GWADW 2015
May 17-22, 2015
Girdwood, Alaska

Coatings
Review talk on the status of the art and known limitations

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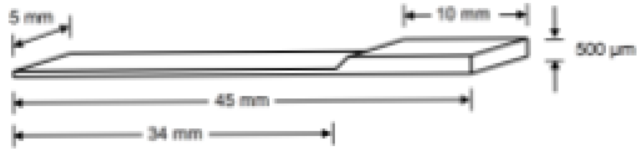
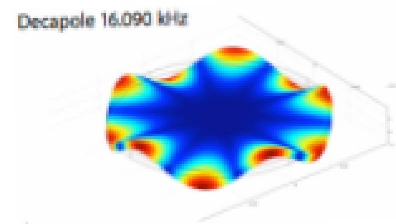
Methodologies

FROM S.PENN PRESENTATION ON MONDAY



- Mechanical loss measurements
  - Cryogenic Measurements on Cantilevers [Glasgow]
  - Room temperature measurements on thin disks AU]

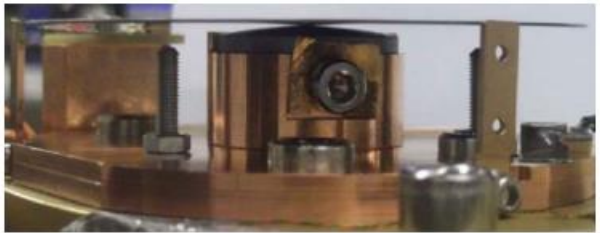


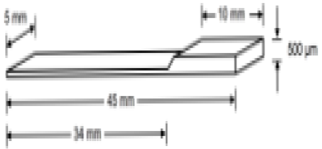
- Structural measurements
  - Bond length and element distribution: EXAFS; FEM; EELS, XRD, NMR [Stanford & Glasgow]
  - Elastic modulus measurements [Caltech & Glasgow]
- Direct Thermal Noise Measurements
  - Optical Cavities [Caltech & Florida]
  - Thermo-optic measurements [ERAU & Whitman]
- Theoretical Models [Florida]
  - Young's Modulus and loss approaching observed values.

Methodologies

LYON: LMA, ILM, LPENS, INL

GeNS: room T and cryo





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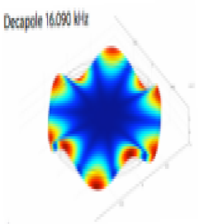

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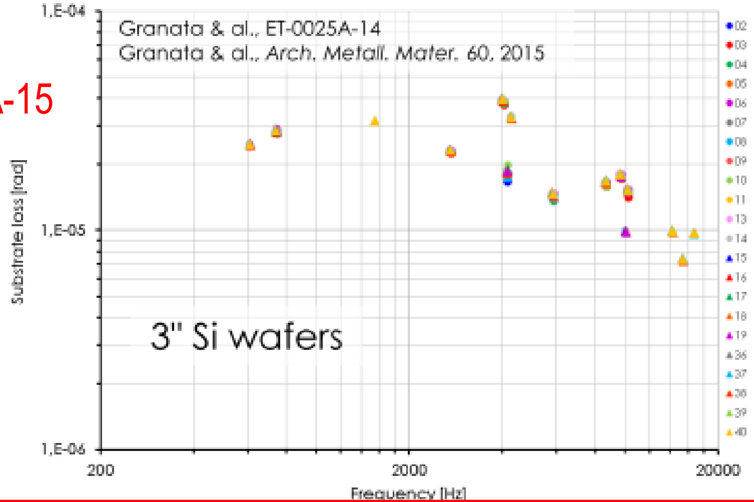

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- Raman, Brillouin [ILM]
- Elastic modulus measurement [LMA, INL]
- Measurement of thermal noise on µ-cantilevers, [10, 2e4] Hz [LMA, LPENS]

Granata, GWADW 2014

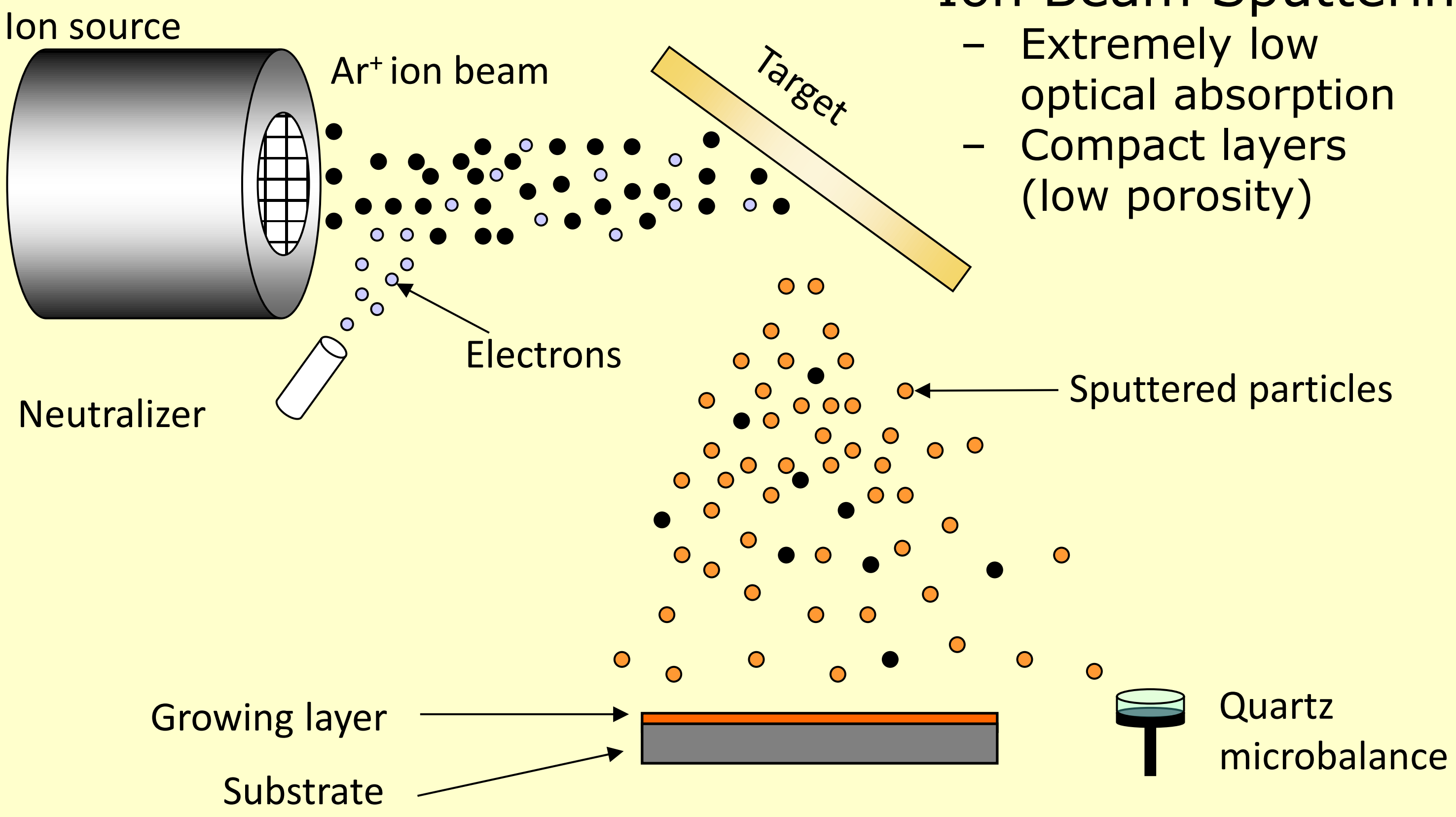
- Molecular dynamics [ILM]
  identification of relaxation mechanisms

a-Silicon Coatings

- From Liu [PRL 113, 025503 (2014)] *"A densely packed and near perfect tetrahedrally bonded amorphous system can be physically constructed without requiring H by growing a-Si at a higher T, which we suggest was the dominant reason for removing the TLSs in both a-Si and a-Si:H. … Recent theoretical work suggests local regions o embedded in a forming at the*

This supports the suggestion made by Phillips 40 years ago, in which he speculated that TLSs may originate from an "open structure" with "low coordination" [5]. He argued that if every atom is linked to more than two neighbors (like in *a*-Si and *a*-Ge), the structure is overconstrained and double-well potentials are unlikely.

The deposition technique

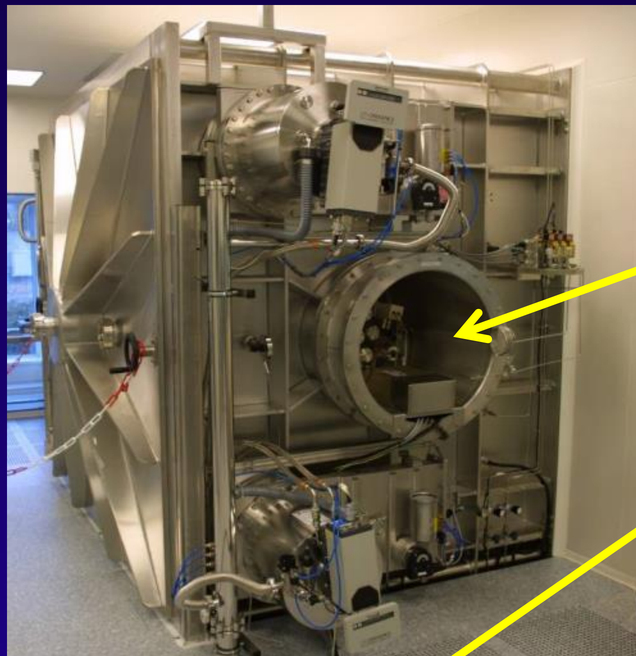


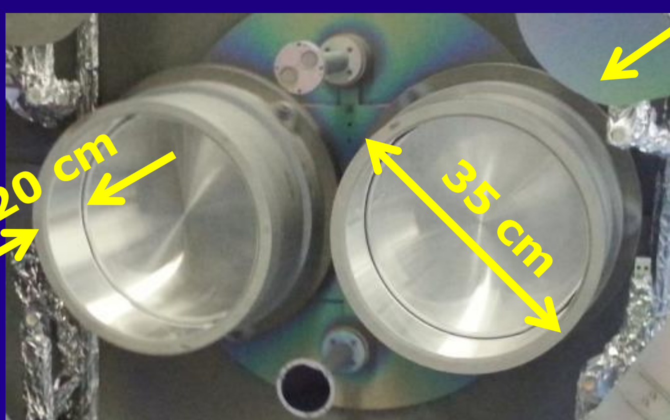
- Ion Beam Sputtering
  - Extremely low optical absorption
  - Compact layers (low porosity)

Benoit Sassolas - LMA

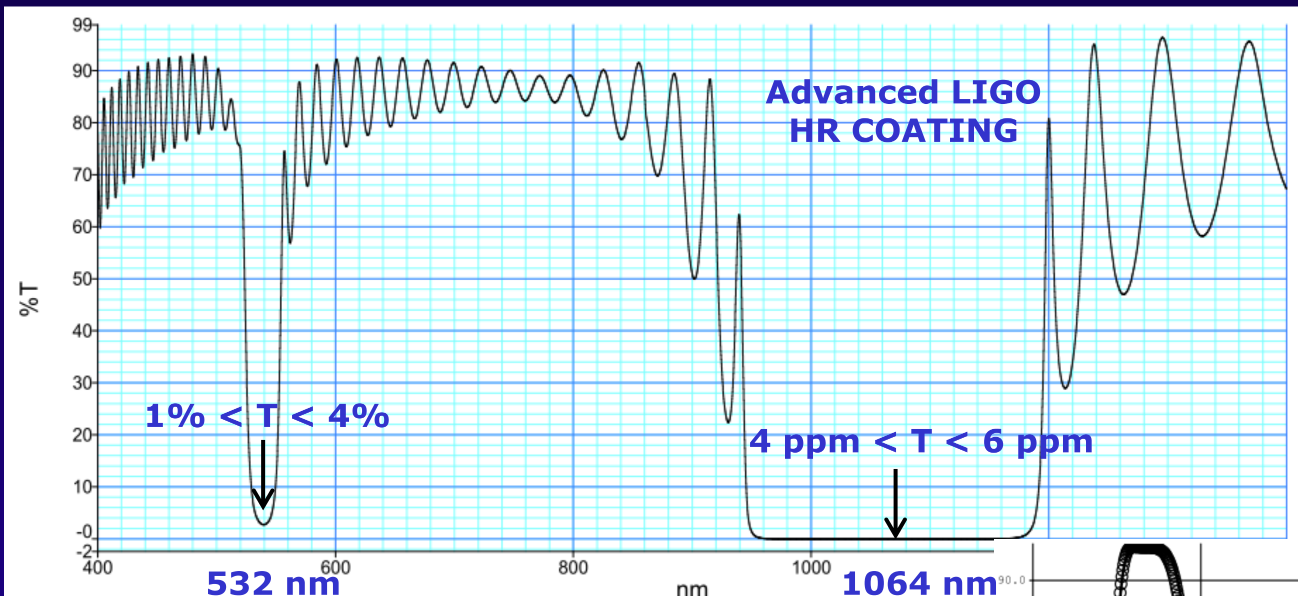
The coater

- Vacuum Chamber 2.4 x 2.4 x 2.2 m
- Pumping Units : 10^{-7} Torr in 1h
- RF Ion sources
- Max coating diameter ~ 1m
- Clean Room class 1(ISO3)
- 2 mirrors at a time



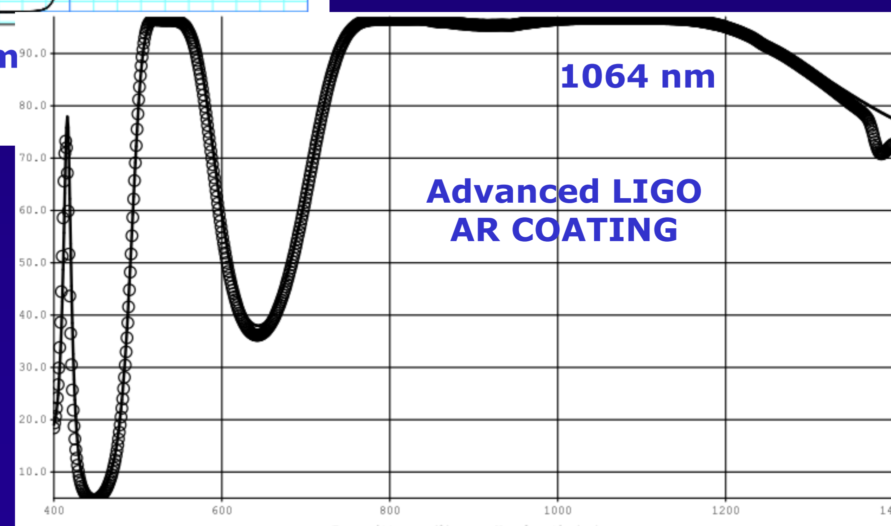


Transmission and Reflectivity

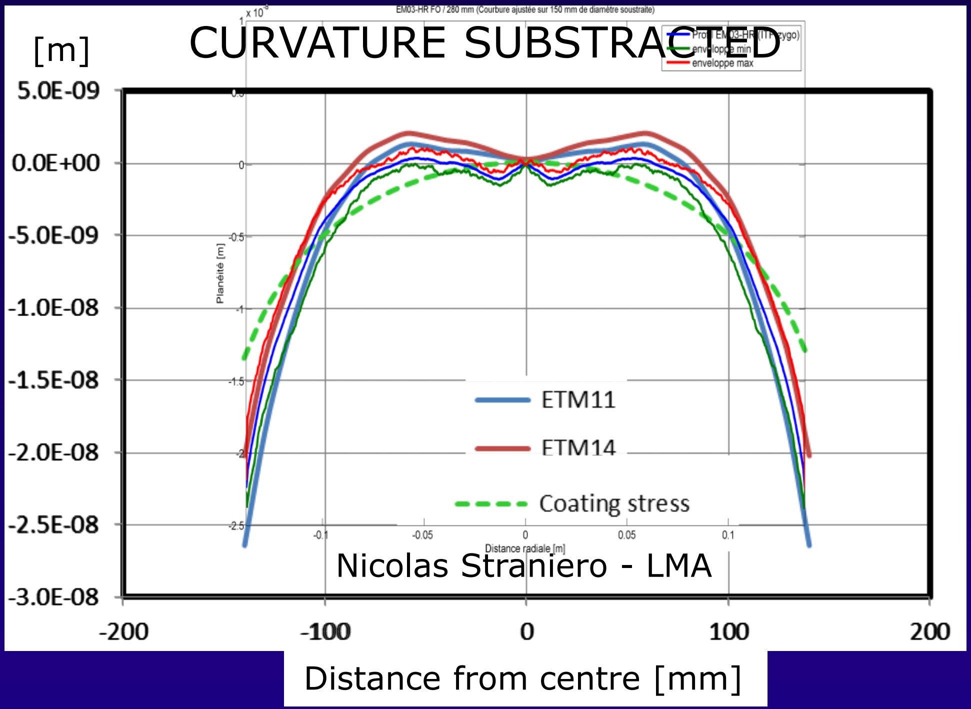


Christophe Michel - LMA

13 ppm < R < 54 ppm

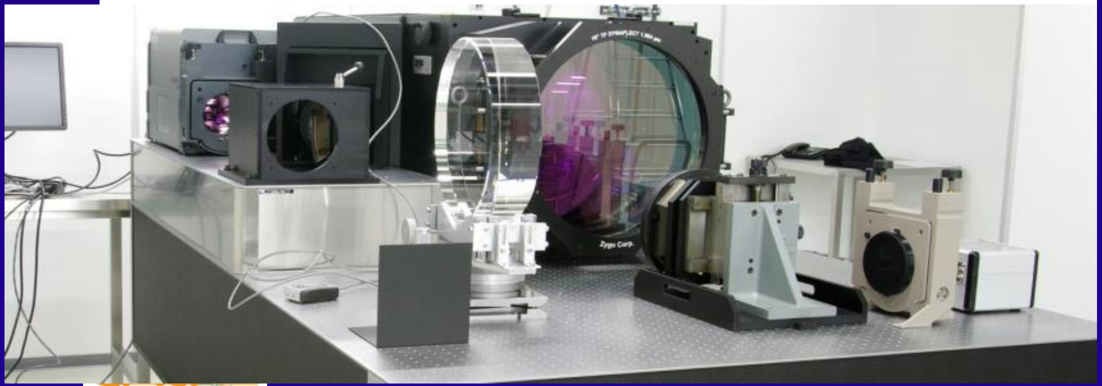


Coating uniformity



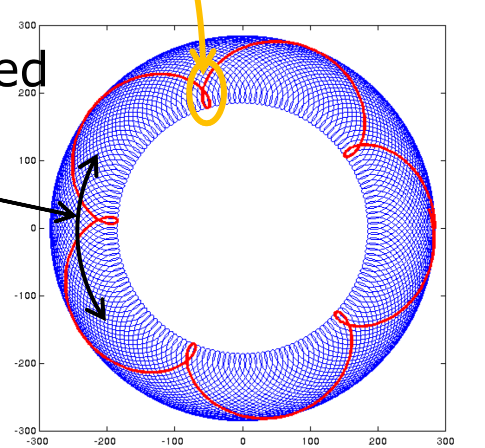
- Profile measured with a wavelength shifting 18” interferometer
- On 160 mm diameter we have a flatness of ~ 0.5 nm (power removed)
- Total coating thickness 6000 nm
- Compressive coating stress

18” WAVELENGTH SHIFTING ZYGO INTERFEROMETER

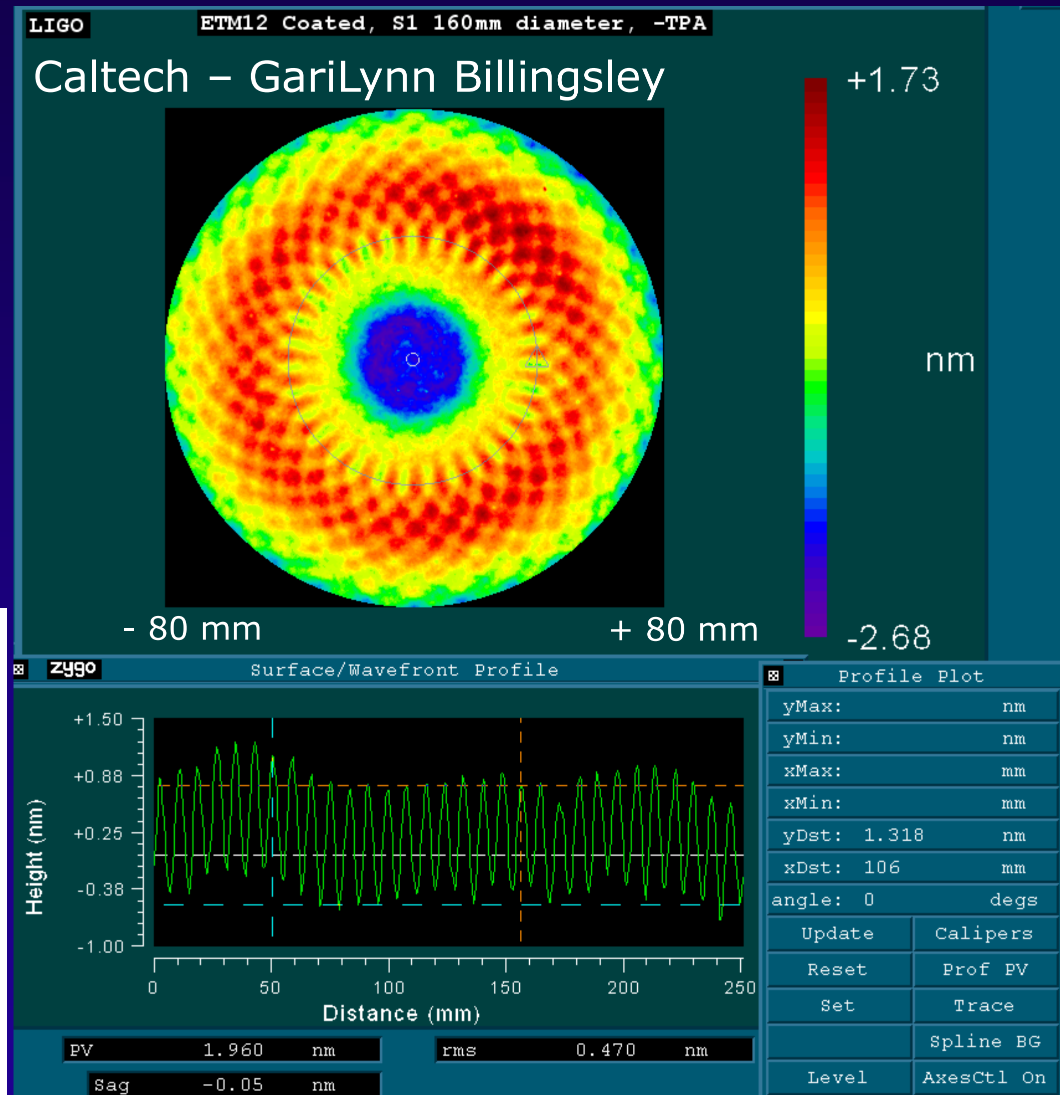


Origin of spirals

- Spiral = consequence of the combination of the planetary motion and the mask
- Amplitude max ~1.5 nm on the 40 mm radius circumference
- The part of the trajectory that is almost radial makes the total amount of deposited material sensitive to the gradient of sputtered material in this direction

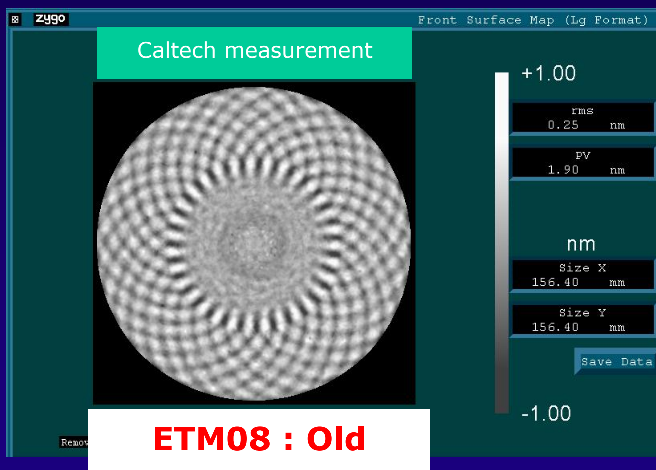


Trajectory of a point at 50 mm from centre

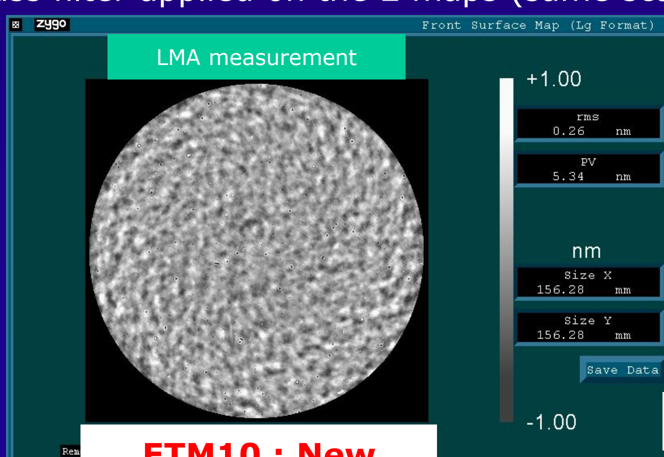


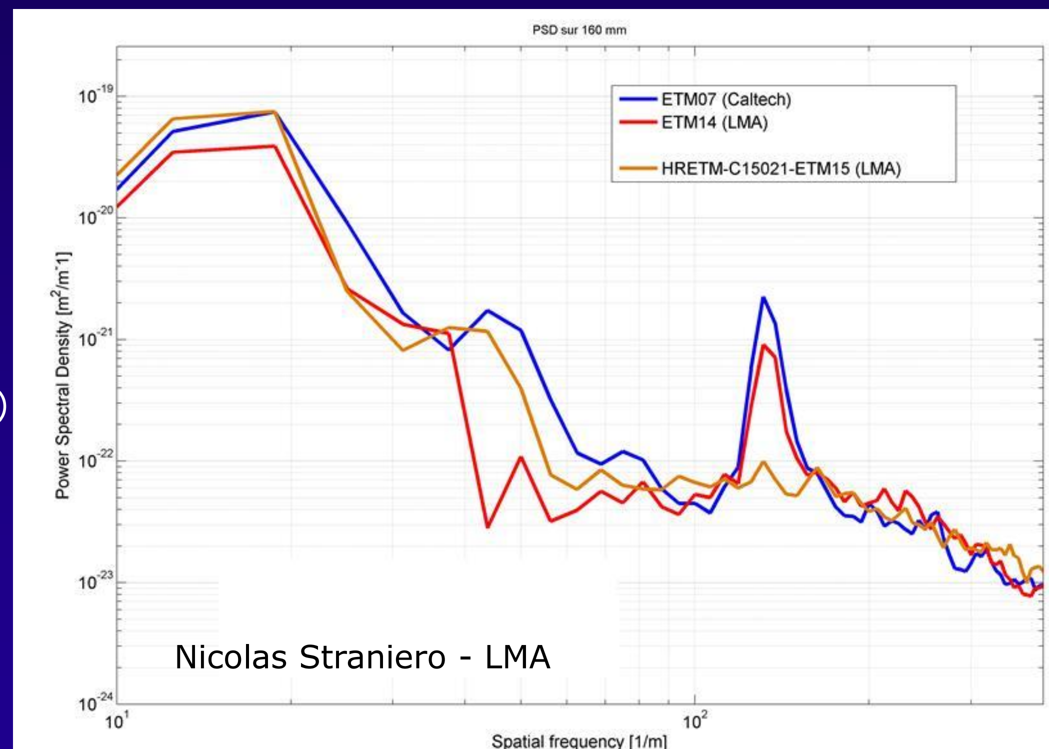
The solution

- Distructive interference between 2 spiral patterns shifted π one w.r.t. the other



High pass filter applied on the 2 maps (same scale)



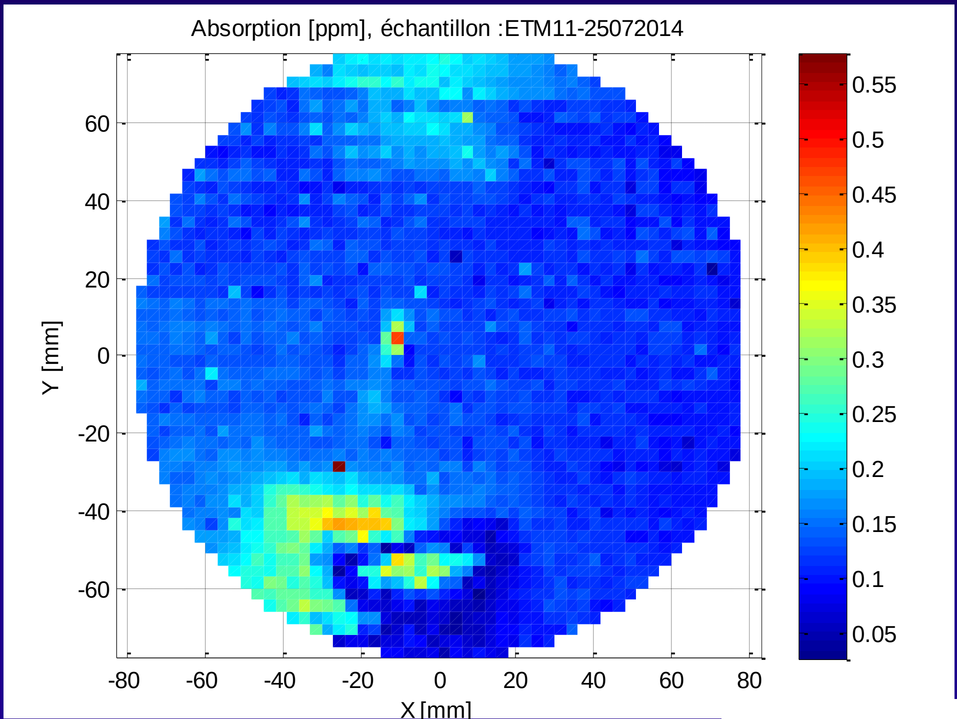


Laurent Pinard - LMA

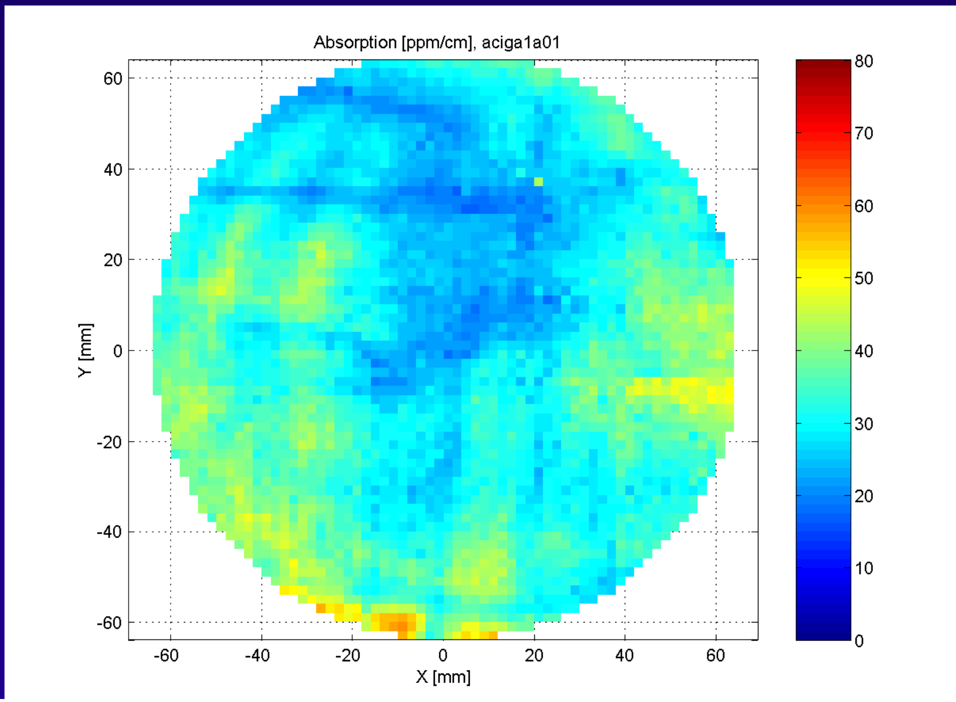
Absorption

- Absorption Map on aLIGO ETM HR coating
- (0.14 +/- 0.05) ppm
- Absorption map ∅150 mm of a Sapphire substrate (2004)

Coating absorption



Bulk absorption

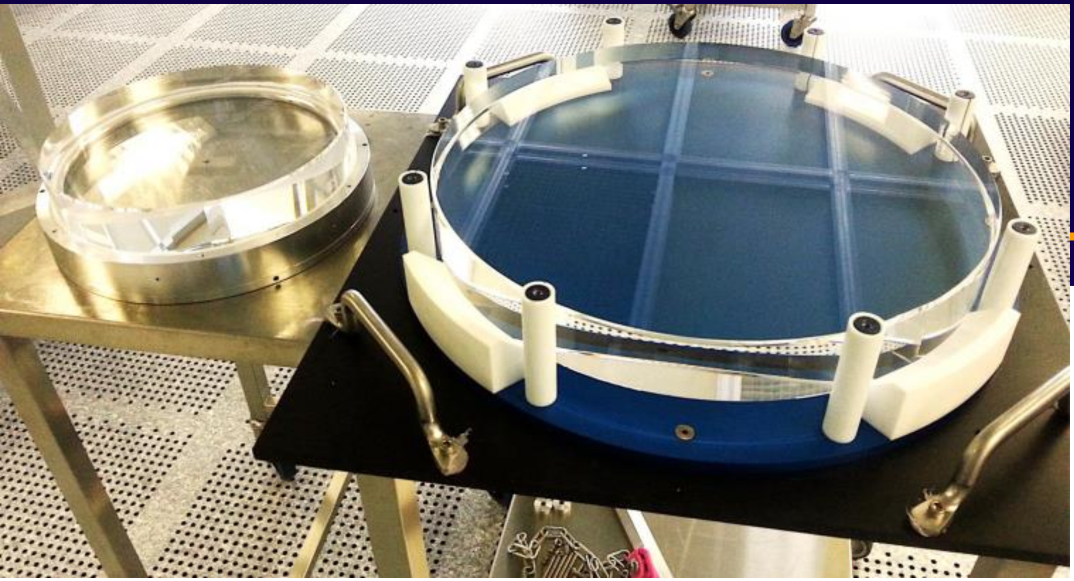


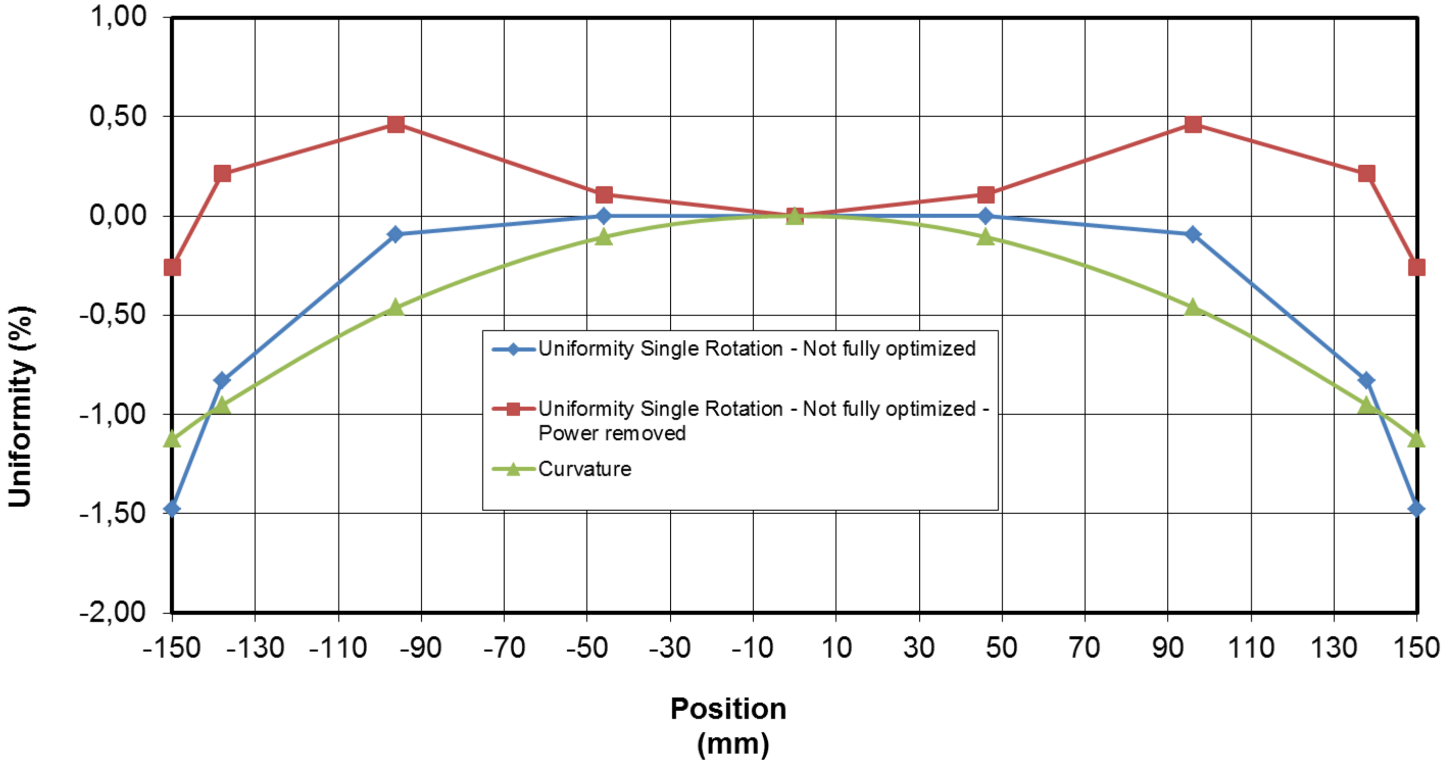
Laurent Pinard - LMA

The future of IBS

- Planetary motion (matched mirrors)
  - Optics with $Ø_{max}$ = 40 cm
  - Uniformity: < 0.5 nm rms on Ø 30 cm
  - Ready by 2016
- Single rotation (1 mirror at a time)
  - No masks, no planetary → no spirals
  - $Ø_{max}$ = 60 cm, 200 kg substrate mass
  - Able to deposit nanolayers
  - Uniformity: < 0.5 nm rms on Ø 40 cm
  - In-situ optical control of coating thickness → matching of transmission between different runs

The Virgo BS

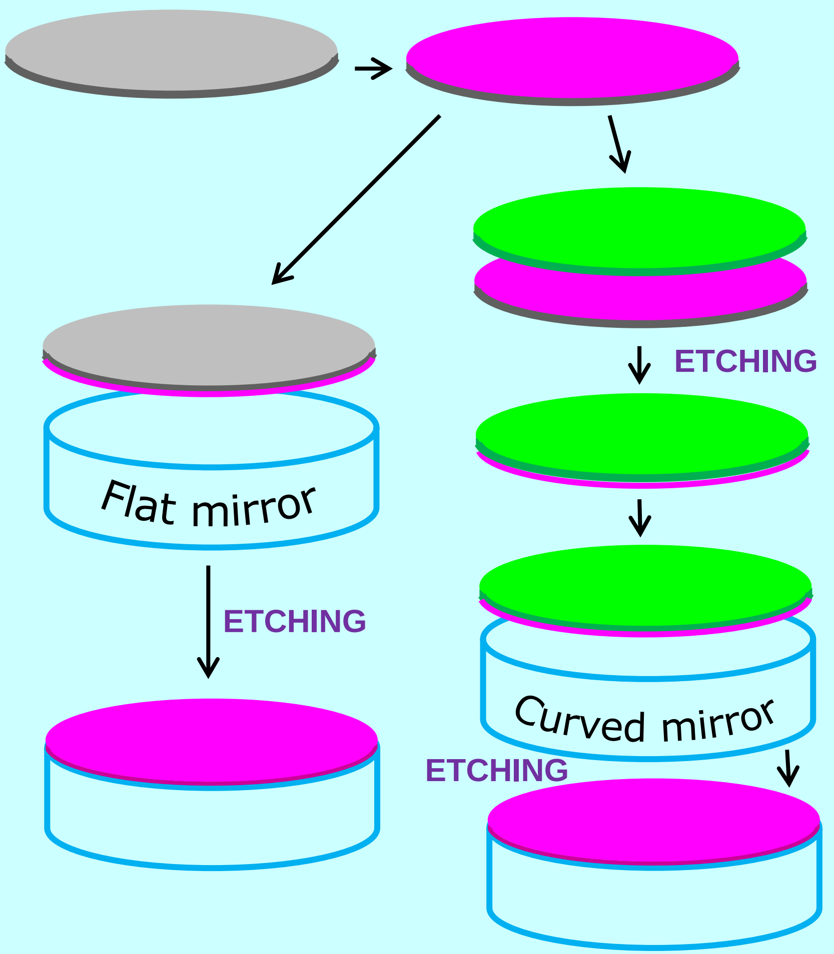




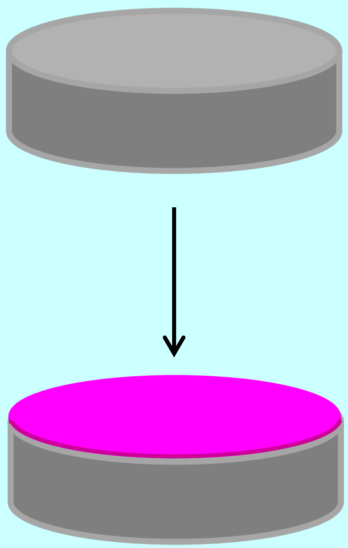
1,00
0,50
0,00
-0,50
-1,00
-1,50
-2,00
Uniformity (%)
-150
-130
-110
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
Position (mm)
Uniformity Single Rotation - Not fully optimized
Uniformity Single Rotation - Not fully optimized - Power removed
Curvature

Cristalline coatings: the technologies

AlGaAs



AlGaP



Cristalline coatings: the issues

AlGaAs

- CONS
  - Wafer maximum dimension
  - Bonding on large surface
- PRO
  - Full stack achieved with good optical properties
  - Choice of the « good » side
  - Choice of substrate

AlGaP

- CONS
  - Full stack not achieved yet
  - One-chance growth
- PRO
  - Simplicity

- Thickness uniformity < 0.5 nm on Ø 40 cm
- Cryogenic operation
- Dedicated MBE