Active illumination focus variation: rivaling confocal microscopy

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METROLOGY

Research environment

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METROLOGY

Confocal
- Confocal
- Confocal Continuous
- Confocal Fusion

Interferometry
- Phase Shifting Interferometry (PSI)
- Coherence Light Interferometry WLI (VSI)

Focus Variation

Reflectometry
- Thick and thin films

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Reflectometry
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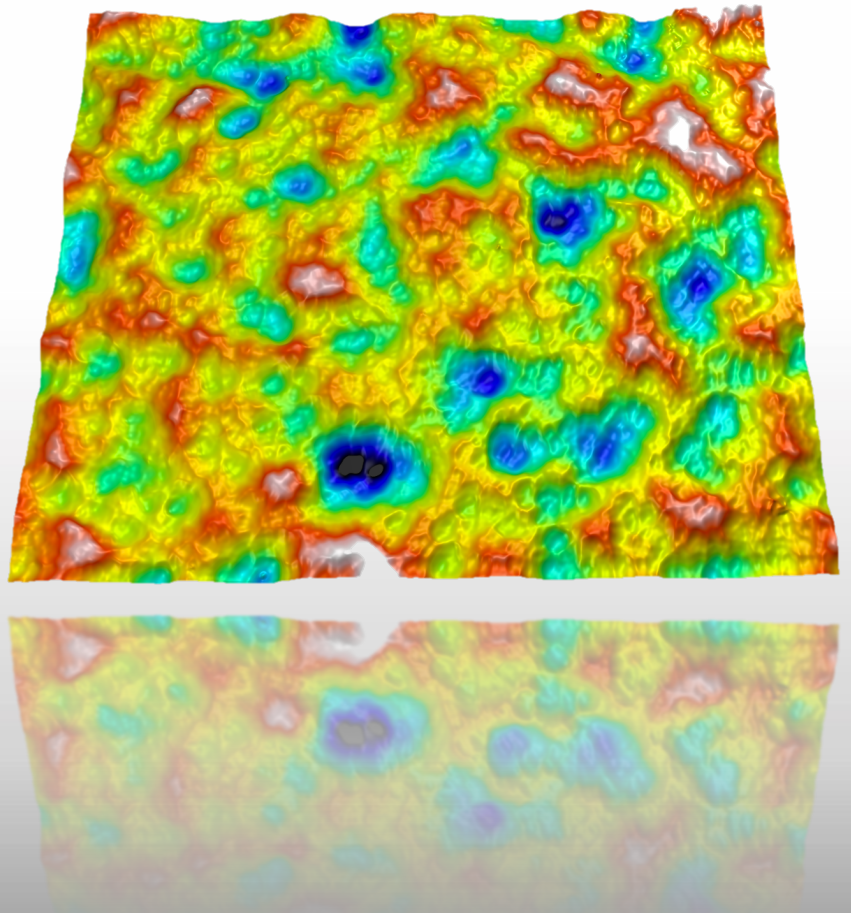

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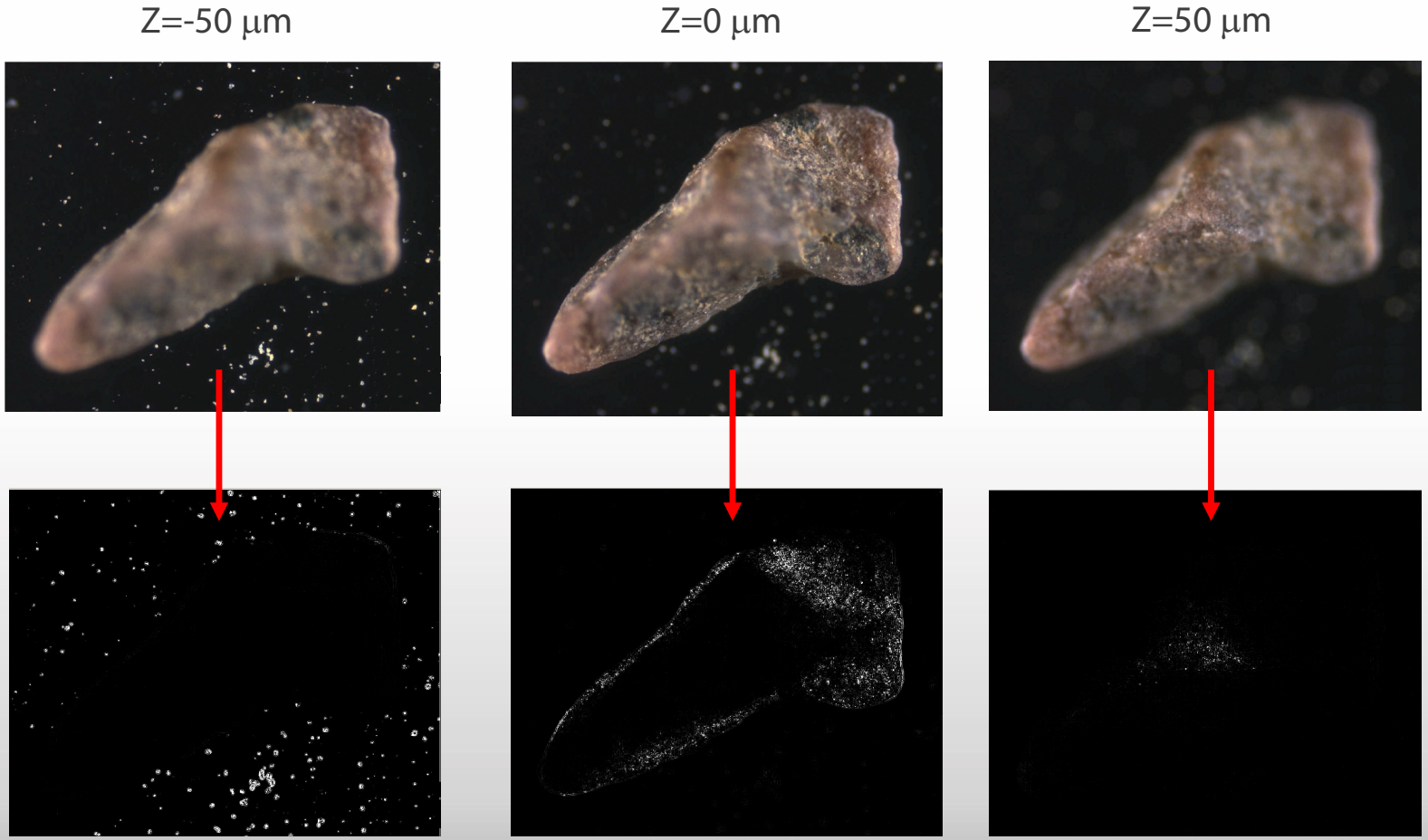
Motivation: Focus Variation



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Motivation: Focus Variation

Focus operators:

More than 30 algorithms explained in the literature.

- **Energy Laplace**: Usually this is a High Frequency algorithm using a kernel filter.

-1	-4	-1
-4	20	-4
-1	-4	-1

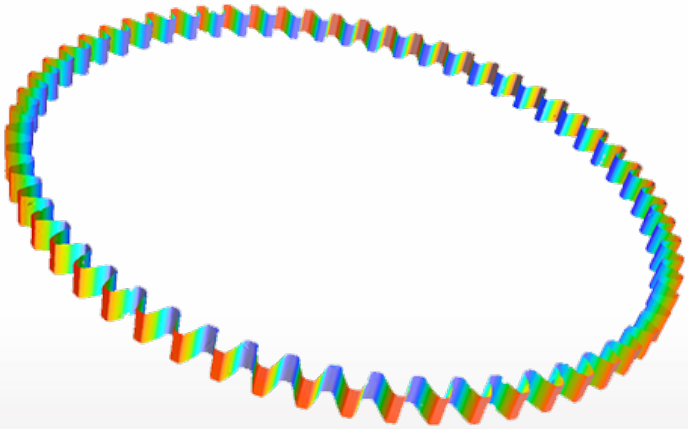
- **Squared gradient**: This is a pixel by pixel algorithm that looks for the variance of the local image.

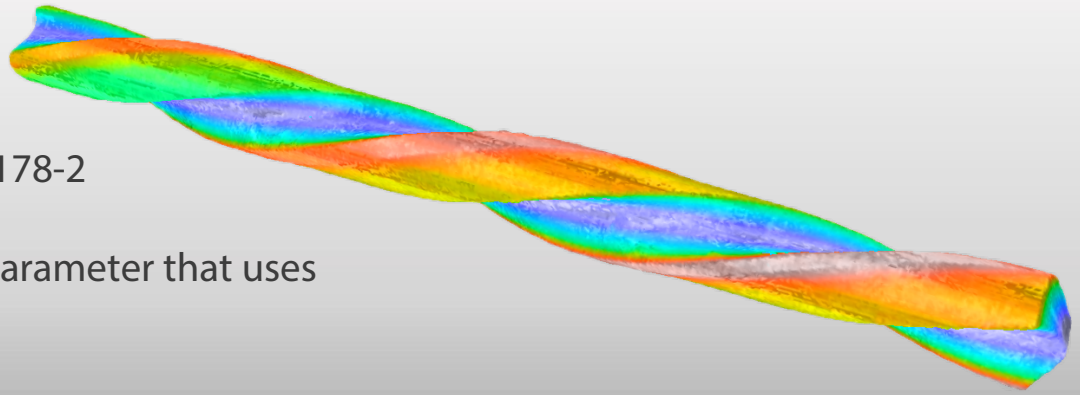
$$Var(z)_{i,j} = \frac{1}{n^2} \sum_{k=-n/2}^{k=n/2} \sum_{l=-n/2}^{l=n/2} (I_{i+k,j+l} - \bar{I})^2$$

- **Tenenbaum gradient, Sum of Modified Laplacian, Wavelet, Variance, Auto-correlation, Histogram based algorithms, …..**

Motivation: Focus Variation

- Focus Variation is a well known 3D metrology technology
- Suitable for any sample that exhibits textured surface for the optical conditions under inspection.
- Not suitable for optically-smooth surfaces.
- Measurement uncertainty and system noise is similar to surface roughness. The technology fits very well for metallic surfaces, additive manufacturing, tooling, etc.
- Height resolution is dependent on NA.
- Lateral resolution is compromised.
- Ok for height parameters from ISO 25178-2
- Non trustable Spatial, Hybrid, or any parameter that uses lateral information.





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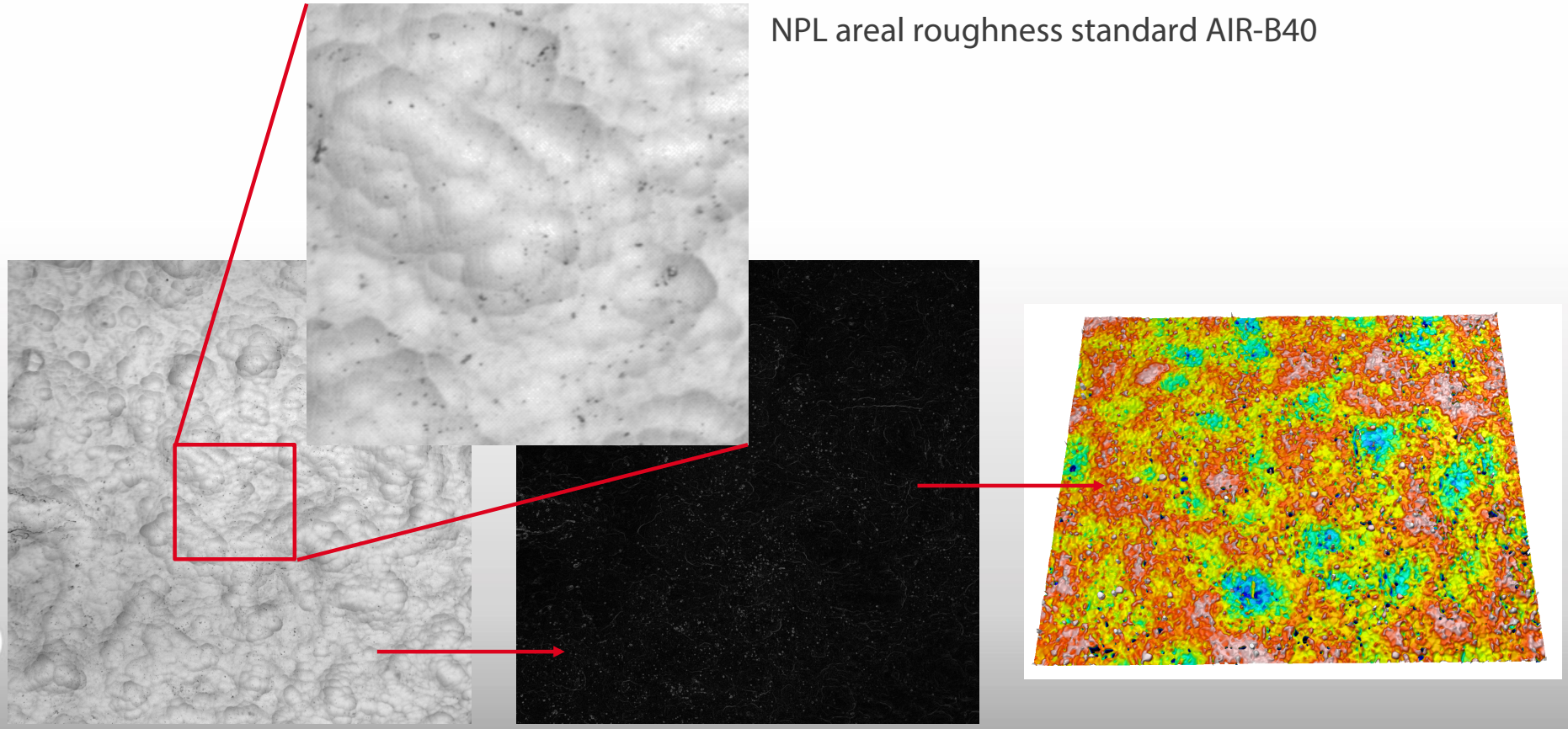
Focus Variation on optically smooth surfaces (limitations)

- On non-textured surfaces, the focus operator does not provide sufficient signal to recognize the best focus position.
- This is typically the case on optically smooth surfaces, providing noisy 3D results

NPL areal roughness standard AIR-B40



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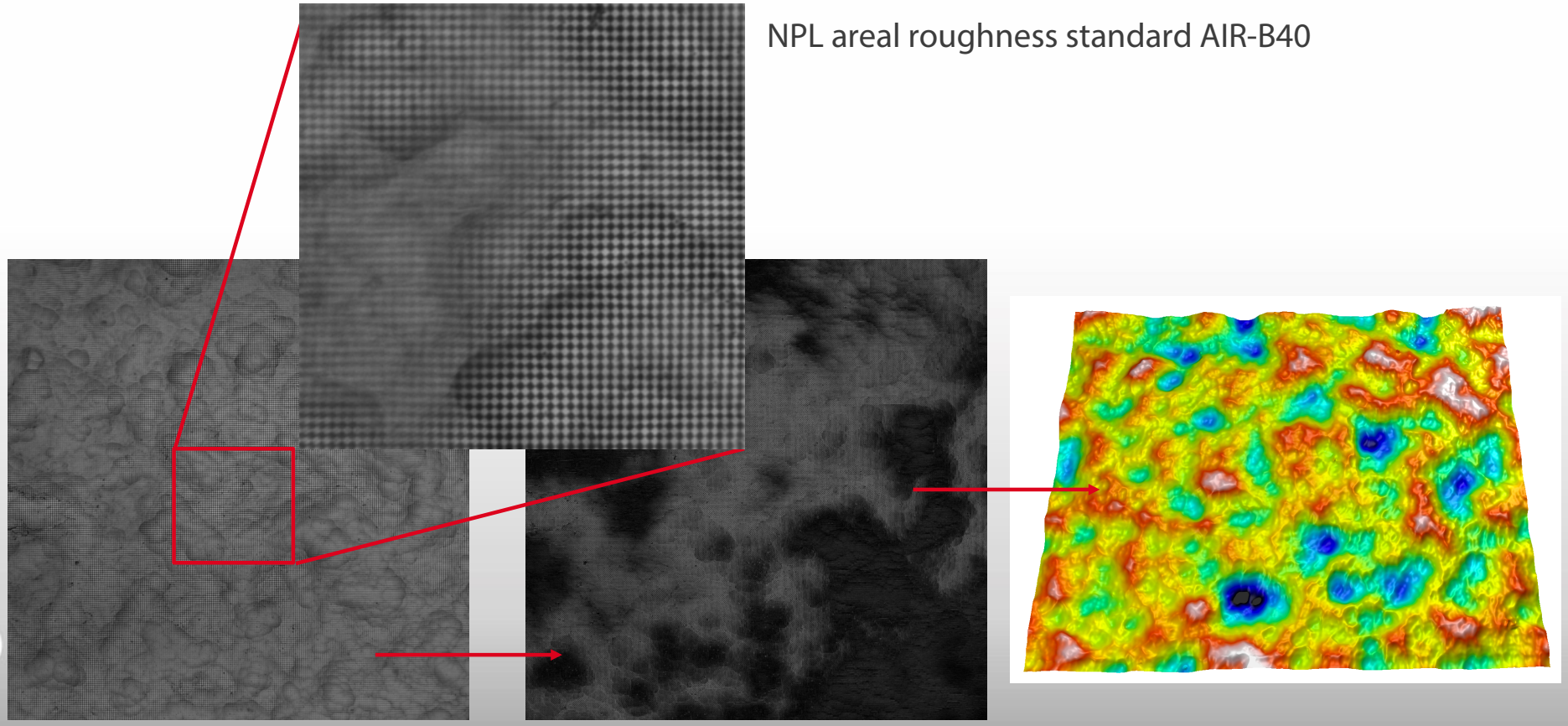
Active Illumination Focus Variation on smooth surfaces

- Superposition of artifical texture by optical means provides strong signal to the focus operator on optically smooth surfaces.

Microscopic shape from focus using active illumination. Noguchi and Nayar (1994)

NPL areal roughness standard AIR-B40



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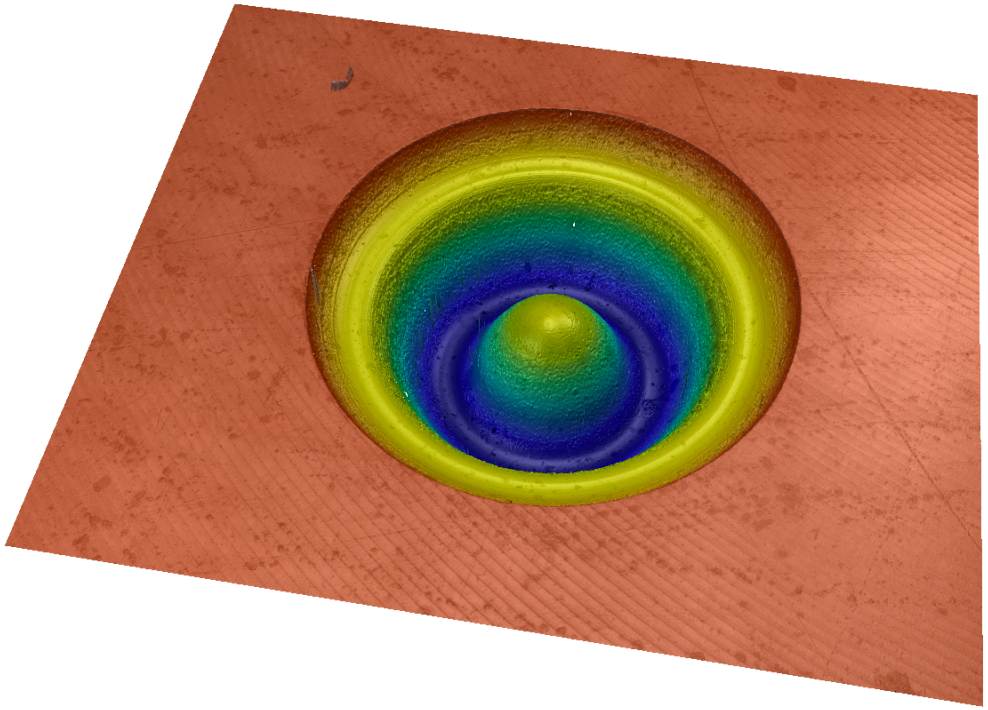
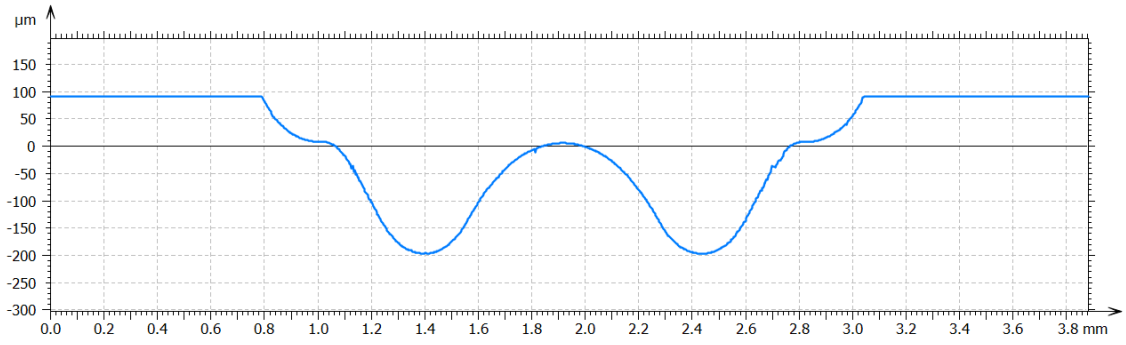
Active Illumination Focus Variation on smooth surfaces

Smooth surfaces with relatively low frequency components, like glass lenses, can be measured with AiFV.





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Diamond turnning micro-lens

Active Illumination Focus Variation implemented on a Microdisplay Scanning Confocal Microscope

New S-neox

5th generation of 3D desktop profiler

February 2019

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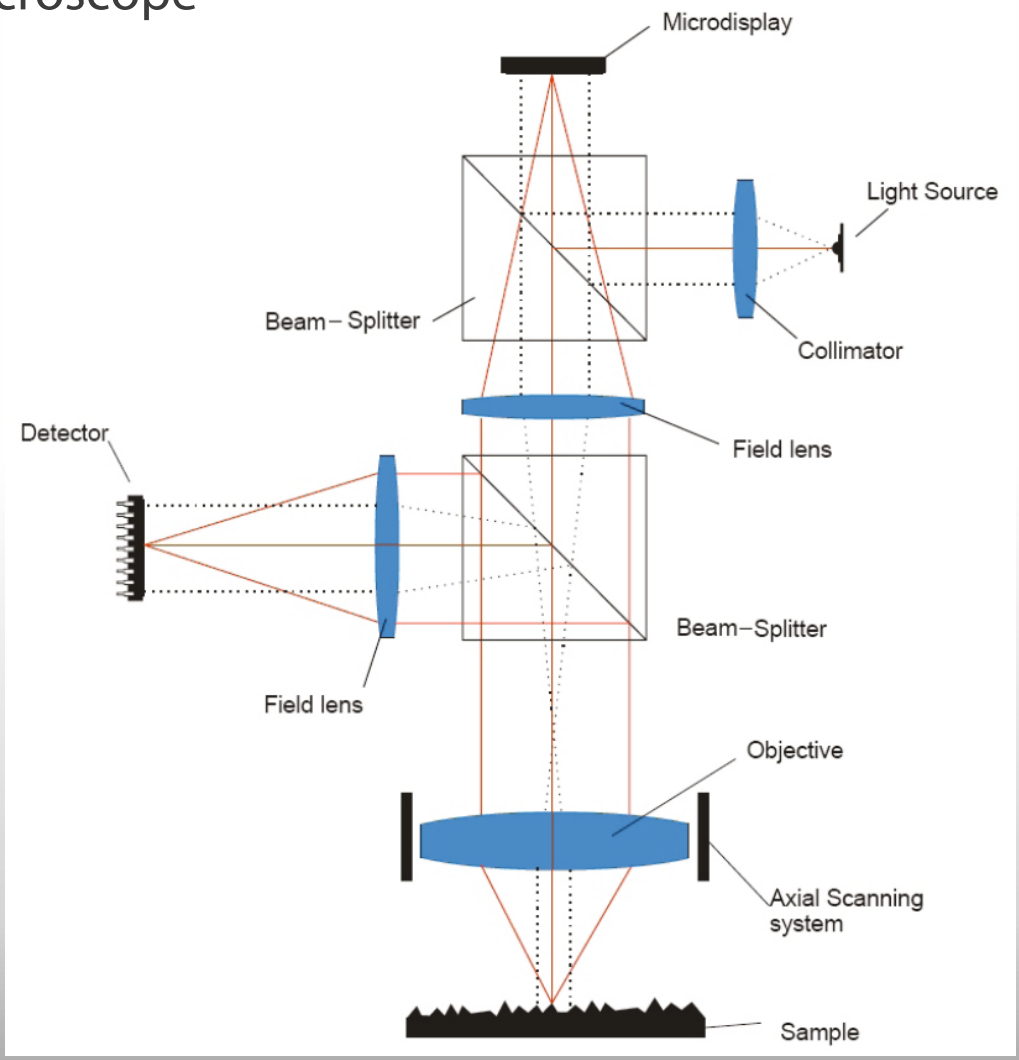
Active Illumination Focus Variation implemented on a Microdisplay Scanning Confocal Microscope



ISO 25178-607

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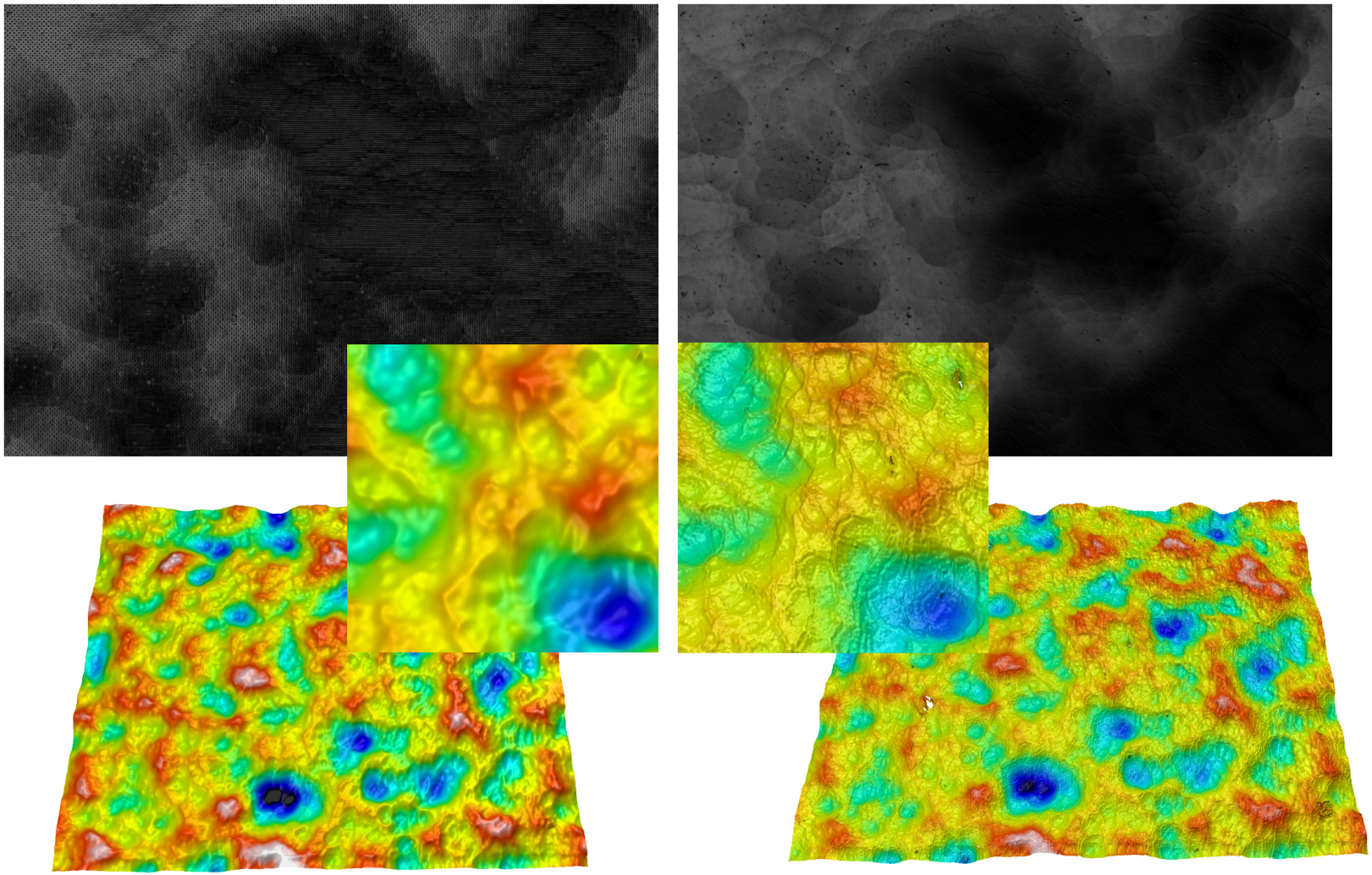
Active Illumination Focus Variation. Comparision with Confocal Microscopy

AiFV

Confocal



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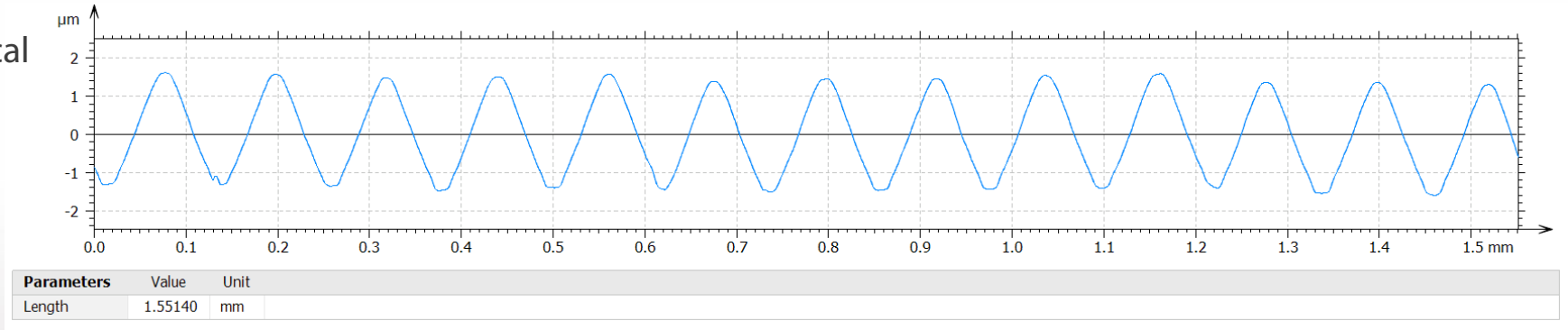
Low frequency samples: roughness standards Type B2

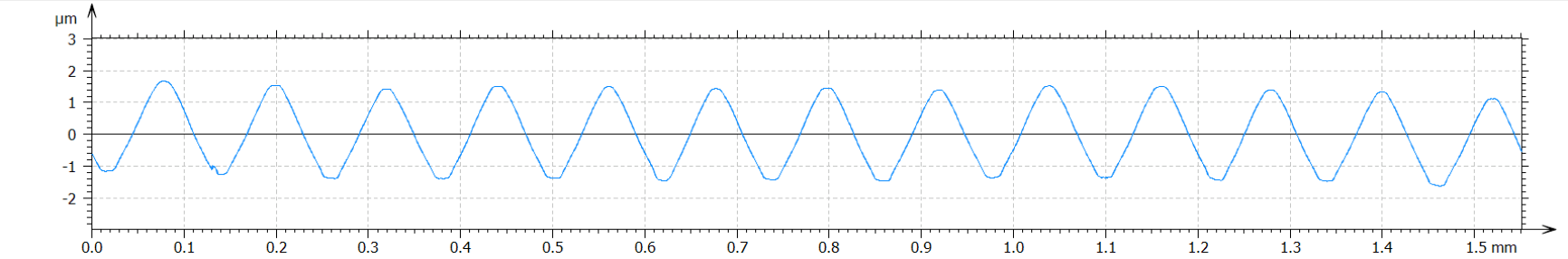
- Mahr roughness standard PRN-3 (glass substrate). Ra=0.88 μm.
- Top: Confocal measure (4 mm length with 50X0.8NA objective). Ra=0.883 μm
- Bottom: AiFV measure (4 mm length with 50X 0.8NA objective). Ra=0.885 μm

Confocal



Parameters	Value	Unit
Length	1.55140	mm

AiFV



Parameters	Value	Unit
Length	1.55140	mm

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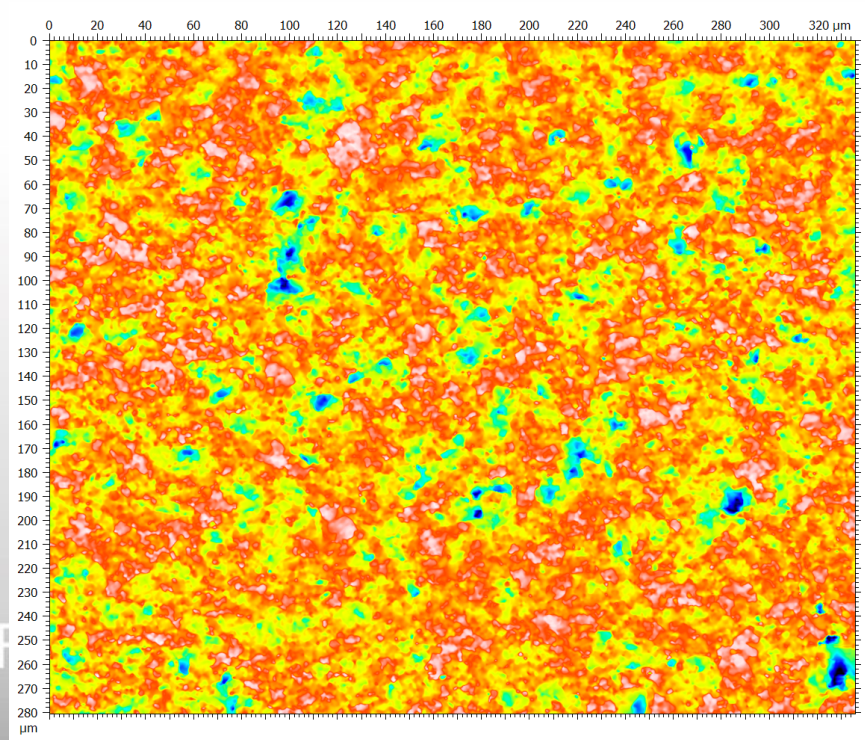
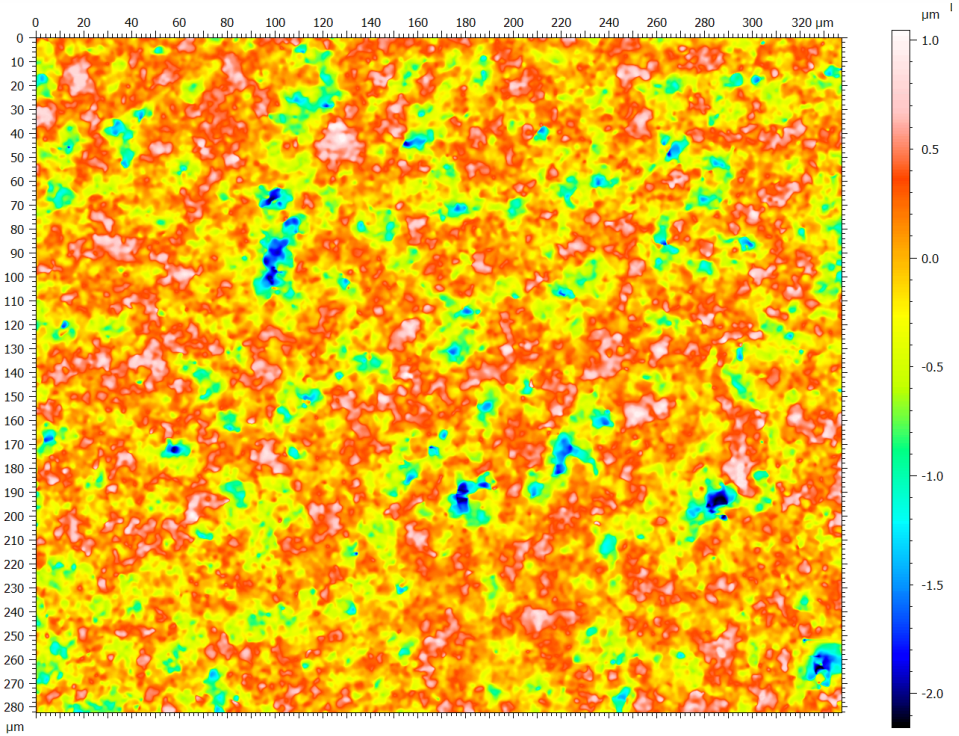
Medium to high frequency samples: random roughess standards

Simetrics ARS-C3 standard. Sa= 0.29 μm

Confocal



AiFV

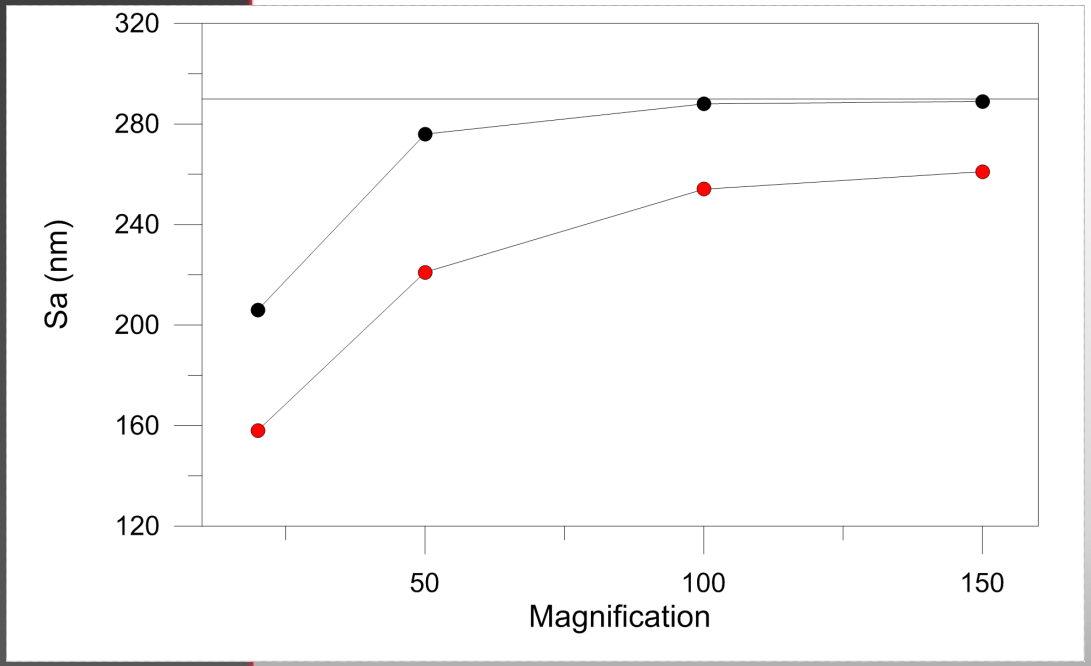


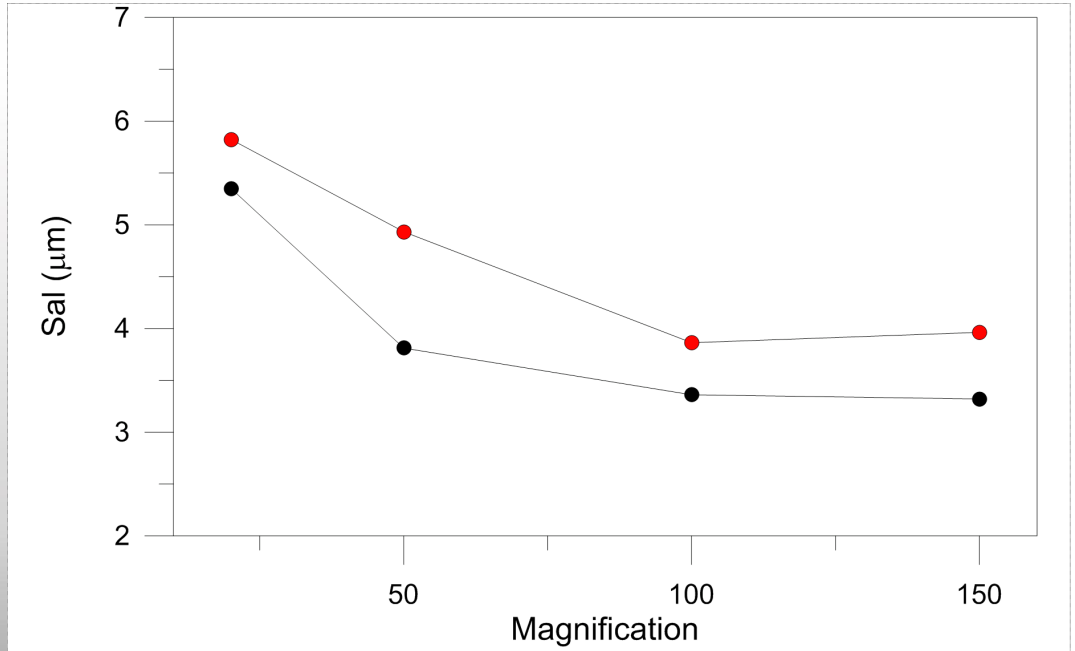
SENSOR

Medium to high frequency samples: random roughess standards

Sa (roughness) and Sal (surface autocorrelation length)

- Simetrics ARS-C3 standard. Sa= 0.29 μm, Sal=2.5 μm
- **Black** Confocal measures
- **Red** AiFV measures
- 20X0.45NA, 50X0.8NA, 100X0.9NA, 150X0.95NA



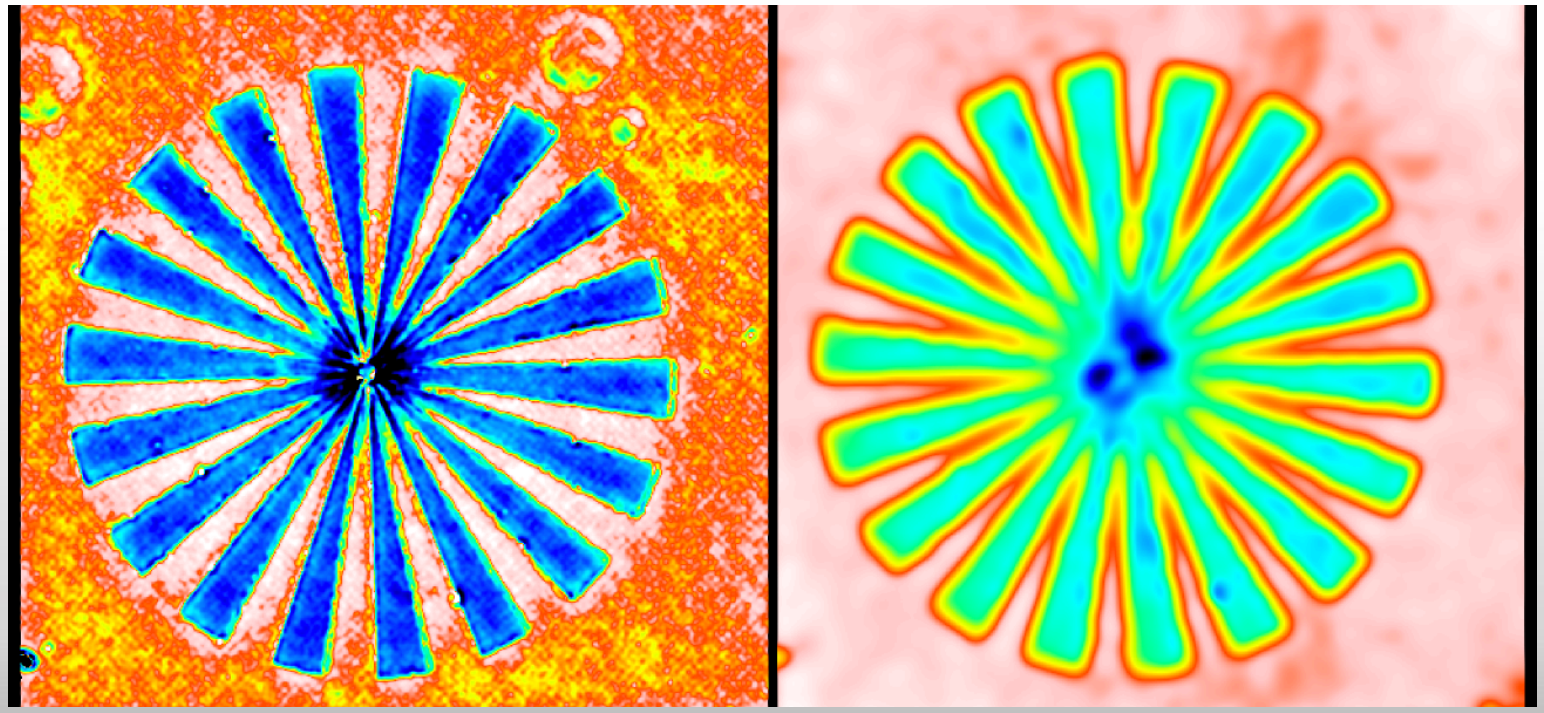


Lateral resolution of AiFV

To measure the lateral resolution a Siemens Star from NPL Bento Box, model ASP-02 P18 is used.

20X 0.45 NA 0.46 micron center wavelength

Confocal AiFV



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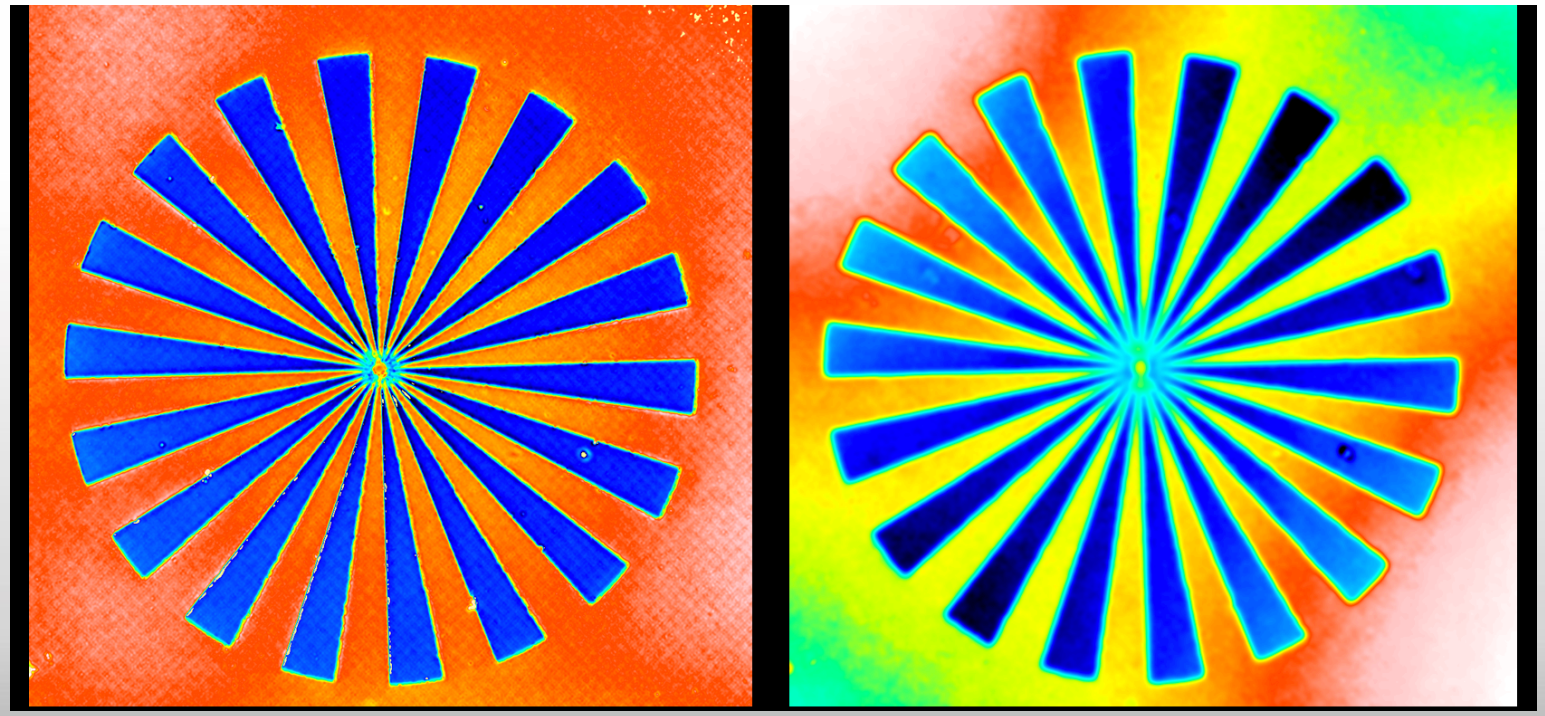
Lateral resolution of AiFV

To measure the lateral resolution a Siemens Star from NPL Bento Box, model ASP-02 P18 is used.

50X 0.8 NA 0.46 micron center wavelength

Confocal

AiFV



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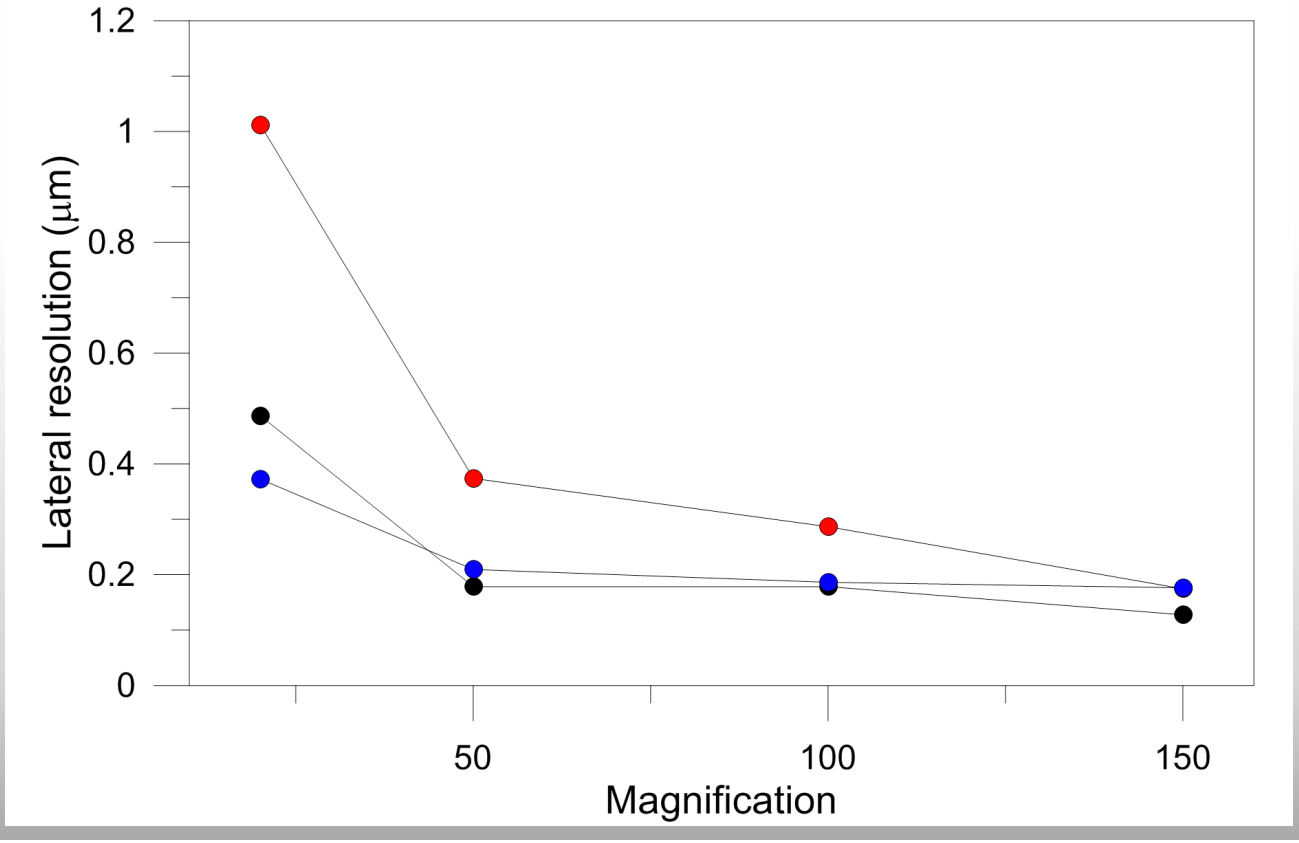
Lateral resolution of AiFV

- Siemens Star from NPL Bento Box, model ASP-02 P18
- **Black:** Confocal measures
- **Red:** AiFV measures
- **Blue:** Difraction limit according to Rayleight criteria
- 20X0.45NA, 50X0.8NA, 100X0.9NA, 150X0.95NA



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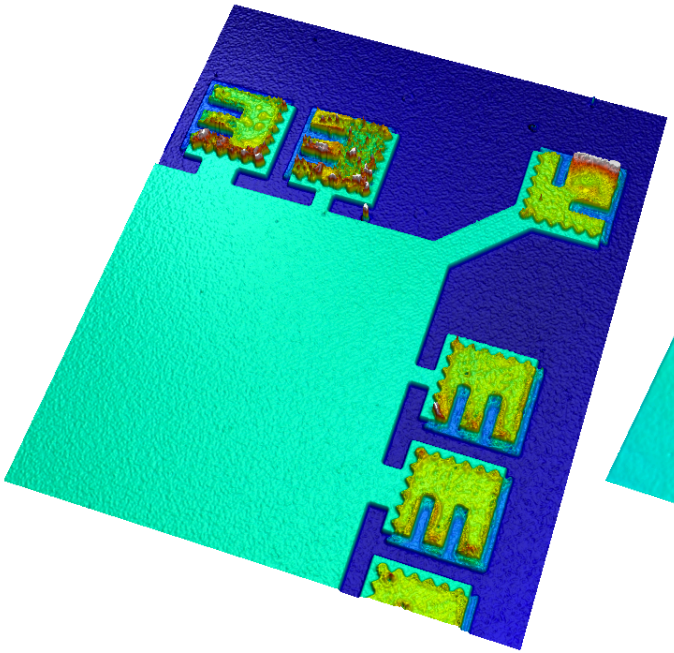
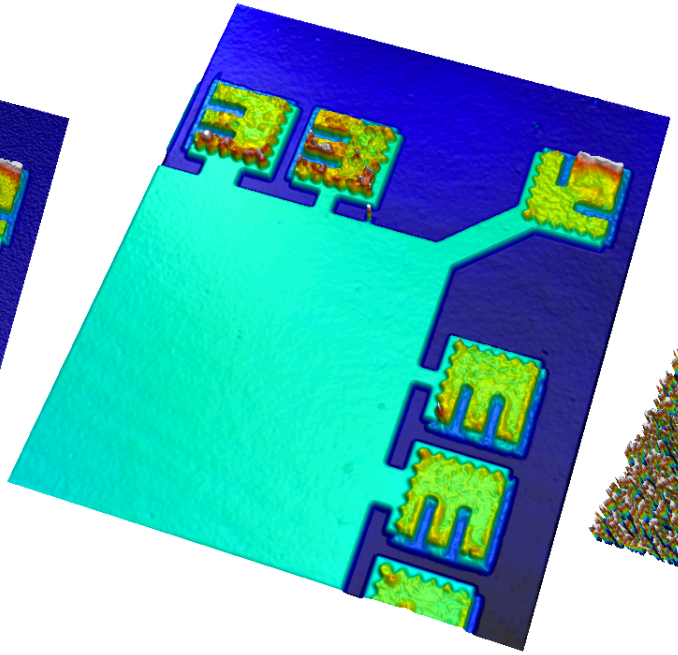
Comparison Confocal / AiFV
(large structures)

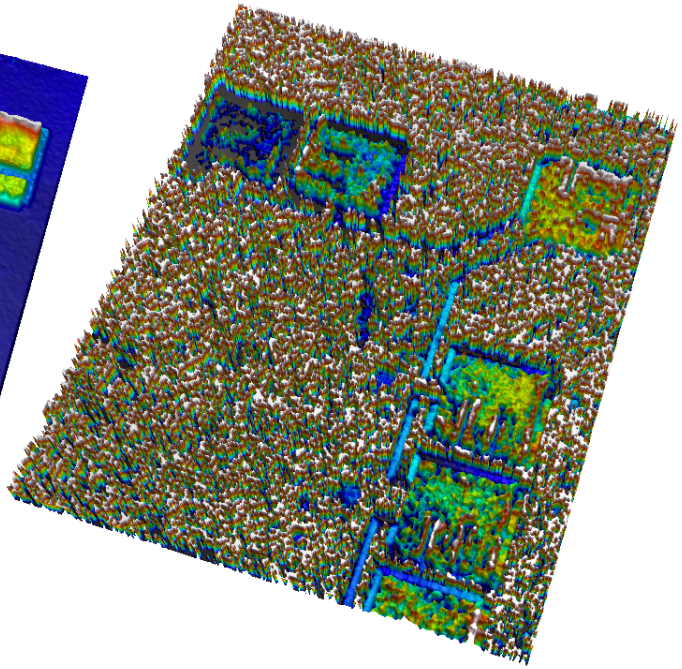
Confocal



AiFV



FV



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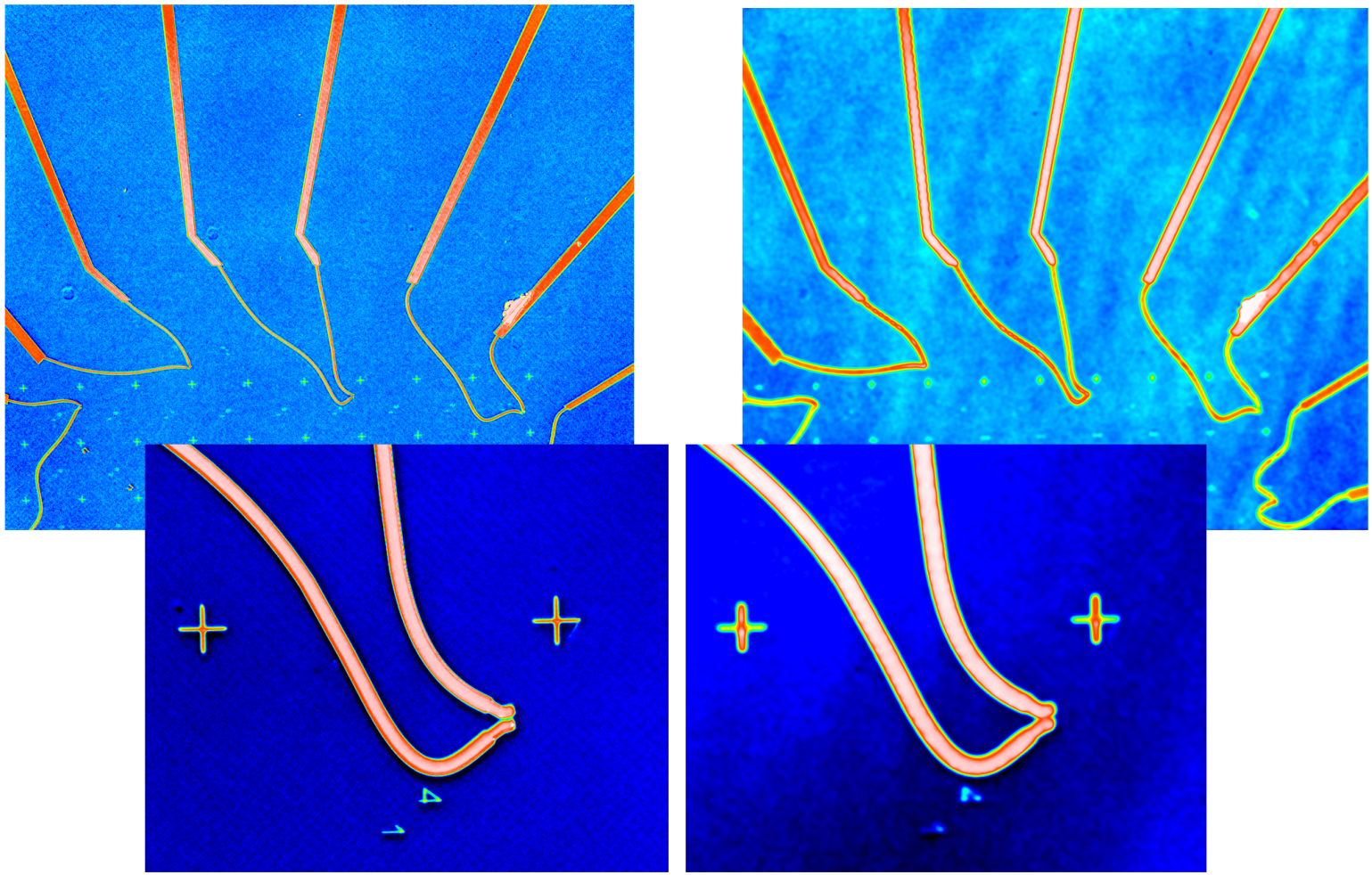
Comparison Confocal / AiFV
(Fine details)

Confocal

AiFV



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Conclusions

- Active Illumination Focus Variation (AiFV) overcomes most of the limitations of FV
    - It provides focus signal to optically smooth and rough surfaces.
    - The focus operator is applied to the smallest possible window
    - Enhances real focus position in the appearance of optical reflexions
- AiFV has been implemented on a microdisplay scan confocal microscope
- Low frequency samples (Sal at least 3 times larger than the lateral resolution) do not compromise the results in comparison to confocal microscopy.
- Geometries with lateral features few times larger than the pixel size can be easily evaluated
- In overall, AiFV can rival Confocal Microscopy in a large number of applications.

Thank you!

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