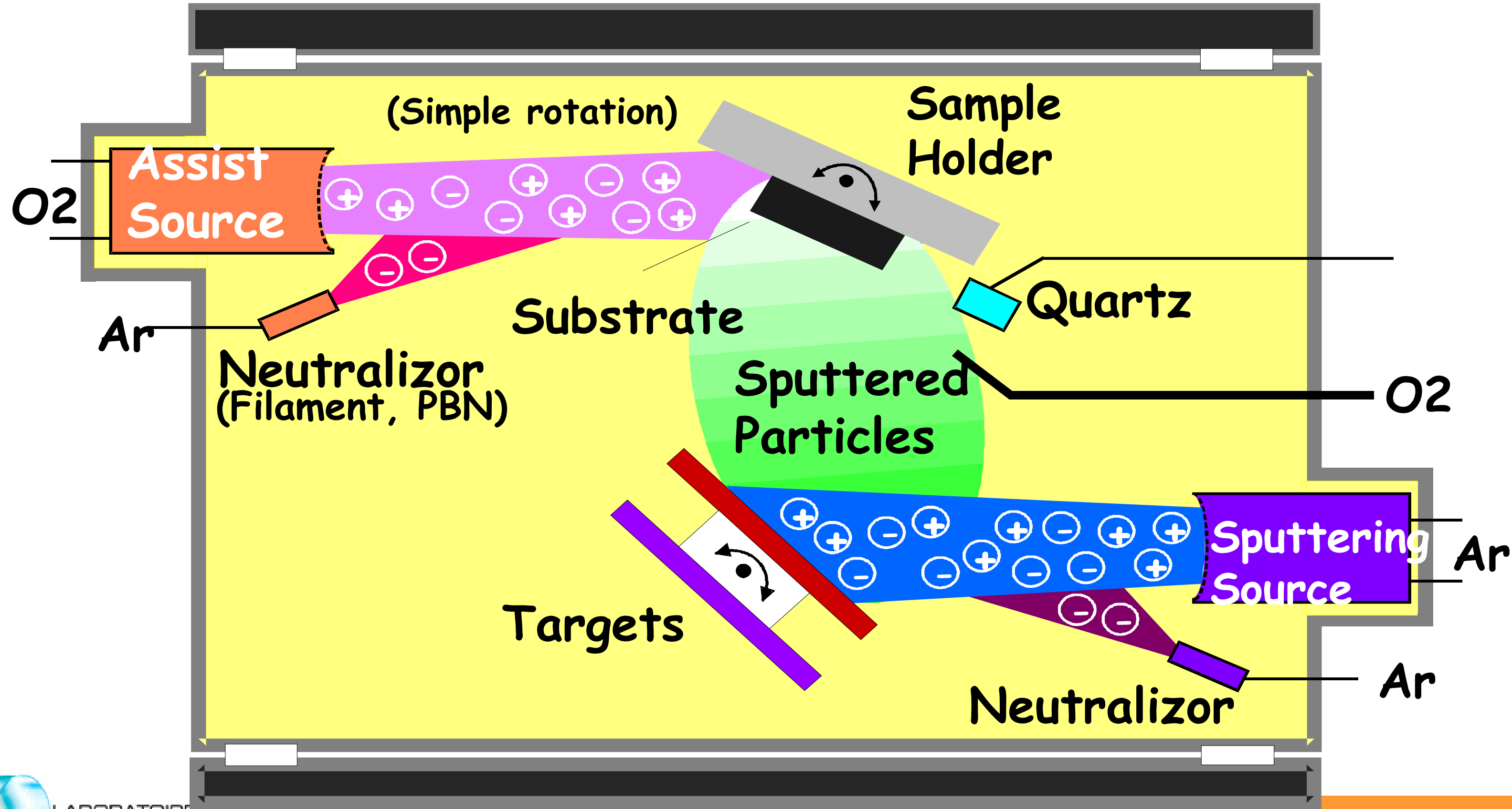
Large IBS Coater

Layers properties : - ultra dense materials

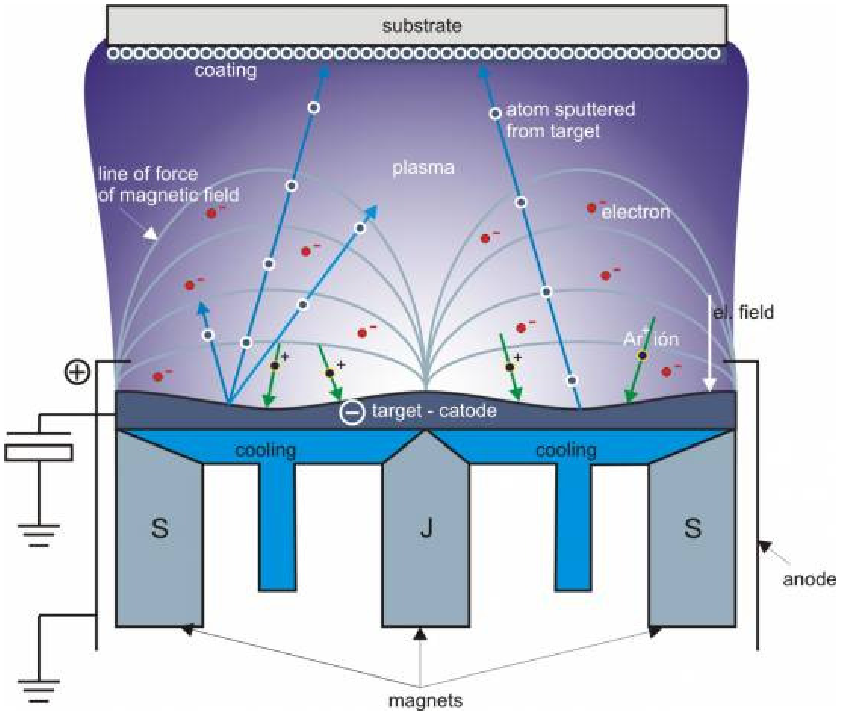
- ultra pure materials

But : - very slow deposition rate (0.5 Å / sec.)

- Stressed coatings



Magnetron Cathodic sputtering



Layers properties : - dense materials

- pure materials
- low cost
- fast deposition rate (100 Å/sec.)

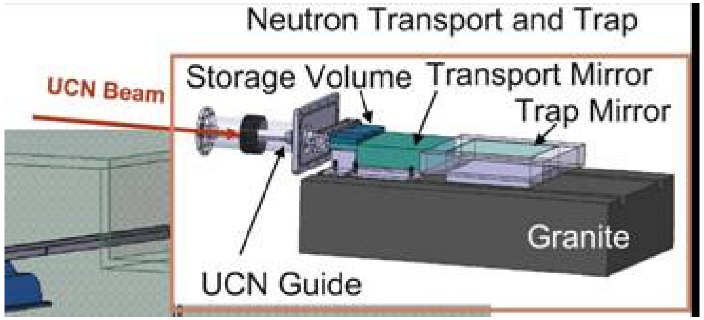
But : some difficulties with dielectric materials

ex : **Carbon**

Leybold Z550

(LMA)

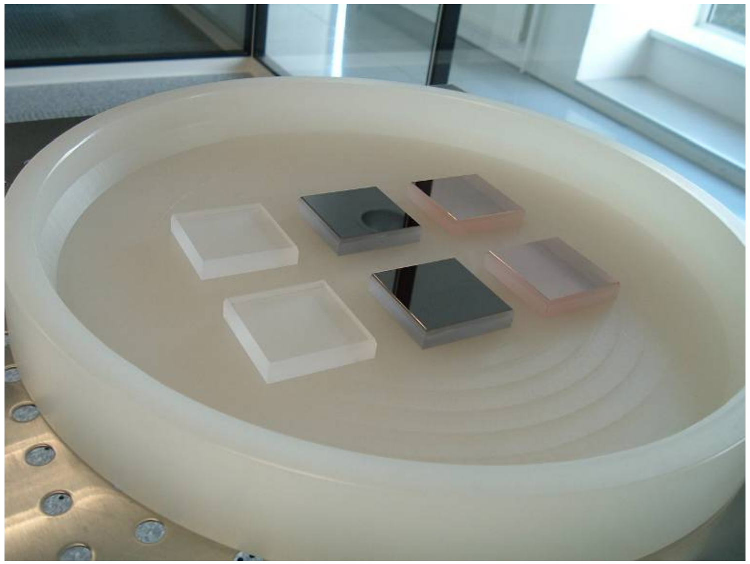
Choice of the coating and material for the walls of the trap



- ➢ Choice and test of the coating layer

Sample : Silica 50 X 50 X 10 mm^3 from General Optics

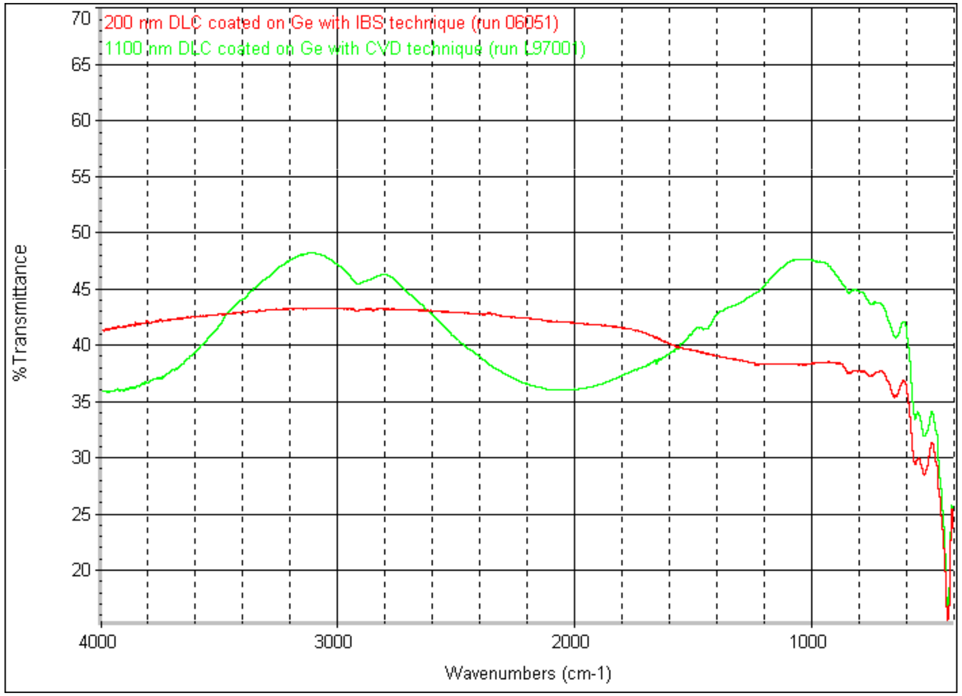
- ✓ 2 without coating
- ✓ 2 with 200 nm copper (RF magnetron sputtering)
- ✓ 2 with 200 nm Carbon IBS (IBS) not as hard as DLC CVD but without Hydrogen



Left : uncoated silica

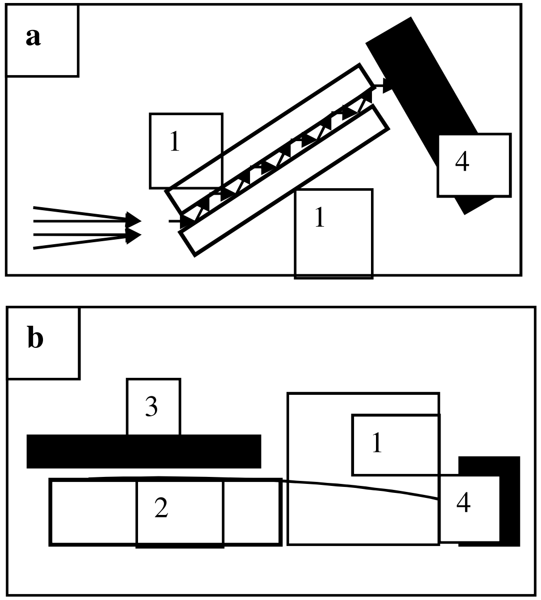
Middle : carbon coated silica

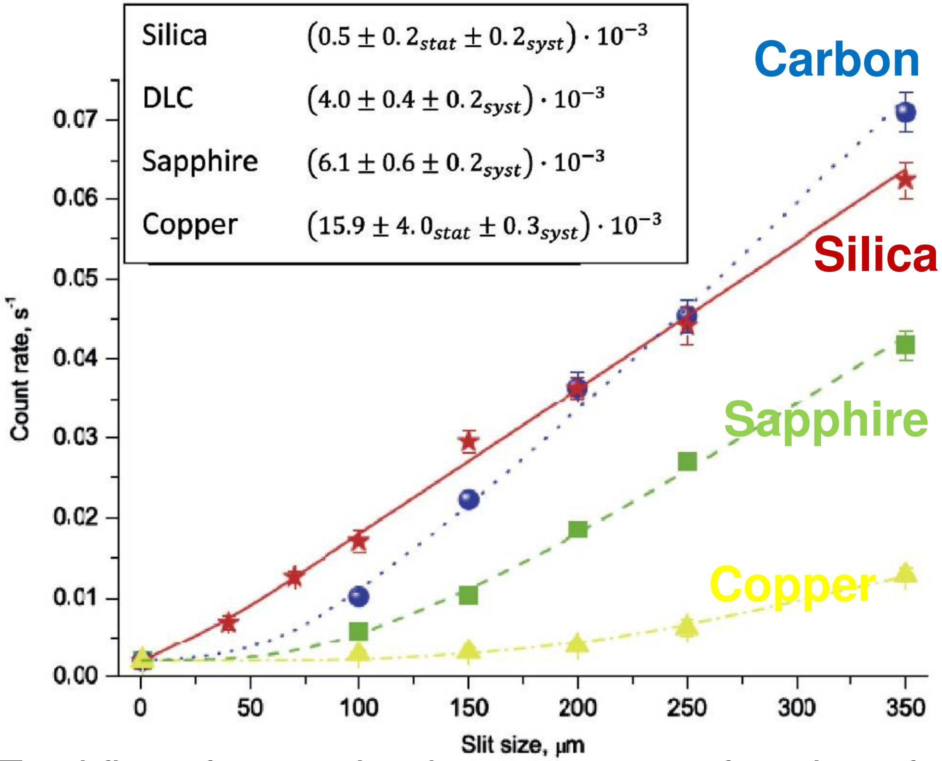
Right : copper coated silica



IR transmission spectra of carbon layers on Ge substrate

Gravitational spectrophotometer





Total flux of transmitted neutrons as a function of slit size

Conclusions :

✓ Silica for mirrors OK,

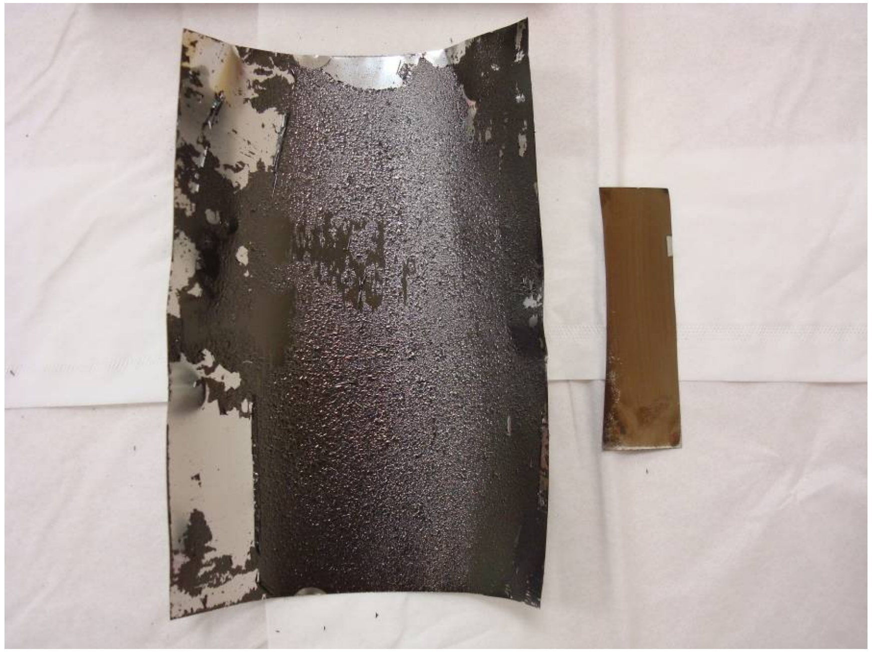
✓ Silica coated IBS Carbon OK, choice for use on the vertical walls of the GRANIT trap

✓ Silica coated copper (large coefficient of UCN total loss) and unstability of the coating

PVD test on 150 X 150 mm^2 stainless steel foils

o **200 nm thick Carbon layer by Cathodic Sputtering deposition**

One week after coating



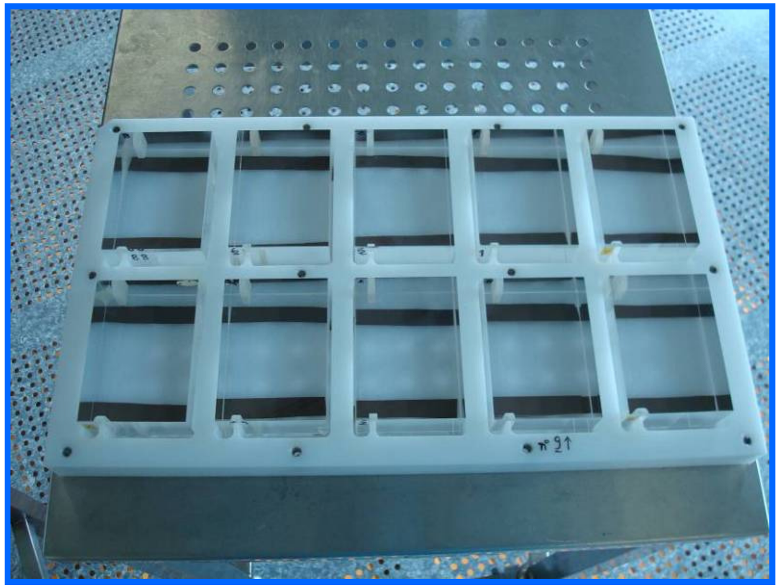
Few months after coating

Poor adhesion and complete delamination of the Carbon layer

✓ **Due to the IBS coating chamber dimensions, each wall is divised into 3 parts**

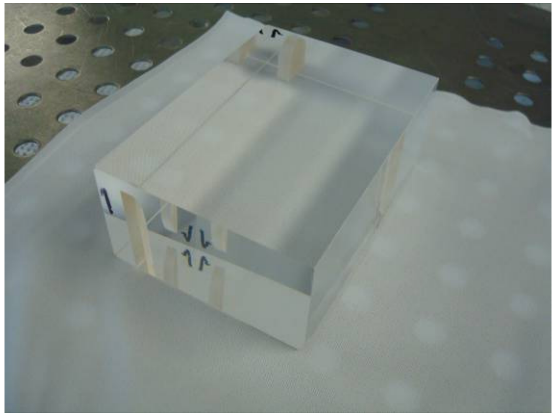
✓ **Shaping and polishing done by SESO (Société Européenne de Systèmes Optiques)**

Pôle d'Activités d'Aix-en-Provence (Les Milles)(France)

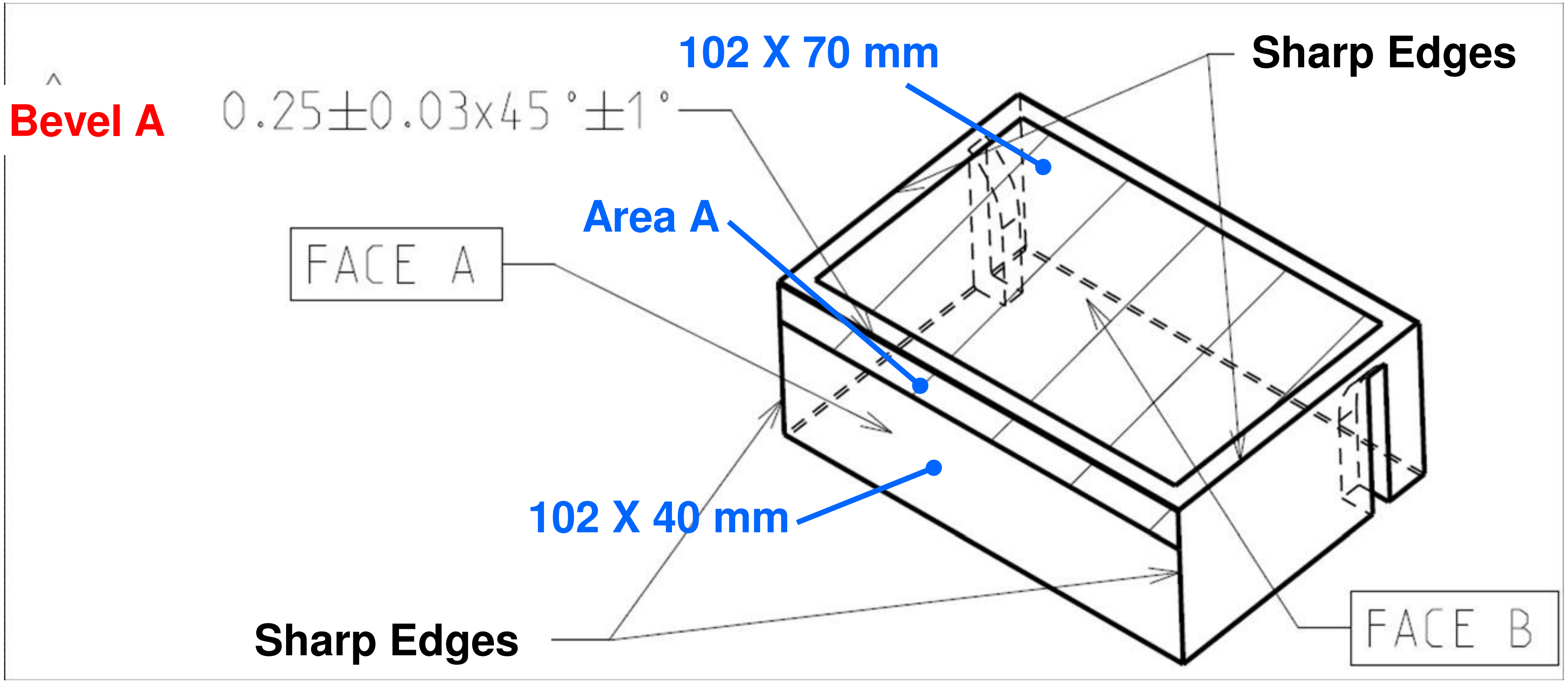


10 over 17 mirrors for the walls

✓ **Optical characterization and Carbon coatings at LMA**



Mirrors for the wall of the trap : in details



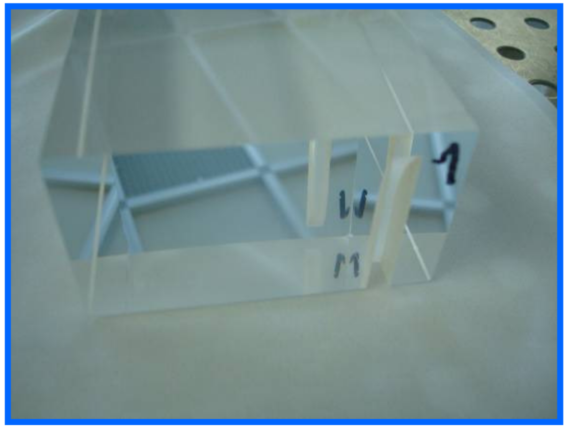
Material : Silica

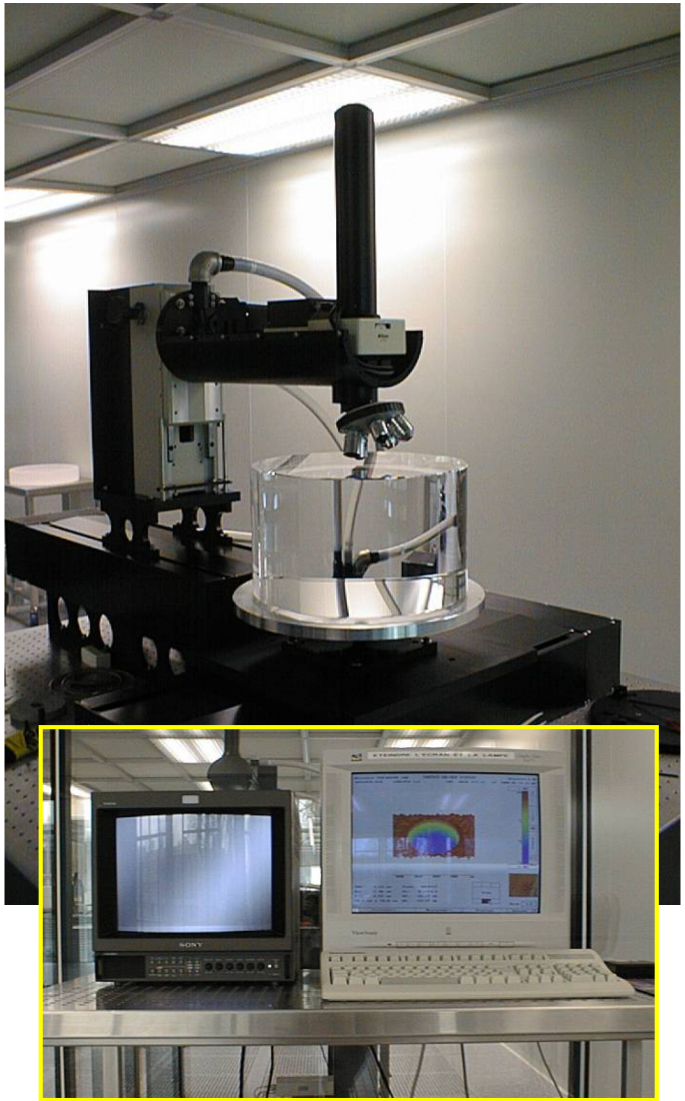
Face A : polishing λ/10 PTV (Peak to Valley) or λ/4 rms @ 633 nm

Face B : polishing λ/4 PTV on the area 92 X 60 mm

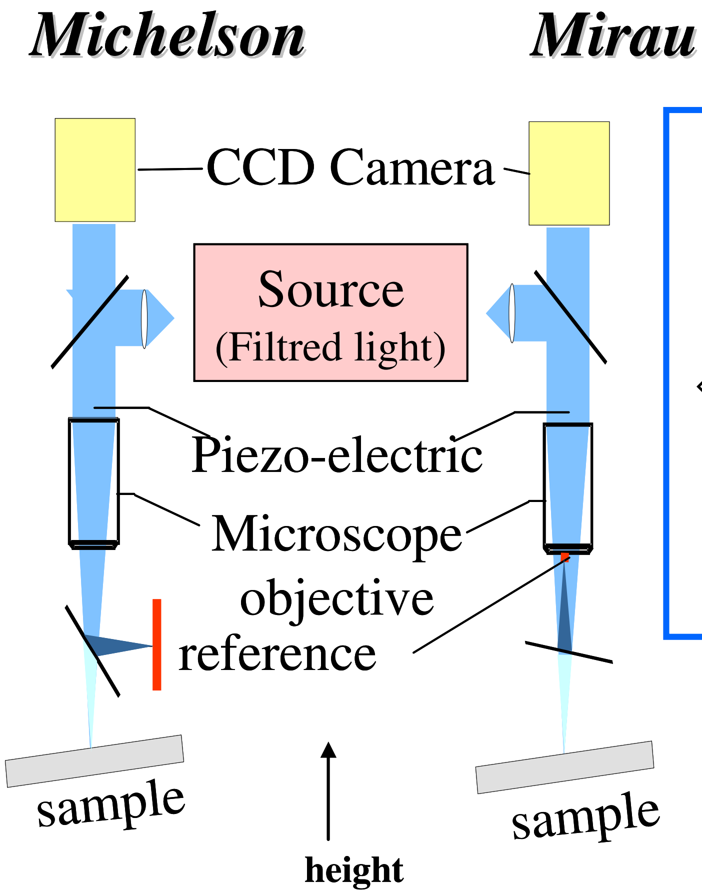
Area A : Roughness 2 Å rms

Bevel A : 0.25 mm +/- 0.03





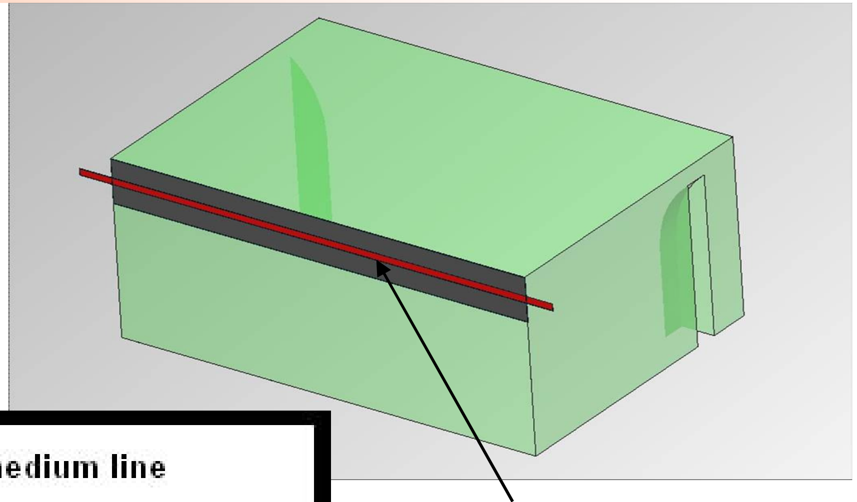
Interferometric Microscope



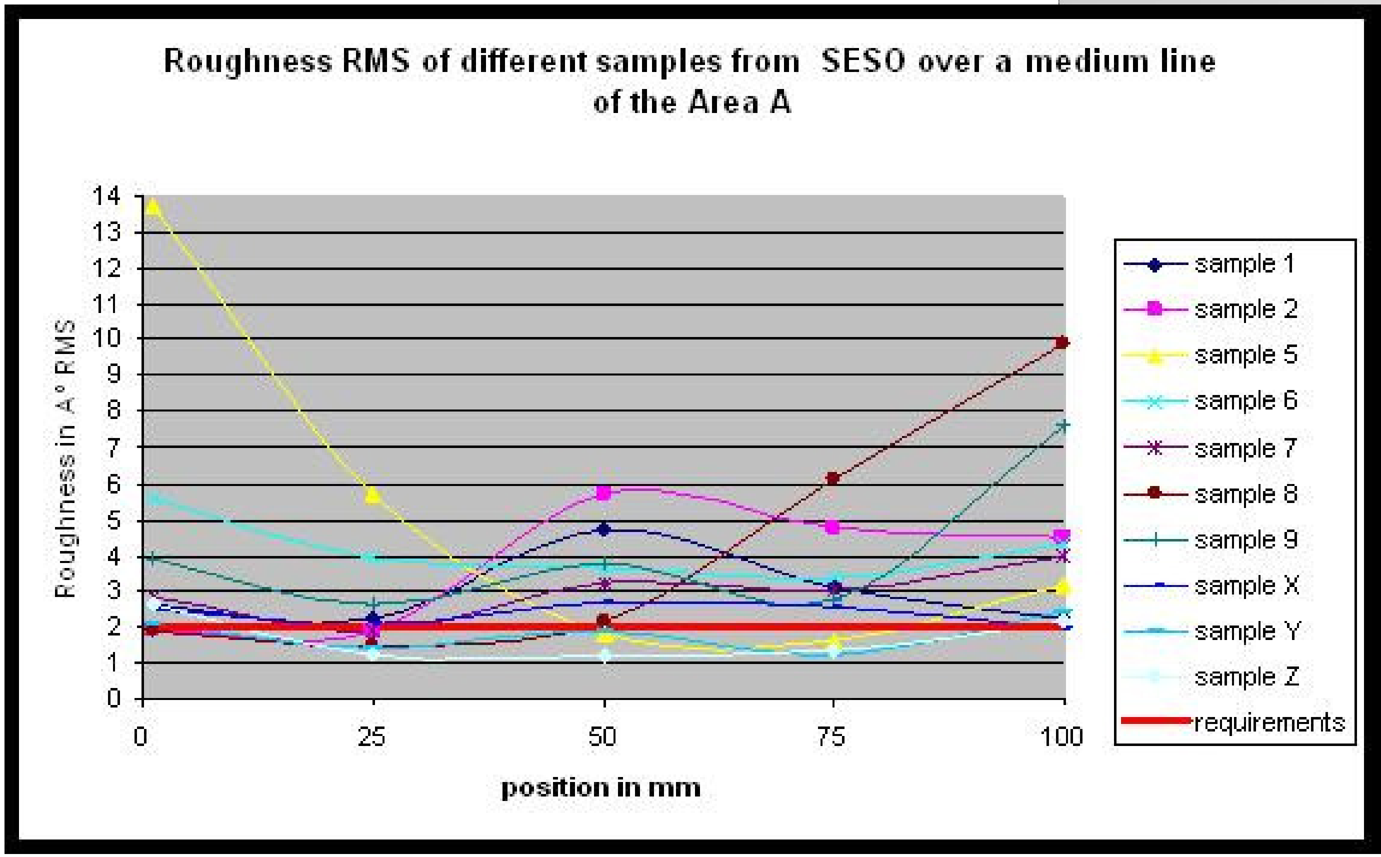
- ◇ **Roughness (.1Å rms)**
- ◇ **Substrate point defects detection (.3 µm)**

Measurements done on 17 samples

Requirements : 2 Å rms



Medium line



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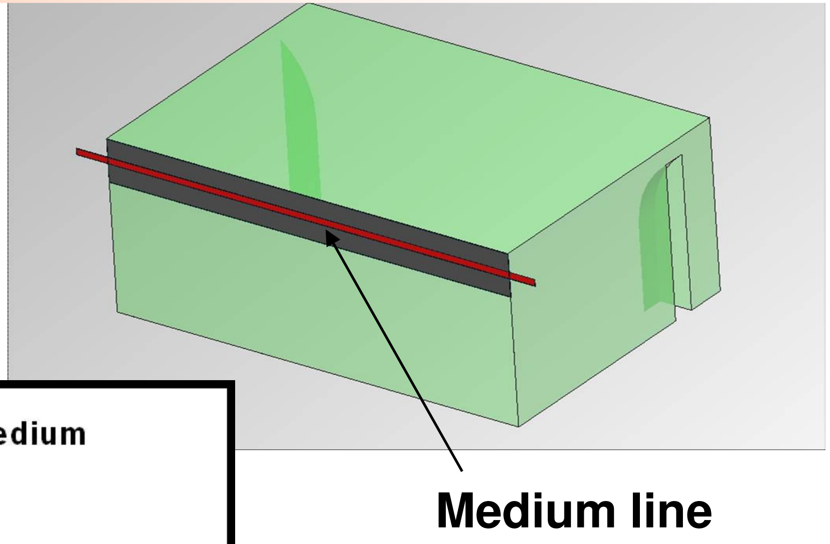
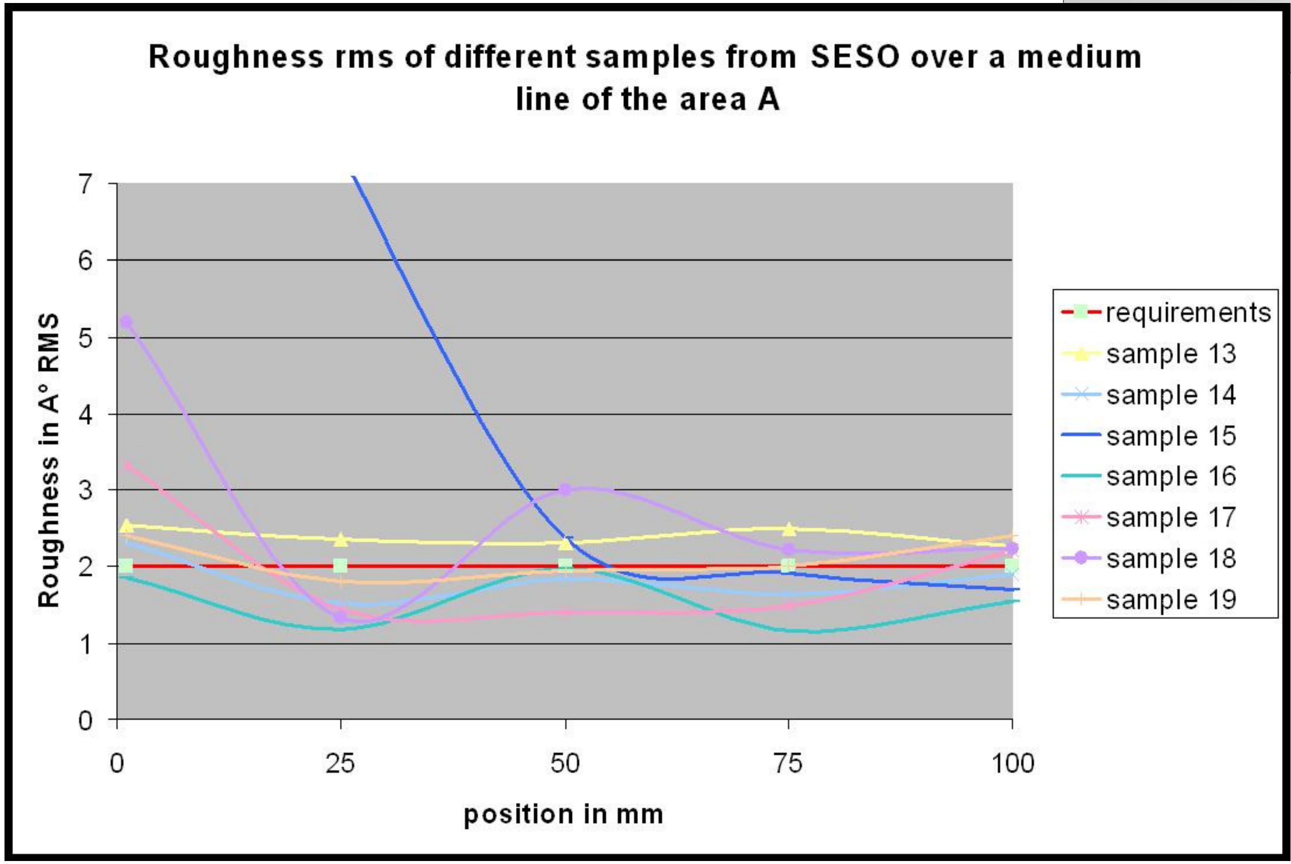
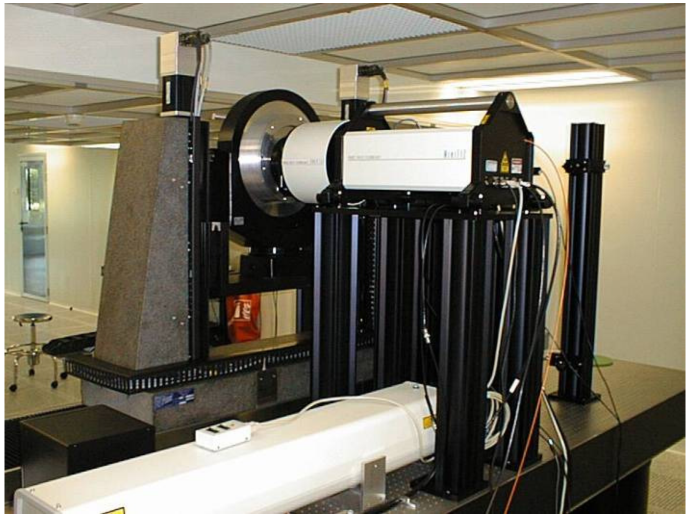
Roughness measurements : Area A (samples 13 to 16)

Measurements done on 17 samples

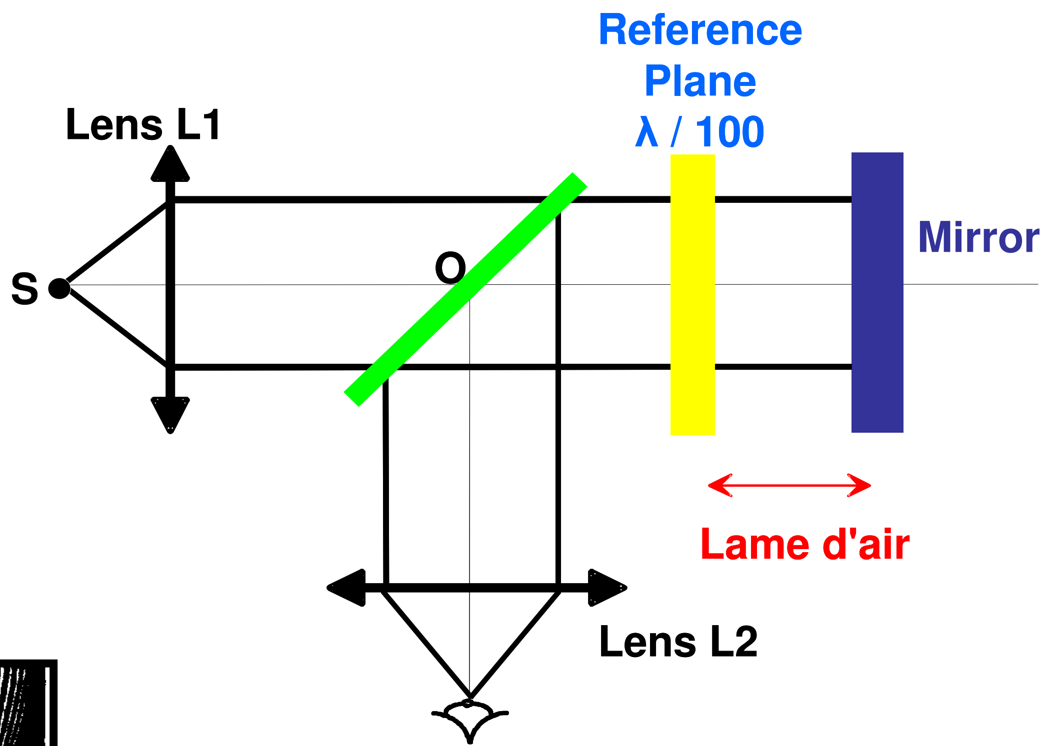
Requirements : 2 Å rms

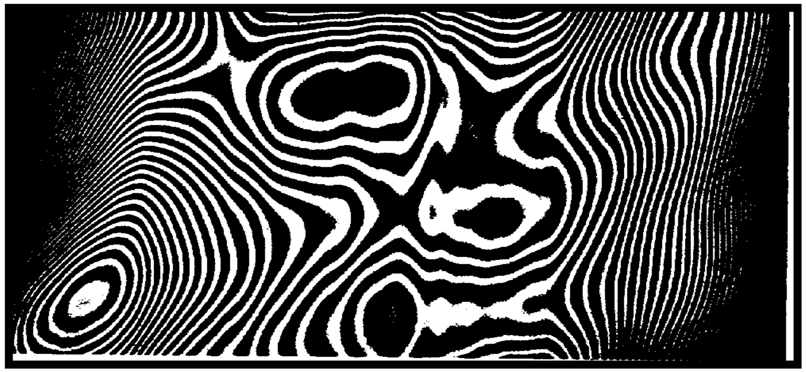






Fizeau Interferometer





Interferences between :

- *reflected wave by the reference plane*
- *reflected wave by the mirror*

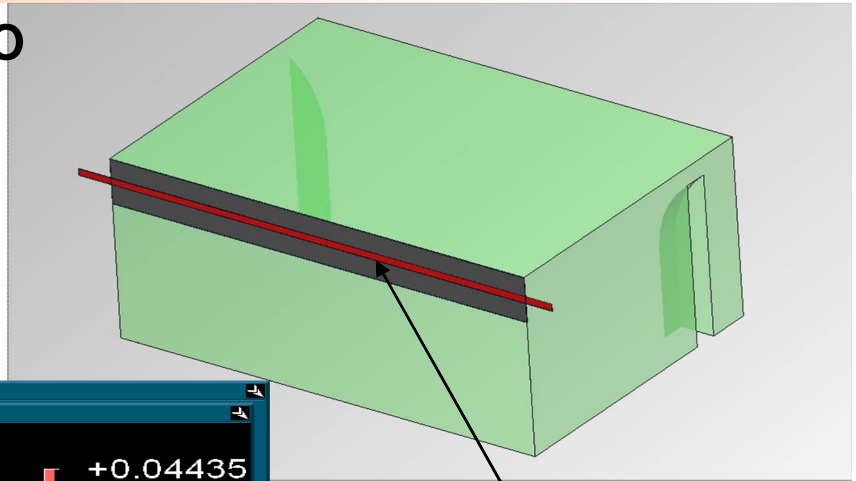
Planeity measurements : Area A

Measurements done on 17 samples from SESO

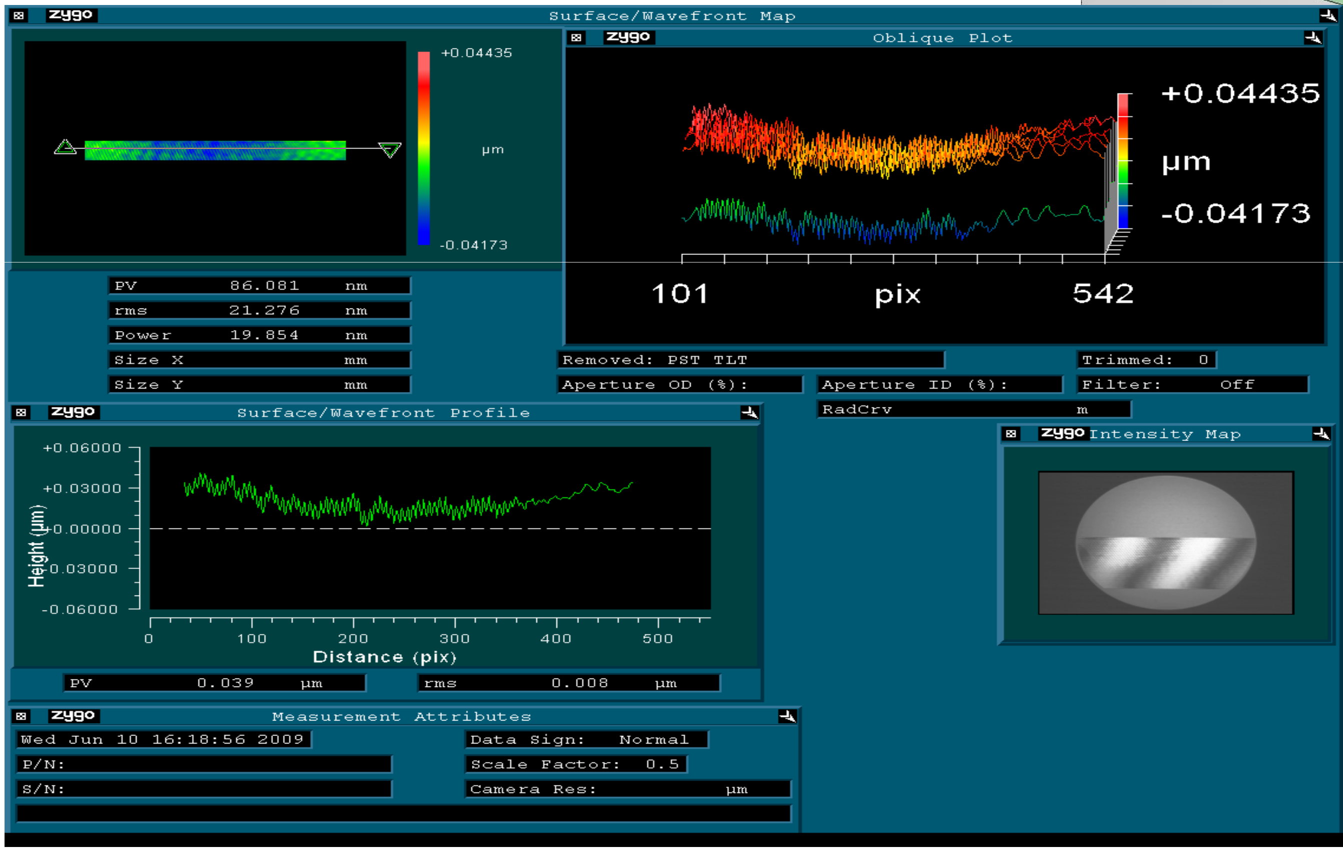
Requirements planeity Area A Face A :

PTV : λ/10 @ 633 nm (63 nm)

Rms : λ/40 @ 633 nm (16 nm)



Medium line



Averaged values :

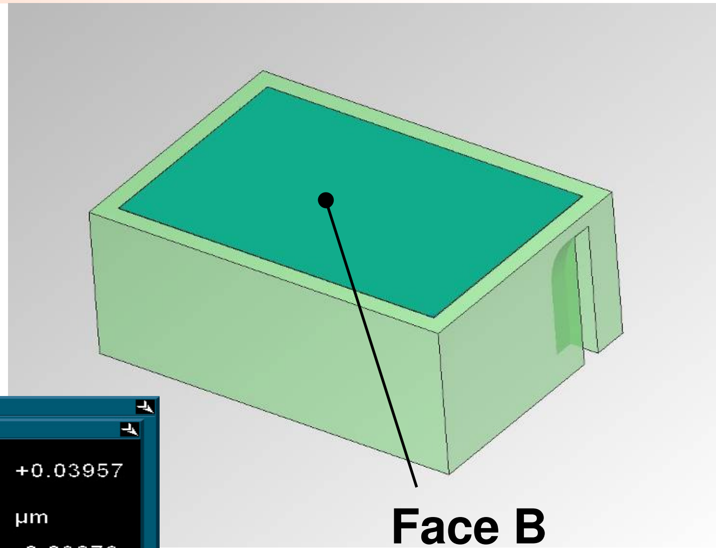
- **PTV : 85 nm (high)**
- **Rms : 16 nm (OK)**

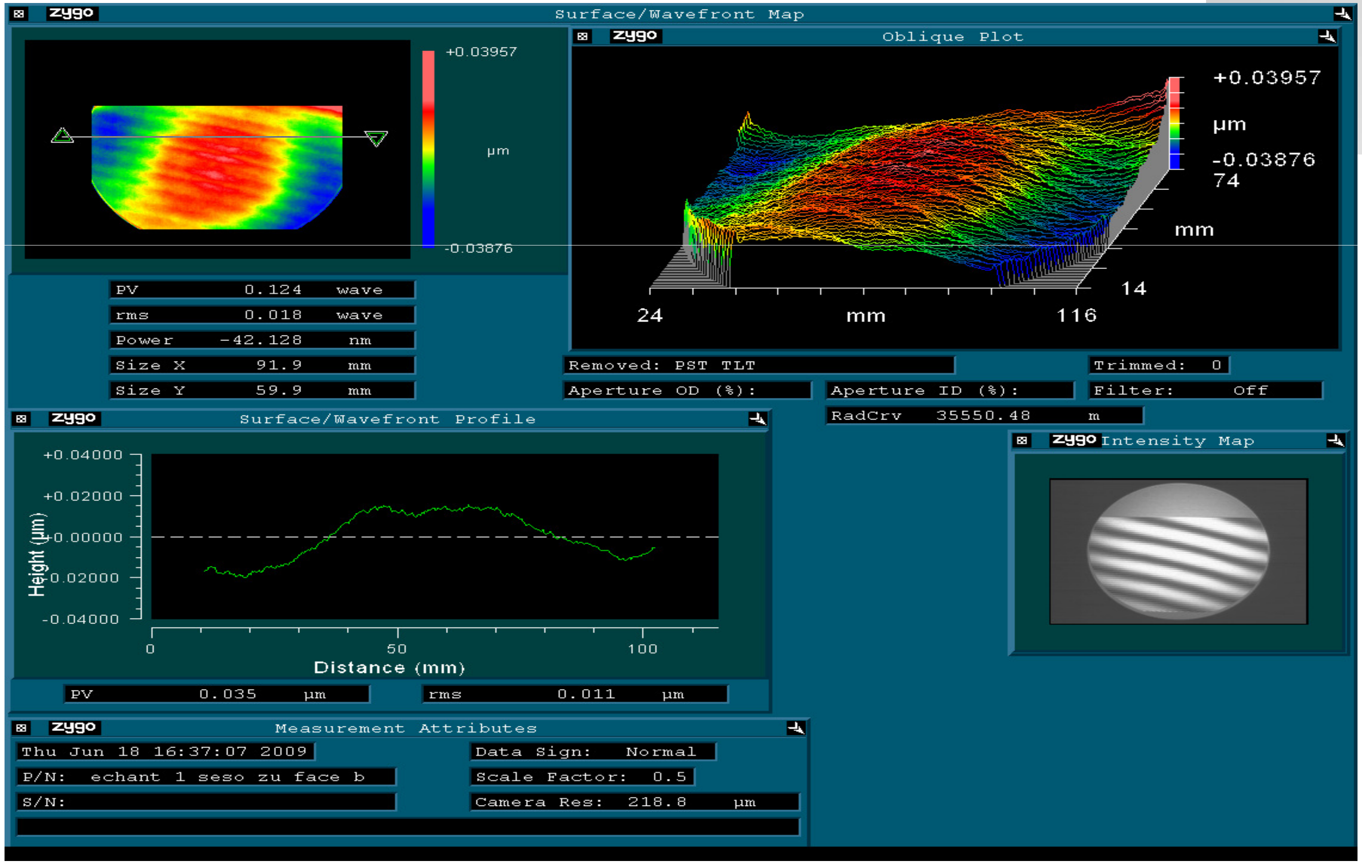
Planeity measurements : Area B

Measurements done on 17 samples from SESO

Requirements planeity Face B :

PTV : λ/4 @ 633 nm (160 nm)





Averaged values :

- PTV : 120 nm (OK)

Preliminary results

✓ **Choice of coating process (IBS) and material (200 nm Carbon)**

✓ **Shaping and polishing of 17 pieces for the walls of the trap (SESO)**

✓ **Characterization of the susbtrate for the walls of the trap**

Next to do

✓ **Choice of the 12 better mirrors for the wall of the trap**

✓ **Coat the wall with 200 nm IBS carbon**

✓ **The pieces for the transportation and extraction will arrive at the end of february from SESO**

✓ **Characterization and coating of the remaining pieces**