REOSC

# DEFLECTOMETRY APPLIED TO FREEFORM AND LARGE OPTICAL SURFACE METROLOGY

## ELBERETH 2020

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Renaud MERCIER YTHIER

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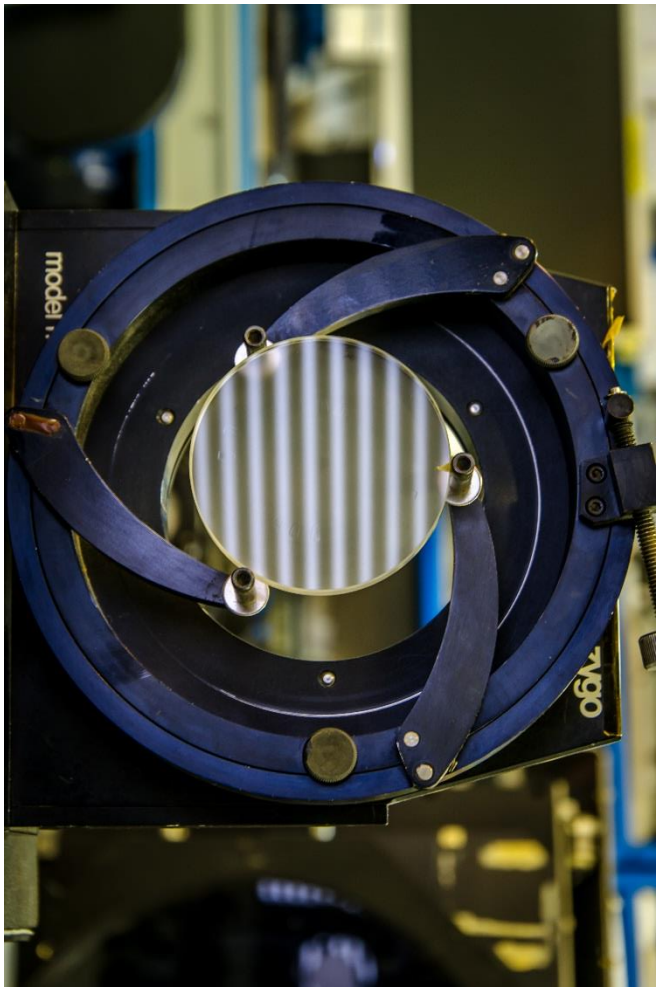
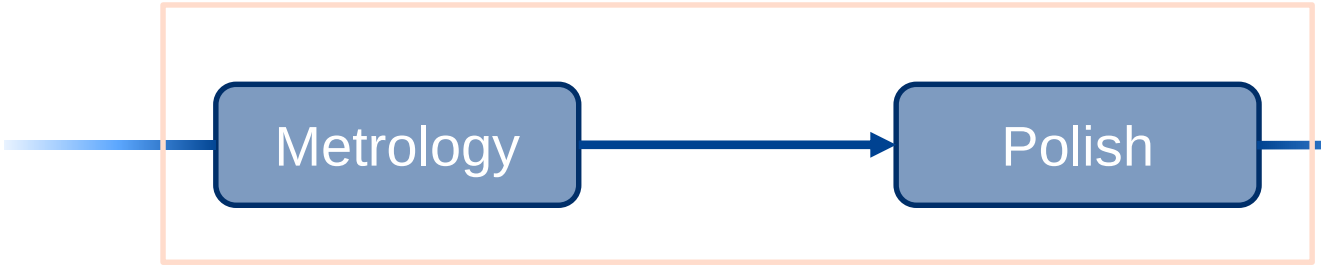


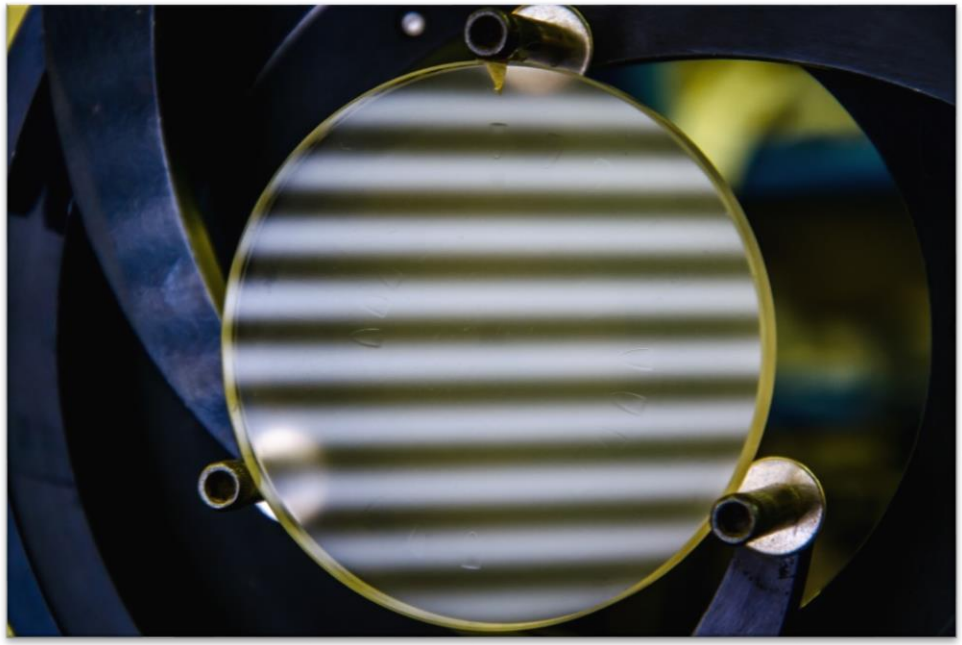
# Sommaire

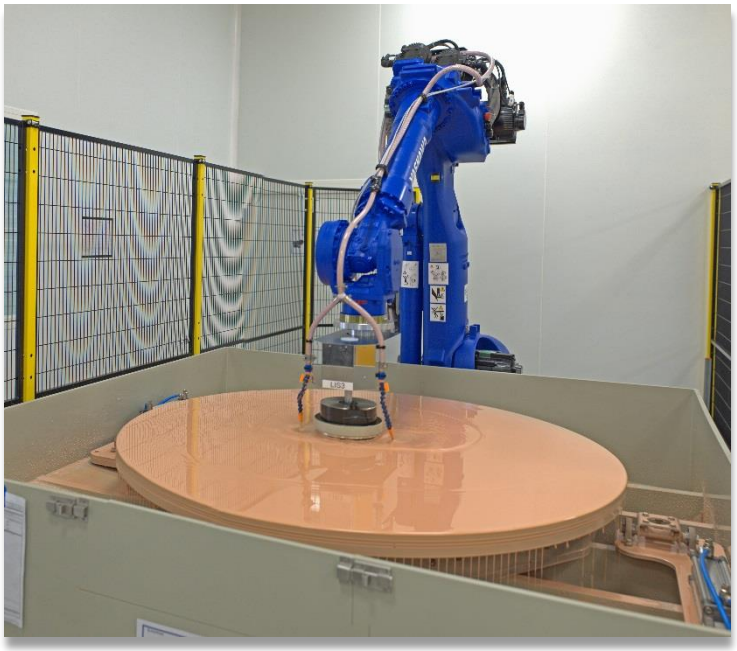
# 1


# OPTICAL FABRICATION

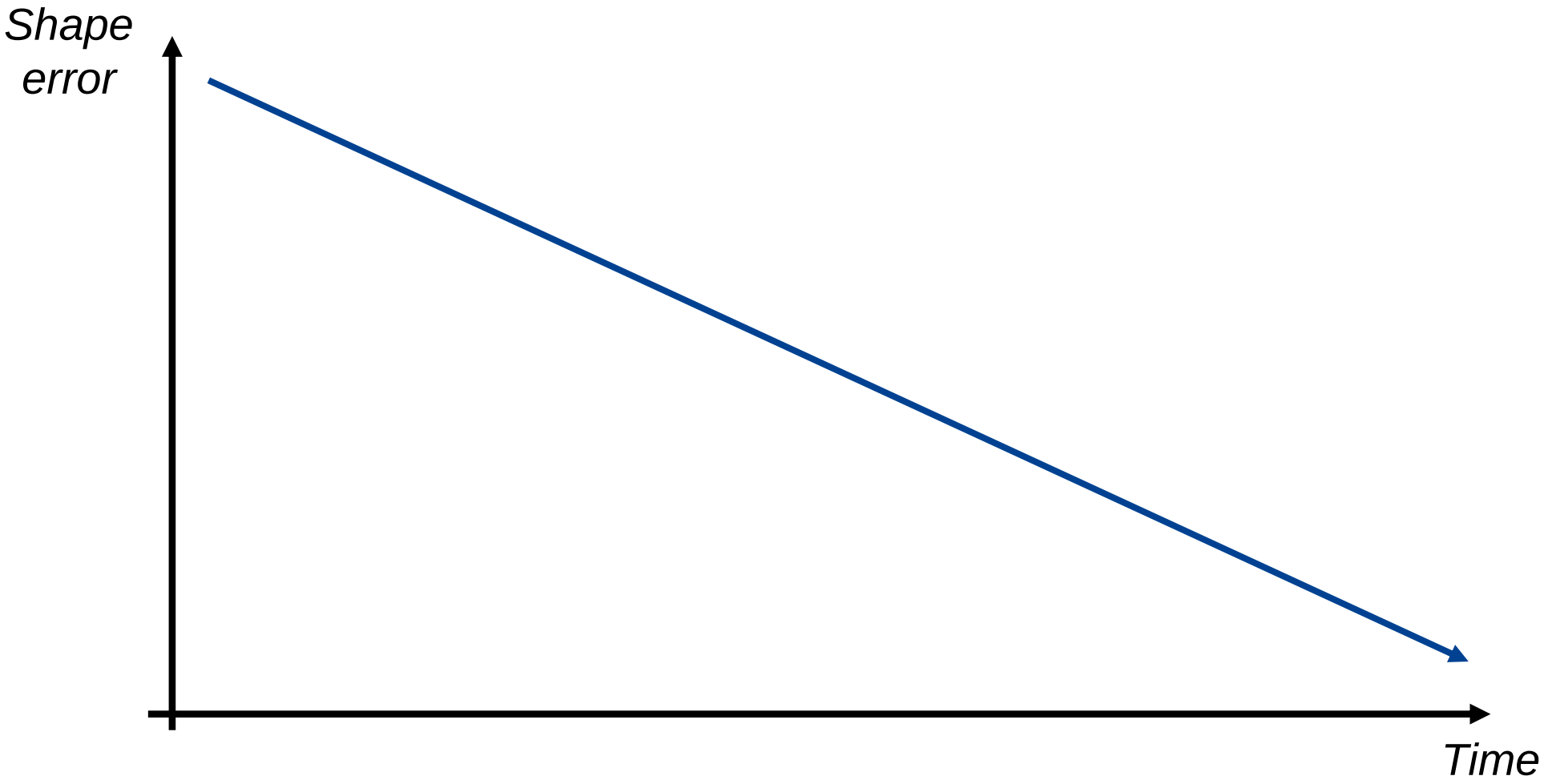
# Optical fabrication : an iterative process





# Polishing progress : large optics



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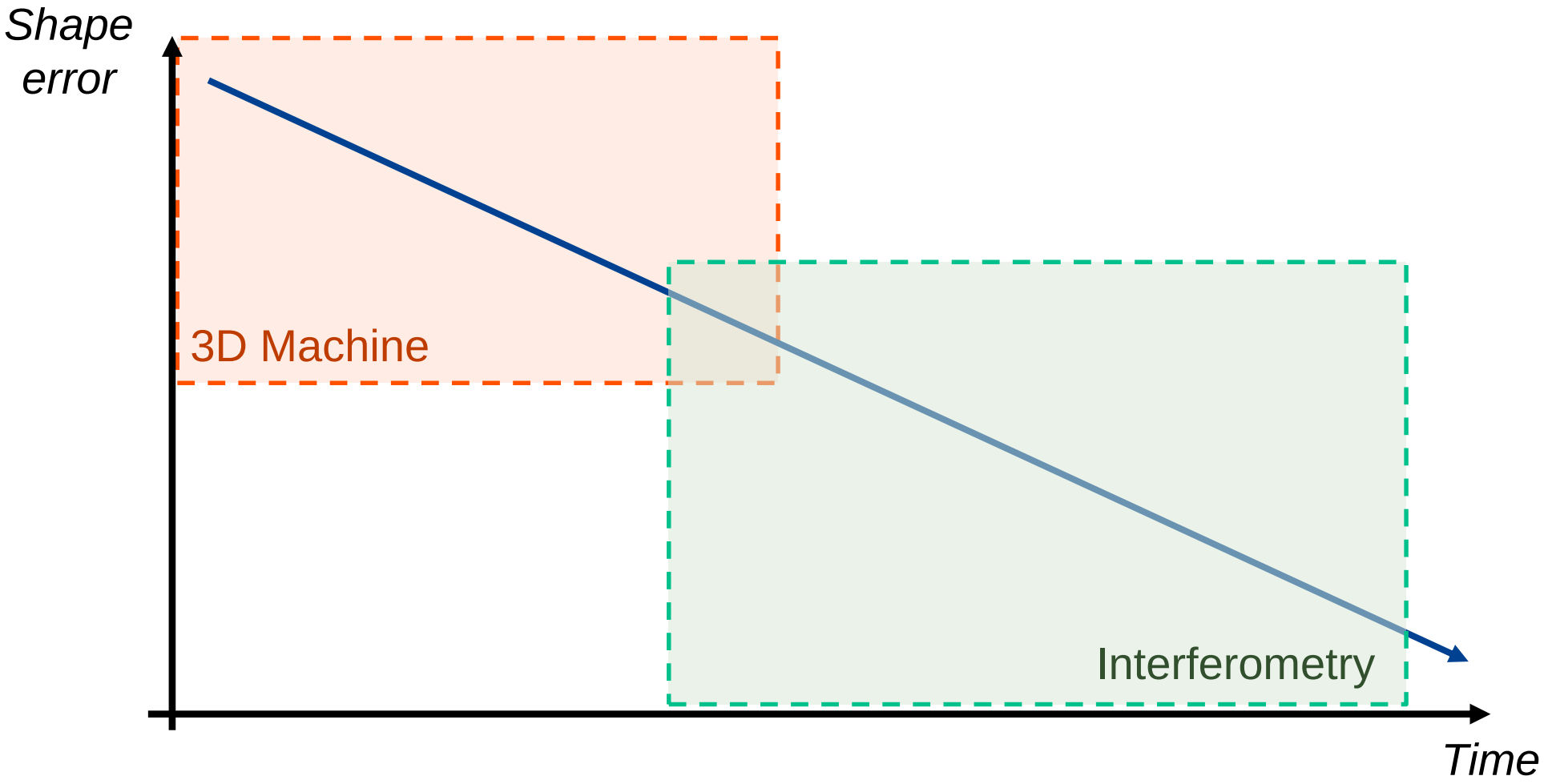

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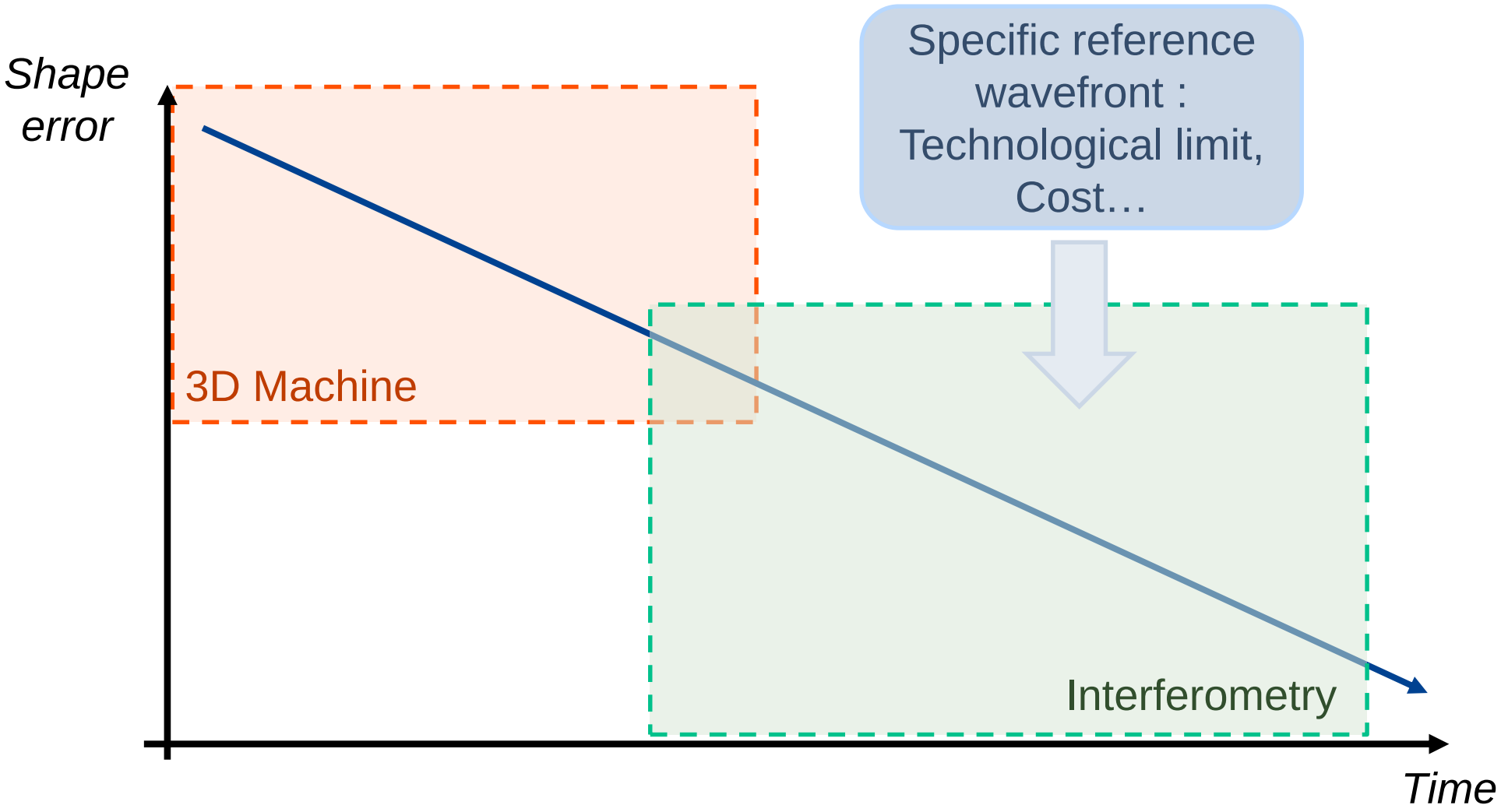

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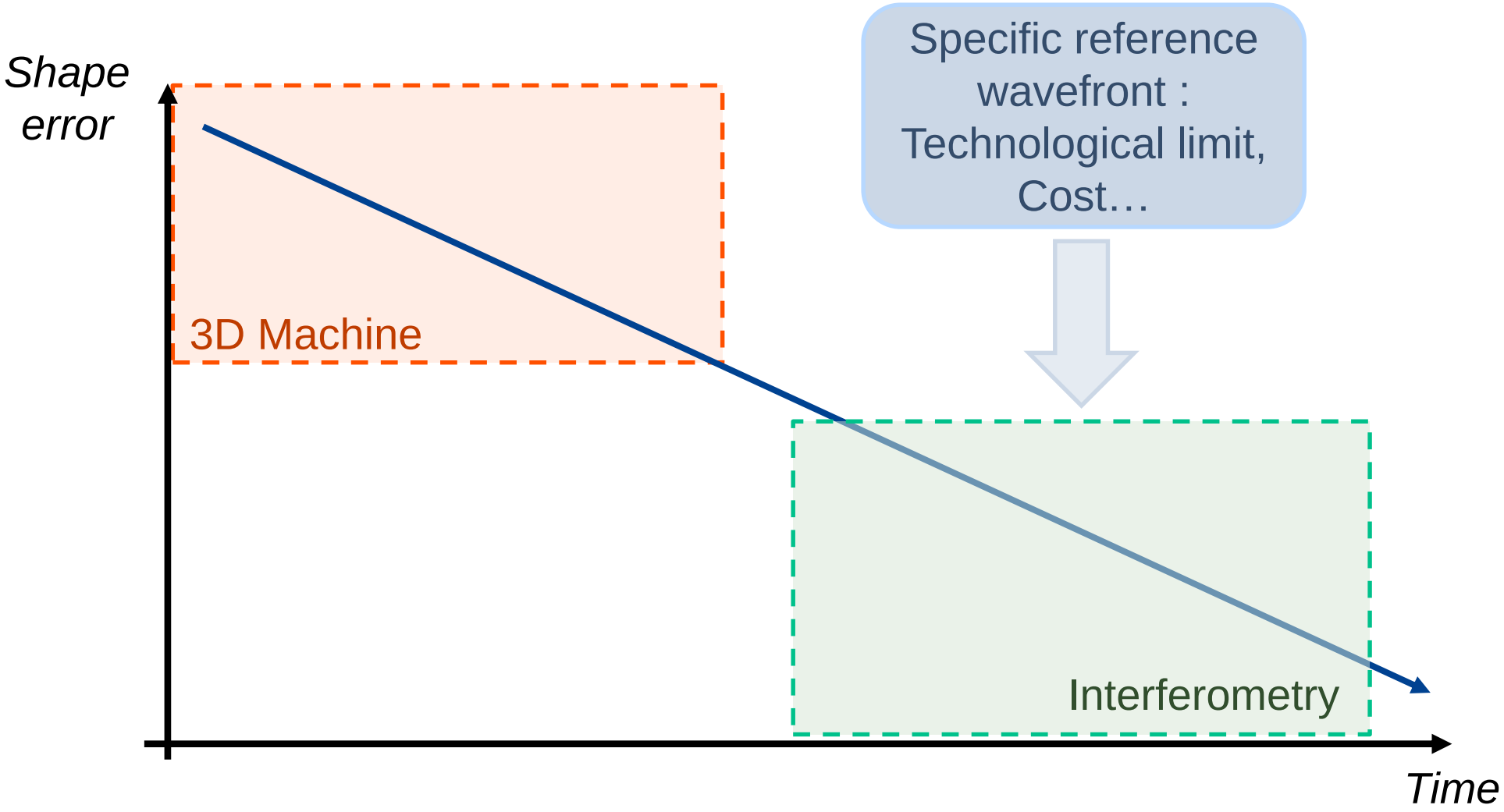

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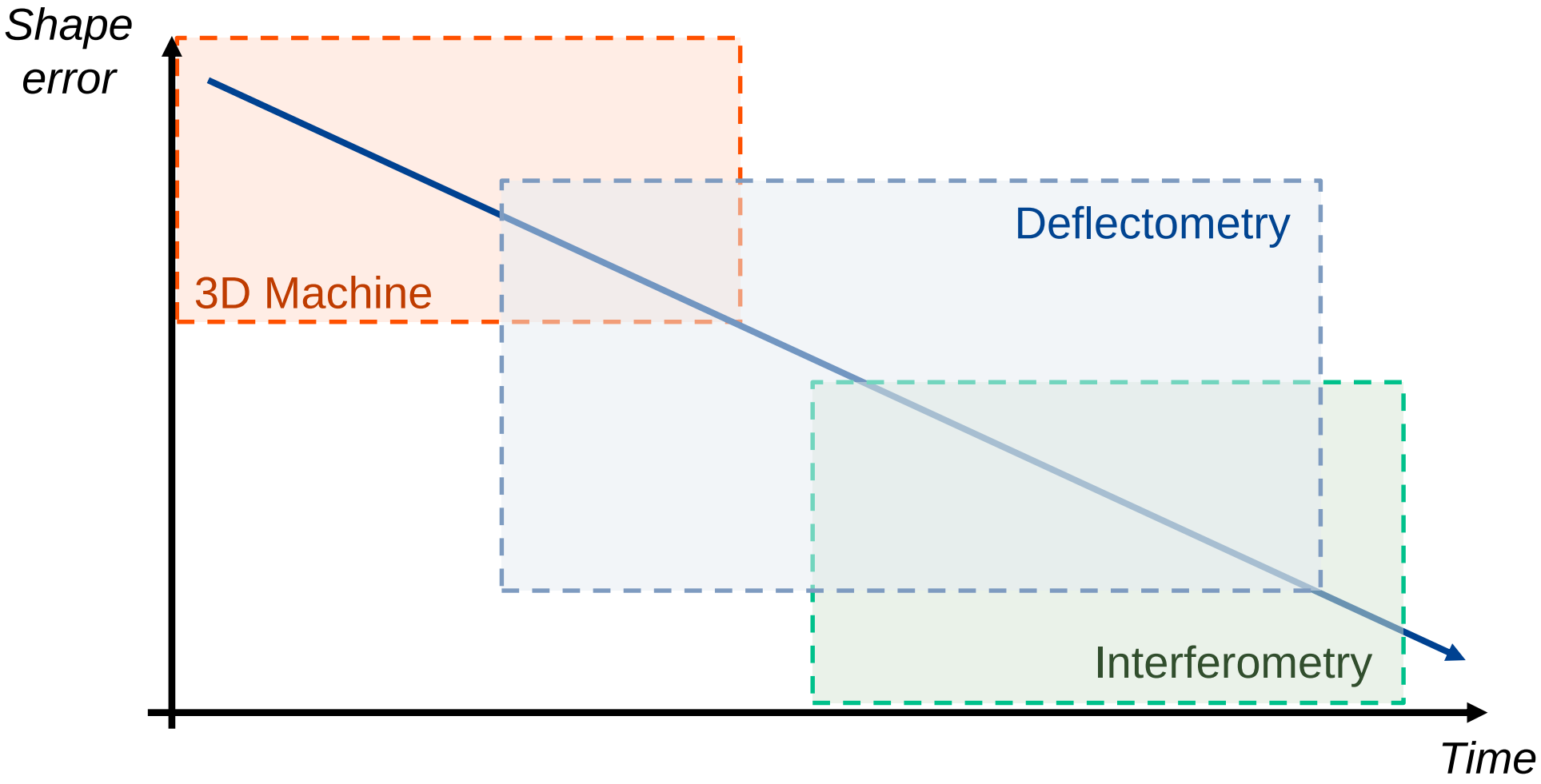

# 2


# DEFLECTOMETRY : PRINCIPLE

# Deflectometry : Principle

Extract a mirror's shape from a pattern's reflexion

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**Image from** *Phase Measuring Deflectometry: a new approach to measure specular free-form surfaces*, Markus C. Knauer, Jurgen Kaminski and Gerd Hausler

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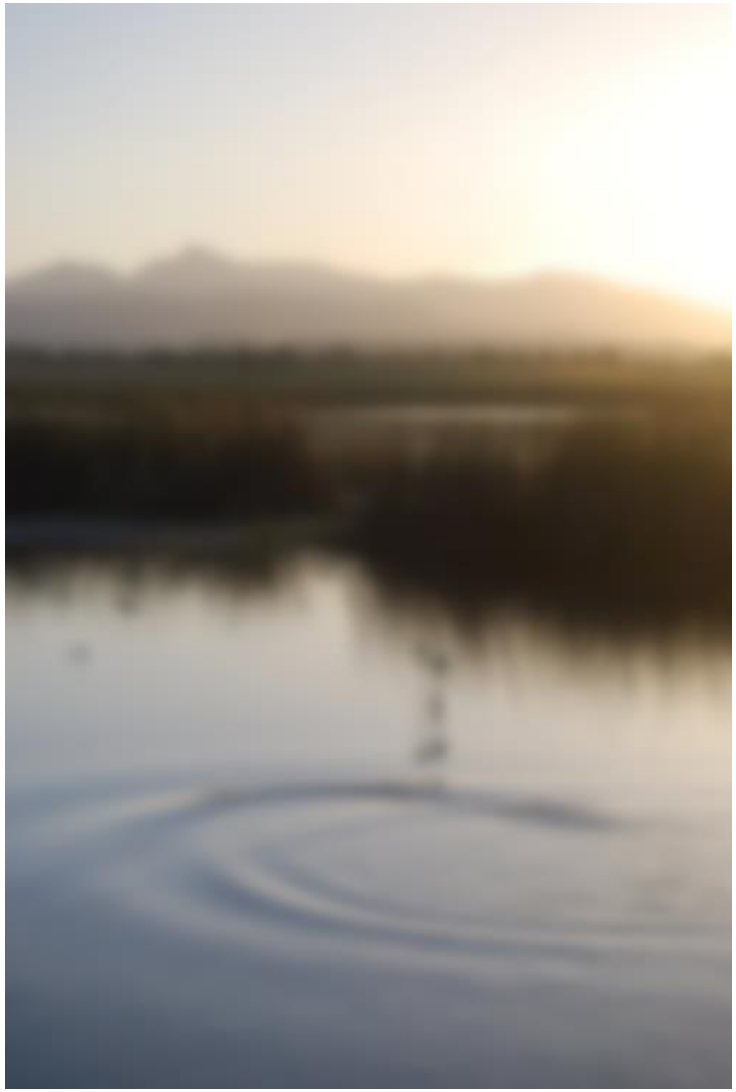

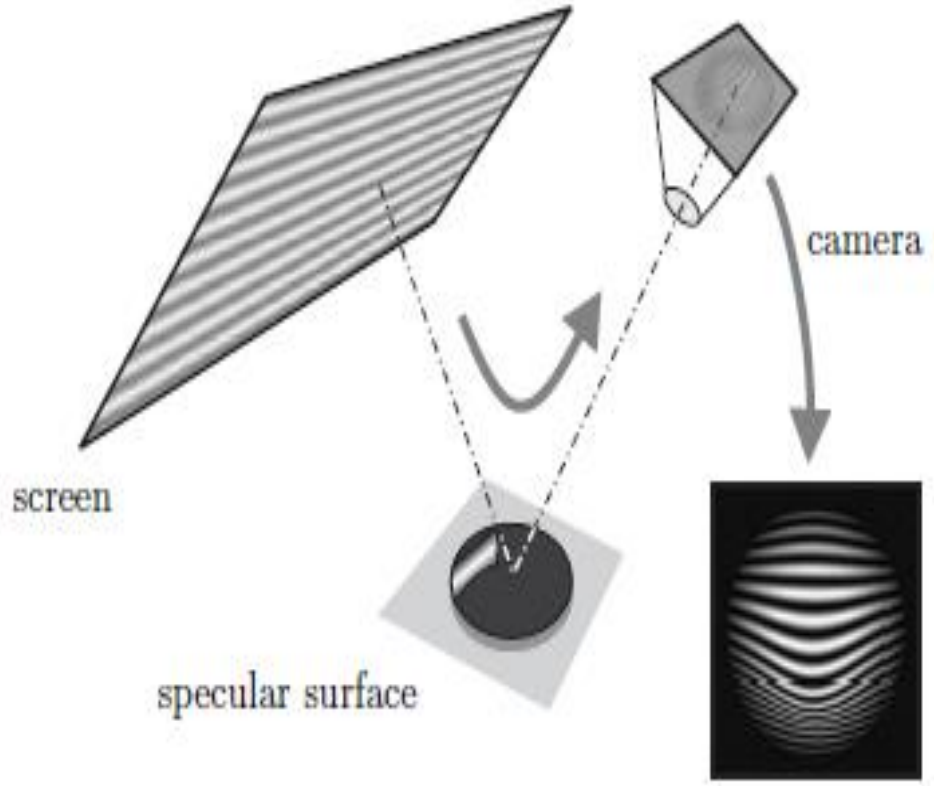

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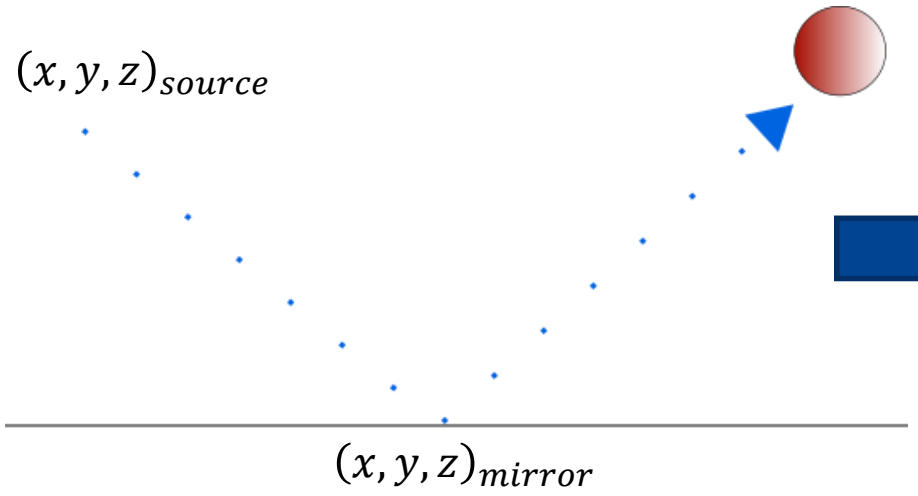
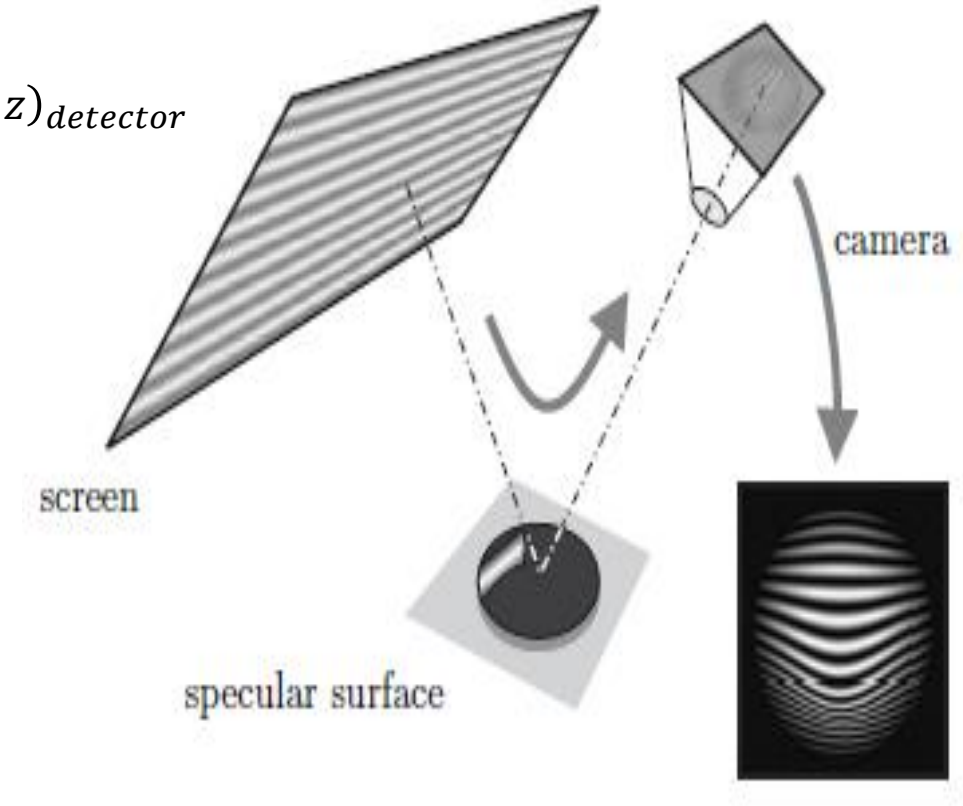
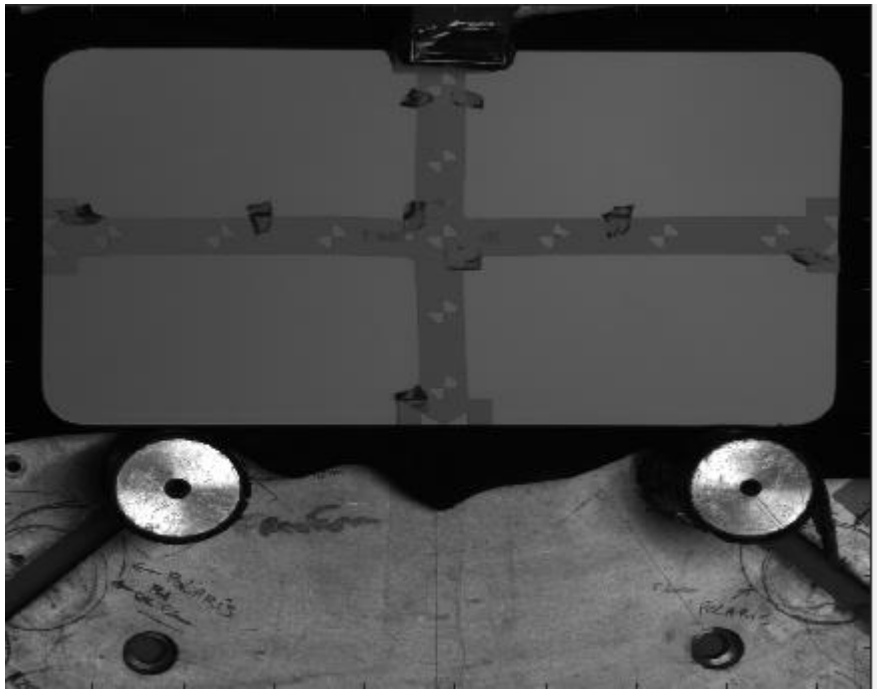
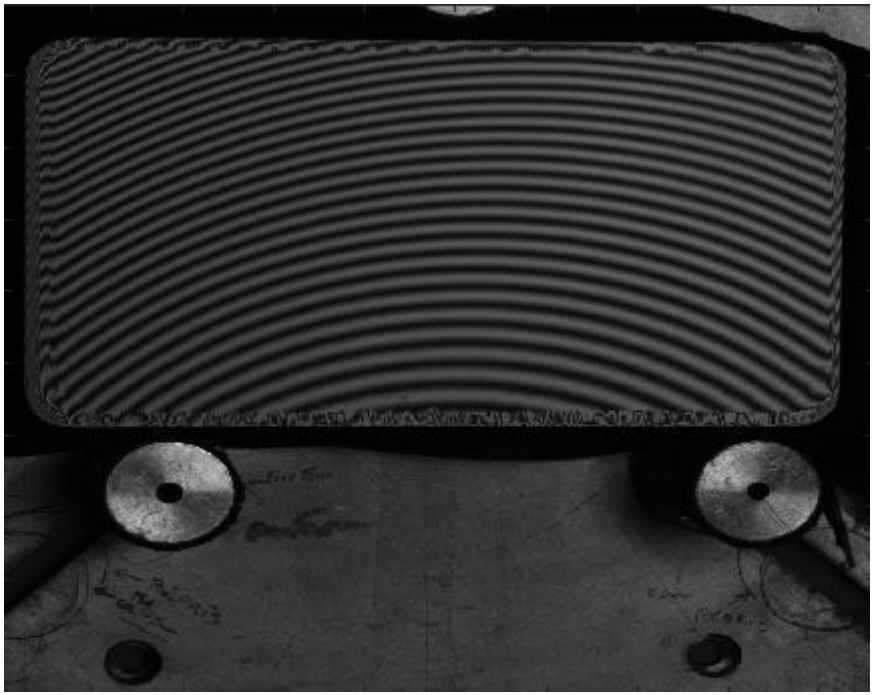


# How to associate source, mirror and detector ?



Fiducials



Phase Shift algorithm

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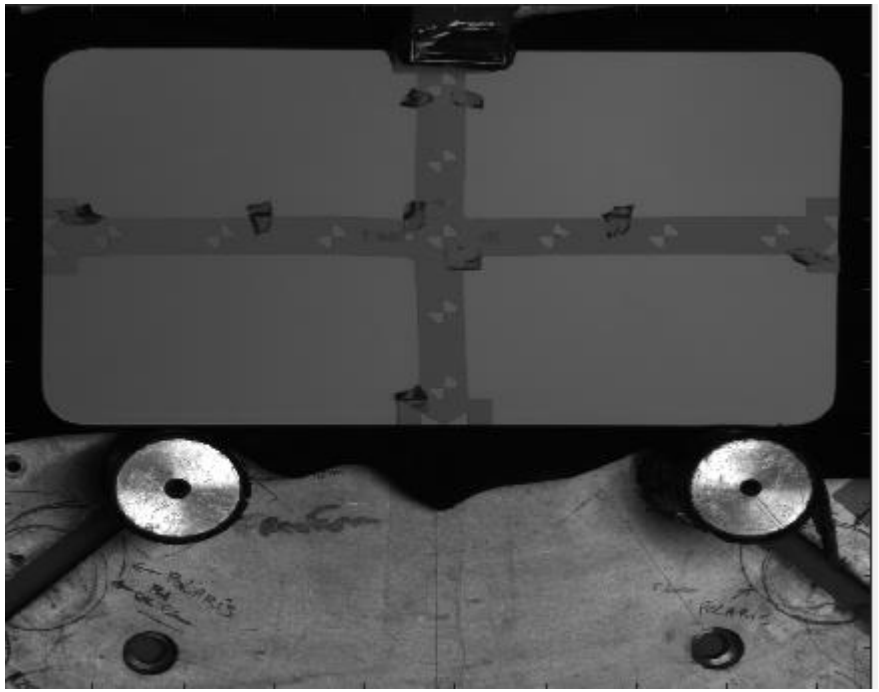

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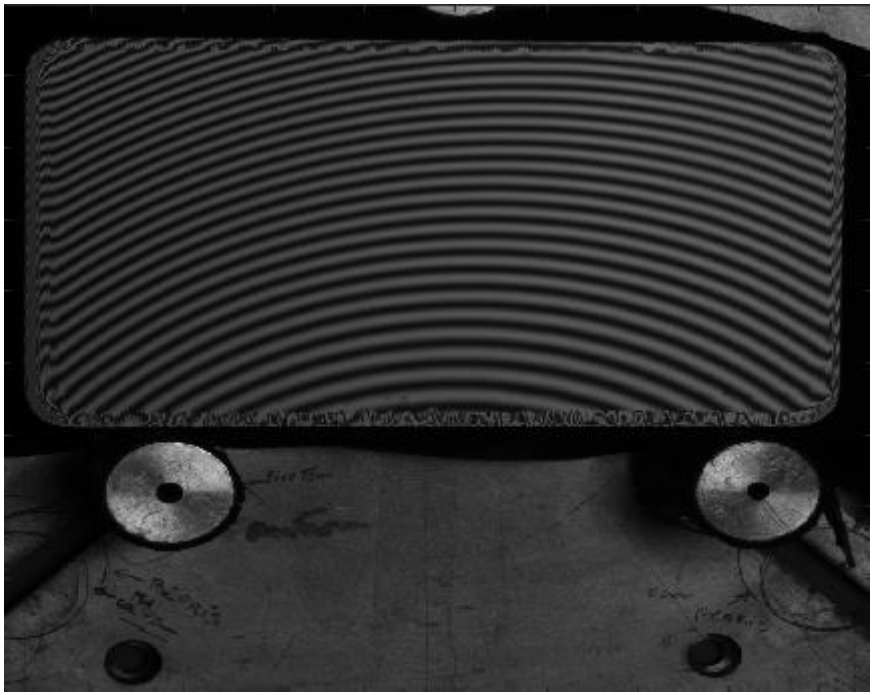

Phase Shift algorithm

1 pixel ⇔ 1 mirror pixel

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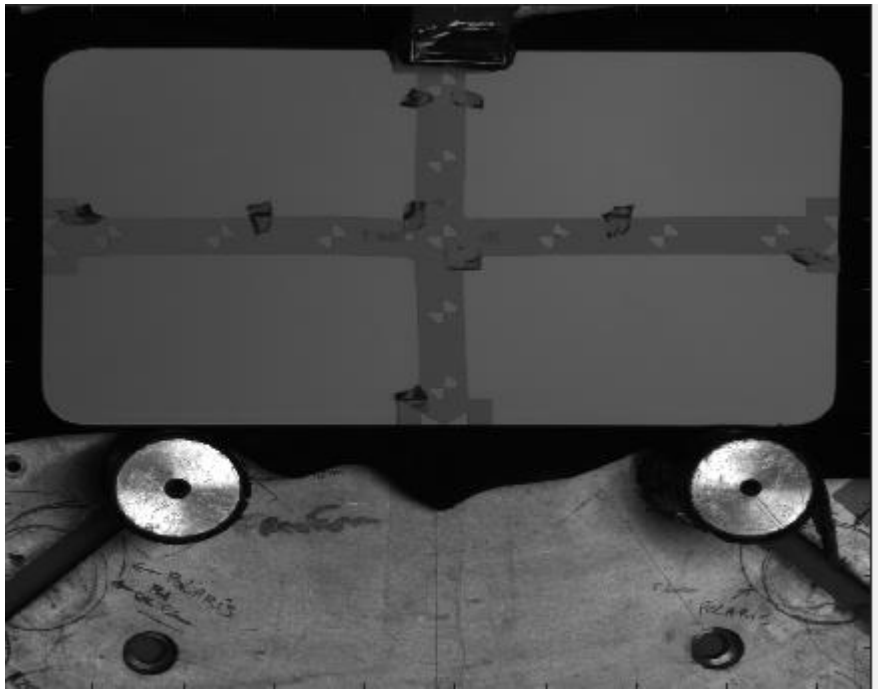

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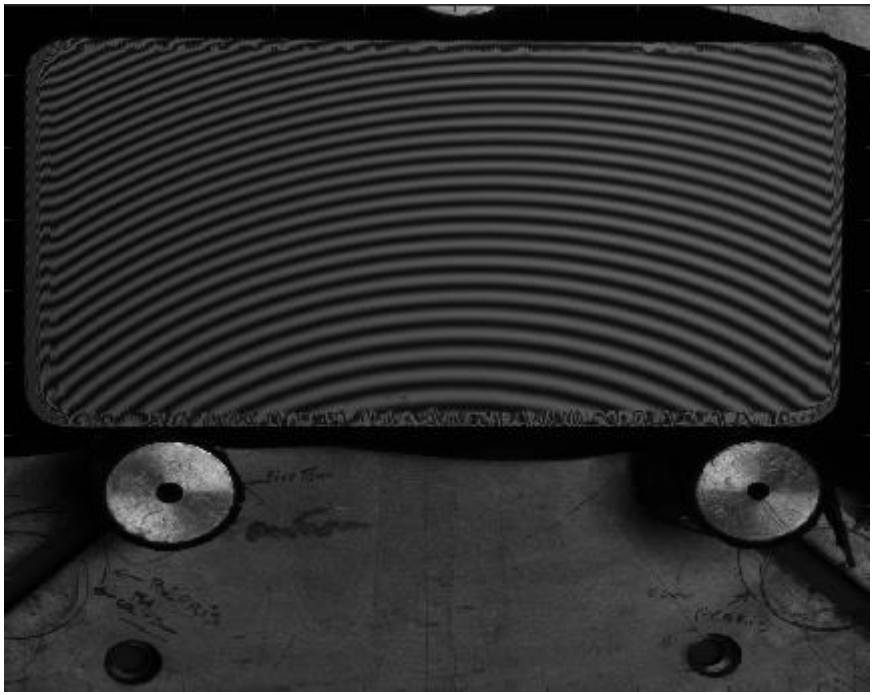
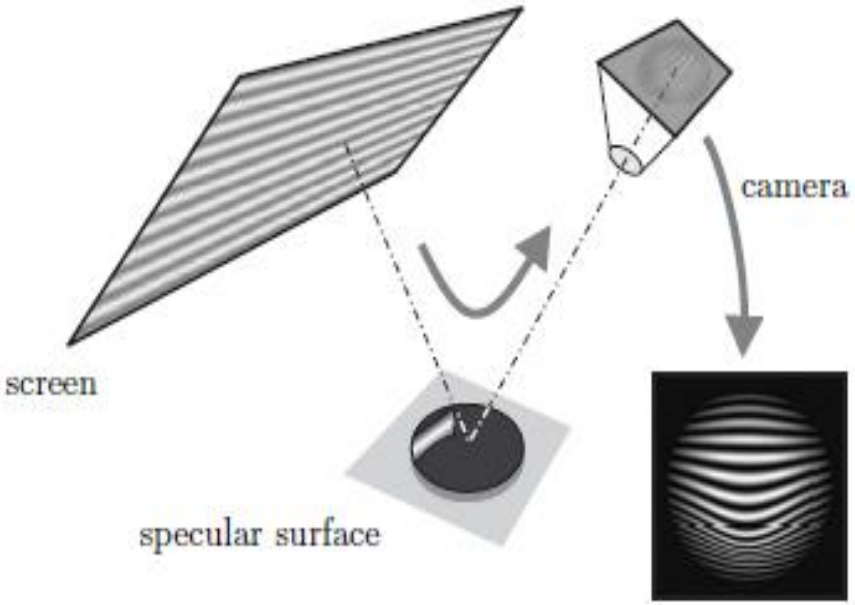


Phase Shift algorithm

1pixel ⇔ 1 source pixel

# Summary :

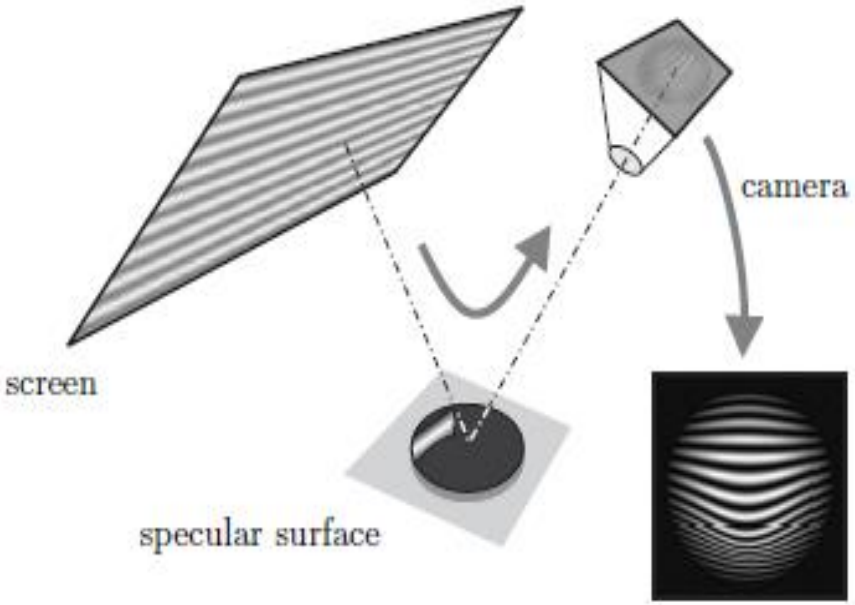



Intensity

Position of source points on the screen

Slopes $\vec{\nabla} z$

# Summary :




Intensity

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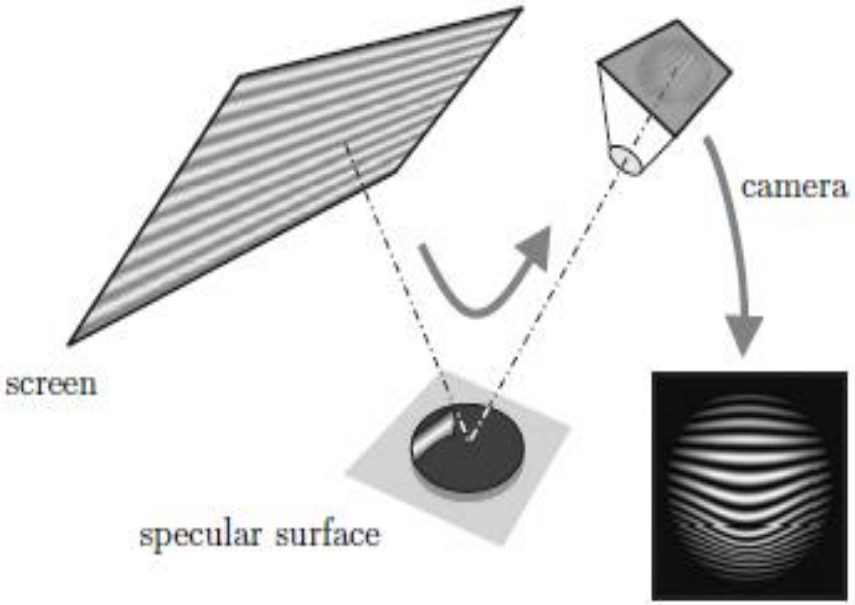
Position of source points on the screen

Non-linear equation

Slopes $\vec{\nabla} z$

# Summary :




Intensity

Phase Shift algorithm

Position of source points on the screen

Non-linear equation

Slopes $\vec{\nabla} z$

Inversion

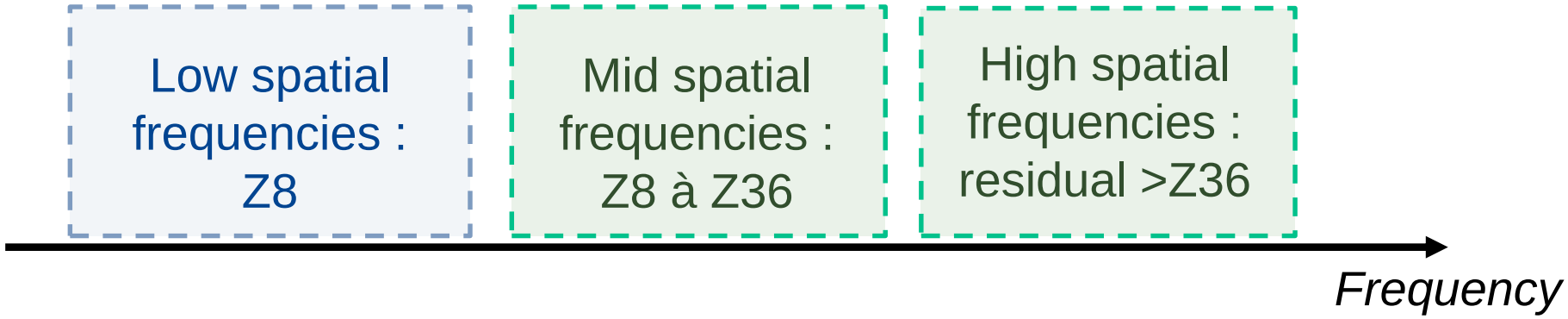
Shape $z$

$$\vec{\nabla} z \rightarrow z$$

# Limitations & axis of research

Geometry errors bias

Print-through bias & error propagation through inversion



# Limitations & axis of research

Geometry errors bias

Print-through bias & error propagation through inversion

Low spatial frequencies : Z8

Mid spatial frequencies : Z8 à Z36

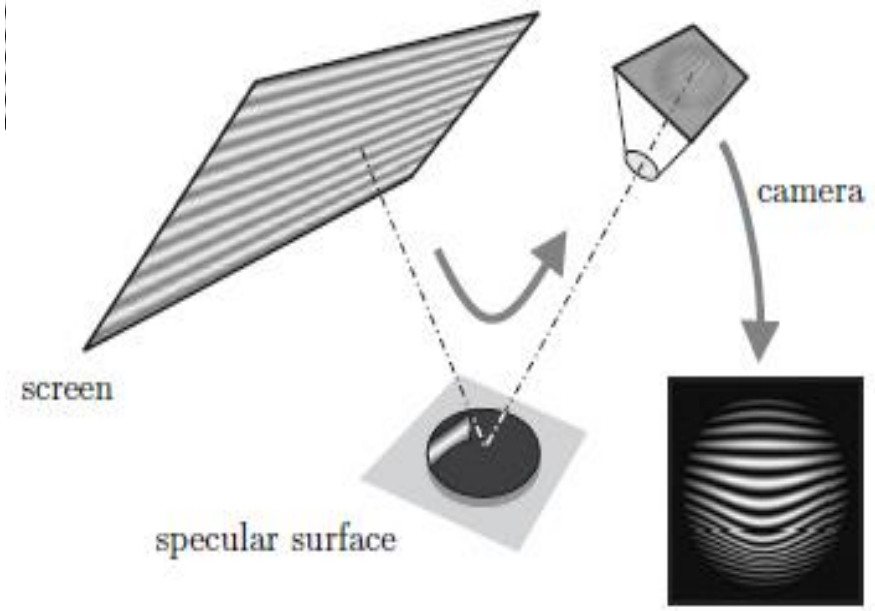
High spatial frequencies : residual >Z36


- Phase Shift algorithm robust against harmonic print-through
- Regularize the ill-conditionned inversion problem
- Auto-calibrating geometric parameters

# 3


# RESEARCH AXIS & RESULTS

# Summary :



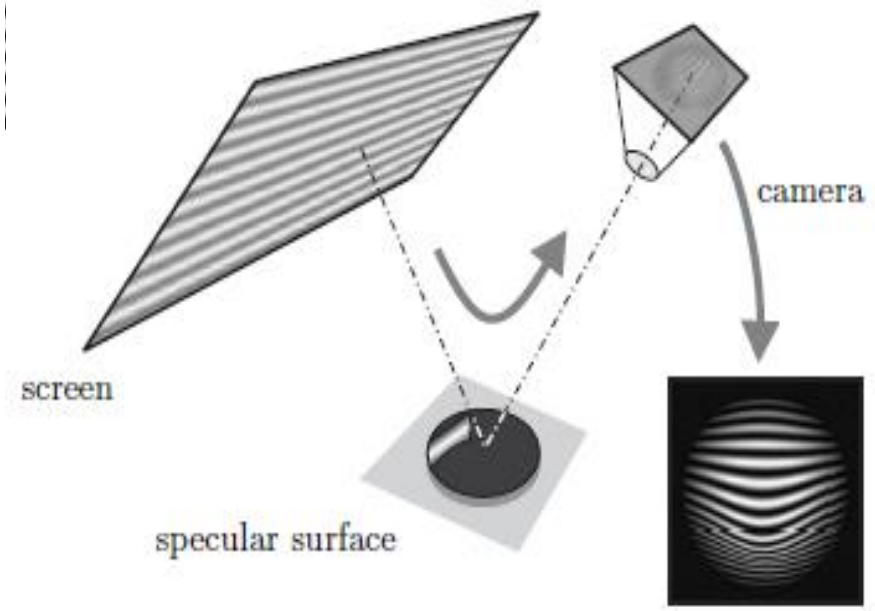

Intensity

Position of source points on the screen

Slopes

Shape

# Summary :




Intensity

Phase Shift algorithm

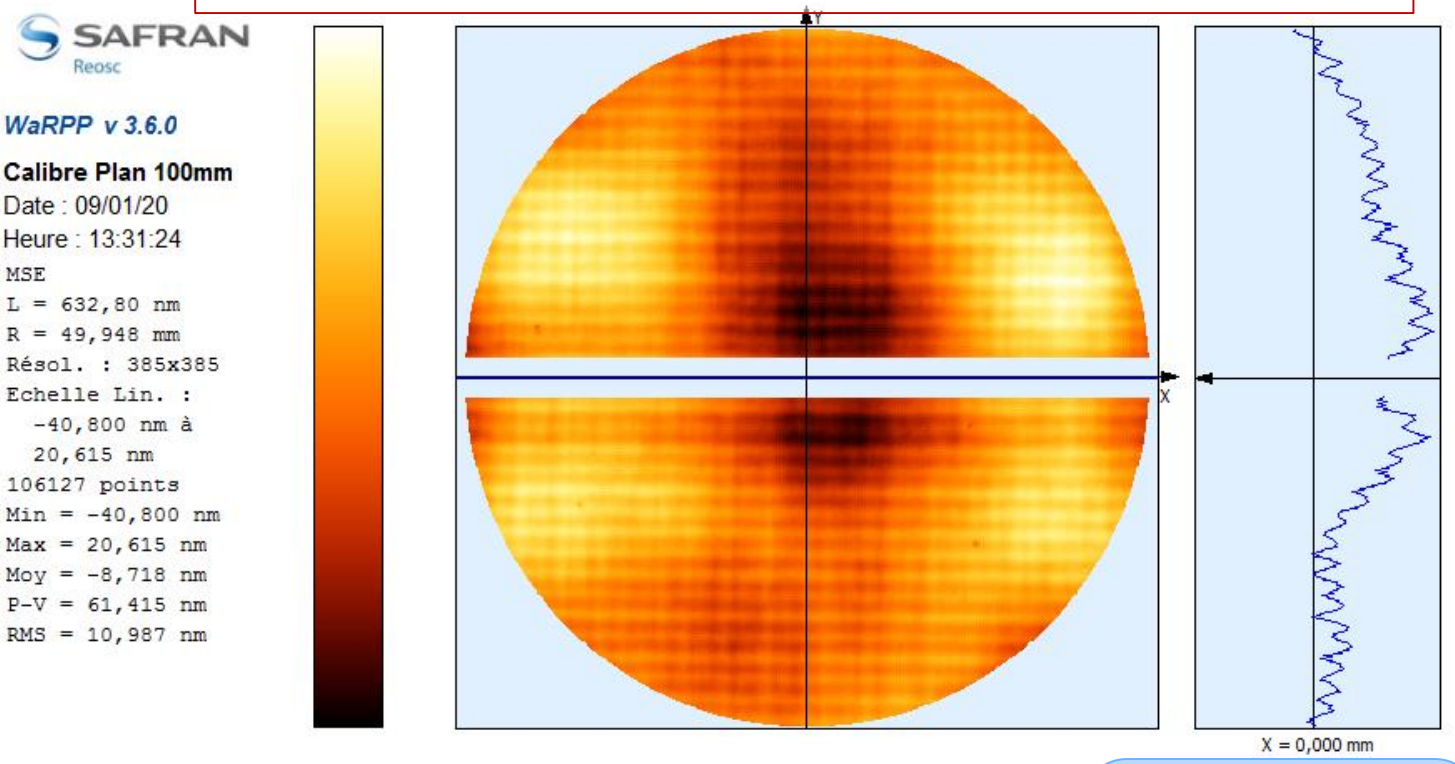
Position of source points on the screen

Slopes

Shape

# Non-linear display impact on shape reconstruction :

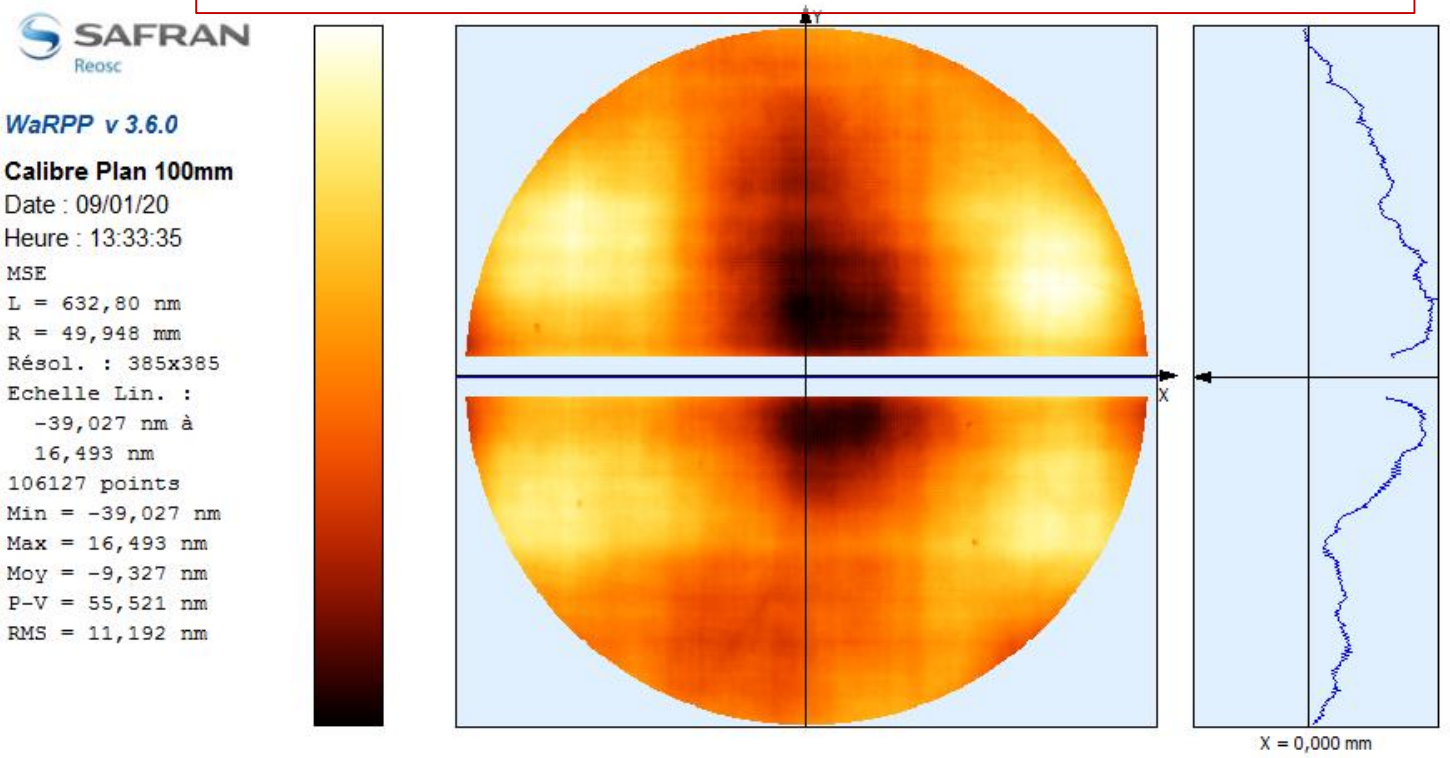
Shape measured, Phase Shift algorithm robust against harmonics <4




Intensity → Phase Shift algorithm → Position of source points on the screen

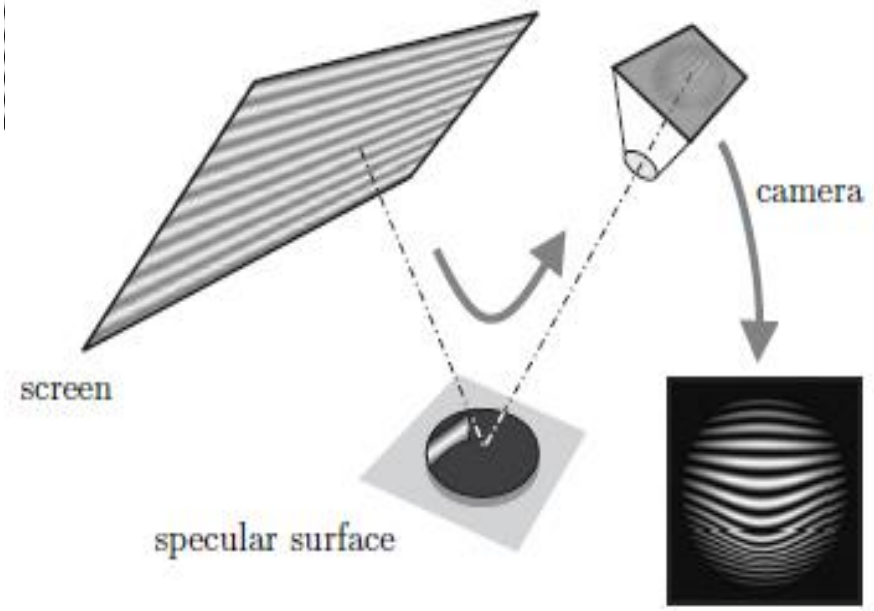
# Non-linear display impact on shape reconstruction :

Shape measured, Phase Shift algorithm robust against harmonics <8




Intensity → Phase Shift algorithm → Position of source points on the screen

# Summary :




Intensity

Position of source points on the screen

Slopes

Shape

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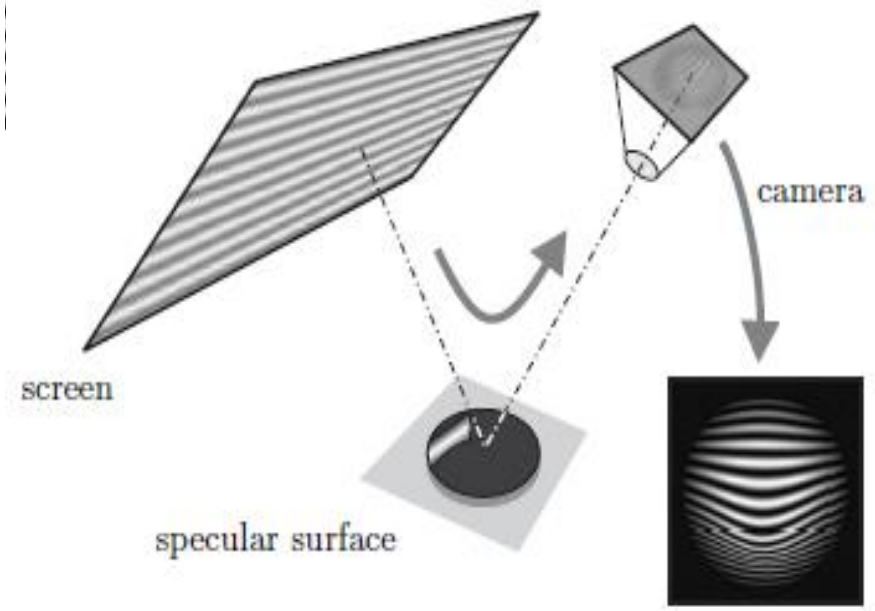


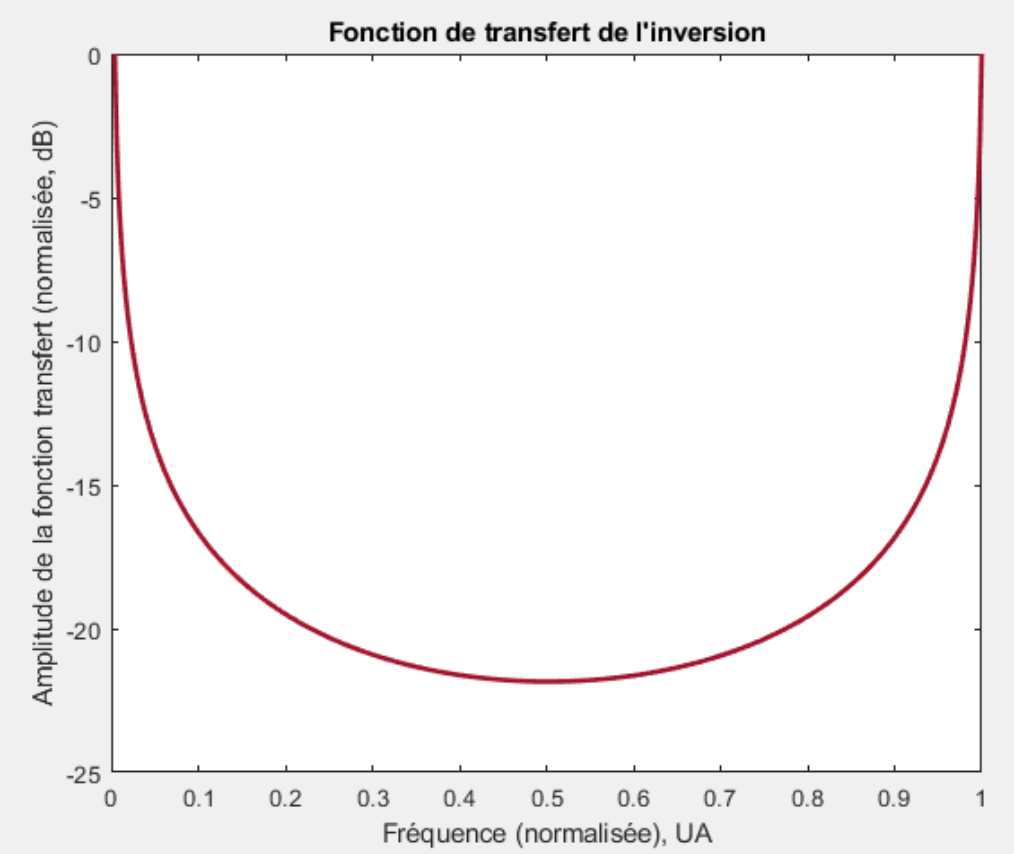

Intensity

Position of source points on the screen

Slopes → Inversion → Shape

# High frequencies performance

Ill-conditionned inversion problem

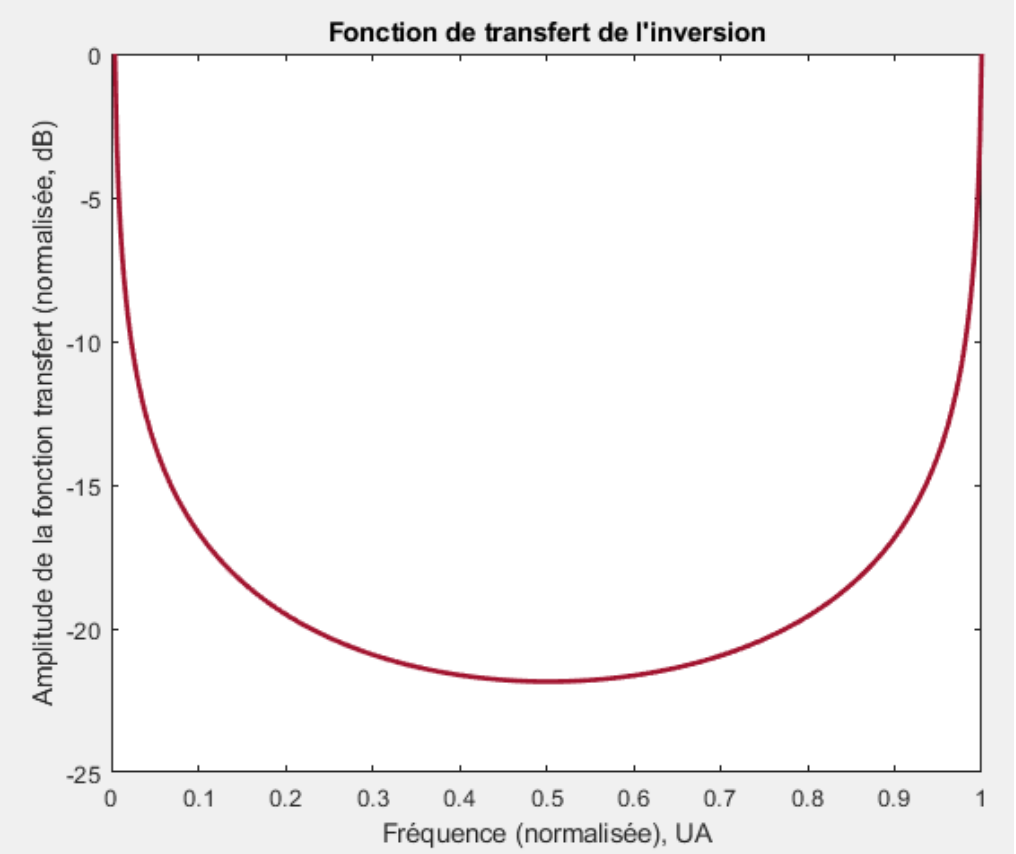



$$\tilde{z}(\vec{k}) = \frac{1}{\widetilde{D}(\vec{k})}\,\widetilde{\vec{\nabla}} z(\vec{k})$$

# High frequencies performance

Ill-conditionned inversion problem

Regularization methods **(Maximum a posteriori estimation)**

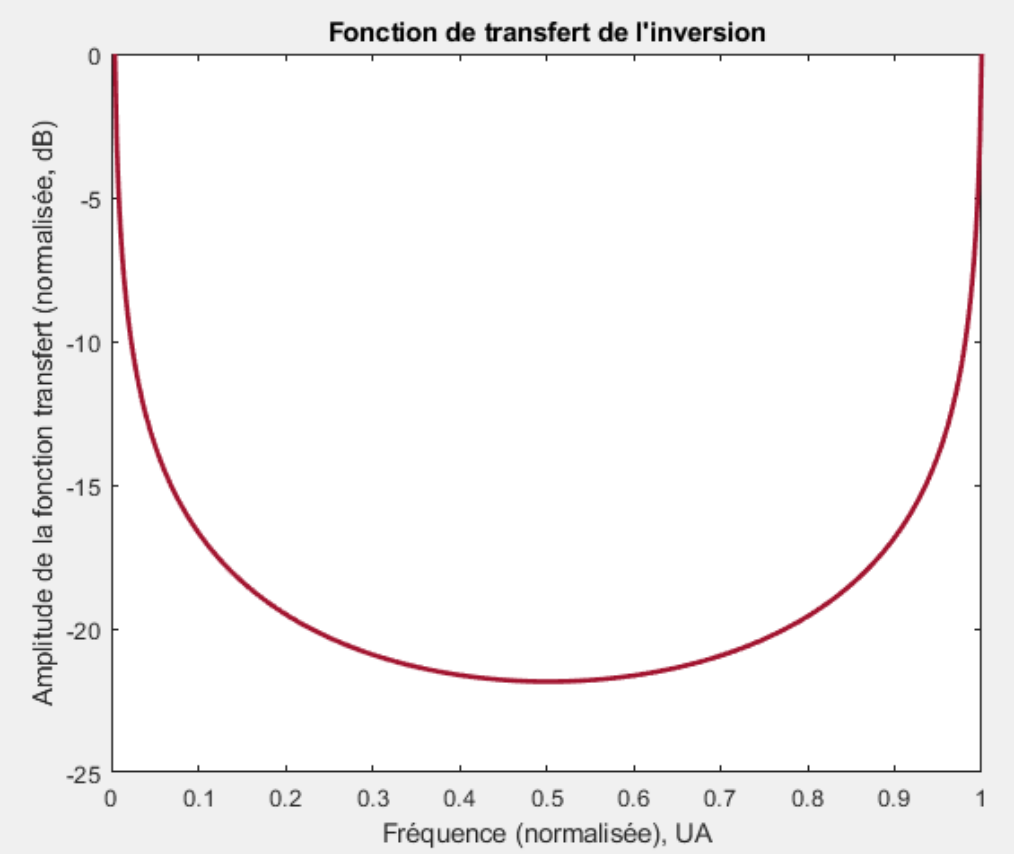



High frequency noise amplification

# High frequencies performance

Ill-conditionned inversion problem

Regularization methods **(Maximum a posteriori estimation)**




Polishing physics
➔PSD distribution hypothesis

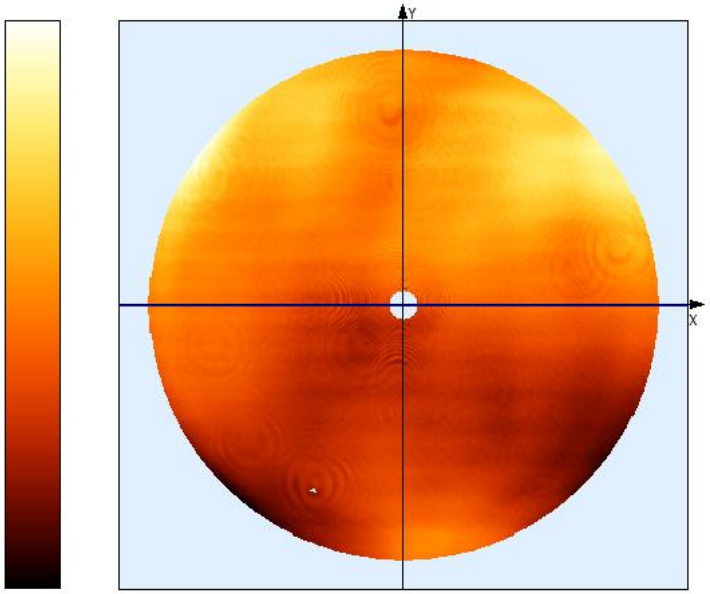
High frequency noise amplification

# Another use of regularization : inpainting

SAFRAN Reosc

*WaRPP v 3.6.0*

**ZU_M1_TX_QM_**
Date : 09/01/20
Heure : 13:53:23
MSE
L = 632,80 nm
R = 71,743 mm
Résol. : 765x765
Echelle Lin. :
-87,101 nm à
172,767 nm
371165 points
Min = -87,101 nm
Max = 172,767 nm
Moy = 26,875 nm
P-V = 259,867 nm
RMS = 44,014 nm

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*WaRPP v 3.6.0*

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Date : 09/01/20
Heure : 13:57:08
MSE
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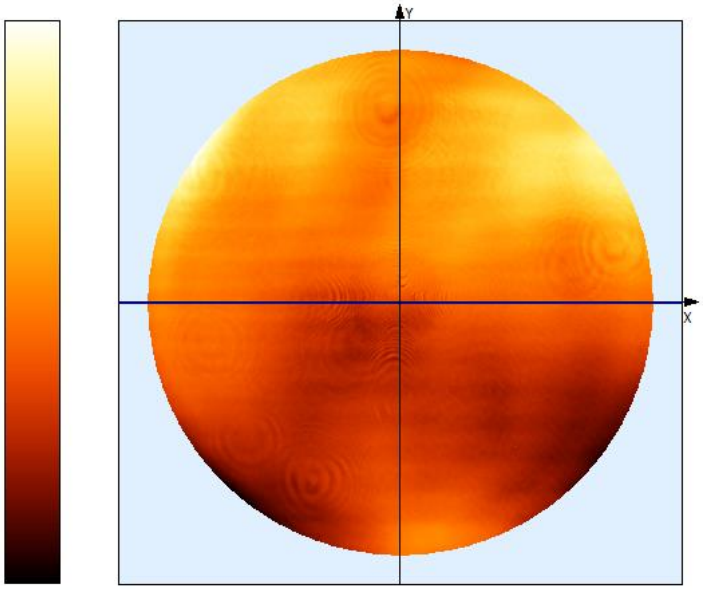


MERLIN : primary mirror of one lightpath

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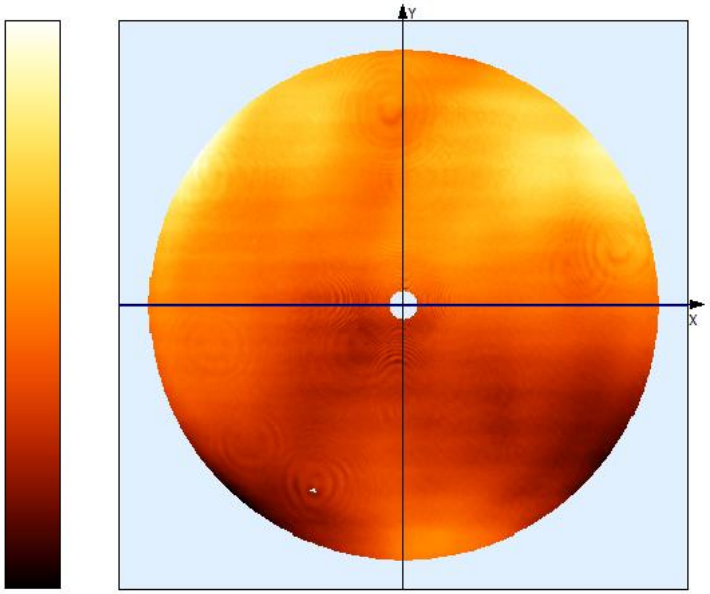


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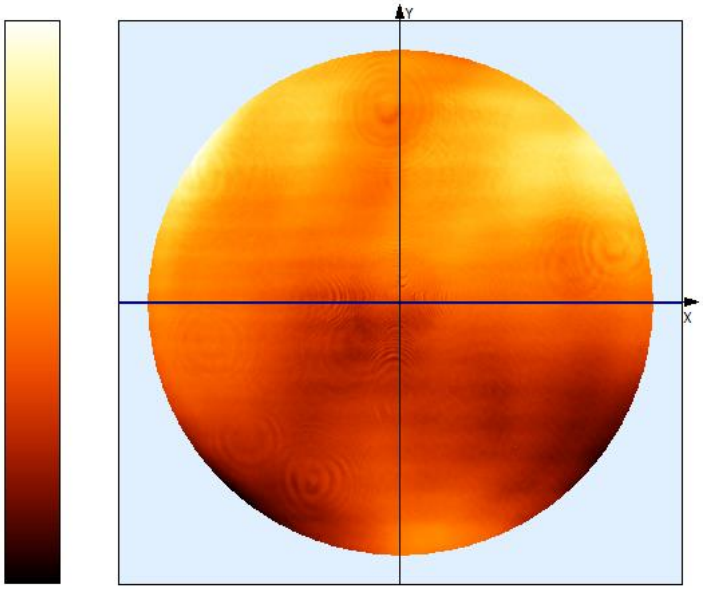
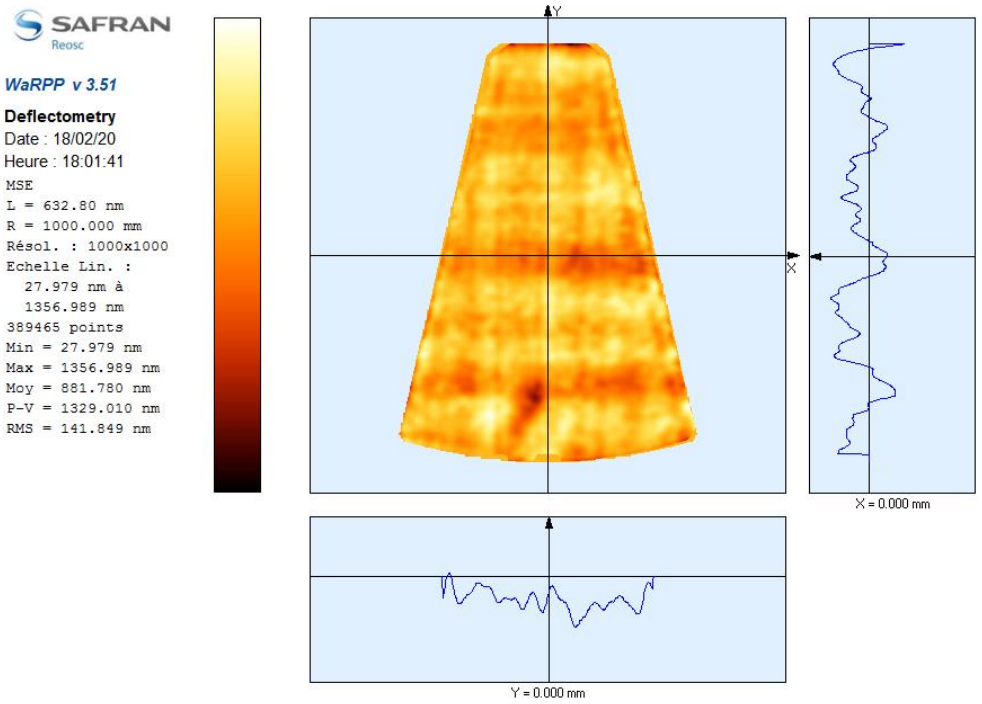
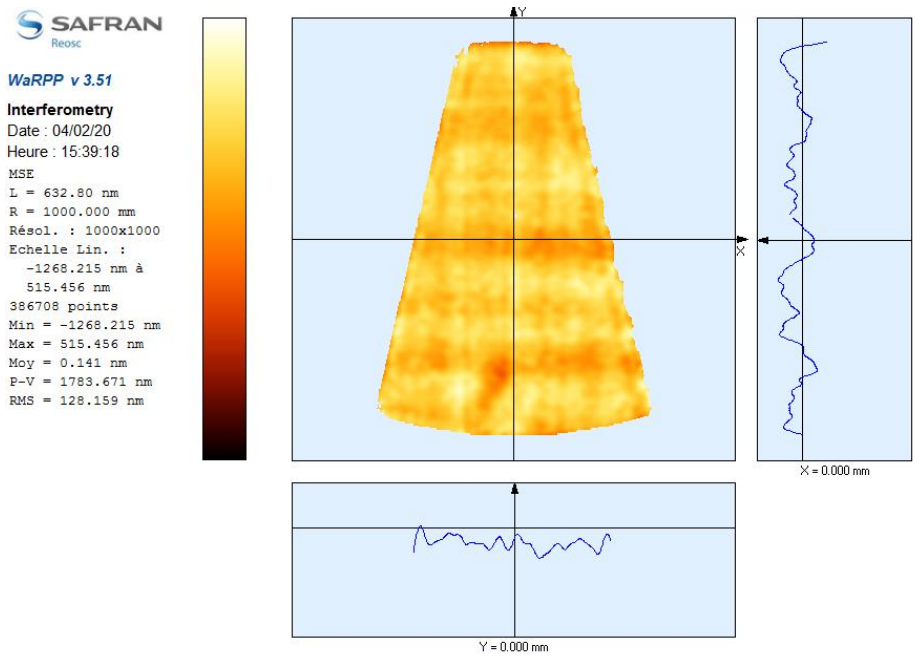



Data processing tool developped for REOSC : in-painting & filtering

MERLIN : primary mirror of one lightpath

# Capabilities :

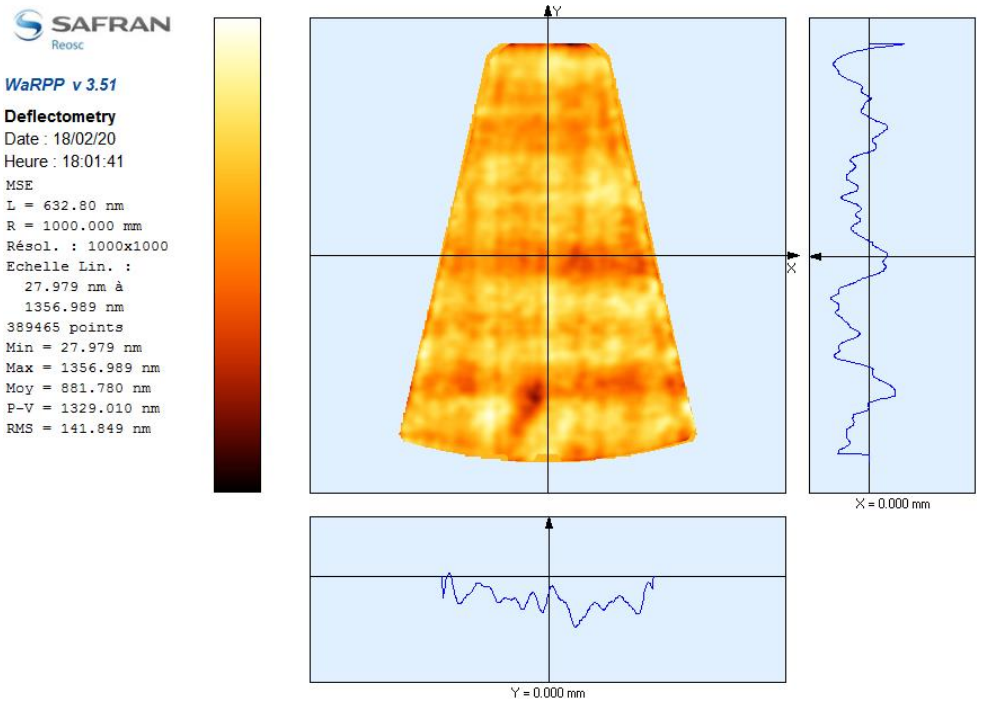


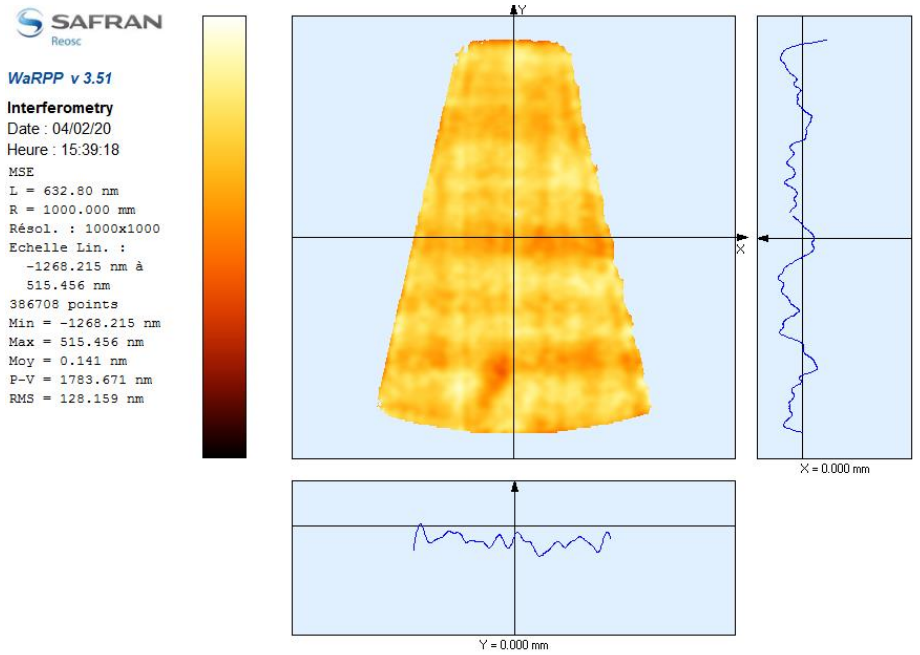




Registration & substraction :
30 nm RMS

ELT M2 Matrix, $\phi = 2000mm$, Sub Zernike 36

# Capabilities :



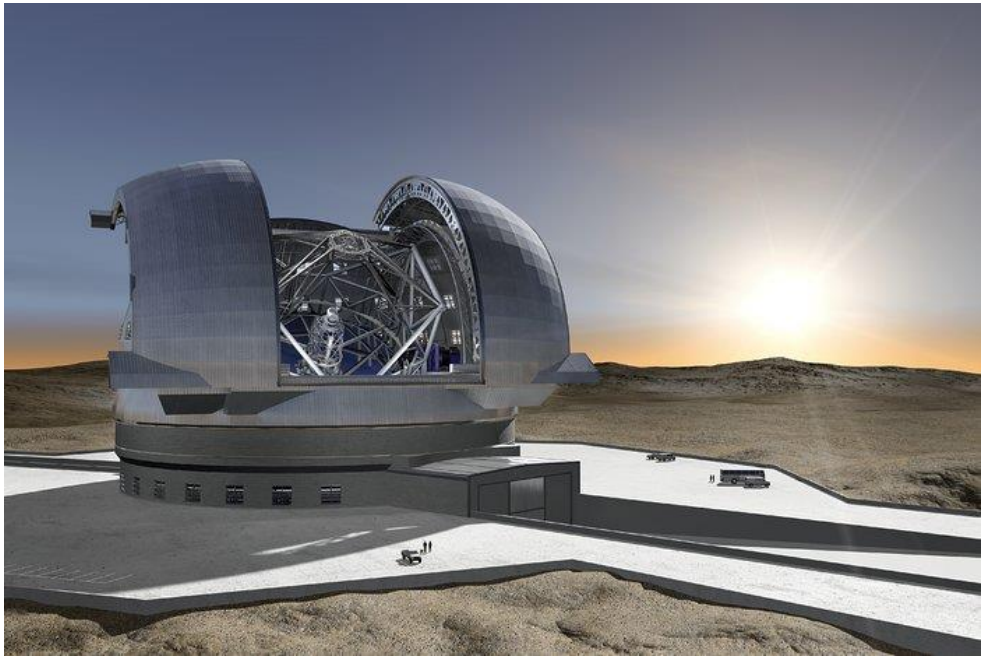

-Fast independant high frequencies measurements
-In situ capabilities

Registration & substraction :
30 nm RMS

-No specific correctors, even for freeform & aspheric mirrors
- Low cost

ELT M2 Matrix, $\phi = 2000mm$, Sub Zernike 36

# Conclusion



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Thank you for your attention !

# Bibliography :


[1] **Design of phase-detection algorithms insensitive to bias modulation,** Yves Surrel, Applied Optics, Vol. 36, Issue 4, pp. 805-807 (1997)

[2] **Software configurable optical test system: a computerized reverse Hartmann test,** Peng Su, Robert E. Parks, Lirong Wang, Roger P. Angel, and James H. Burge, Applied Optics, Vol. 49, Issue 23, pp. 4404-4412 (2010)

[3] **Non-null full field X-ray mirror metrology using SCOTS: a reflection deflectometry approach,** Y. W. J. H. B. a. K. K. a. M. I. Peng Su, Optics express, Vol. 20, Issue 111 (2012).