WAVEFRONT SENSORS

DEFORMABLE MIRRORS

METROLOGY SYSTEMS

ADAPTIVE OPTICS SOLUTIONS

Ultra-High Resolution Wavefront sensing using AI

Rafael Porcar

About Imagine Optic

- **Founded** in 1996
  Independant privatly owned company
- **Sales** 7,2M €
- **Employees** ~ 60
- **Patent applications** 30+

> 2 000 sensors deployed !!

Member of:

Certification:

Some applications of Artificial Intelligence

Language translation

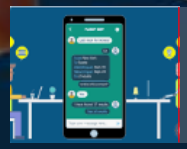
Autonomous vehicles

Generative AI

Recommendation systems

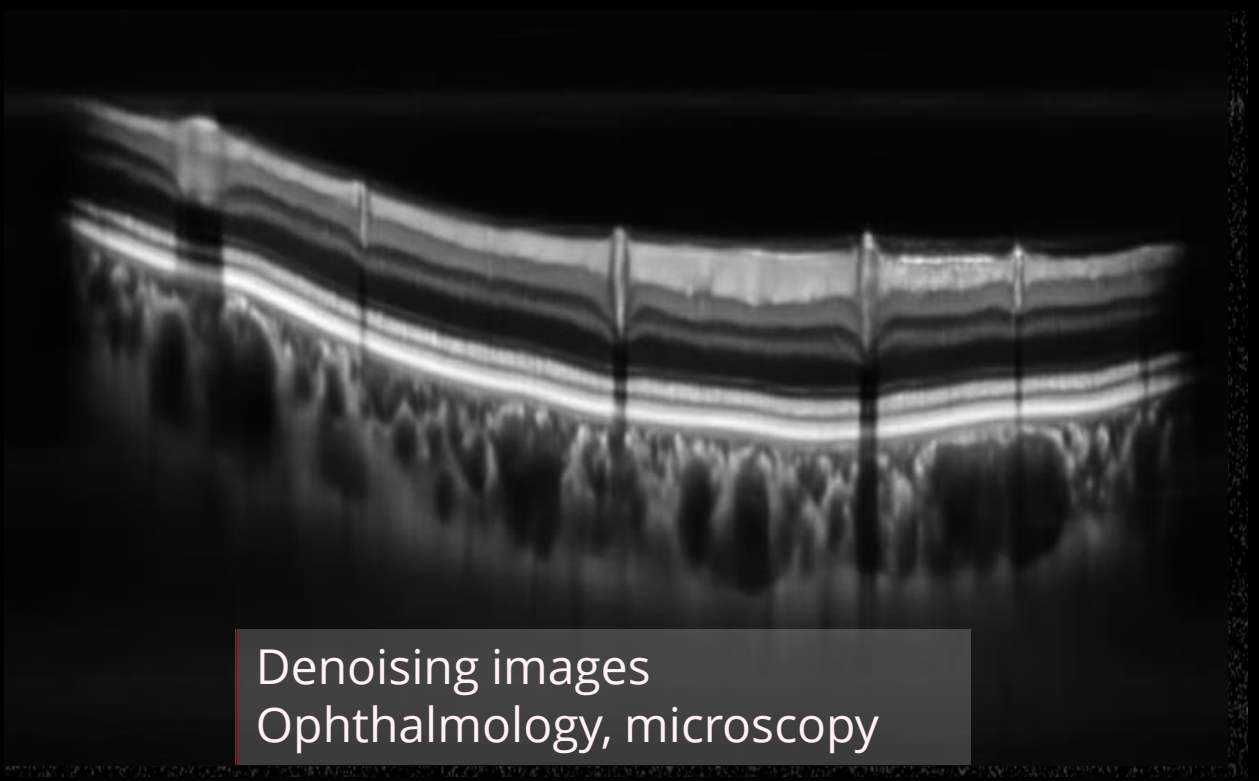
Digital assistants

Advertising

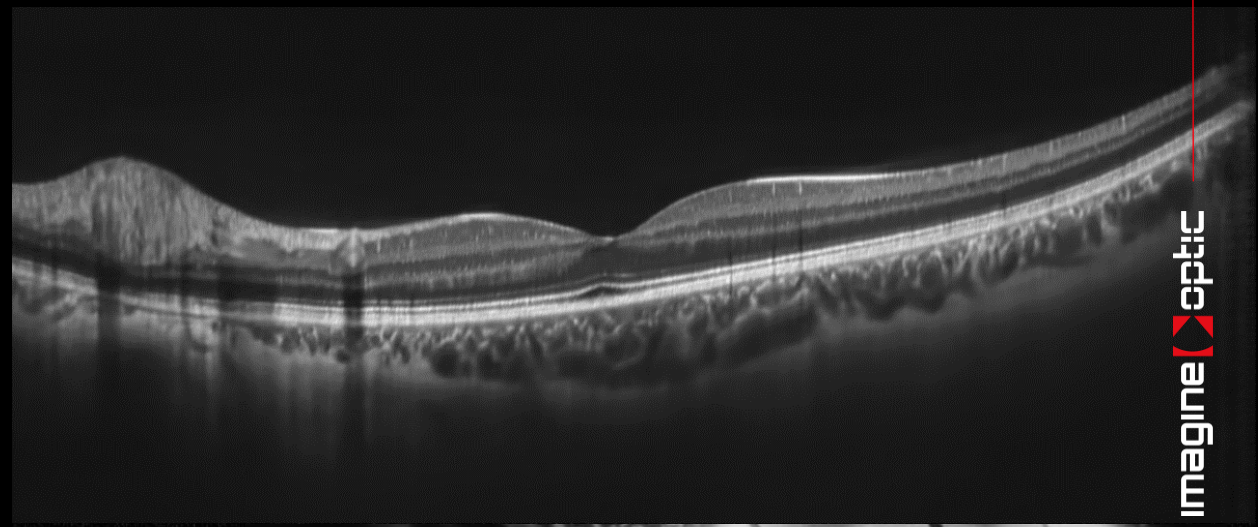


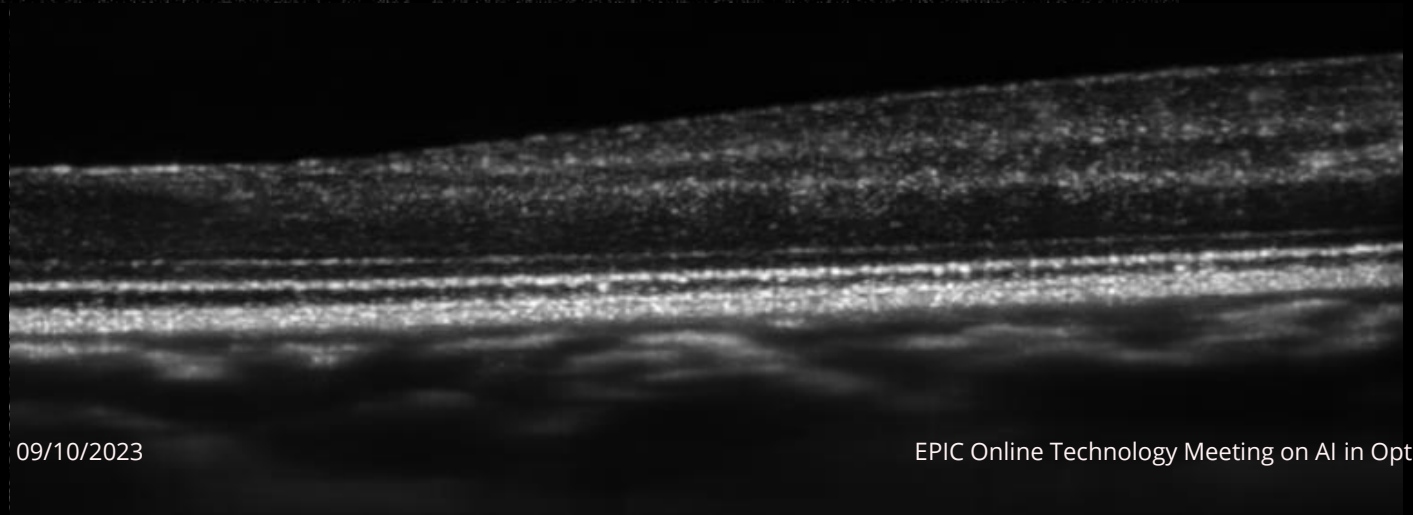
Chatbots

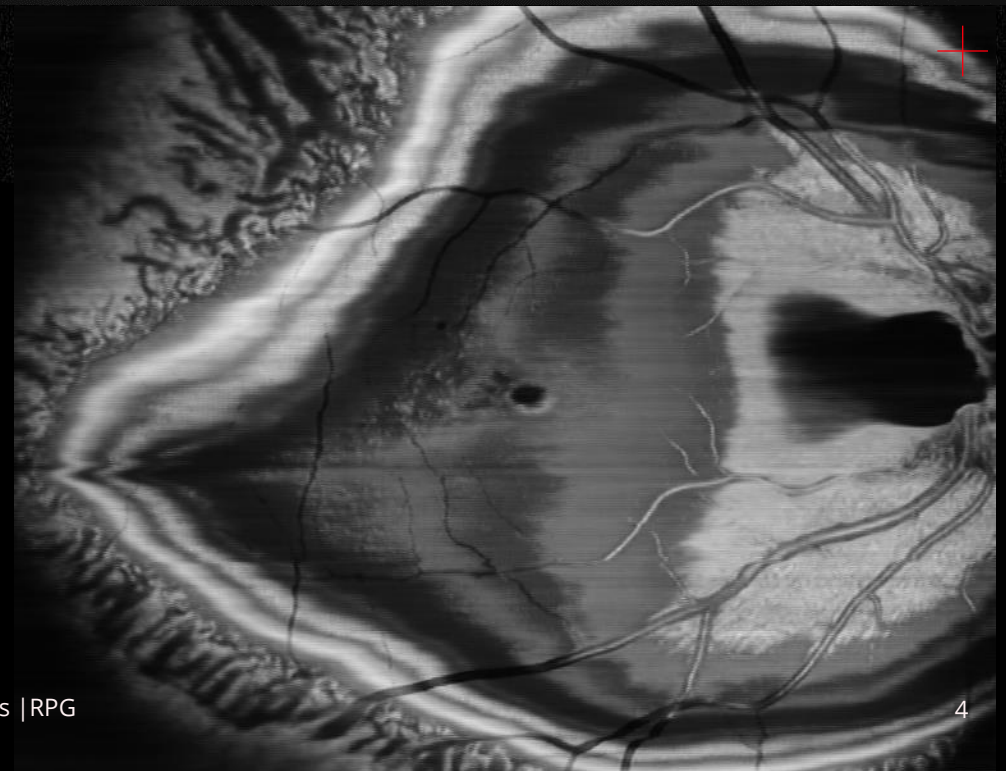
About Artificial Intelligence at Imagine Optic

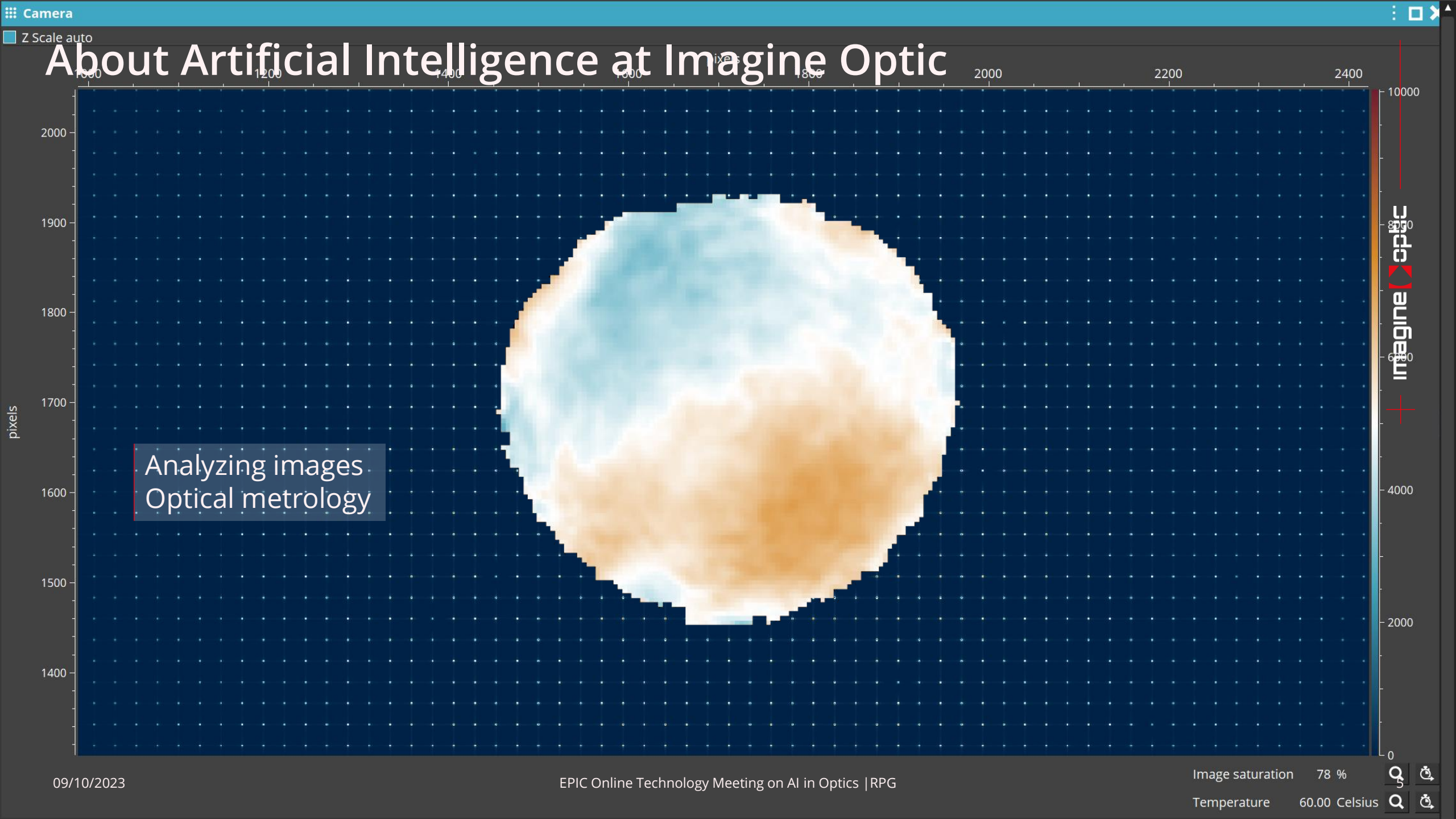


Denoising images
Ophthalmology, microscopy

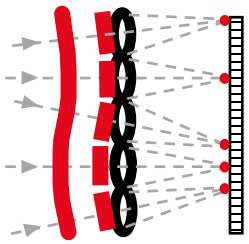


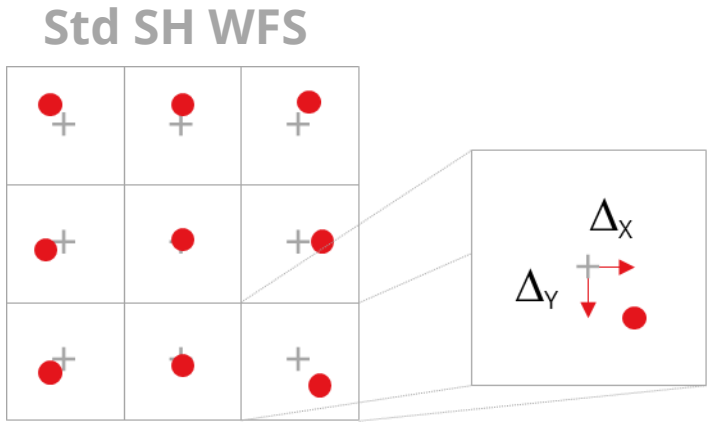


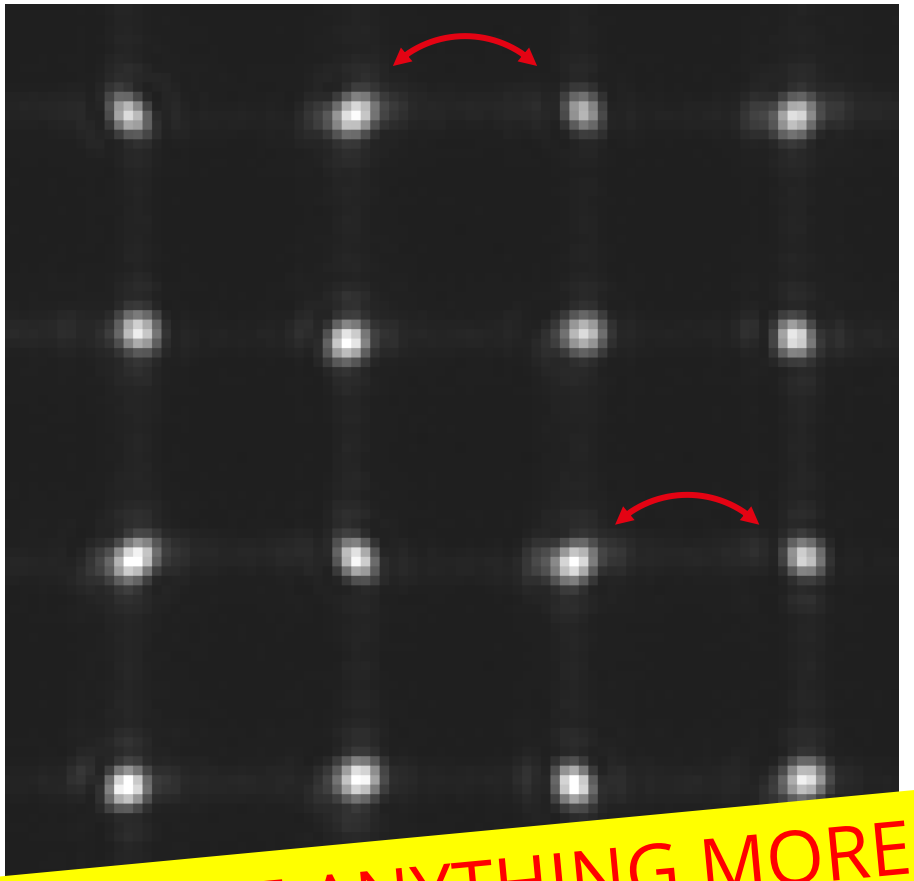



Camera
Z Scale auto
About Artificial Intelligence at Imagine Optic
pixels
1000
1200
1400
1600
1800
2000
2200
2400
2000
1900
1800
1700
1600
1500
1400
pixels
10000
8000
6000
4000
2000
0
imagine optic
Analyzing images
Optical metrology
09/10/2023
EPIC Online Technology Meeting on AI in Optics |RPG
Image saturation 78 %
Temperature 60.00 Celsius

Introduction to UHR wavefront sensing (LIFT-based)

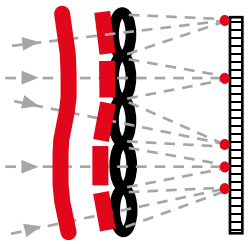




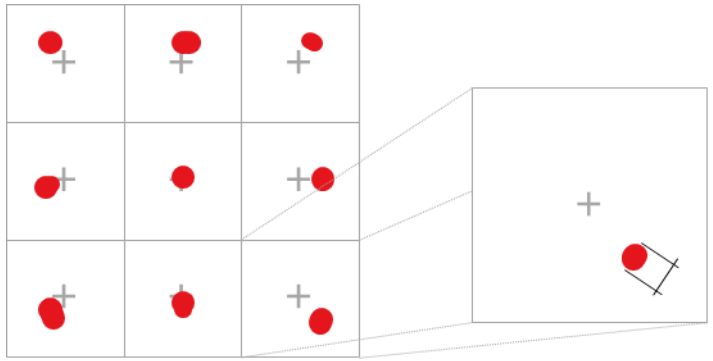


IS THERE ANYTHING MORE WE CAN DO ?

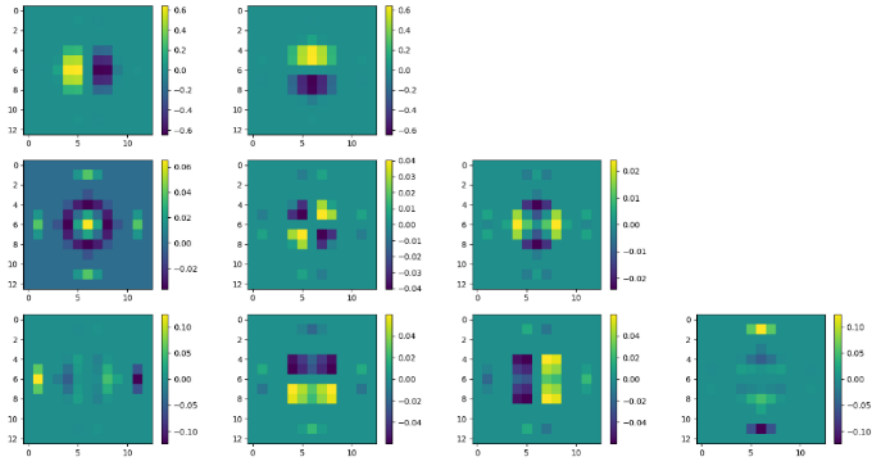
Introduction to UHR wavefront sensing (LIFT-based)



LIFT WFS



9 modes per µL

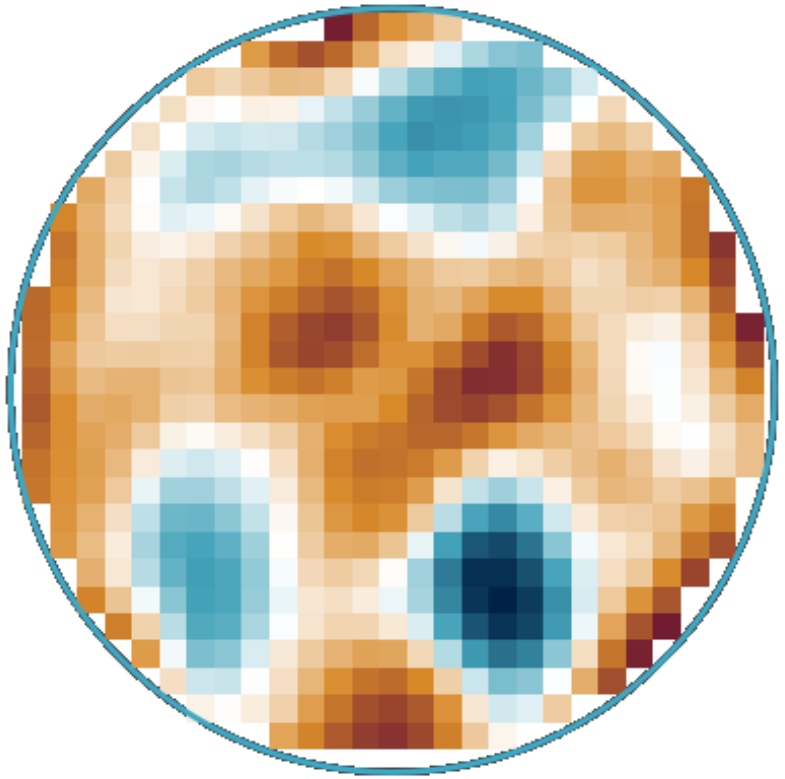


[1] S. Meimon and al ONERA, "Sensing more modes with fewer sub-apertures: the LIFTed Shack–Hartmann wavefront sensor", May 15, 2014 / Vol. 39, No. 10 / OPTICS LETTERS
[2] C. Plantet, and al, "Experimental validation of LIFT for estimation of low-order modes in low-flux wavefront sensing", 15 July 2013 | Vol. 21, No. 14, OSA
[3] R. Gonsalves, "Small-phase solution to the phase-retrieval problem", Opt. Lett., Vol. 26, No 10, pp. 684-685 (2001)

WE CAN RECONSTRUCT COMPLEX PHASES AT THE MICROLENGTH LEVEL !

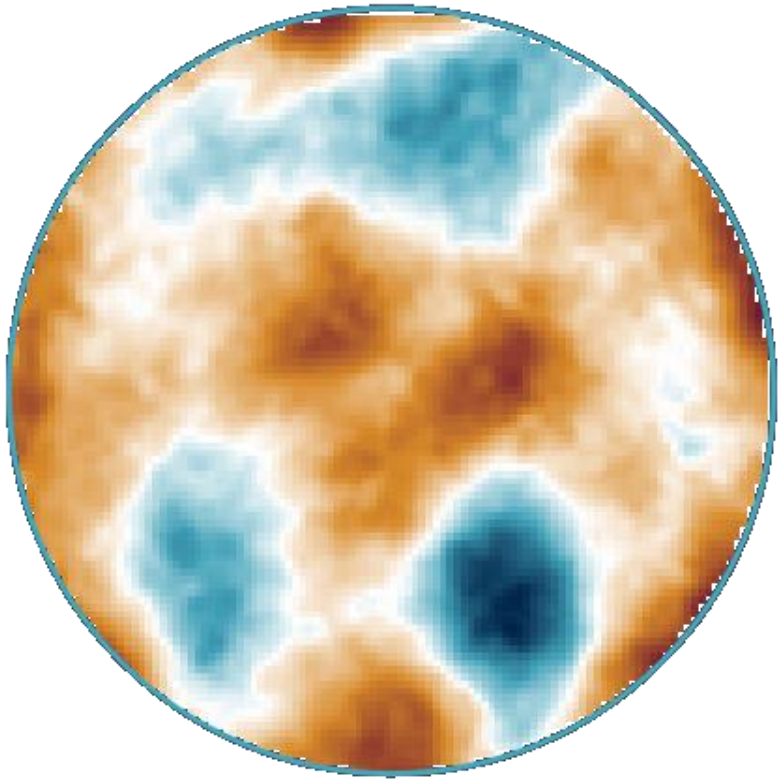
Introduction to UHR wavefront sensing (LIFT-based)

Std HASO SWIR



Resolution = 28 x 28
PV = 2.350 µm, RMS = 0.444 µm

HASO SWIR LIFT



Resolution = 112 x 112
PV = 2.552 µm, RMS = 0.452 µm

Introduction to UHR wavefront sensing (LIFT-based)

LIFT = 680 x 500 phase points per pupil of analysis

HASO LIFT

Wavefront sensor
Ultra High Resolution

The OEC®

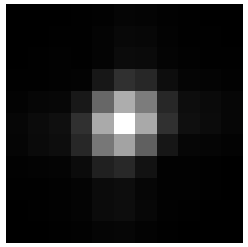
Modular system
for **lab and R&D**

MESO

Robust instrument
for **industry & production**

What can AI do for LIFT wavefront sensing?

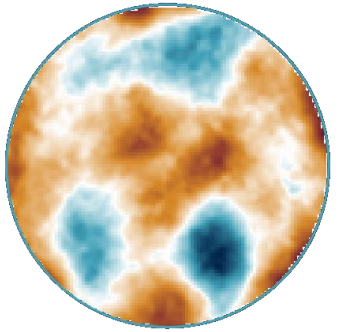
Processing flow



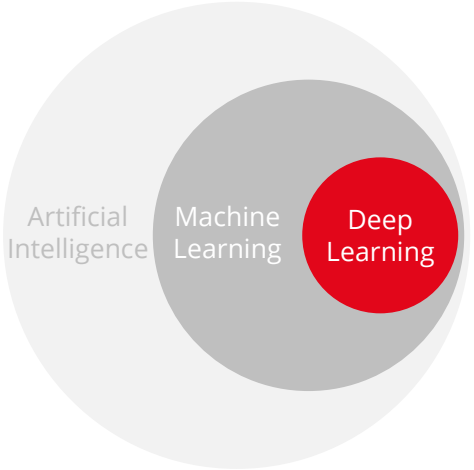
Interaction matrix

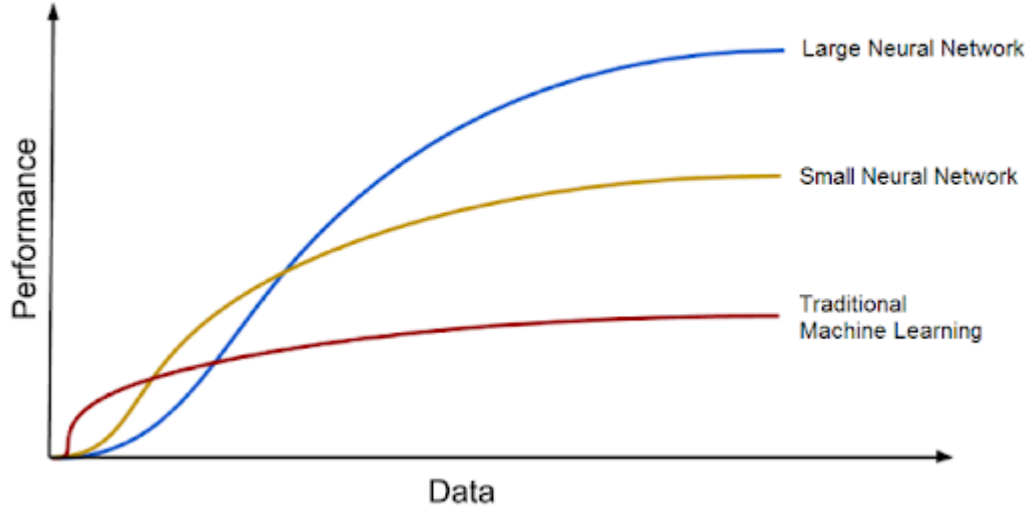
IA Network

Legendre coef.	L3	L4	L5	L6	...
Deformation (nm)	3.61	-29.01	-4.10	-4.86	...



Deep learning: subcategory of machine learning, consisting of algorithms with multi-layer neural networks, trained on large amounts of data.

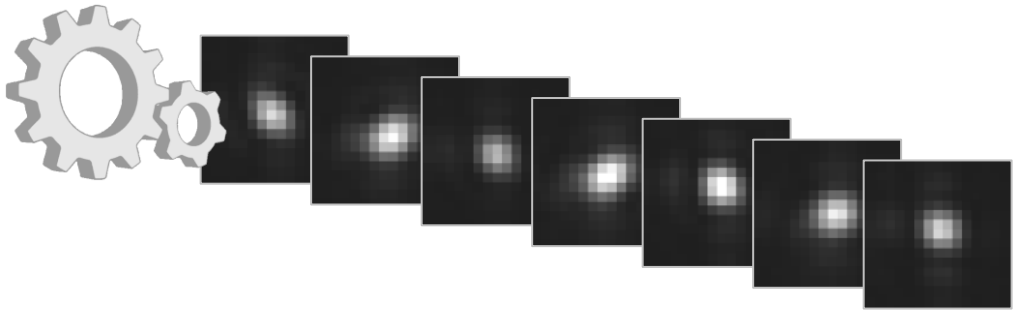




What can AI do for LIFT wavefront sensing?

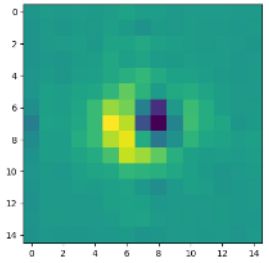
Data generation

+ Generation of ‘infinity’ of centroids
+ Each corresponding to aleatory phase combinations
+ Simulation of camera behavior/noise
+ Some signal effects difficult to recreate

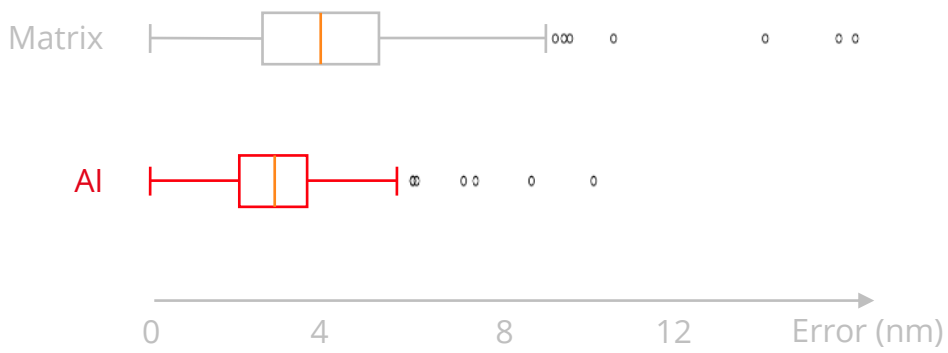


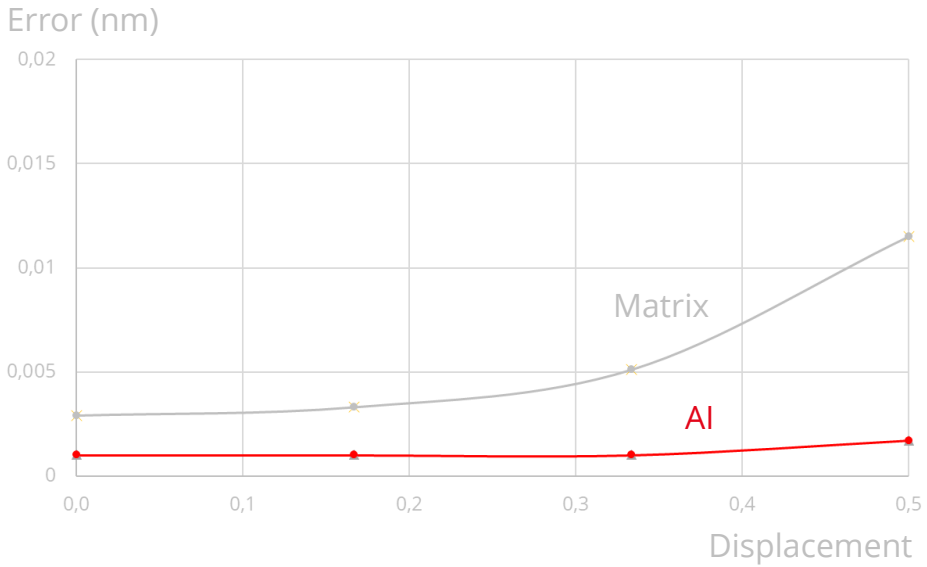
Training

+ 190 000 LIFT training pictures
+ 10 000 LIFT tests pictures
+ Iterations = 500
+ Learning rate = 0.001



AI-based LIFT vs matrix-based LIFT





Accuracy

IS THAT ALL?

Dynamic range

What can AI do for LIFT wavefront sensing?

	Matrix-based LIFT	AI-based LIFT
Sensor performances	✓ Robustness *-training related-*	✓ Accuracy ✓ Dynamic range
Sensor usability	✓ Speed (proc. freq.) *as implemented*	
Sensor production	✓ Factory calibration time	

imagine optic

Thank you for your attention

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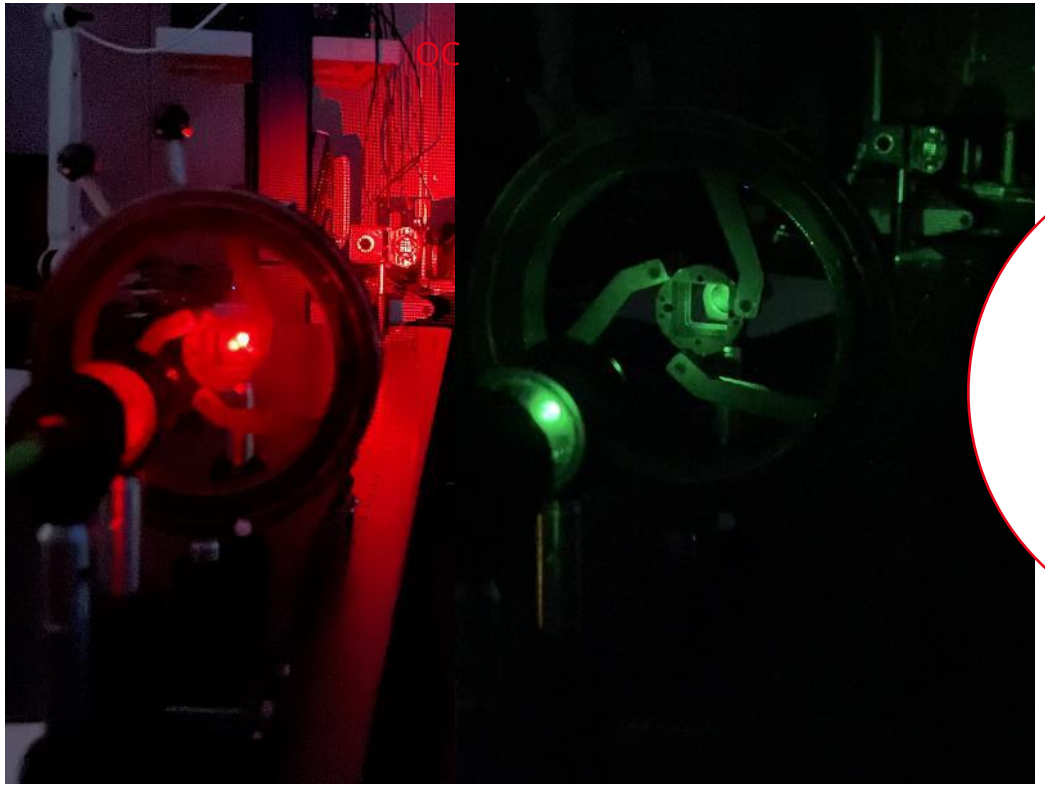
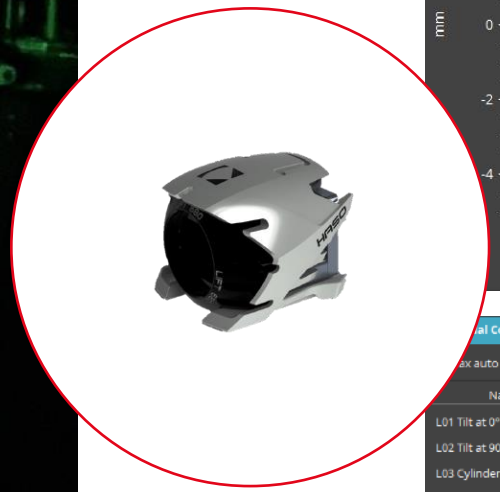
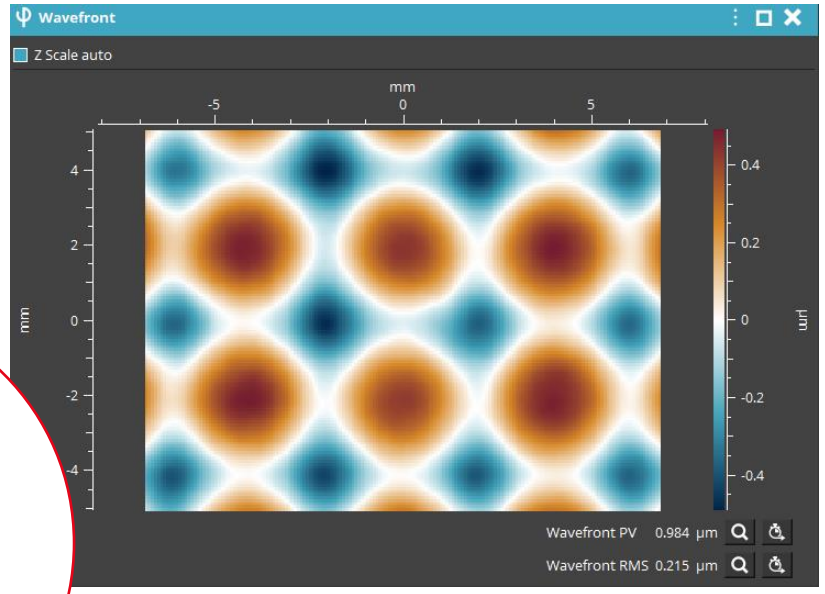
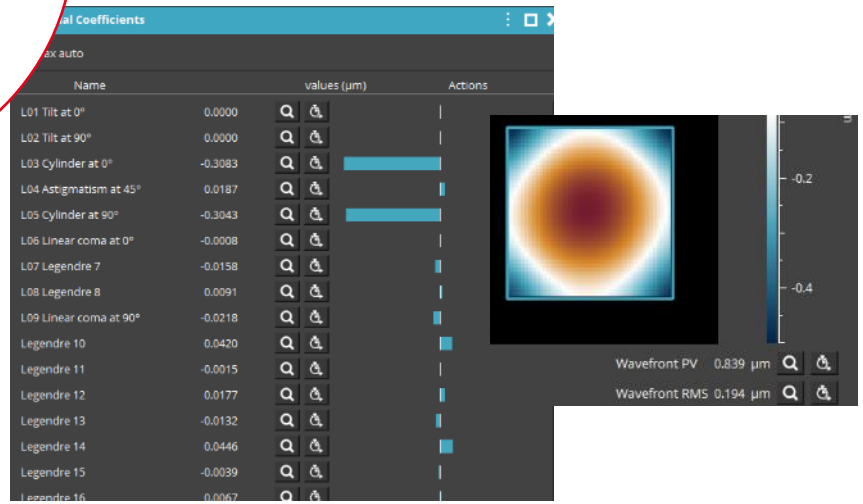
imagine-optic Imagine Optic Wavefrontrunners imagine-optic.com

LIFT metrology for industry | Microoptics production







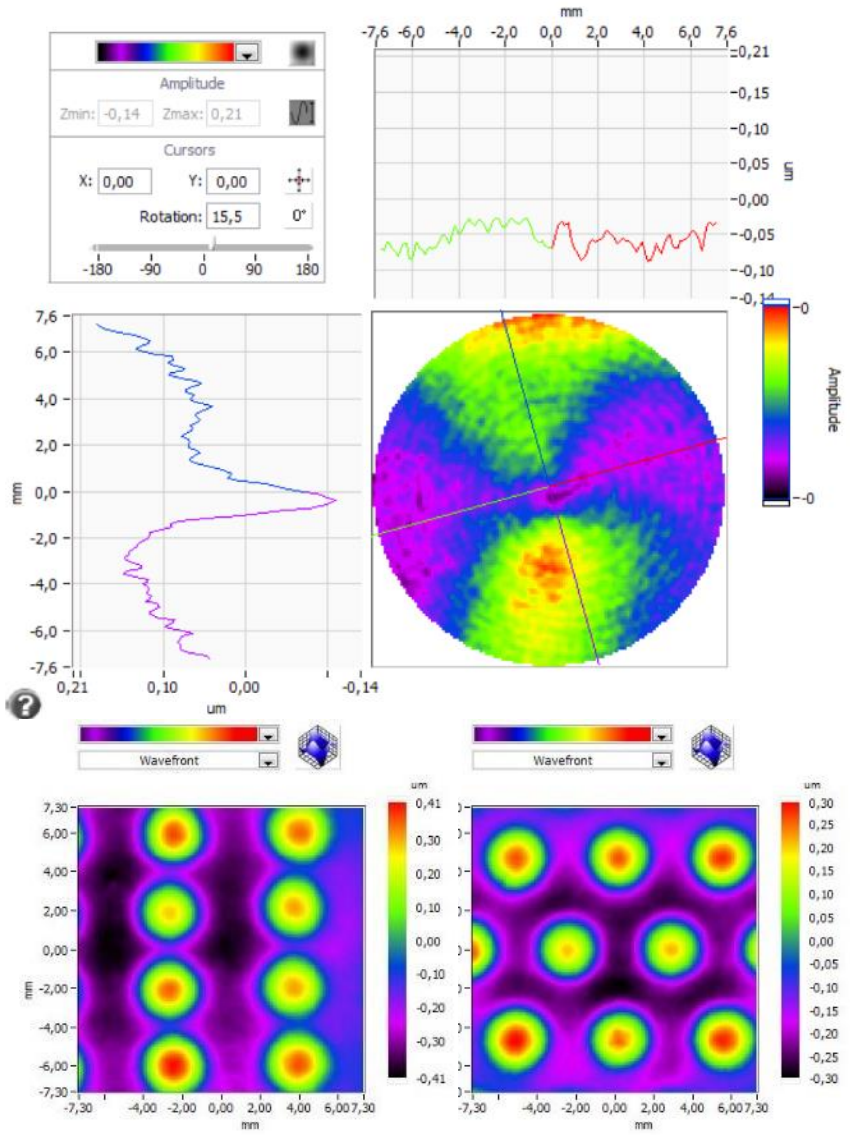


Optical testing **at multiple wavelengths**

LIFT metrology for industry | Microoptics production

Surface quality testing

Injection mold validation



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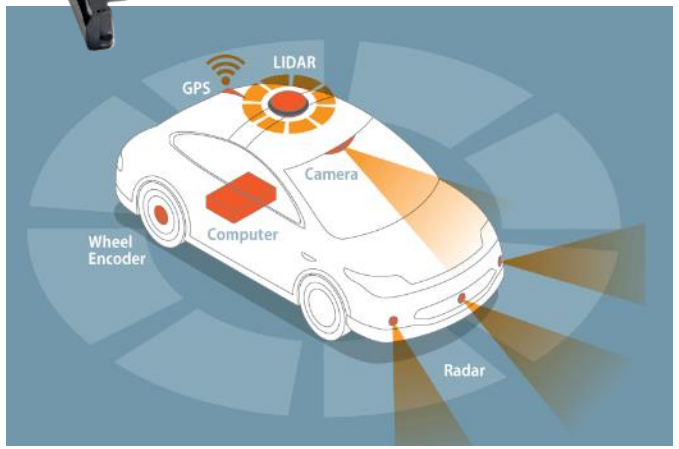
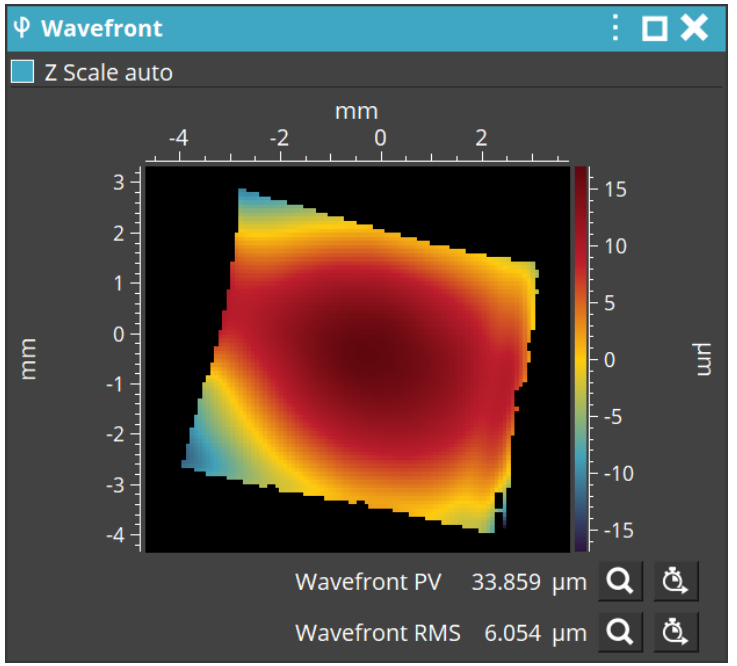
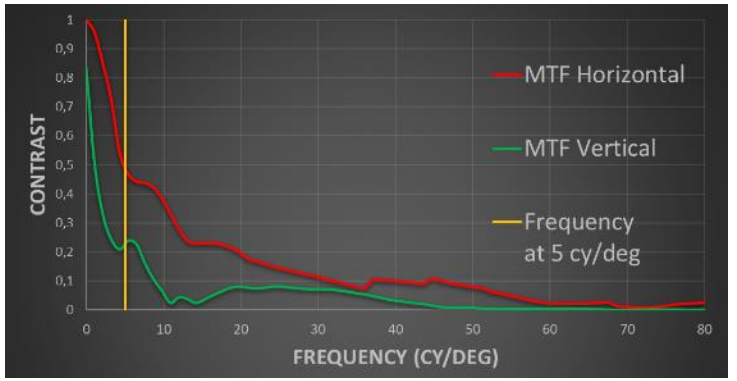
LIFT metrology for industry | Automotive sensors







Surface shape in reflection

Mold dev. & validation

Optical quality in transmission

MTF measurement

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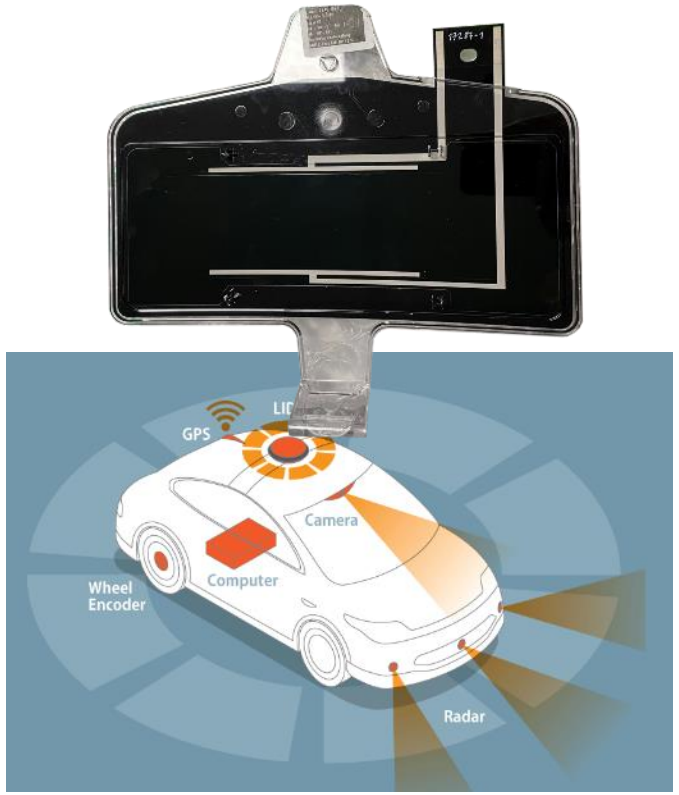
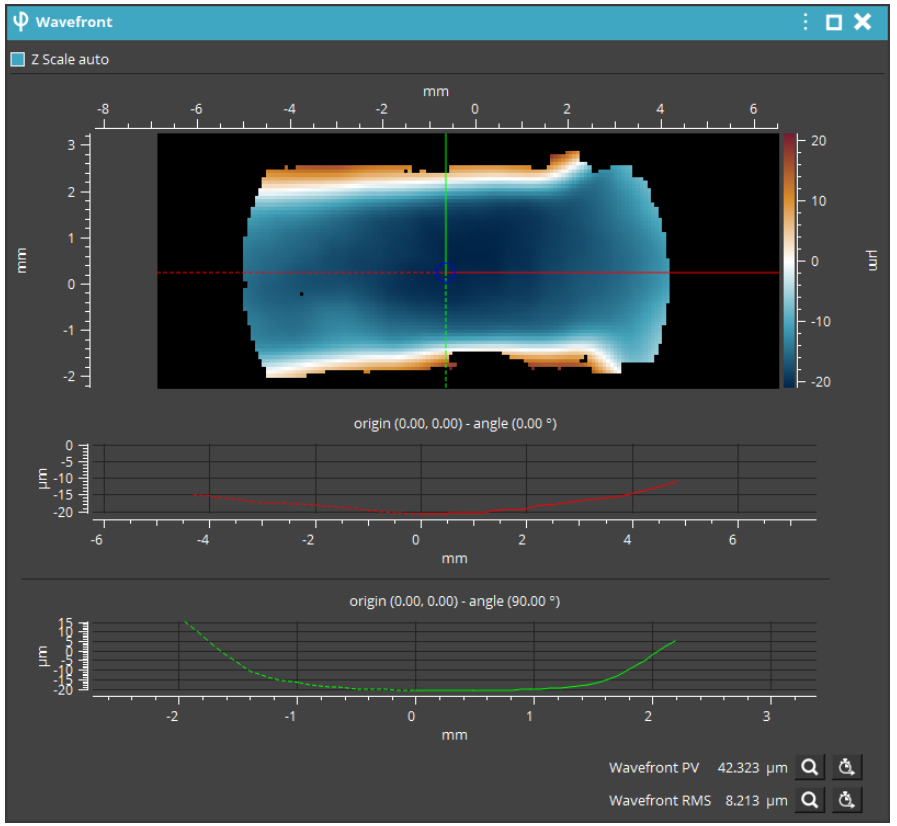
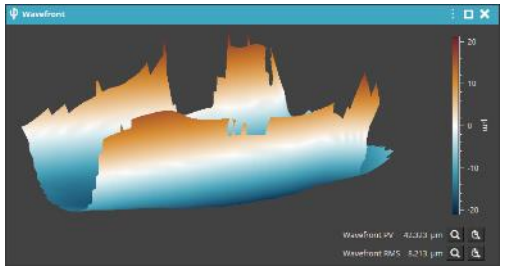
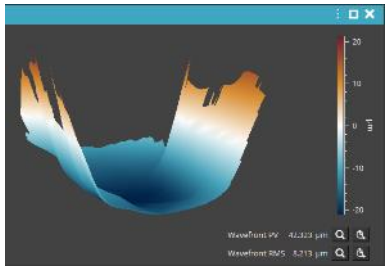
LIFT metrology for industry | Automotive sensors









Transmission Wavefront Error

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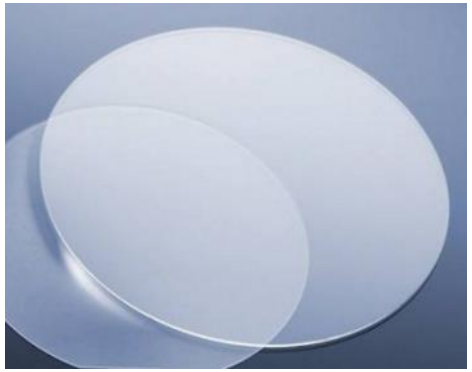
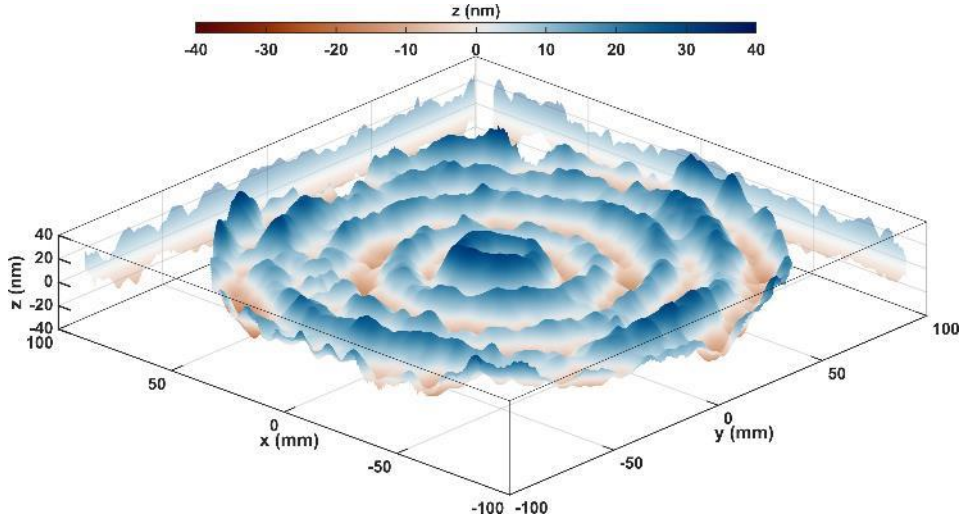
LIFT metrology for industry | Glass manufacturing

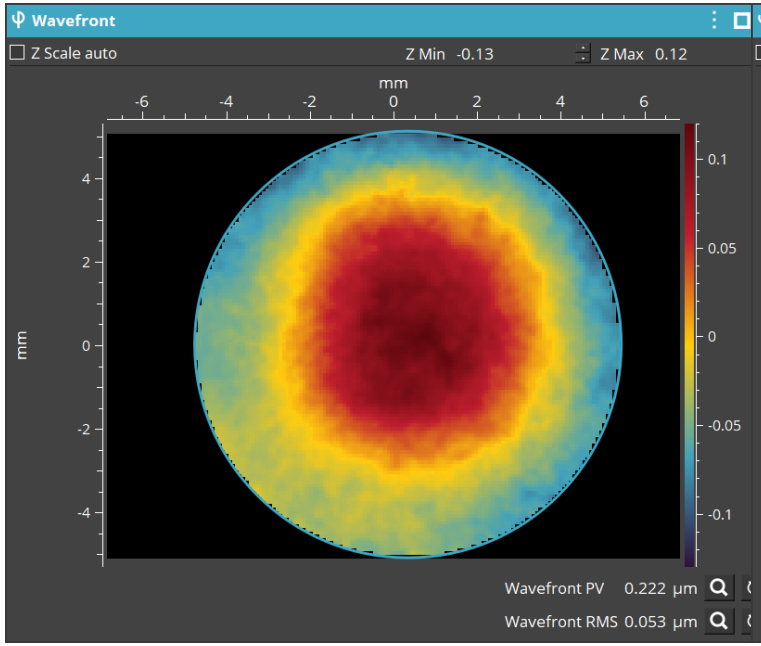


Polishing quality
Coating-induced stress



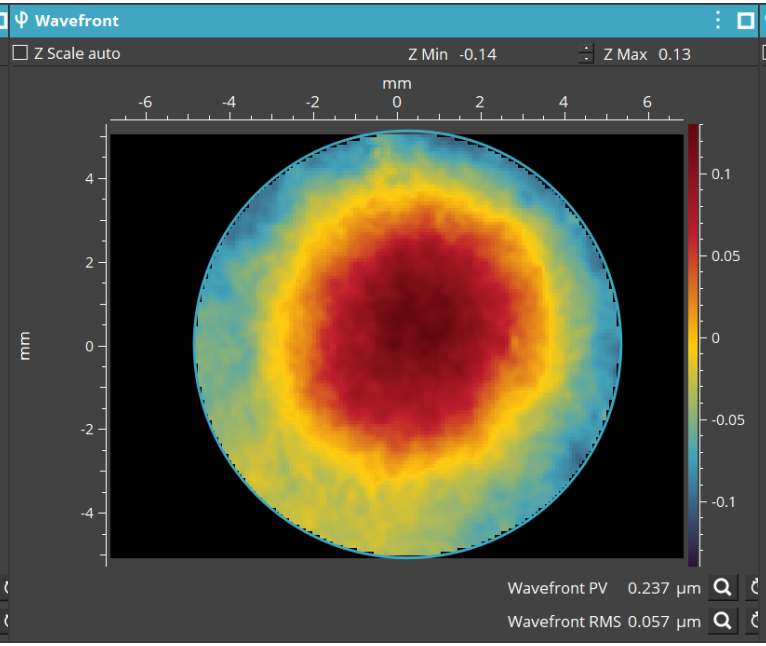
Support information | Achromatism

λ = 402 nm



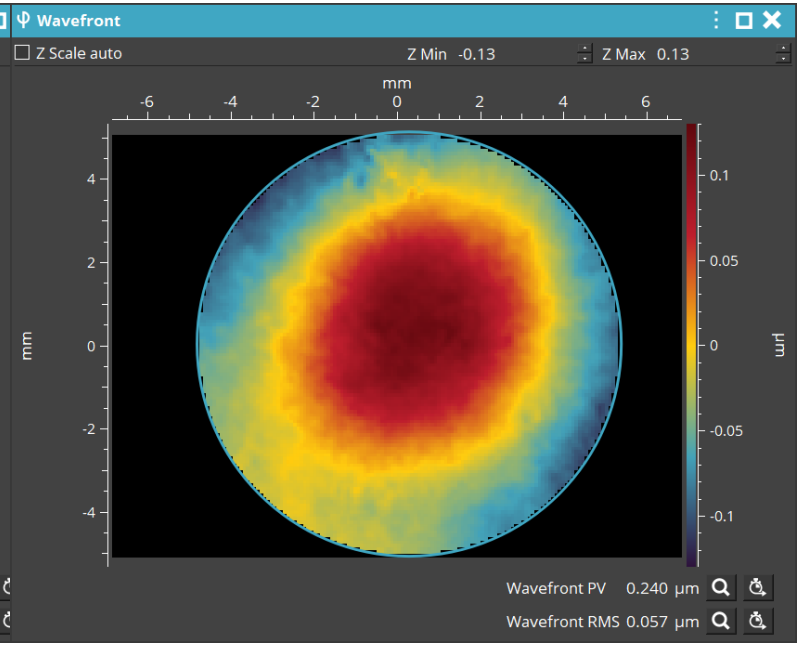
RMS = 0.053 µm

λ = 635 nm



RMS = 0.057 µm

λ = 785 nm



RMS = 0.057 µm

For more info, download our whitepaper “At wavelength metrology ”