Flat top beam interferometer to depress mirror thermal noise

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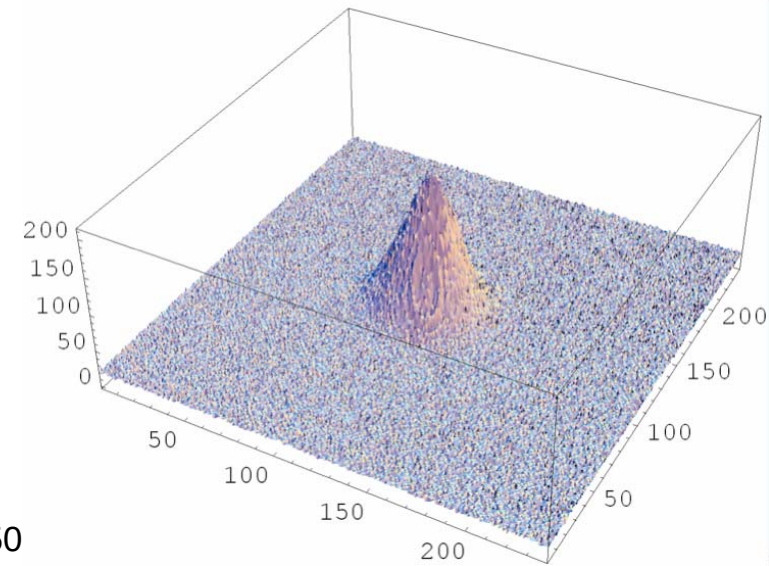
Caltech/LIGO

Outline

- Interferometer lab status
  - (Marco Tarallo)
- Mirror production status
  - (Alban Remillieux)
- Mirror analysis
  - (Erika D'Ambrosio and Juri Agresti)

Lab Status (Marco)

- Asbestos removal and lab re-hab lasted more than expected
- Will start unwrapping cabinets and equipment and realigning optical tables by Easter
- Prepared beam profile measurement software and piezo drivers



Mexican Hat Mirror Production status (Alban)

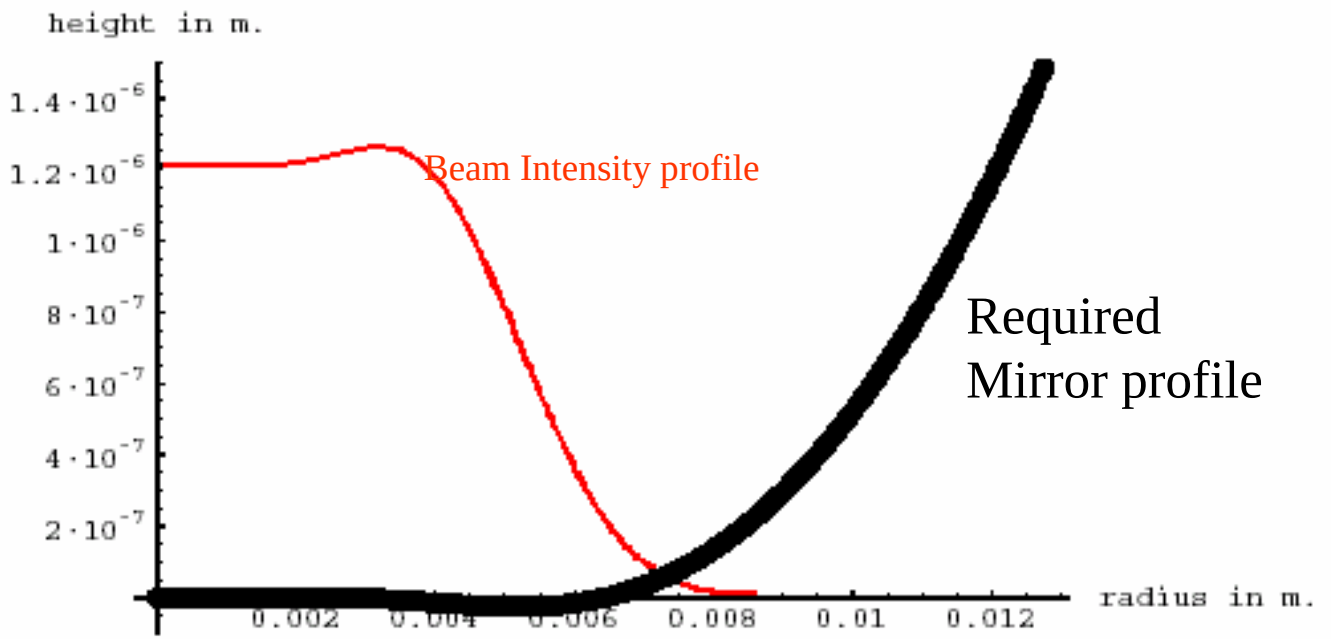
A three step process:

1: General shape coating

2: Corrective treatment

3: HR Coating

Beam Design



The beam intensity profile is flat and then falls off much faster than a Gaussian

The beam diameter at the mirror can be as large as 50% of the mirror diameter

25% of the mirror surface is sampled (up from 2.2%)

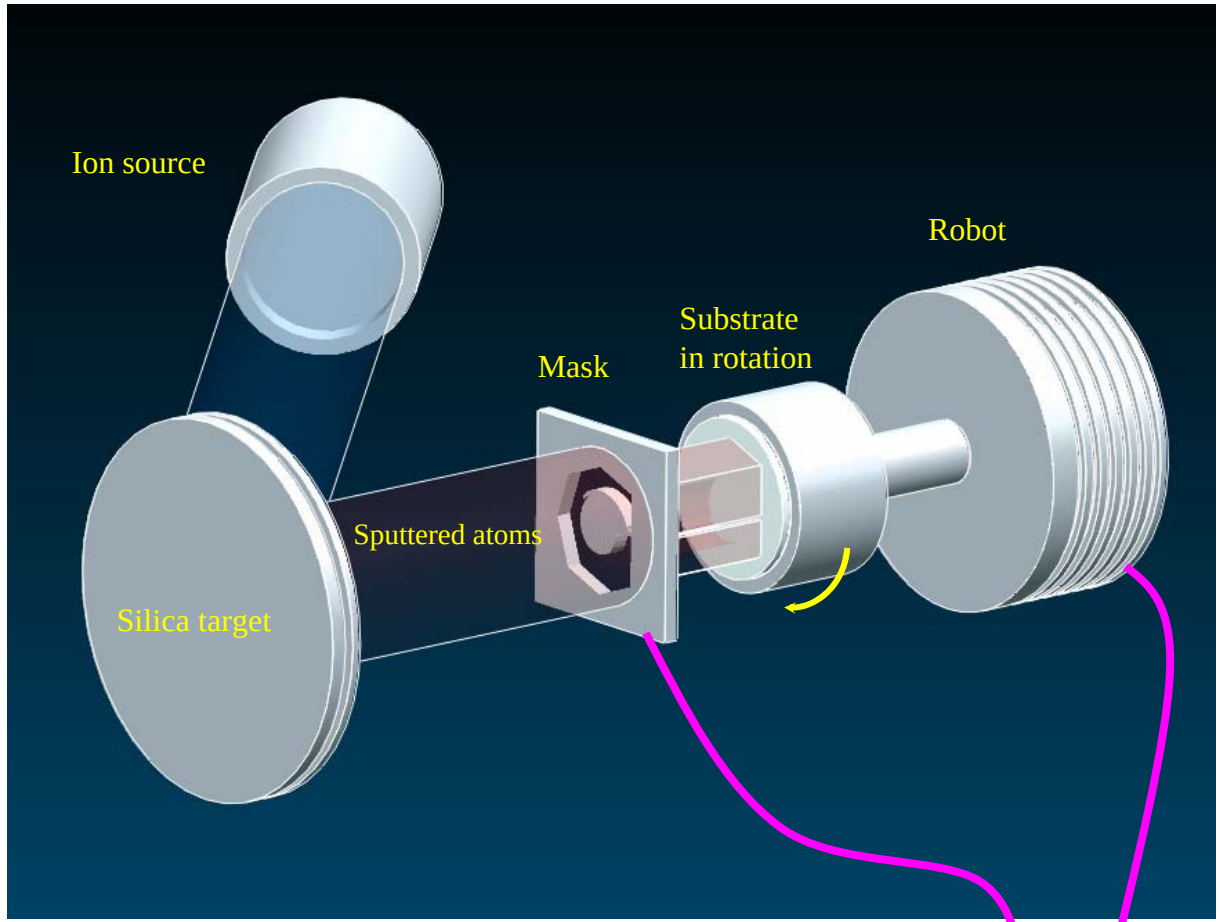
Much improved thermal noise performance

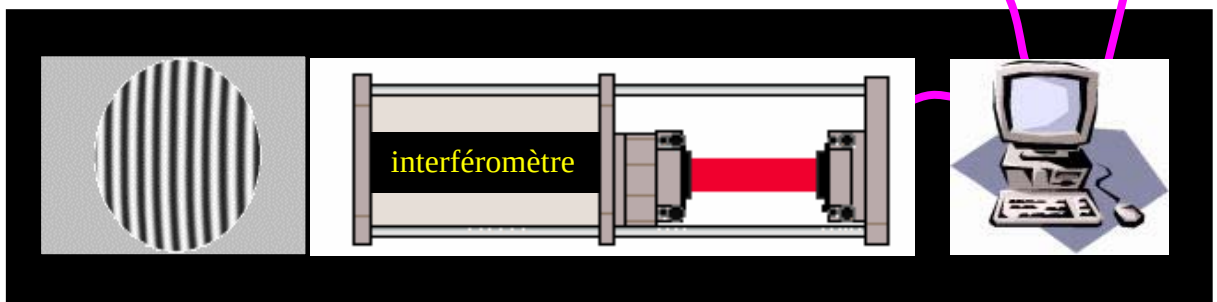
The mirror is not spherical! Manufactured with a special procedure

1: General shape coating

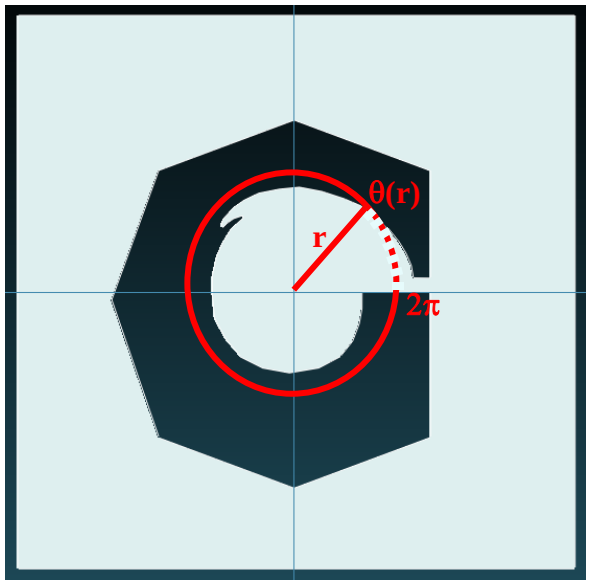
99%+ of the mirror Profile is generated with this Dead-Reckoning Deposition step

A mask between the ion source and the rotating beam substrate is calculated to deposit the required thickness where needed





1: General shape coating



Mask calculated so that :

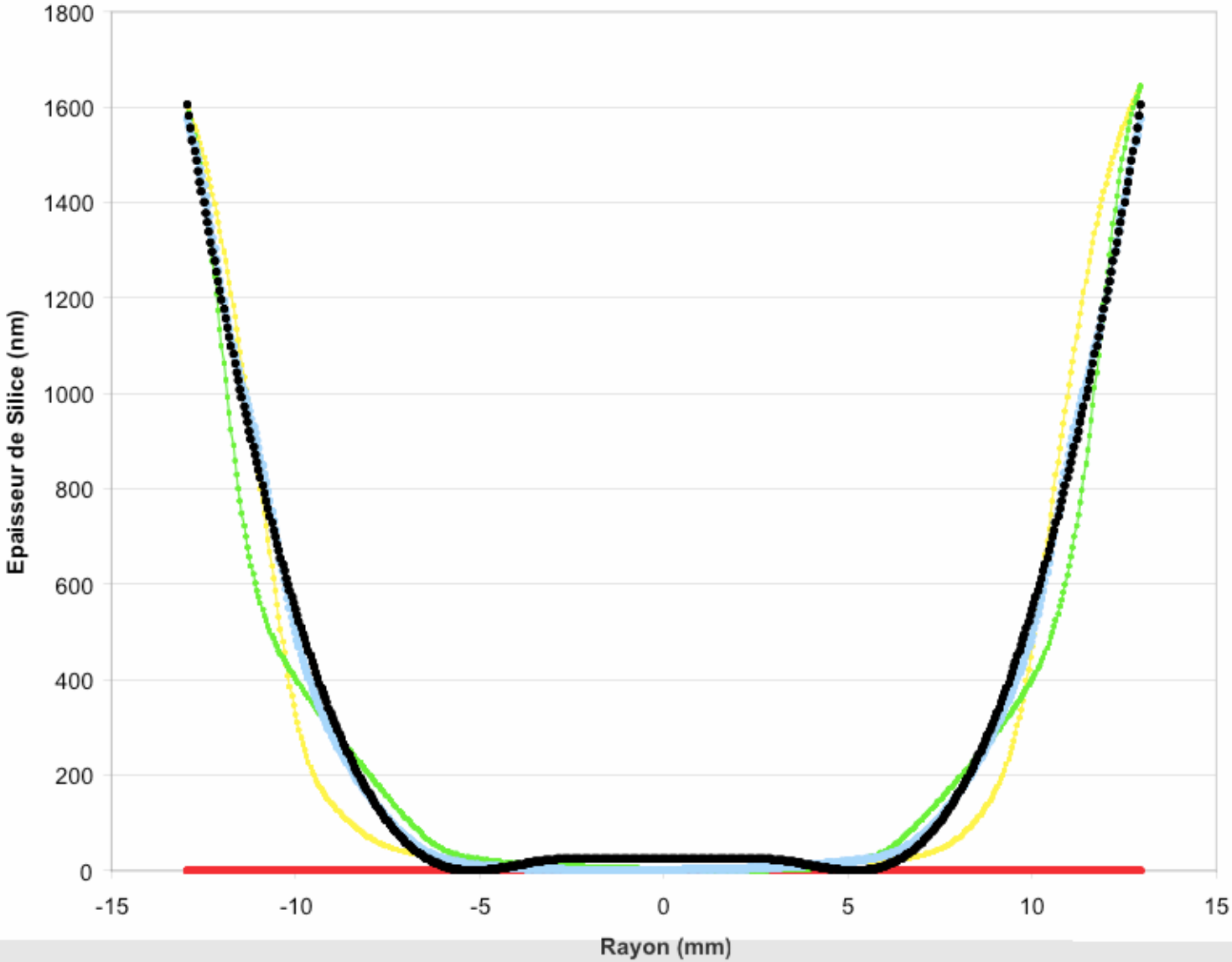
The sputtered atom profile
Generats the
Mexican Hat profile

Assumption:

The axis of rotation of the substrate must be at the center of the mask

Problem in first prototypes: rotation axis offset of 0.82 mm! (under vacuum)
offset changing from run to run
eventually found and solved problem (more later)

1: General shape coating



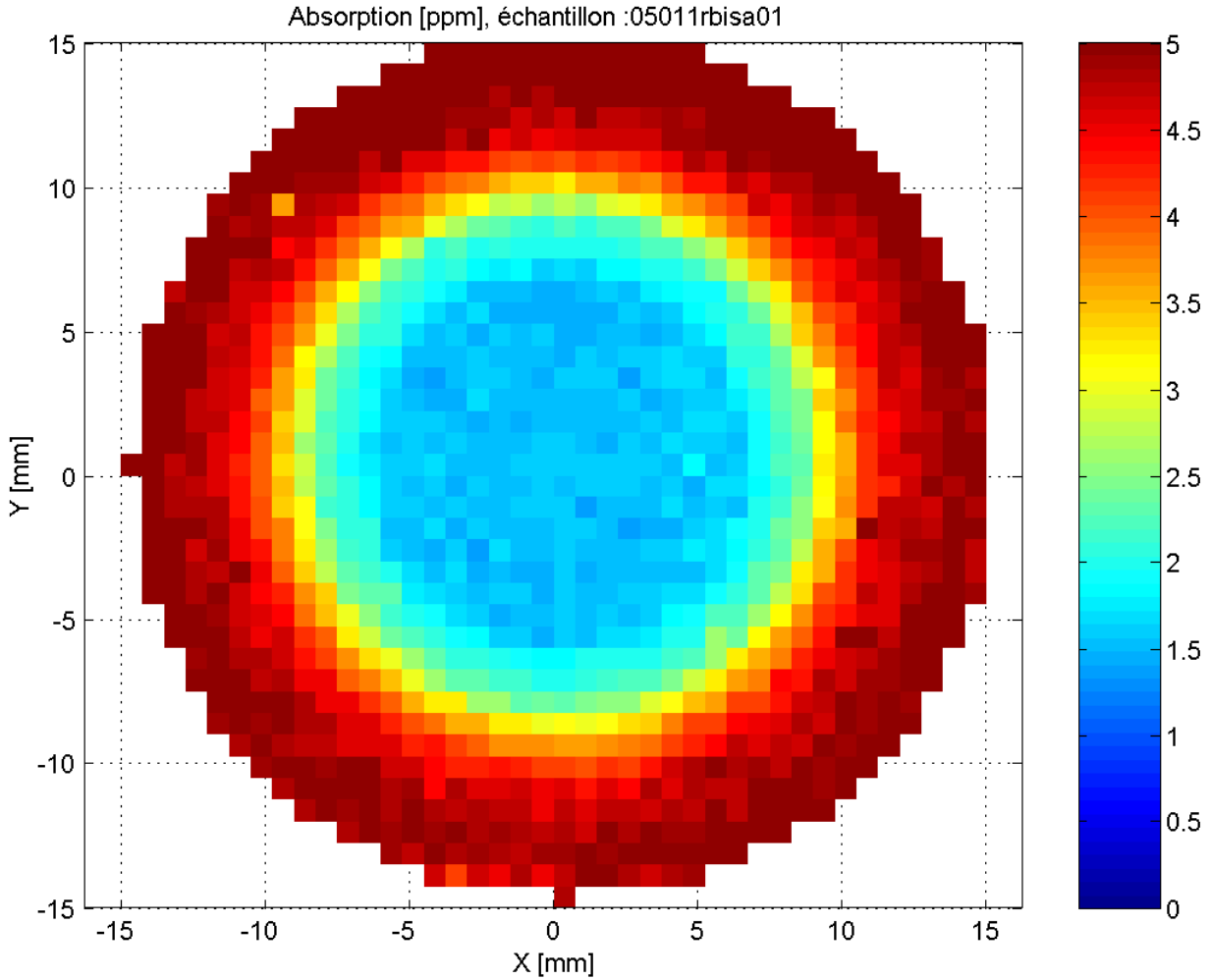
4 masks
Numerical Tool
Machine manufacture

1: General shape coating

Absorption mapping of the general shape Coating

5 ppm OK

BUT



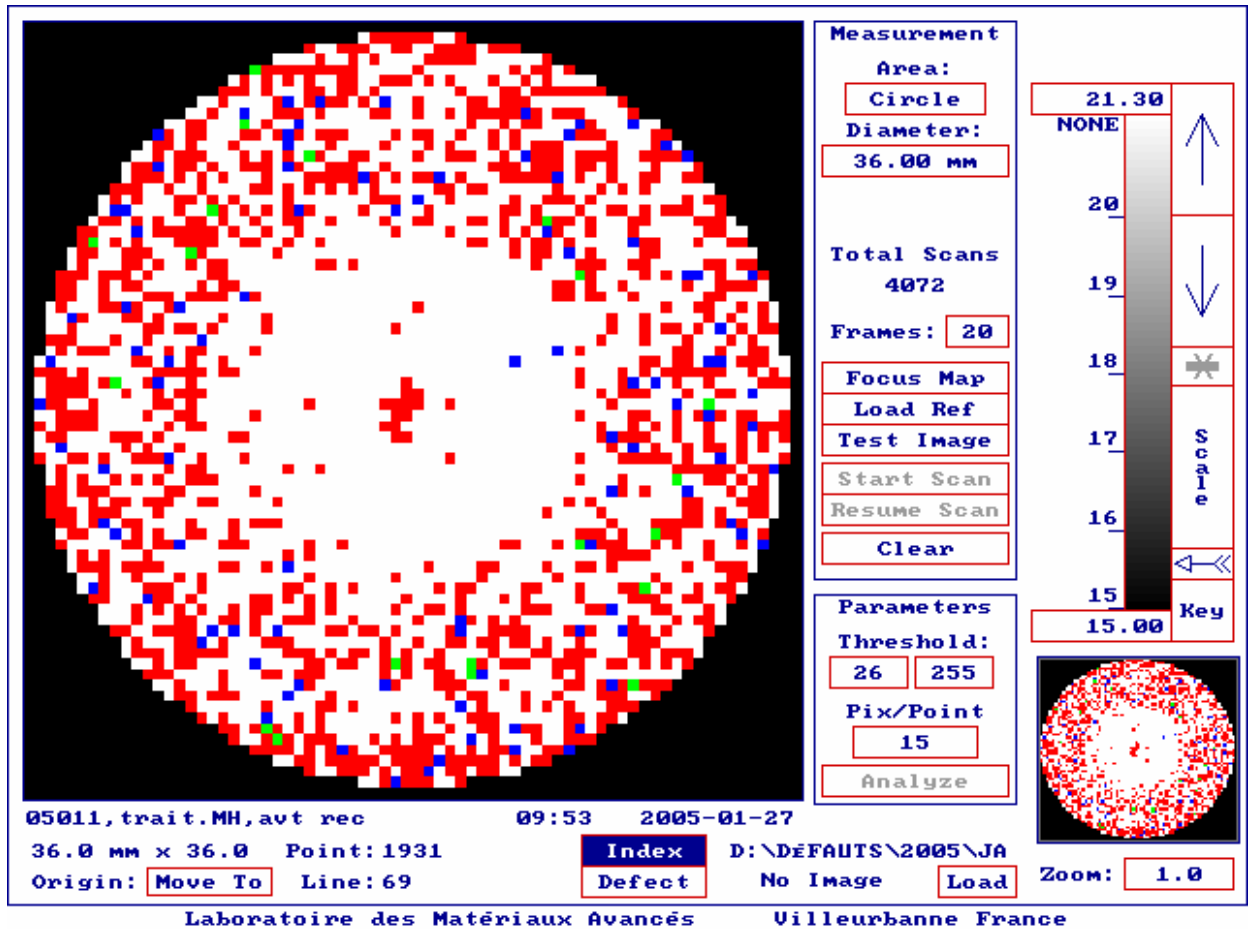
Extinction coefficient $K=2.10^{-7}$

1: General shape coating

05011

Defect detection
Before annealing

Unusually
Large number of
Defects generated



1: General shape coating

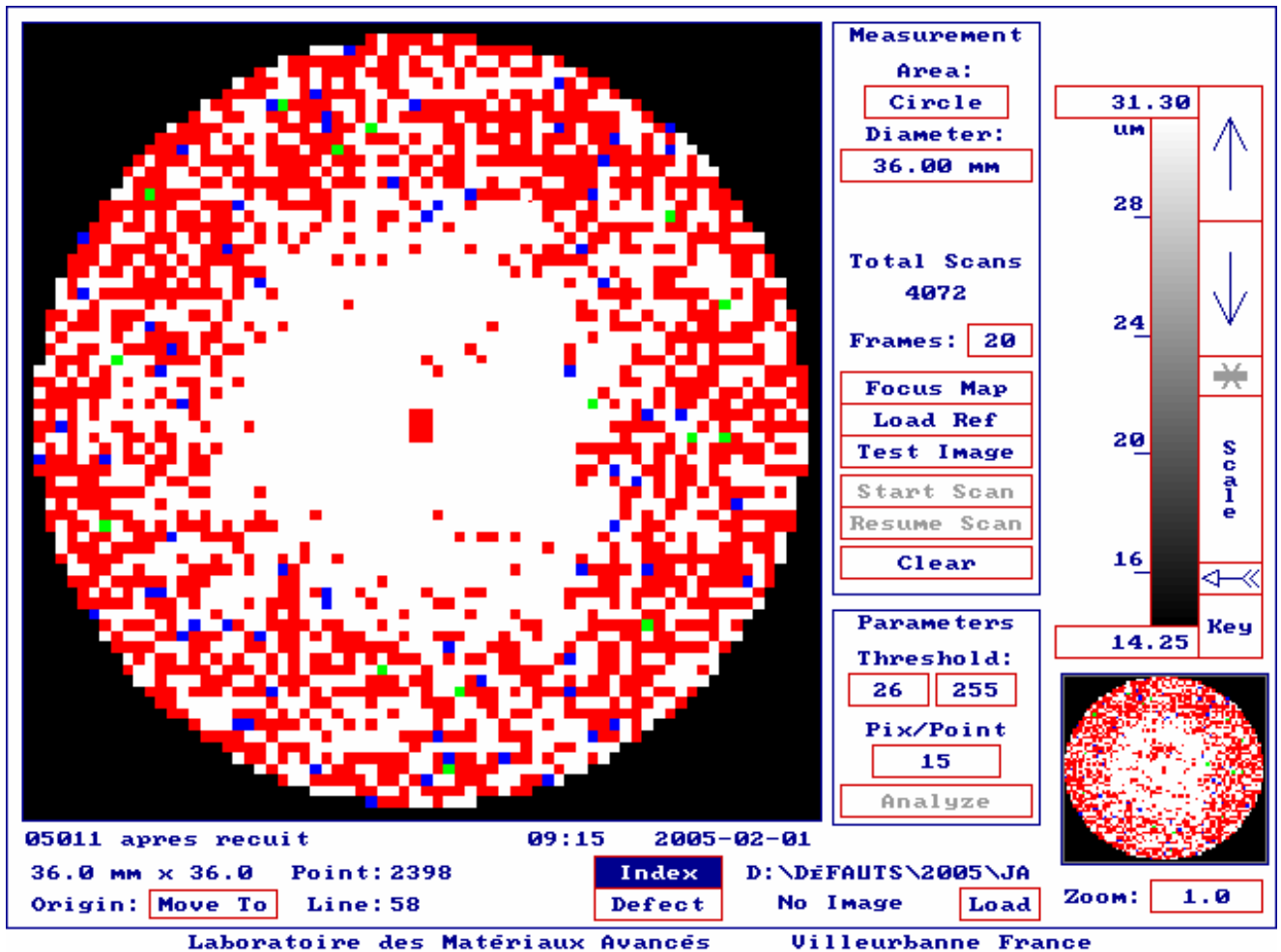
05011r

Defect detection
After annealing

Even more defects
Generated

Nucleation centers?

Problem from mask
(More later)

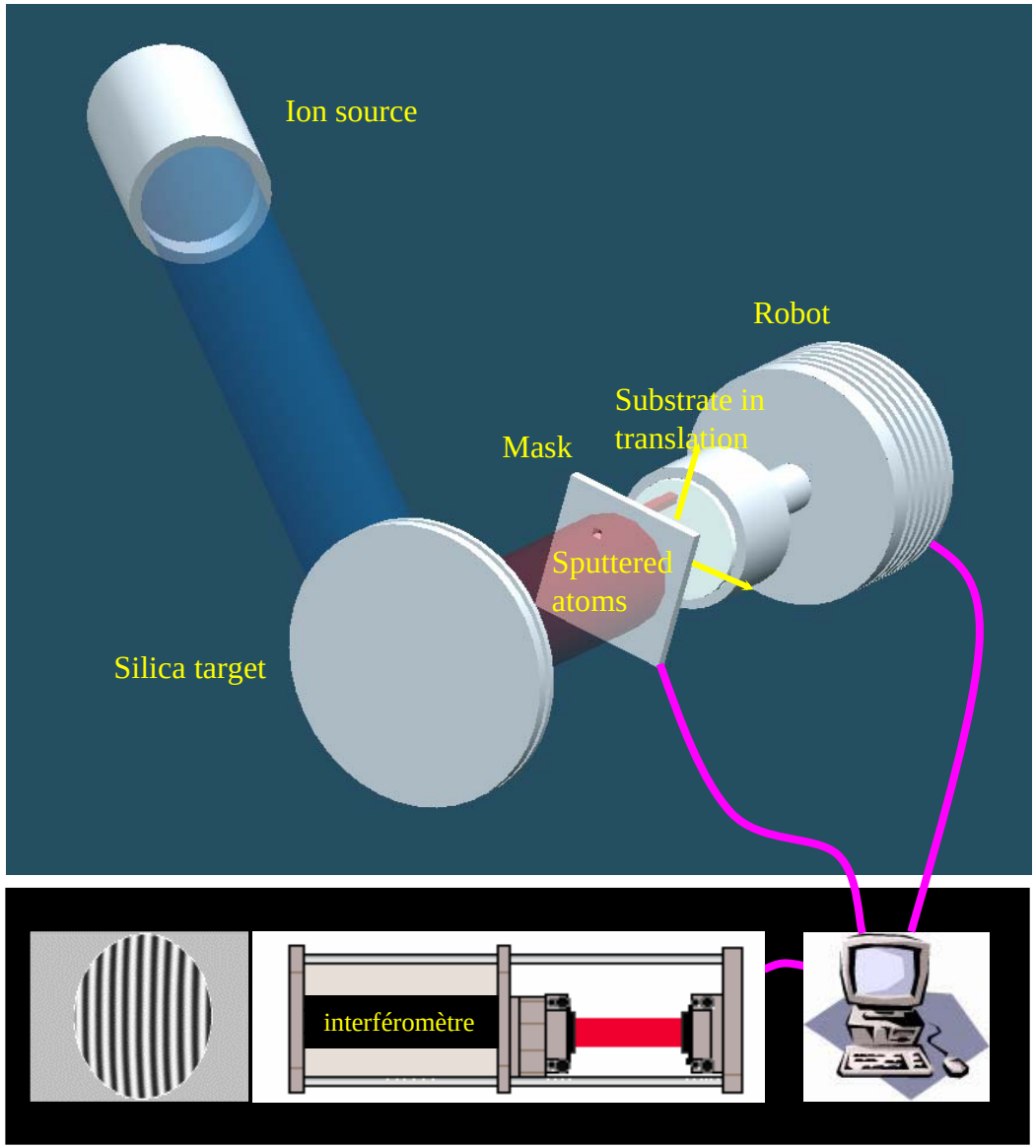


2: Corrective treatment

In this step the mirror profile generated by the general shape step is measured,

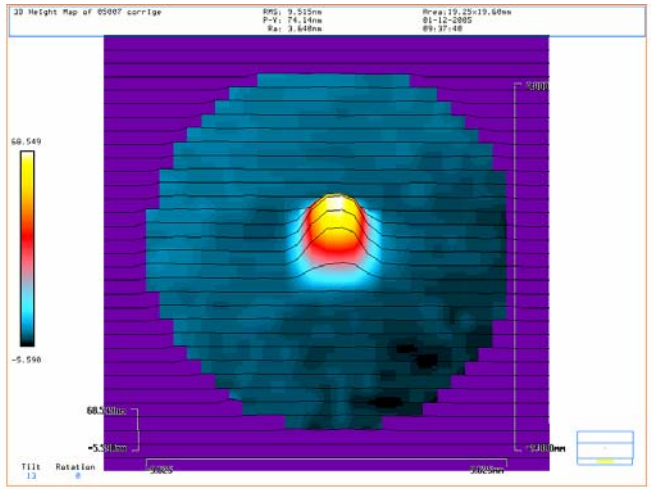
A map of its deviation from the ideal profile is generated

The deviations are corrected under numerical control with a SiO_2 molecular beam pencil

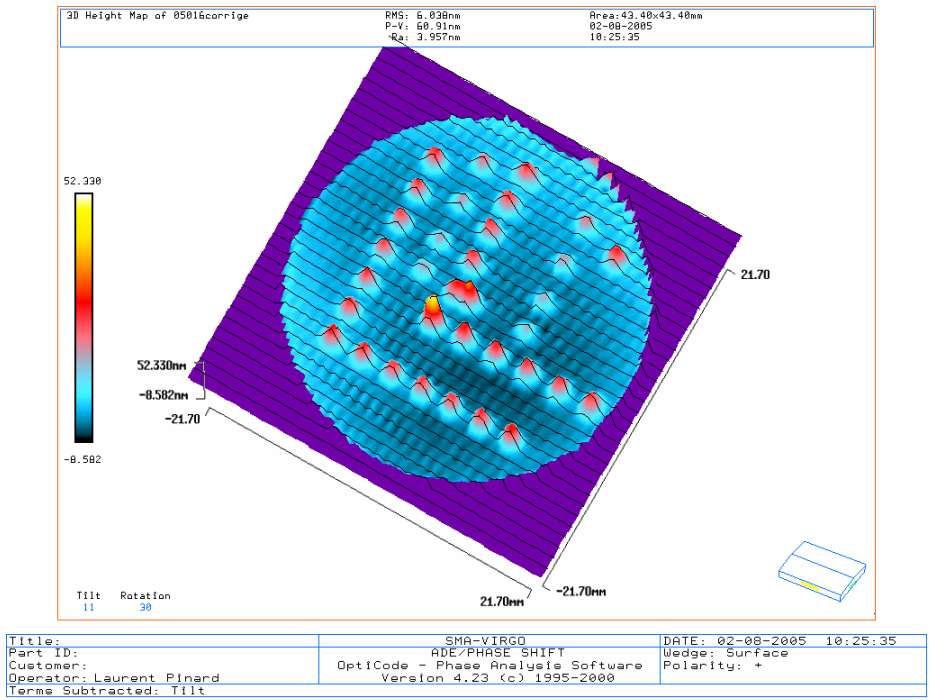


2: Corrective treatment

Measurement of the projection footprint of the pinhole that has been chosen for the corrective treatment.

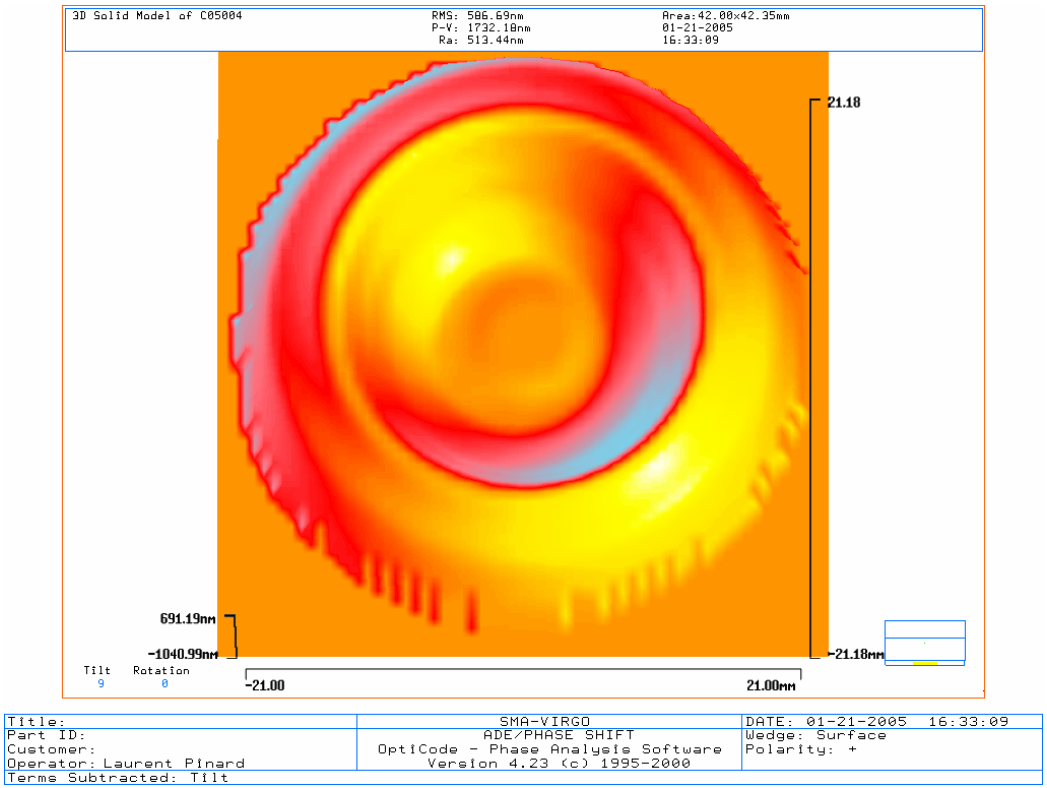


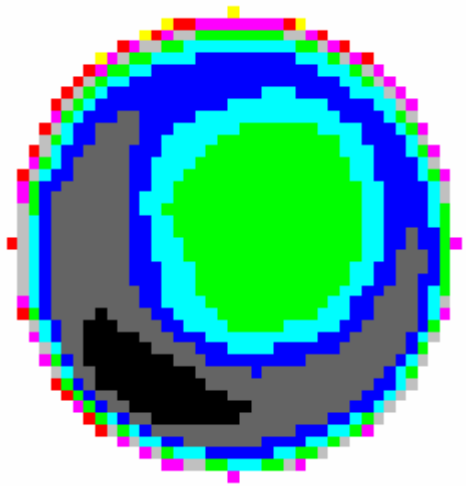
Measurement of the position of the Footprint for offset calibration.
Under vacuum, offset of several mm !



2: Corrective treatment

First corrective attempt on a 20 mm thick substrate:

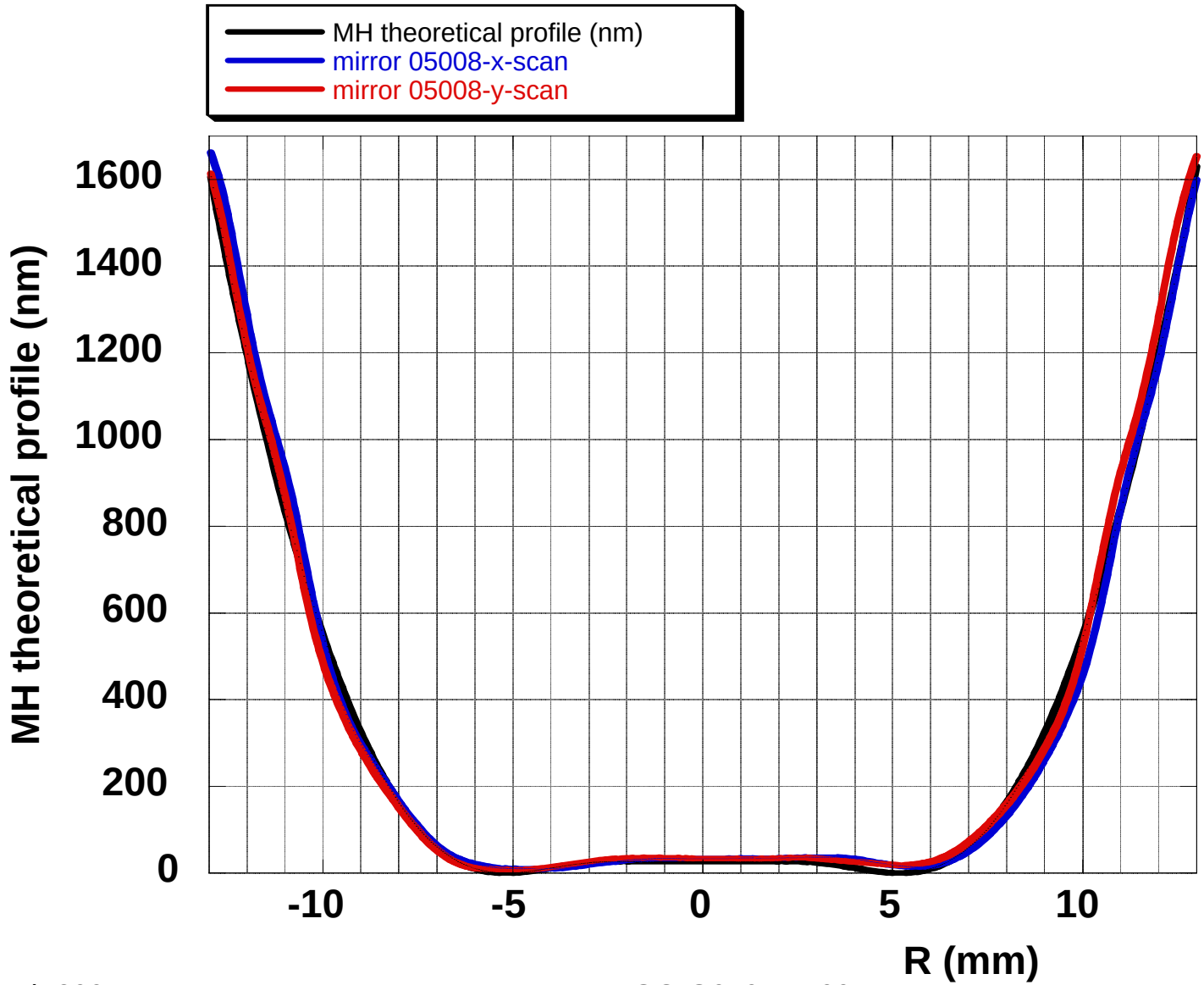




Again
Offset of 0.9 mm on X !
and 0.7 mm on Y !

2: Corrective treatment

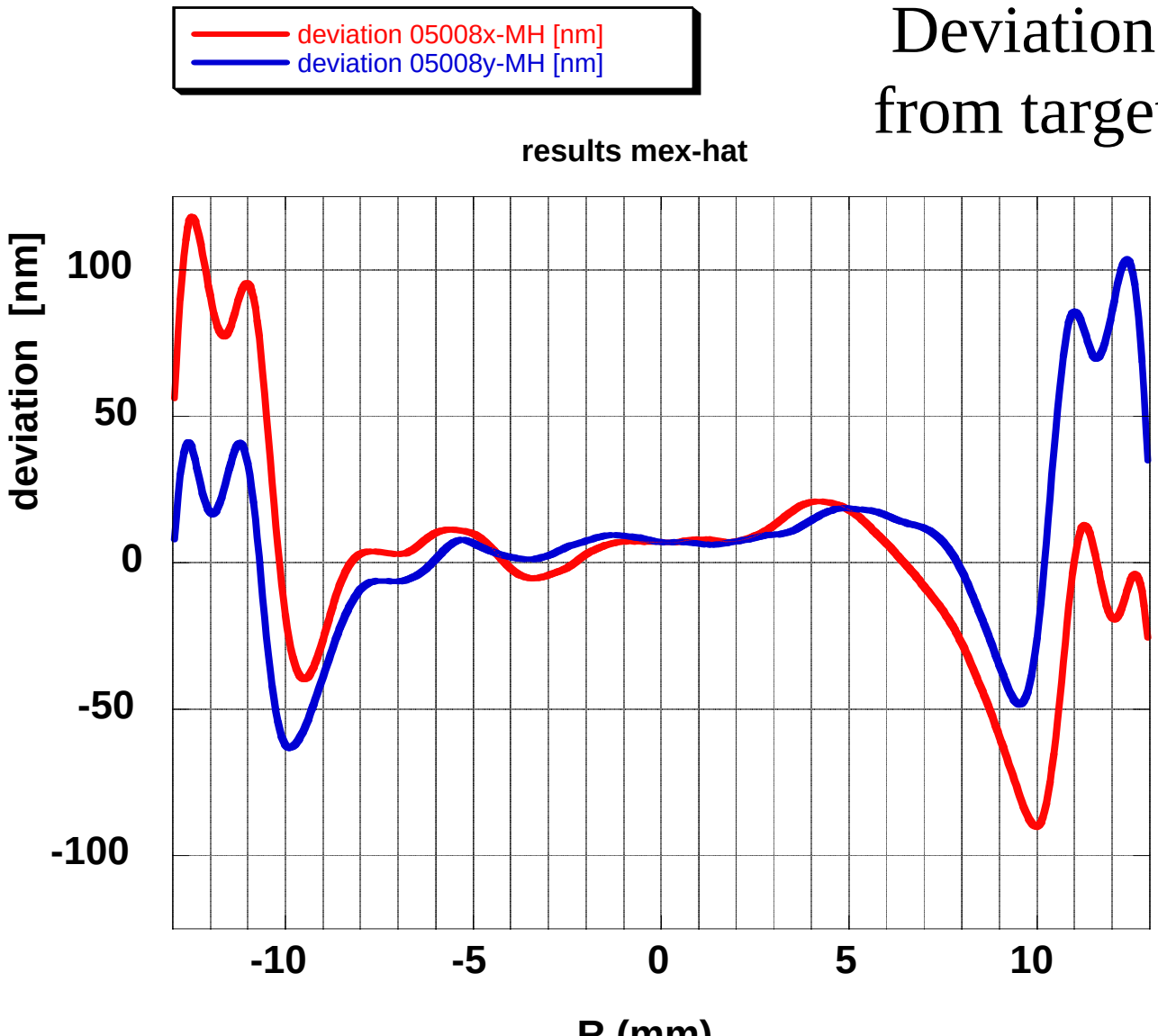
First attempt on a 20 mm thick substrate:



2: Corrective treatment

First attempt on a 20 mm thick substrate:

Deviation from target



2: Corrective treatment

- The alignment problem has been found and fixed

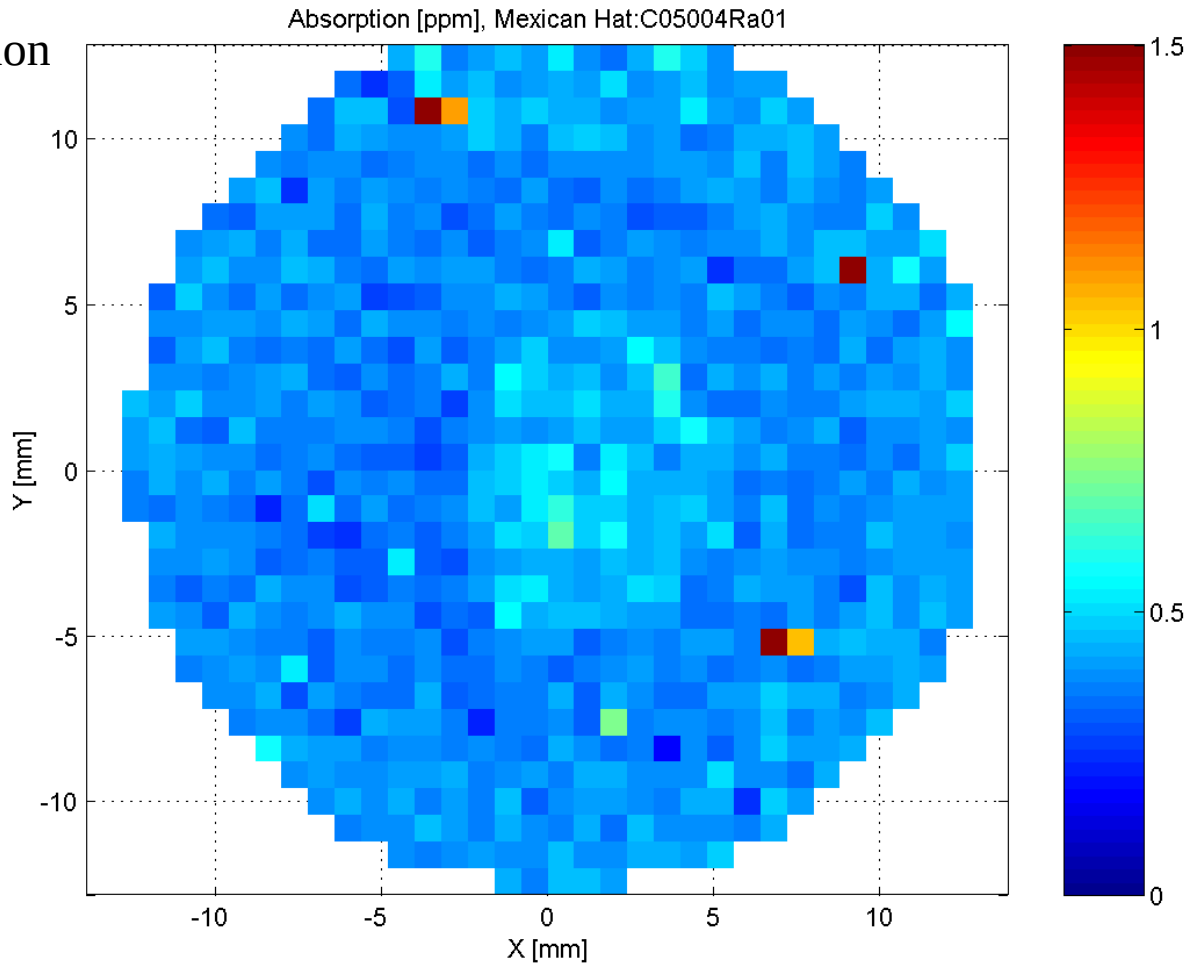
- The precision movement corner was hitting on the closed vacuum chamber during calibration procedures

3: HR Coating

absorption map
on Ø 26 mm : 0.5 ppm

At the center we guess a zone with corrective treatment with somewhat higher absorption (0.55 ppm).

Outside the central zone we have three absorption centers with 9, 16 and 26 ppm

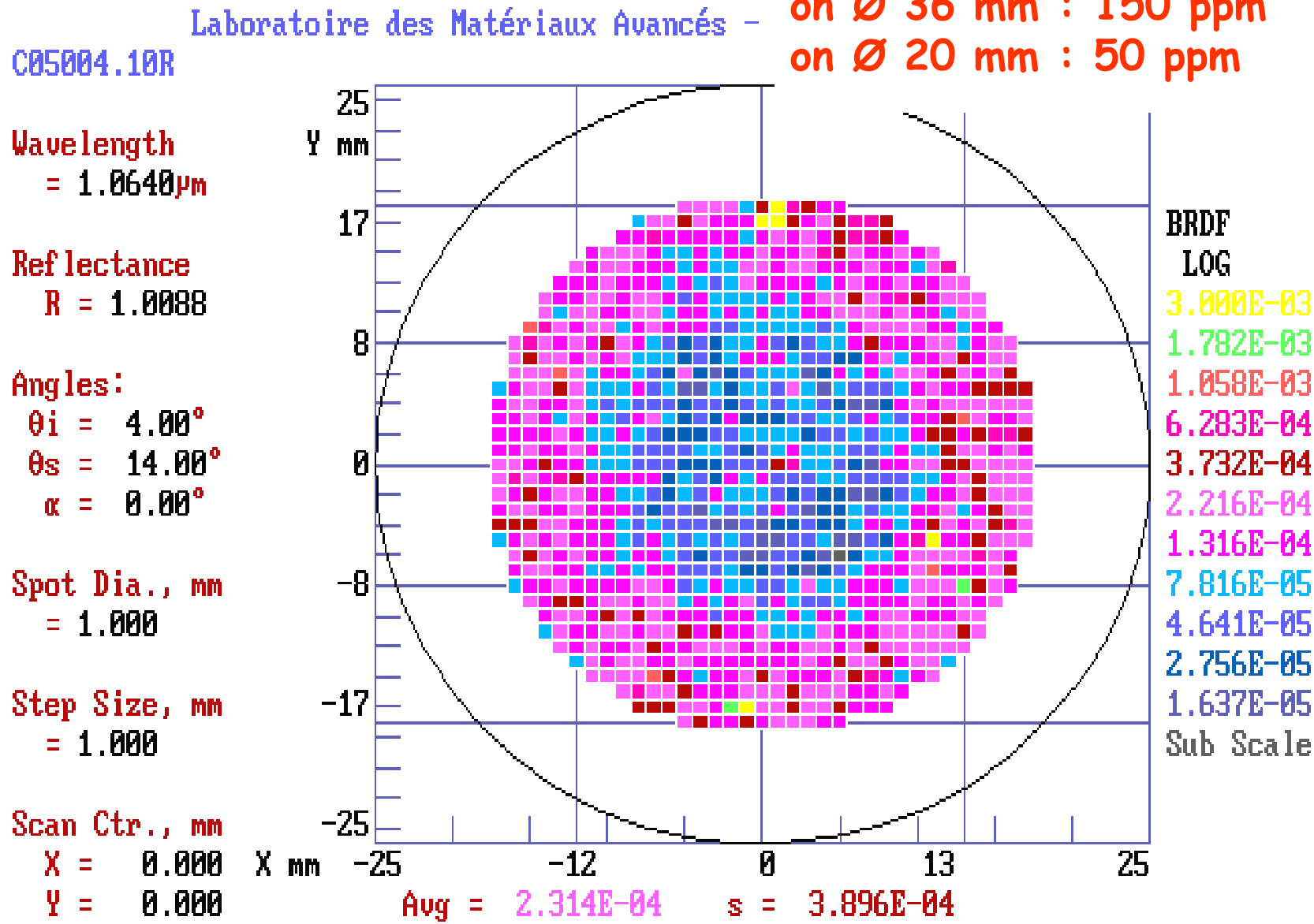


3: HR Coating

Diffusion map (marker down)

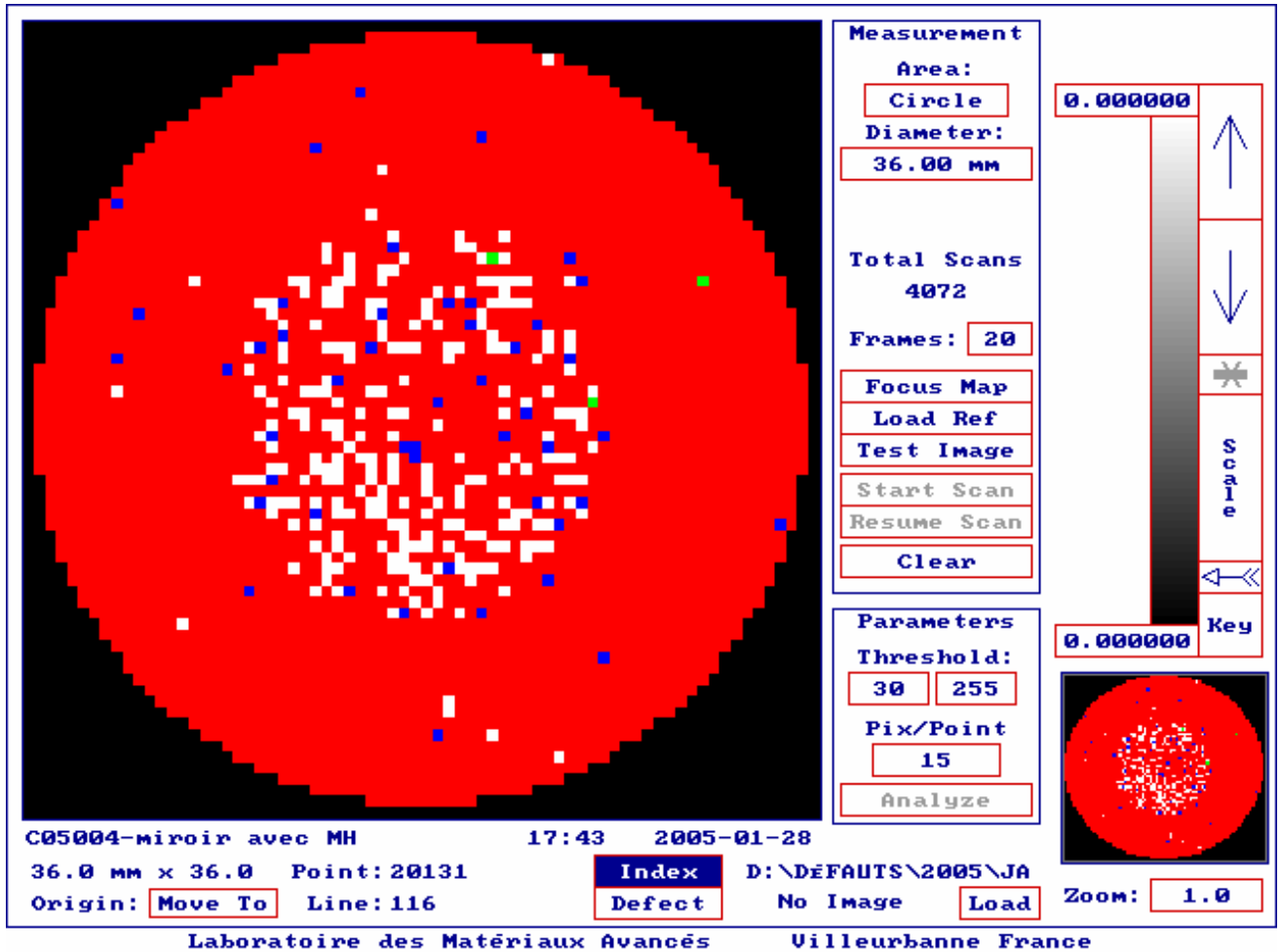
on Ø 36 mm : 150 ppm

on Ø 20 mm : 50 ppm



3: HR Coating

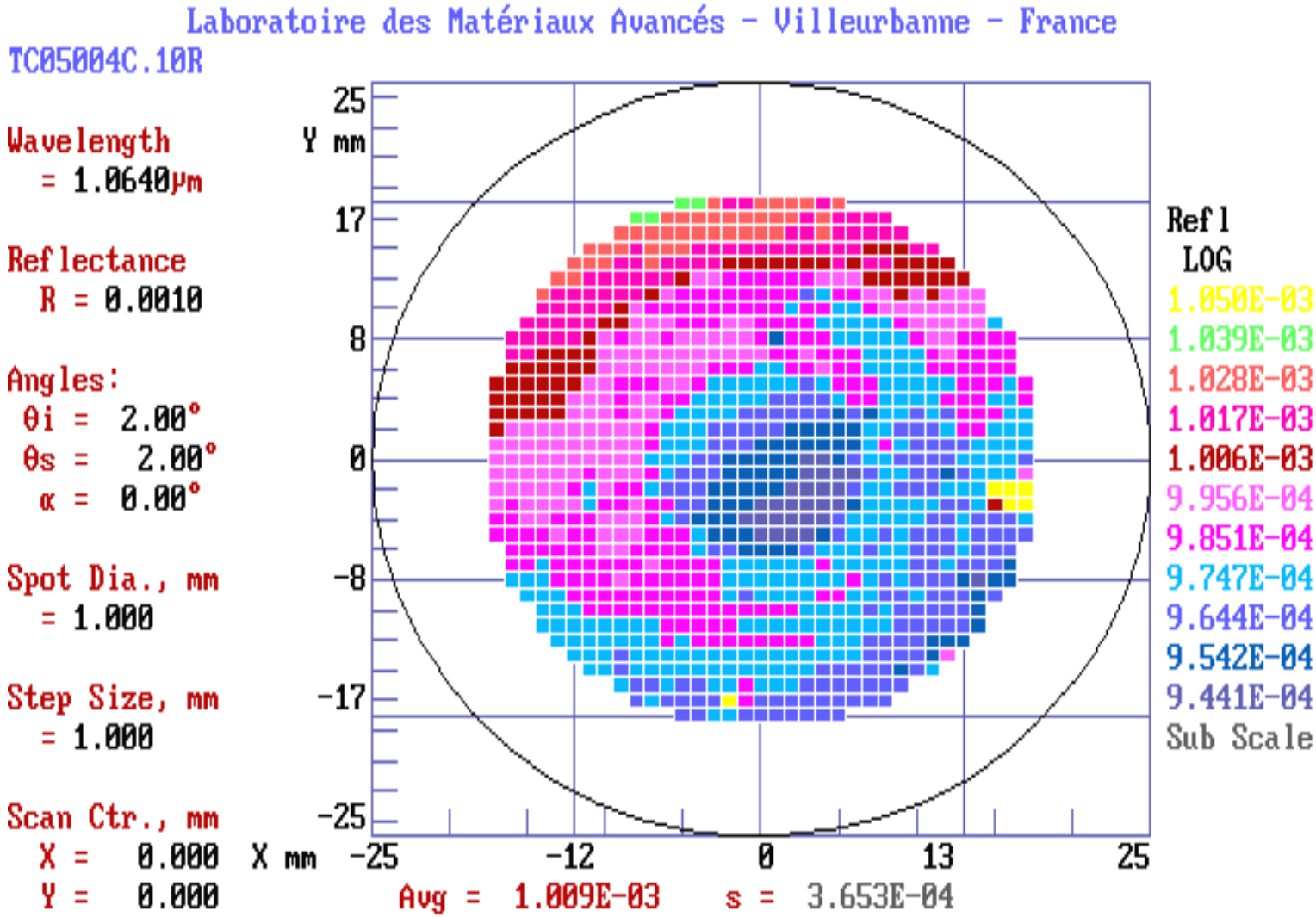
Defect detection
Again unusual
Defect
production



3: HR Coating

Transmission map (2° incidence)

1009 ppm



3: HR Coating

The slope (50 ppm variation between the two edges)
is due to a difference of thickness deposited during the deposition of the reflective coating
(the mirror was not properly rotating during HR deposition).

Next time, this asymetry will not be present.

3: HR Coating

A (HB)11HBB mirror (run C05004) has been coated on the previous MH profile (05008)

- Absorption is good, 0.5 pmm
- The Transmission is around 1000 ppm, as specified.
- Diffusion is bad 50 ppm on 20 mm diameter
  (150 ppm on 36 mm diameter).

- Diffusion is much higher than usual (a few ppm).

- The quality of the silica deposited is not good,

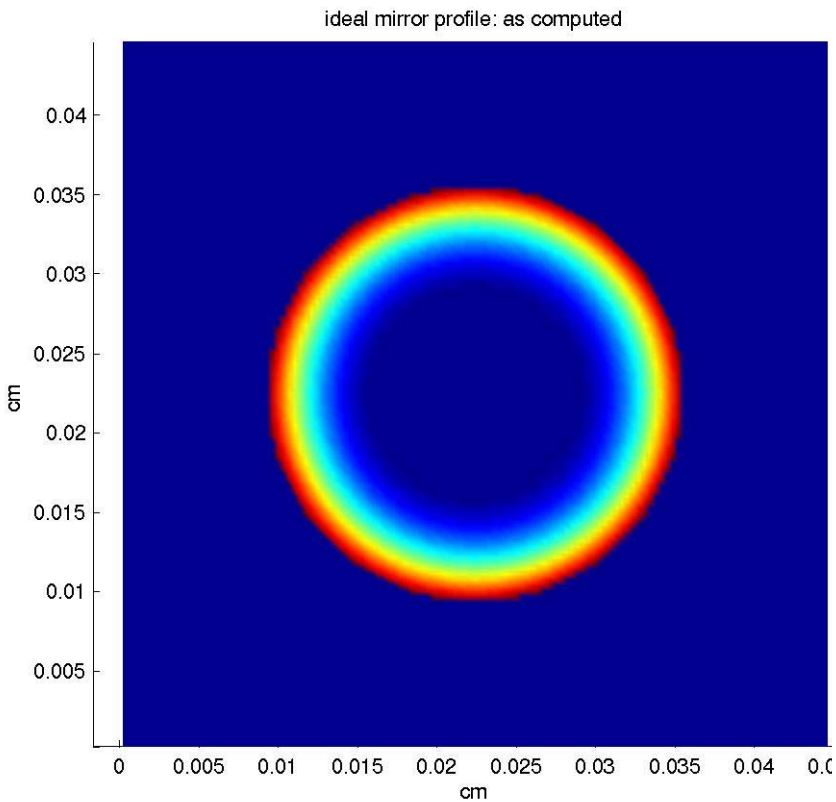
More on mirror manufacturing

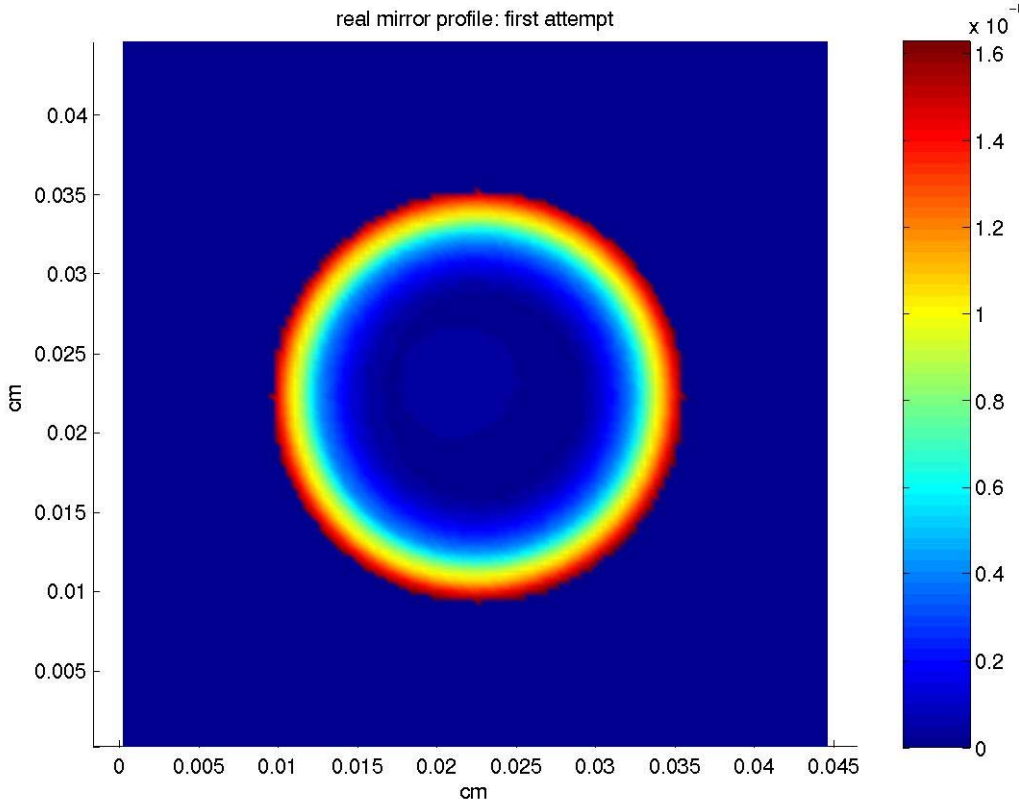
- The high diffusion and absorption losses are probably due to material ripped off the masks by the passing molecular beam thus generating nucleation centers
- Lots of time spent in solving this problem
- Sharp edge coated masks used in future
- Problem diminishing with larger sizes

Evaluation of expected performance of first pre-prototype

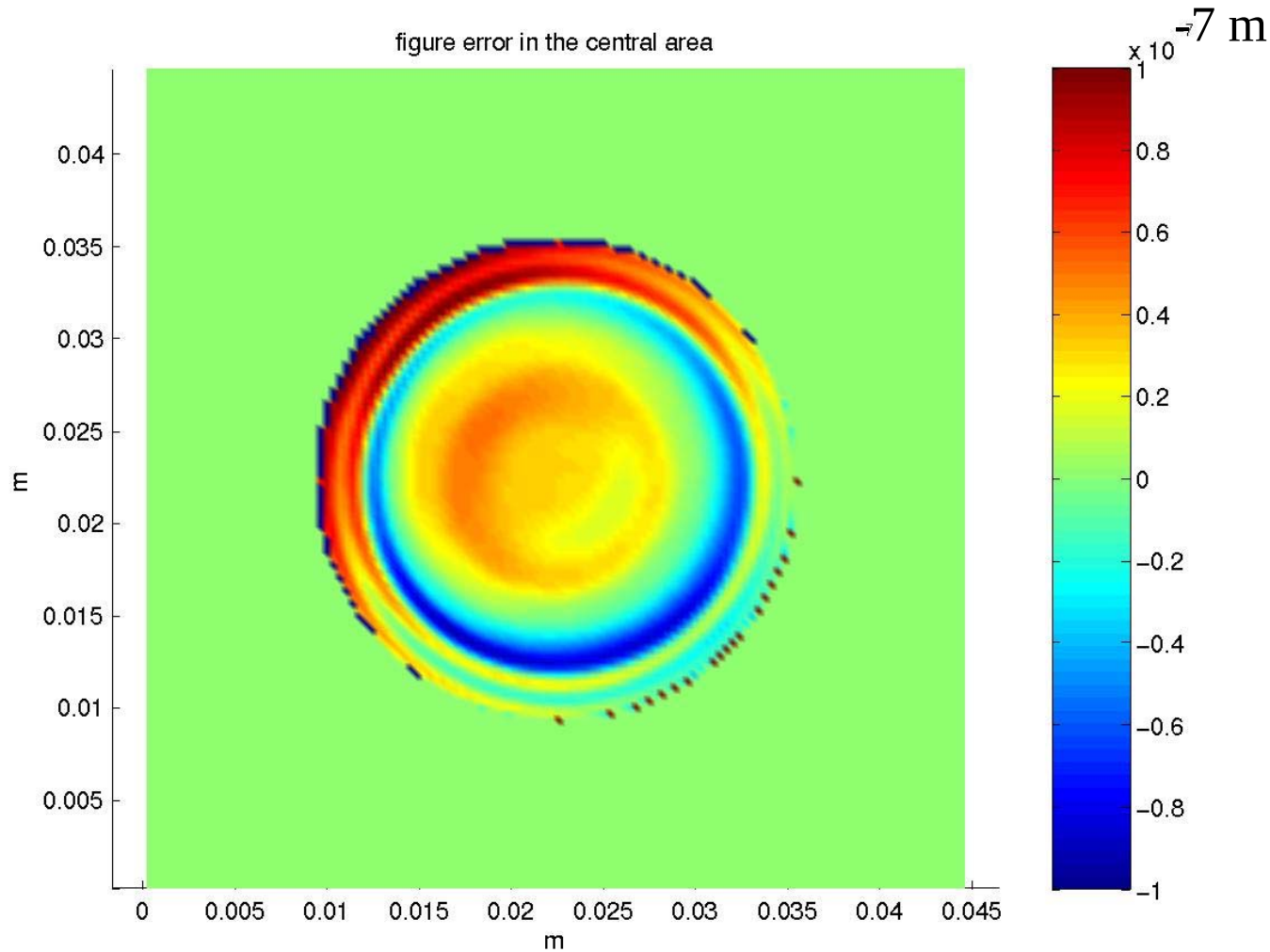
Mirror prototype analysis (Erika and Juri)

- Required and first prototype mirror shape



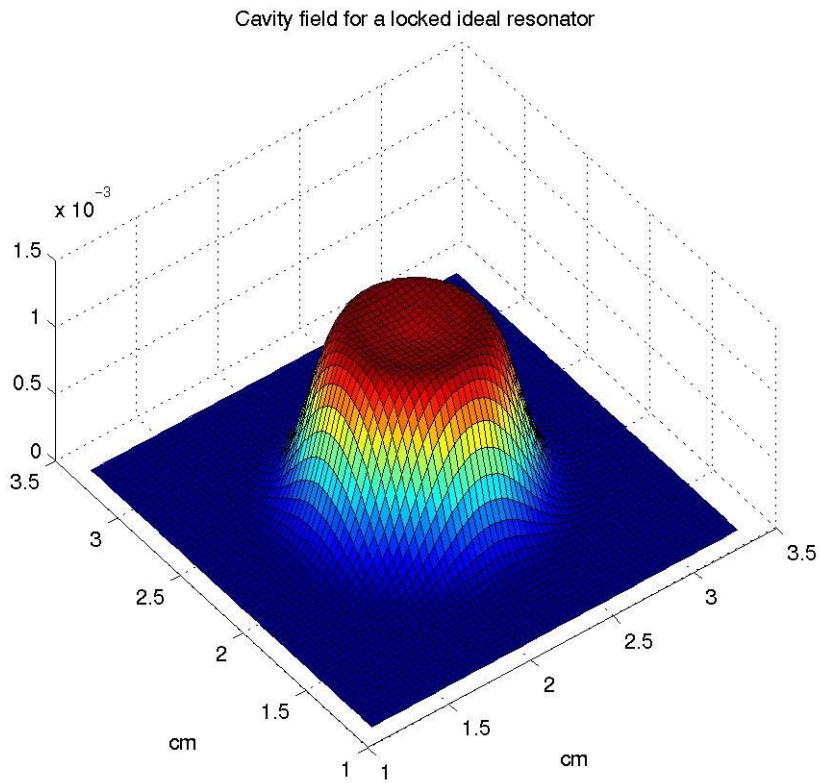


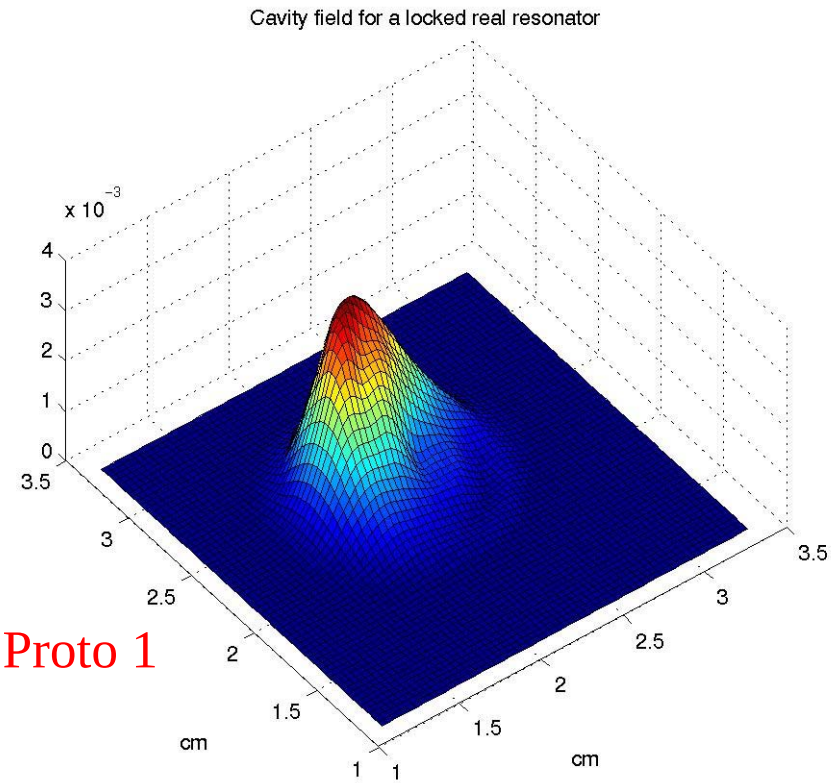
Deviation from ideal (first proto)



Simulated effects on beam profile

- Ideal and first prototype beam profile





Proto 1

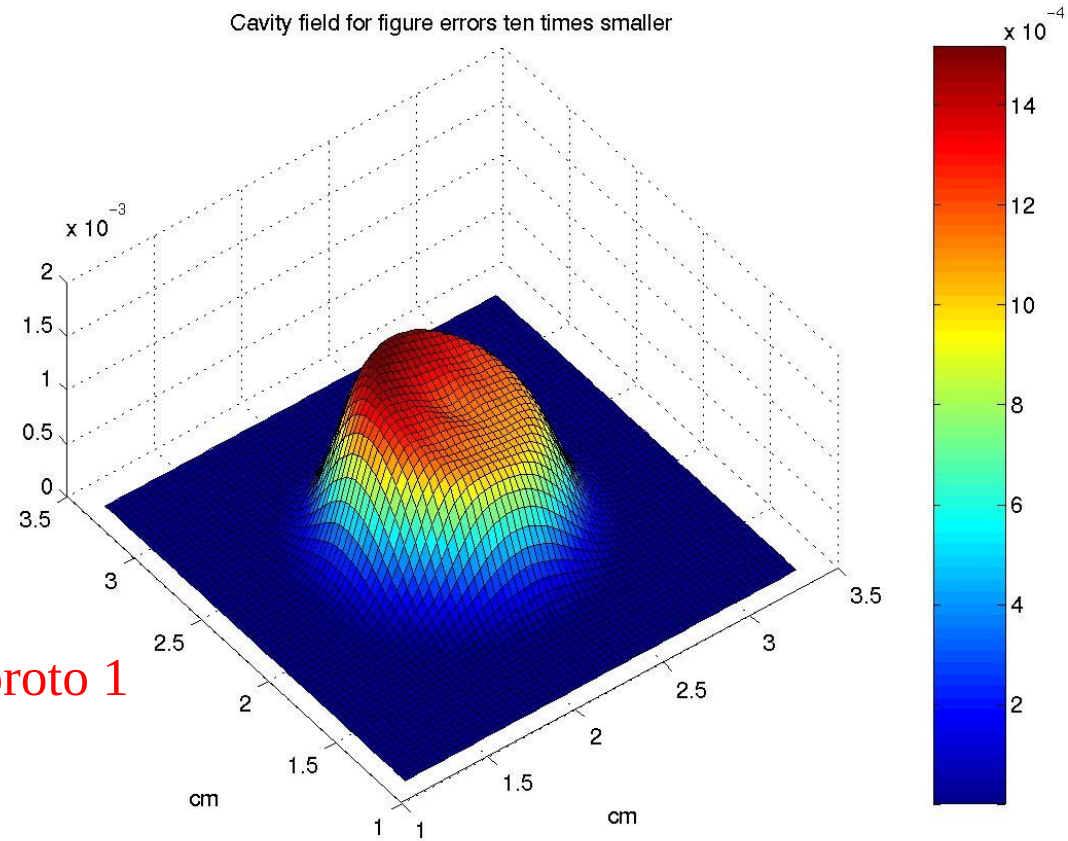
Erika's Alignment strategy

- Using perturbation theory
  to determine the ideal realignment

- Apply 10% of deviation on an ideal mirror
- Simulate beam profile of "improved" mirror
- Calculate correction tilt with perturbation theory, observe and optimize effect
- Apply 10x tilt on original mirror and calculate effect

Alignment strategy

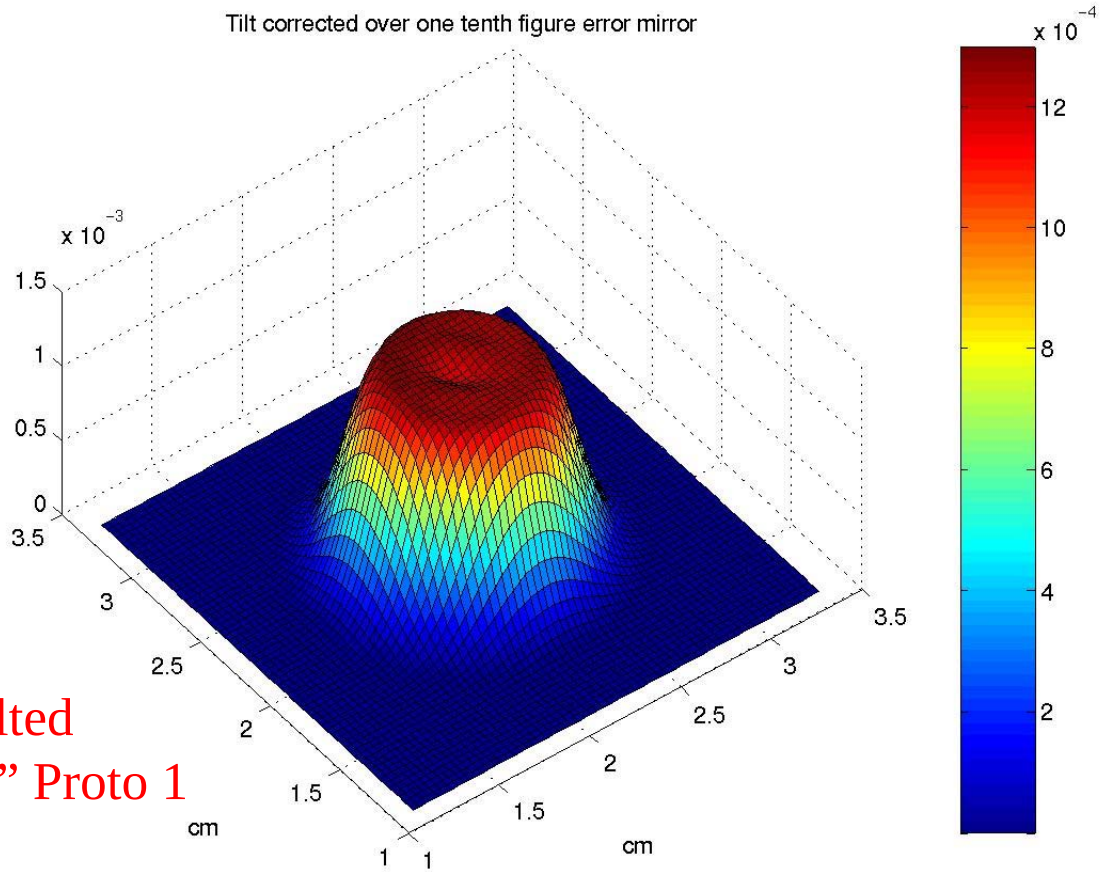
- Apply 10% of deviation on ideal mirror
- Simulate beam profile of “improved” mirror



“improved” proto 1

Alignment strategy

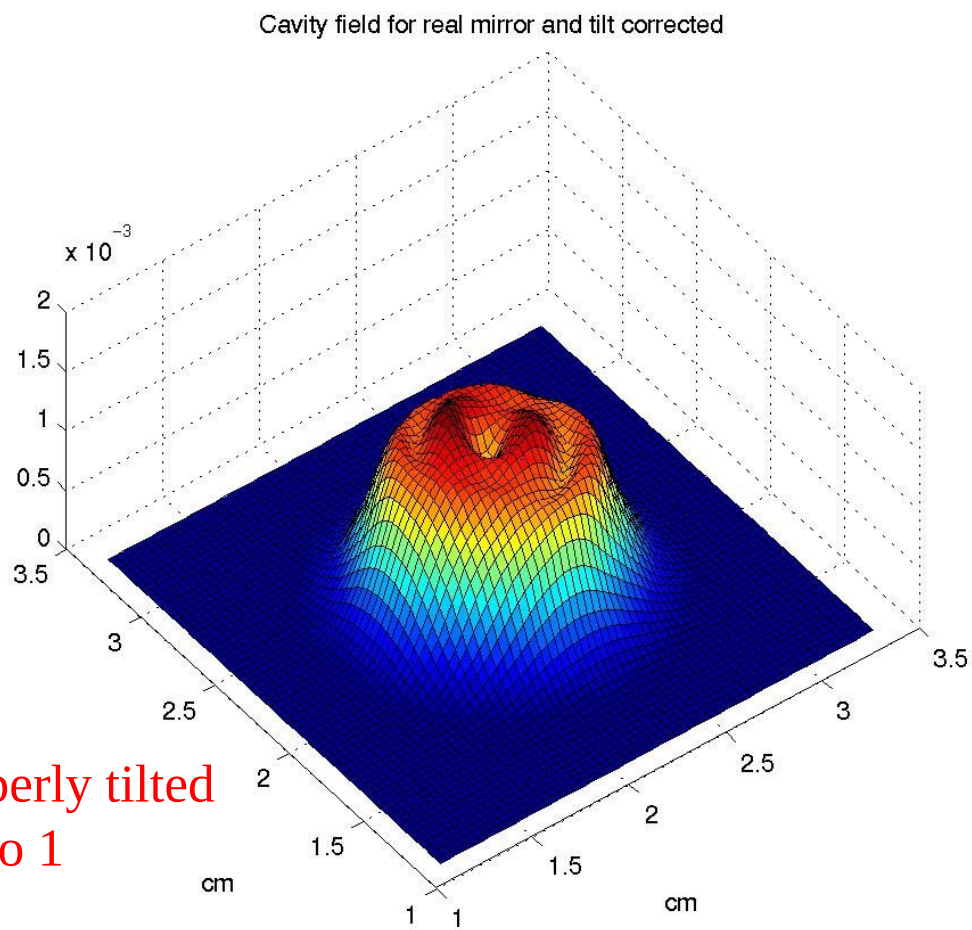
- Calculate correction tilt with perturbation theory, observe and optimize effect



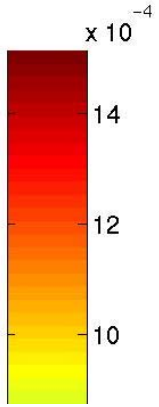
Properly tilted
"improved" Proto 1

Alignment strategy

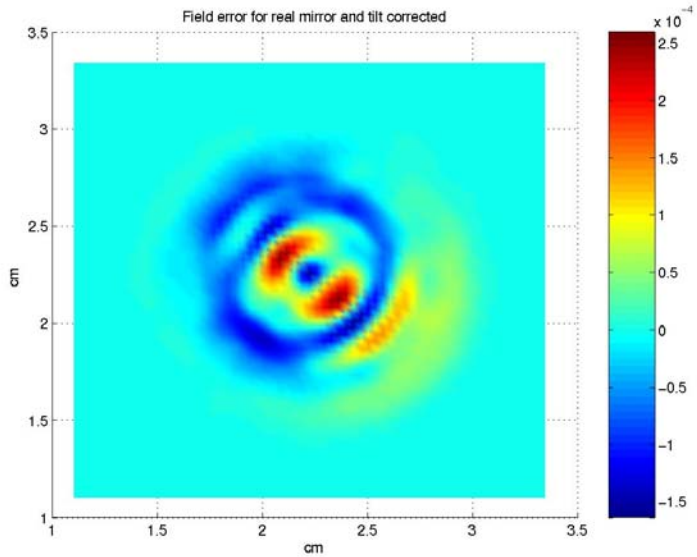
Apply 10x tilt on original mirror and calculate effect on beam



Properly tilted
Proto 1



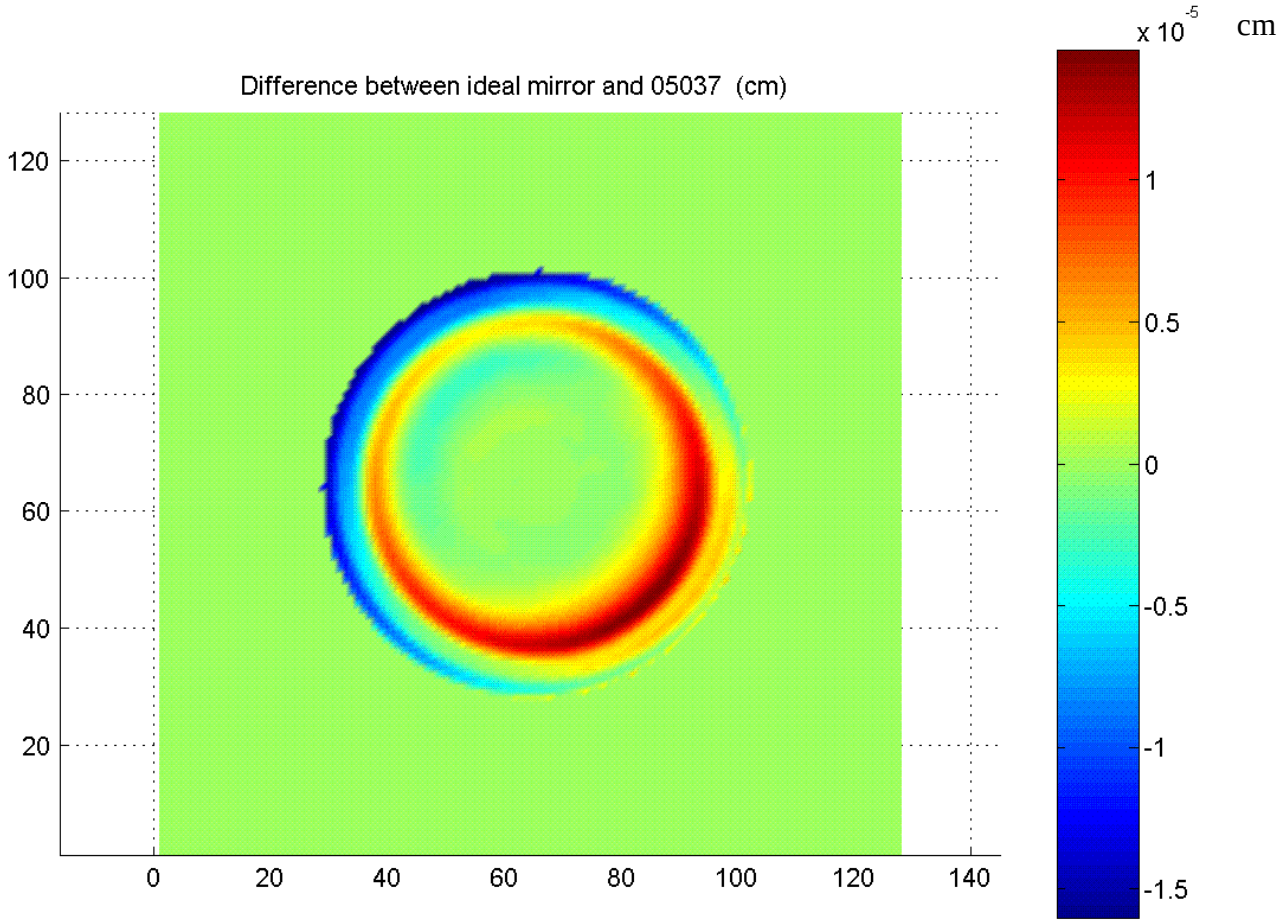
Variations from ideal beam profile



First production item

preliminary

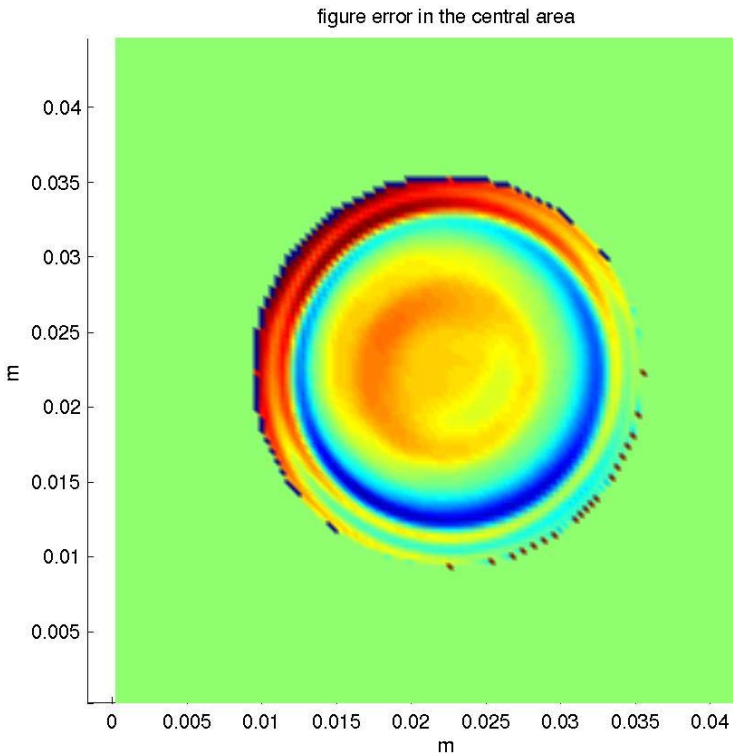
- Unfinished
- General coating only !
  no corrective coating yet ! ! !
- Deviations from ideal profile



First production item

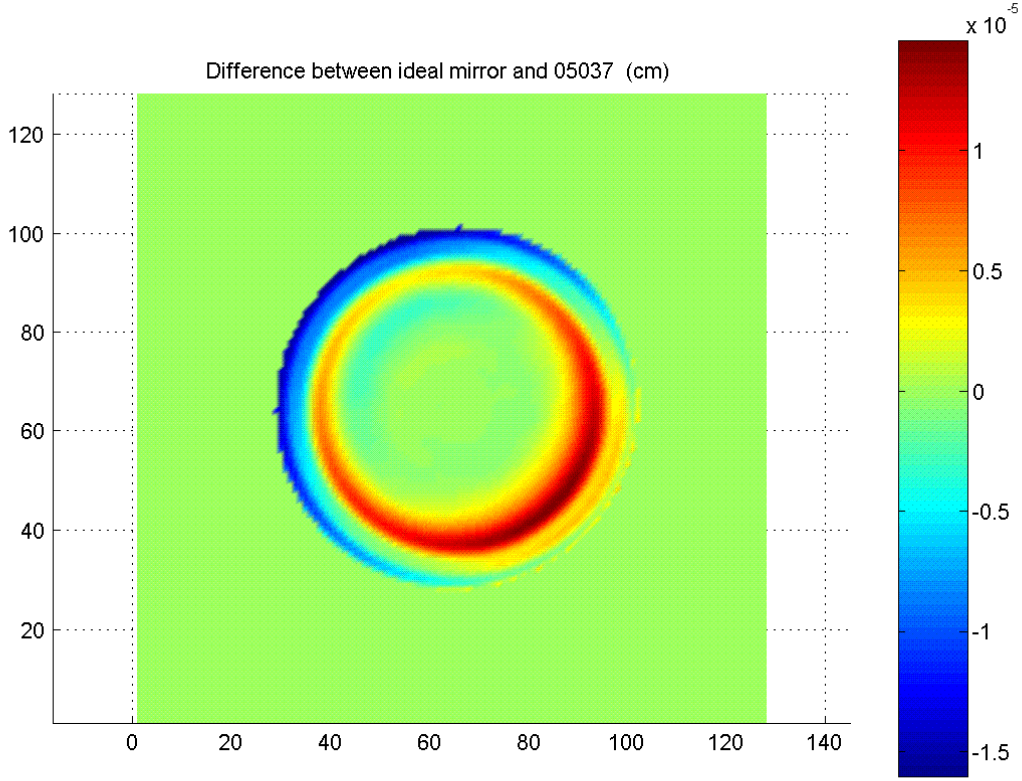
preliminary

Finished pre-prototype



This scale 50% finer

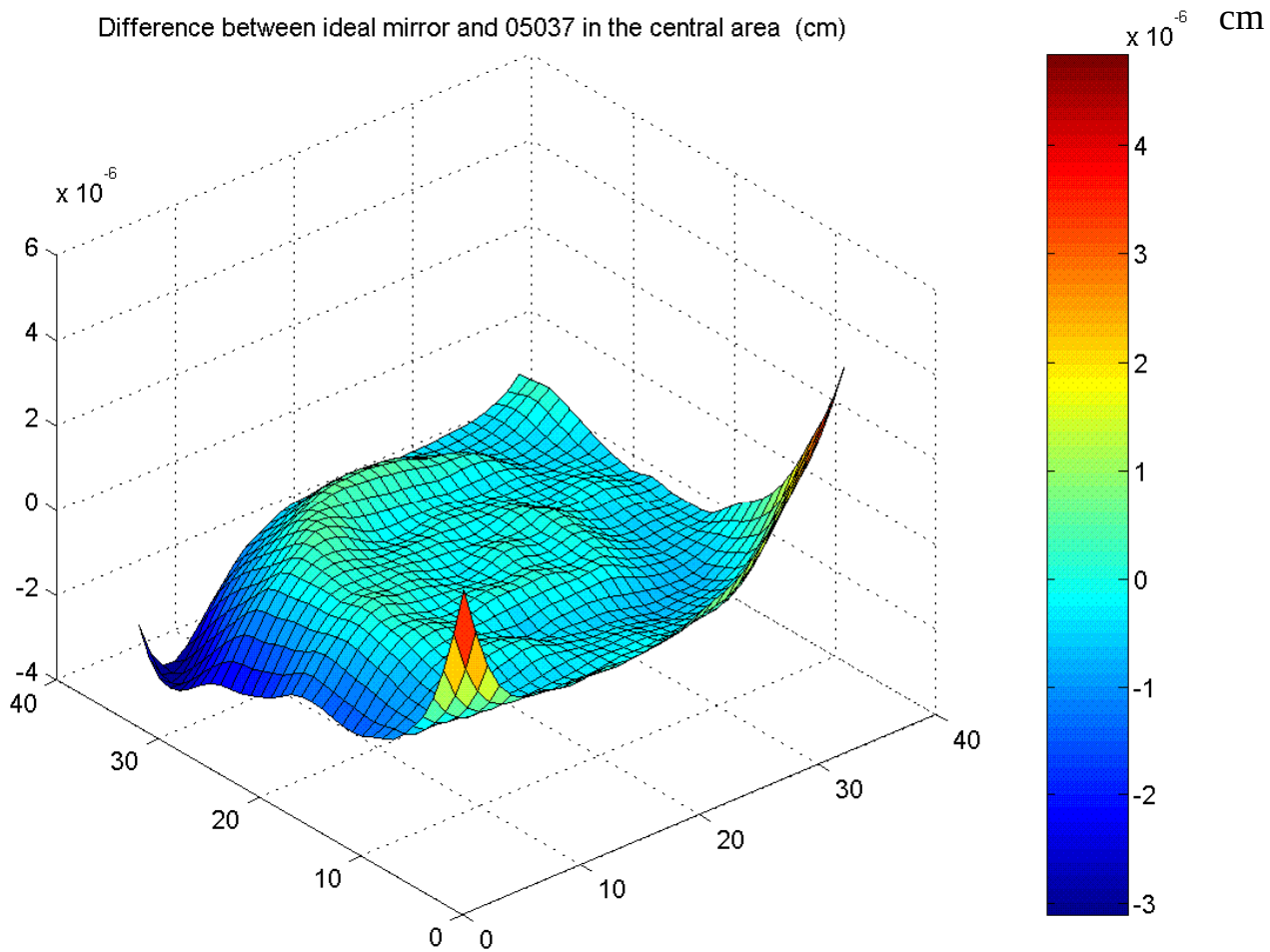
Uncorrected first item



First production item

preliminary

- Unfinished
- General coating only !
  no corrective coating yet ! !
- Deviations from ideal profile



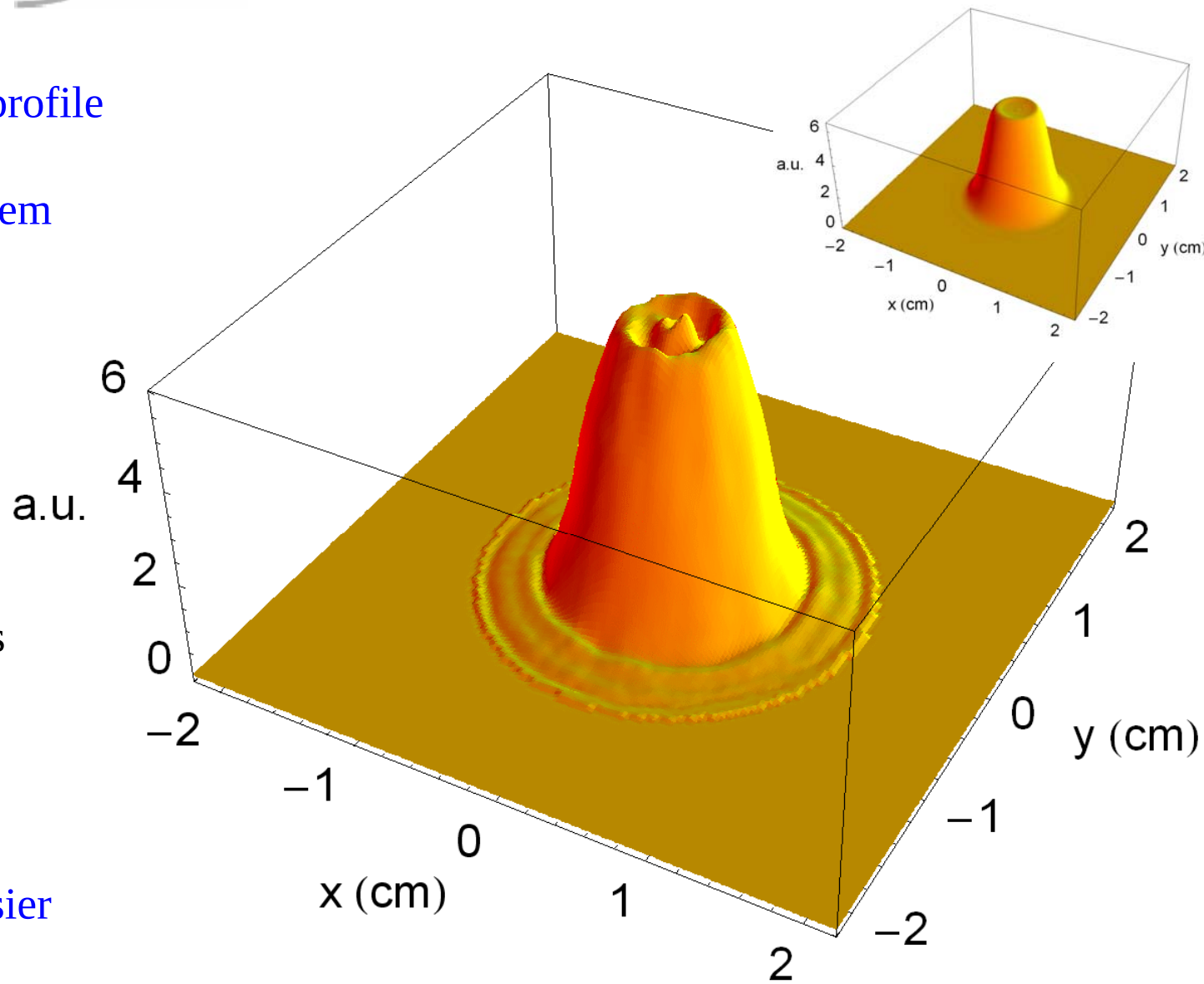
First production item

Calculated beam profile
With unfinished
First production item
MH mirror

The corrective
Coating steps
Is expected to
Further improve

Long long process
But approaching
Manufacturing
Success

Larger mirrors easier



Conclusions

- MH mirrors have been successfully manufactured
- Lots of problems but the production items will be greatly improved
- Even the first prototype would be satisfactory ! !
- Look forward for installation on interferometer of both first prototype and first production MH mirrors to verify the simulation results
- The MH beam interferometer will soon come back online and make a real test the new mirrors

Next steps

- Study the static and dynamic properties of the FT beams
- Study the problem of producing MH mirrors for concentric cavities
- Design a TN interferometer for MH mirrors