A new Phase-shift Microscope Designed for High Accuracy Stitching Interferometry

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Outline

1.1. Motivations

1.2. The goal and the solution selected

1.3. The way of how it was developed

2.The instrument :

- 2.1 : First prototype
- 2.2 : NanoPro Instrument

3. Results

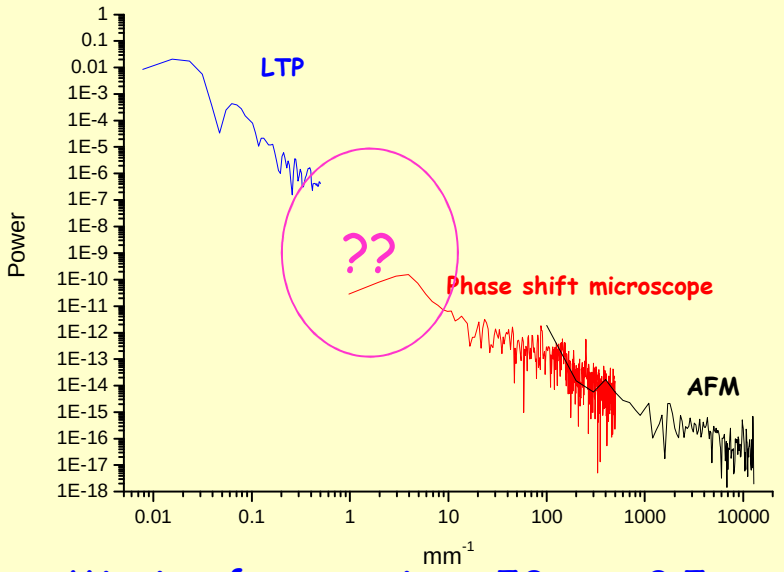
4. Conclusion

1.1 : Motivations : Improving measuring performances

1. The absolute goal :
   Diffraction limited optics
   at any wavelength $\Rightarrow$ Shape errors << 1 nm

2. Are we specifying what we can't measure ? (e.g. nanofocusing beamline)

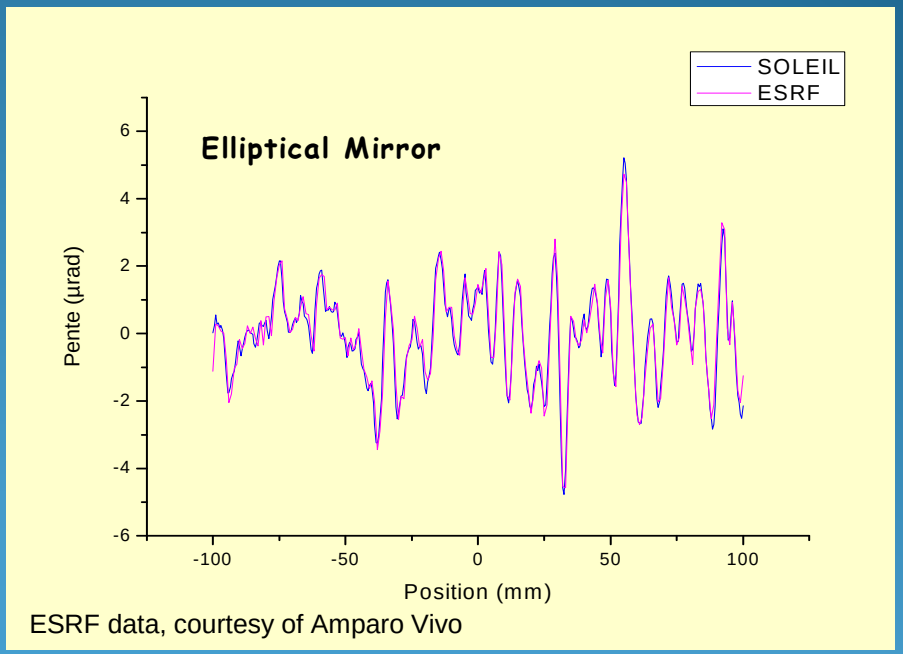
Spatial frequency coverage



→ Missing frequencies : 50 μm- 0.5 mm

PSD of a plane mirror of Metrolgy beamline

Local polishing side effects



ESRF data, courtesy of Amparo Vivo

↑ Frequency of defects increases ?

1.2 : Our goal :

→ Interferometry + stitching.

Needs:

1. Frequency range > 50 µm
2. Field > 5 mm
3. Precision < 1 nm
4. Sensitivity : the best !
5. Keeping curvature measurement

Therefore :

1. Optics control
2. Acquisition control
3. Computing and calculation controls

Manufacturers contacts

1. Taylor Hobson
2. Sensofar
3. Veeco
4. Zygo

The commercial solutions did not satisfy all our requirements

1.3 : Choice of developing the whole instrument

→ Control of all parameters: lightsource, optics, mechanical parts, computing and treatment.

Experiences :

- LTP : Home made LURE-SOLEIL
- Wave Front Sensor : Collaboration with Imagine Optic : for stitching measurements for strong curved mirrors and in situ measurements on beamline.

Collaborations with :

MBO-Metrology : M. Bray

EOTECH : J.J. Servant et G. Koeller

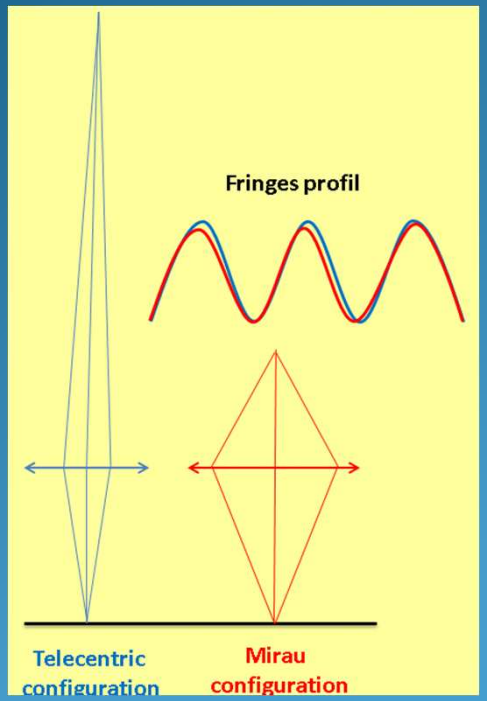
Funding : îledeFrance + SOLEIL SYNCHROTRON

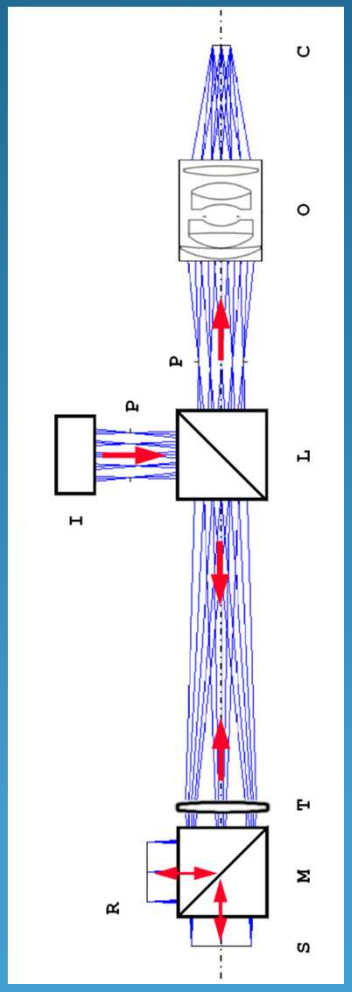
2.1 The instrument : First prototype :

Telecentric objective

- **Distortion limited**
- Fringes deformation limited
- Larger field : > 10 mm
- Larger depth of field

- Calculated by M. Bray





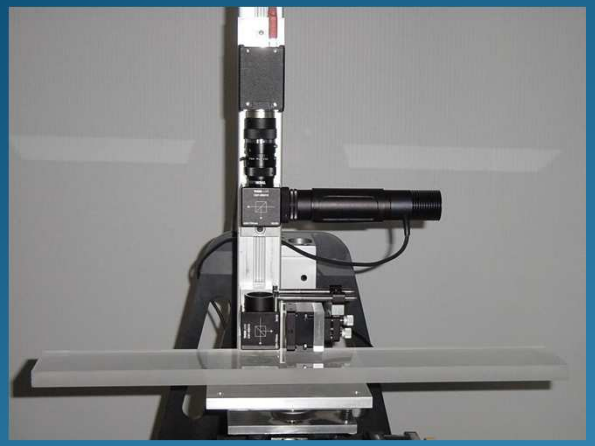
Michelson configuration

Light source

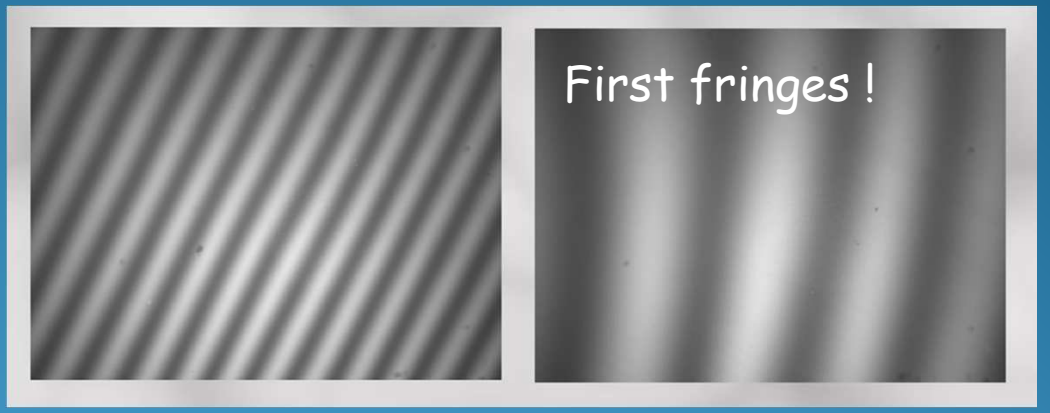
- Michelson interferometer ⇒ OPD=0
- We can use a polychromatic source
- Also helps in finding the right focusing distance, no speckle effects
- LED @ 505 nm
- No heat !
- $\Delta\lambda$ = 10 nm (with a filter) :

R	: Reference surface
S	: Sample
M	: Mixing cube
T	: Telecentric lens
L	: Illumination cube
I	: Illumination source
P	: Stop (Pupil)
O	: Objective lens
C	: Camera

2.1. First prototype (2)

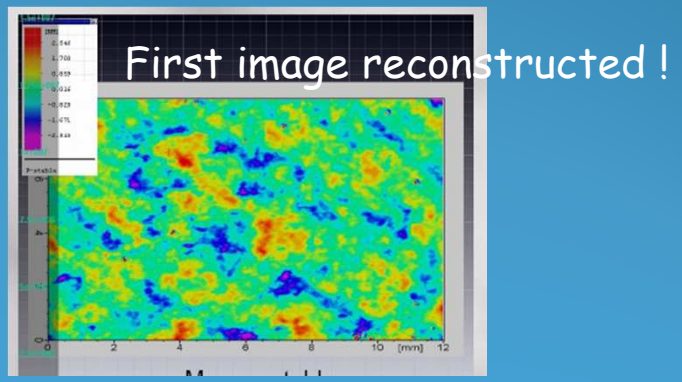


Chosen Software
- Optosurf software developed by EOTECH for phase shifting driving and image acquisition.
- Use of the phase unwrapping



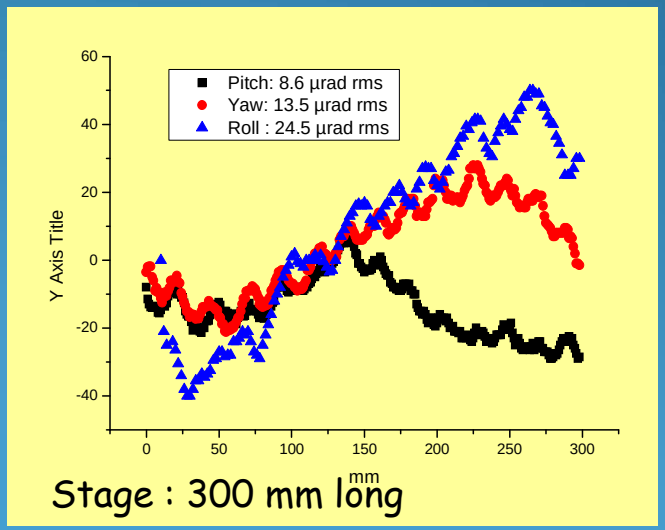
First prototype: (July 2010)

- ✓ Validation of the objective
- ✓ Validation of the light source.
- ✓ Validation of the focus system
- ✓ Test of repeatability
- ✓ Validation of the acquisition control
- ✓ Field size 12 X 16 mm^2 (1 pix = 20 μm)

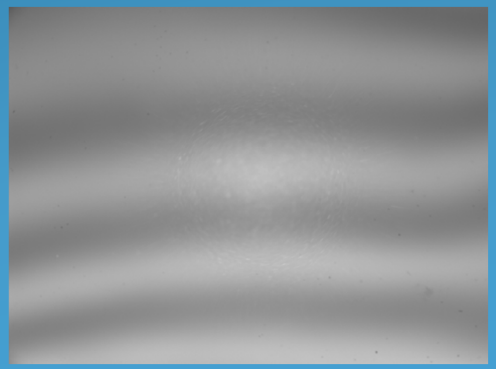


2.2 : The instrument : Second prototype:

- Optics @ λ/20 (special design)
- CCD camera : 780X580 pix,
- Athermal objective lens
- Dedicated room : temperature and humidity control.
- Ability of using either
  - EOTECH Optosurf sofware
  - MBO metrology software for independent treatment
- Complete modularity for easy upgrade of any element



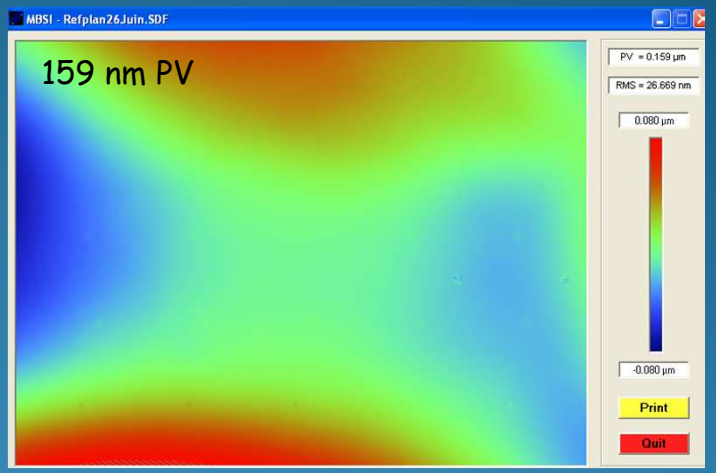
Stage : 300 mm long



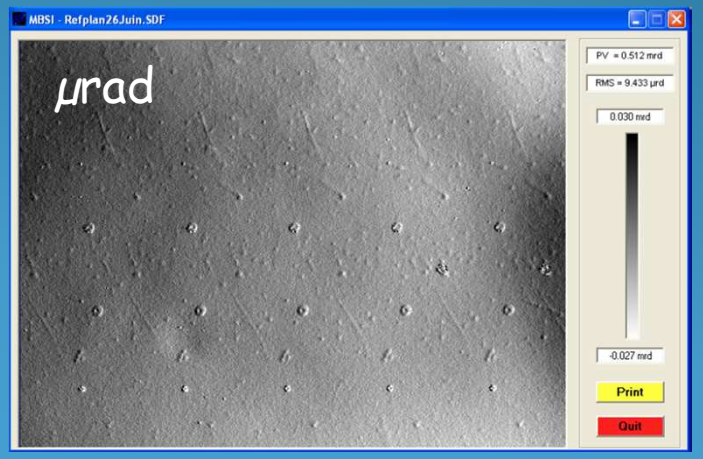
Non homogeneous illumination
⇒ contrast varies in the field

3.1 : Results : repetitivity first ! Then reference calculation

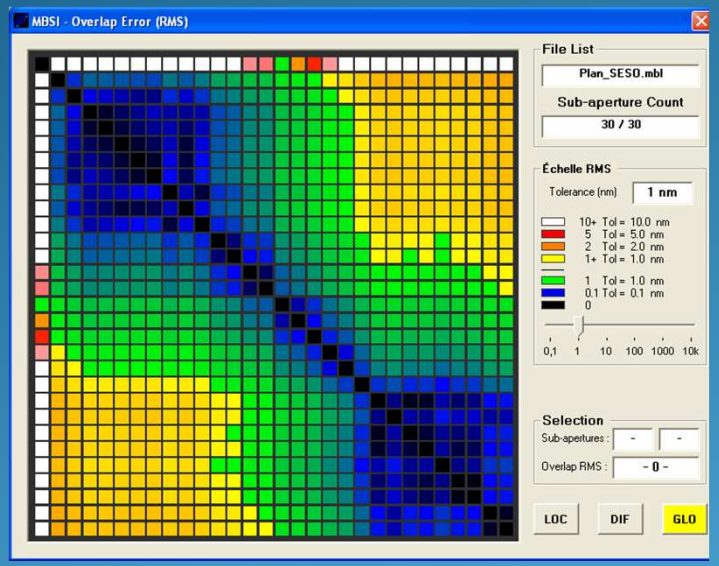
Reference calculation



26 nm rms, 9 µrad rms



Repetitivity : Overlap Errors



No filters used !!!

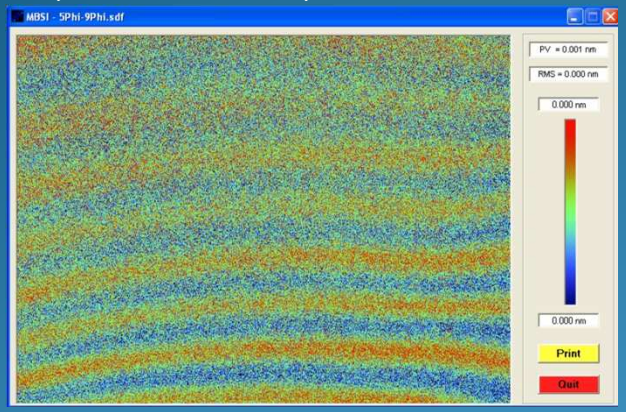
Reference mounting must be upgraded and distortion evaluated

3.2 : Results : Phase shift correction

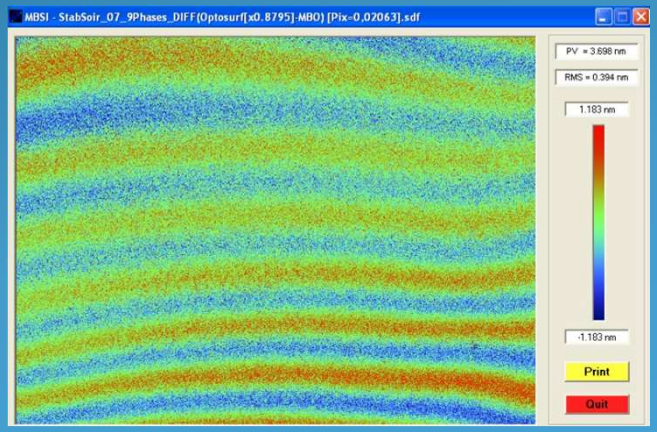
For the moment only linear step correction → Fringes needed !!

MBSI phase correction :

9 phase shifts – 5 phase shifts : 0.001 nm PV !



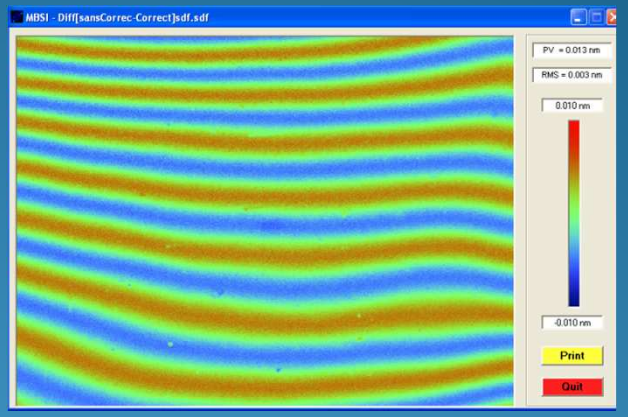
MBSI – Optosurf : 3.7 nm PV



9 phase shifts

MBSI phase correction :

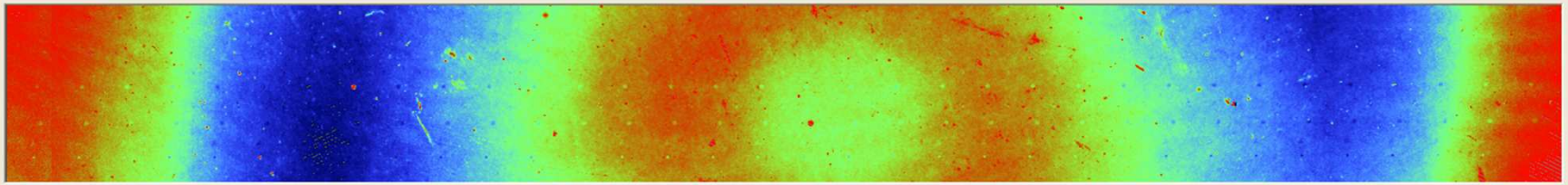
With – without phase shift correction 0.013 nm PV



- Phase shifts correction must be optimized
- How many phases ?
- Vibrations ?

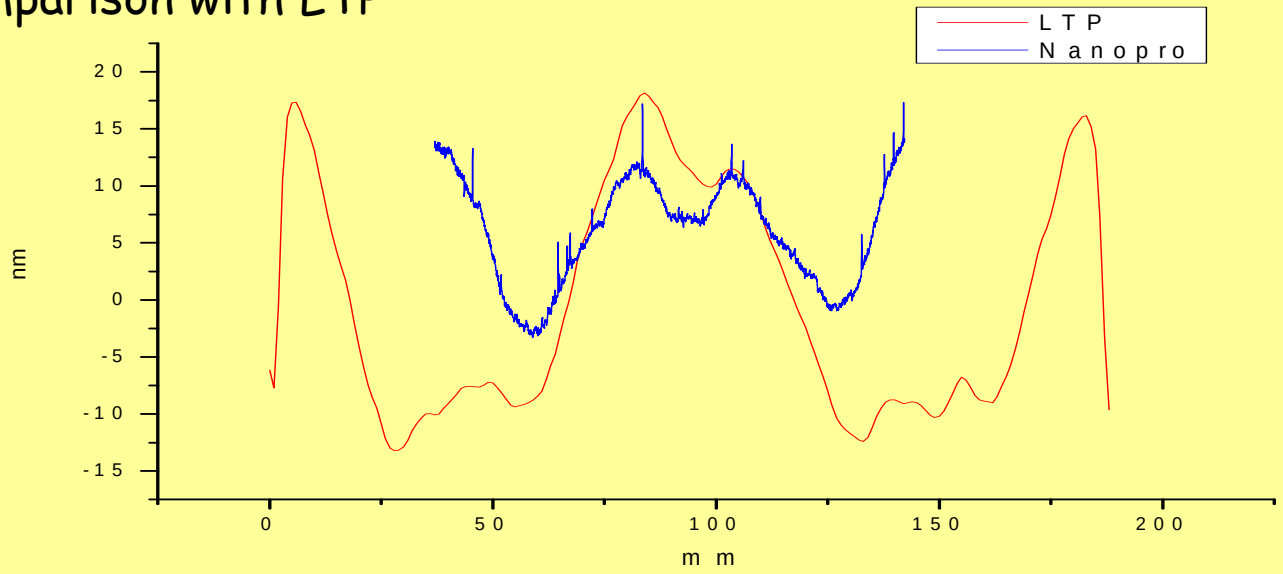
3.3.1 : Results on Stitching procedures :

Optosurf stitching mirror 4.8 nm rms



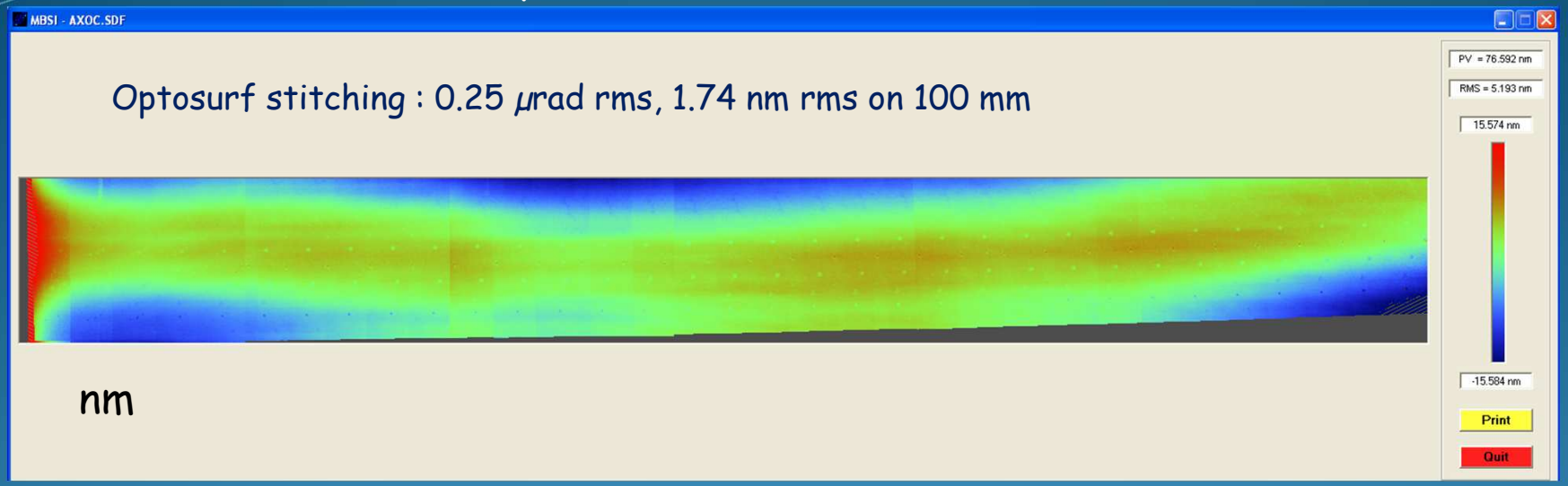
90 mm long

Comparison with LTP

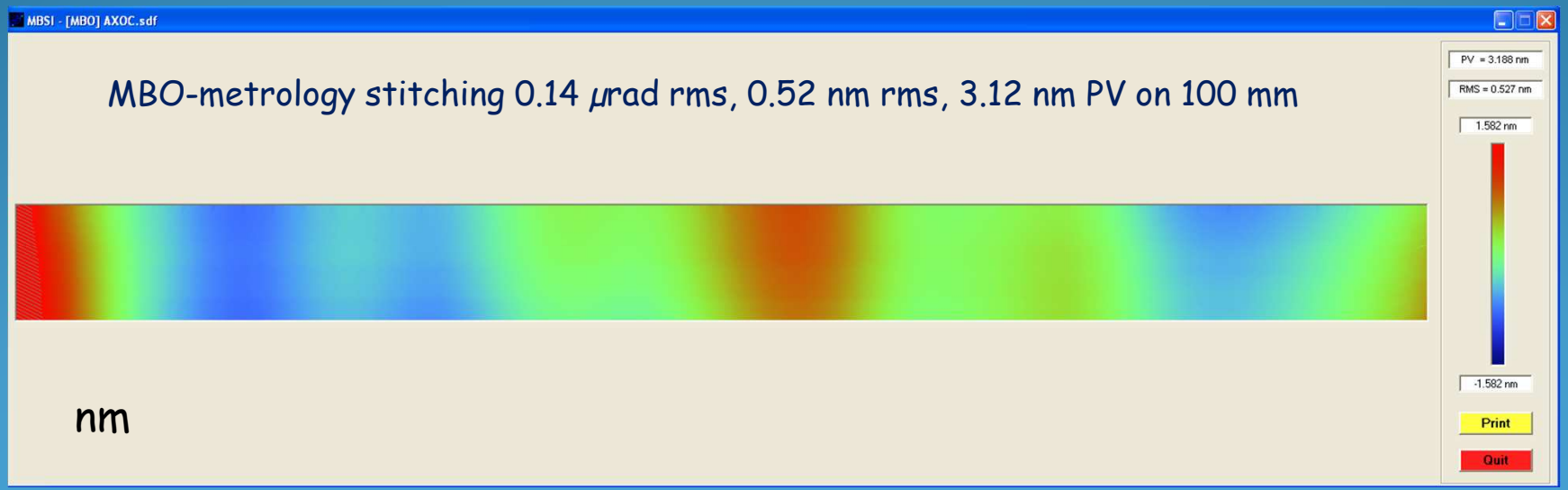


3.3.2 : Results Stitching procedures AXOC mirror :

NanoPro : 135 mm steps : 3 mm



LTP : 0.14 µrad rms, 0.89 nm rms, 3.1 nm PV on 150 mm



4. : Conclusions

- ✓ A versatile instrument for research !
- ✓ In controlled environment
- ✓ Effective vibration damping ???

  Still needs improvements
- ✓ Illumination uniformity correction
- ✓ Phase shift linearity correction
- ✓ Curvature of the reference unknown

  to be compared to LTP measurements

- ✓ 2 commercial stitching procedures under test +

  + 1 under development (talk of François Polack).

Round Robin measurements to be considered !!!

5. Aknowledgments :

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- Sylvain Brochet, Gilles Cauchon, Blandine Capitanio (Optics Group)
- Steve Duigou and Yan Rahier (Building group)
- Amparo Vivo, Optics group ESRF

Thank you for your attention !