

Multiscale samples for simple scanning probe microscope calibration

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Design

Single sample, measure anywhere at any scale with any instrument, no alignment

Lateral scale

AFM – fine (100s of nm) lattice
Optical – large (100s of μm) lattice
And everything between – details at all scales
Optical contrast – material density (fill ratio)

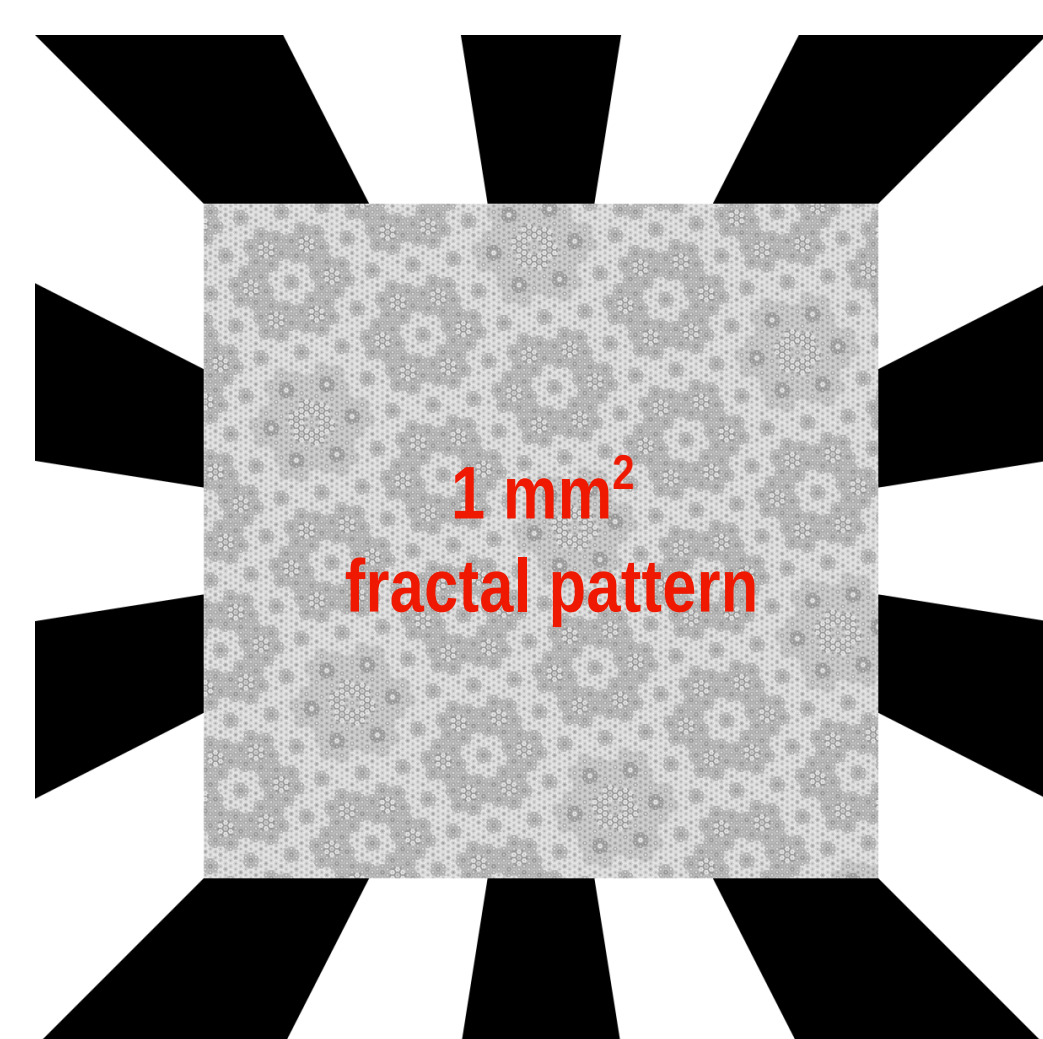
Vertical standard

ALD fabrication – well-defined
Single height – low complexity & cost
AFM scanning & optical contrast compromise

Other consideration/features

Isotropic edges – tip characterisation
Different at every scale – blind size estimation
Stable, hard material – oxide

Final design
1.5 mm \times 1.5 mm
75 nm Al_2O_3 layer on Si – antireflection condition

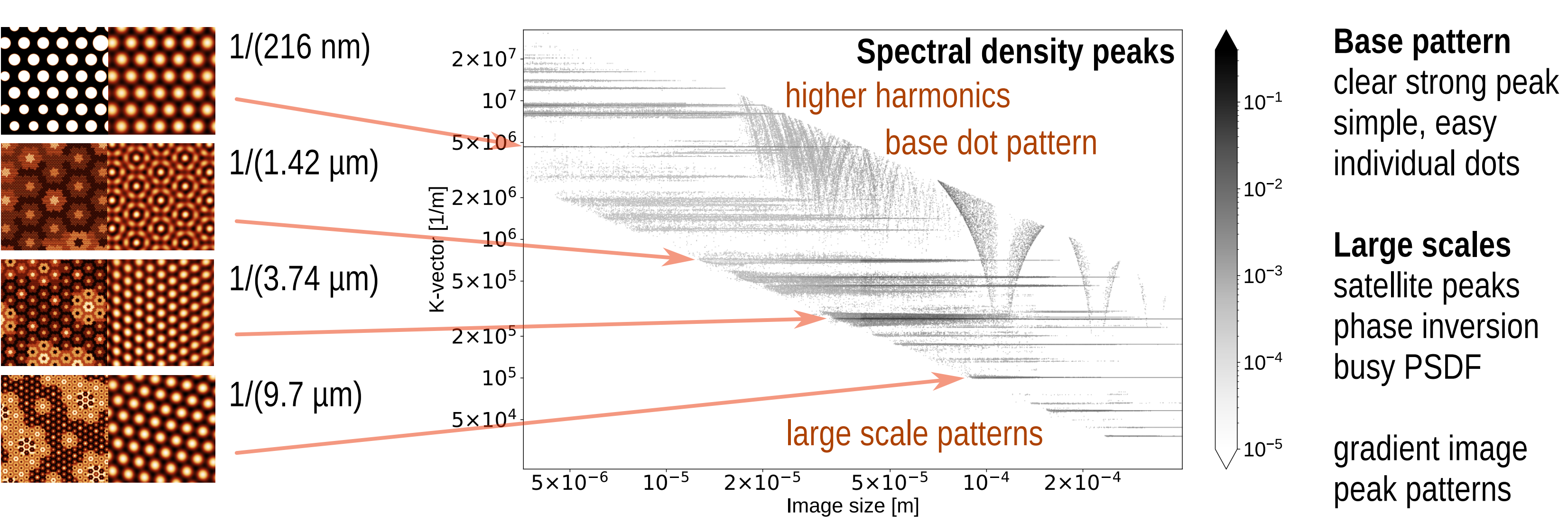
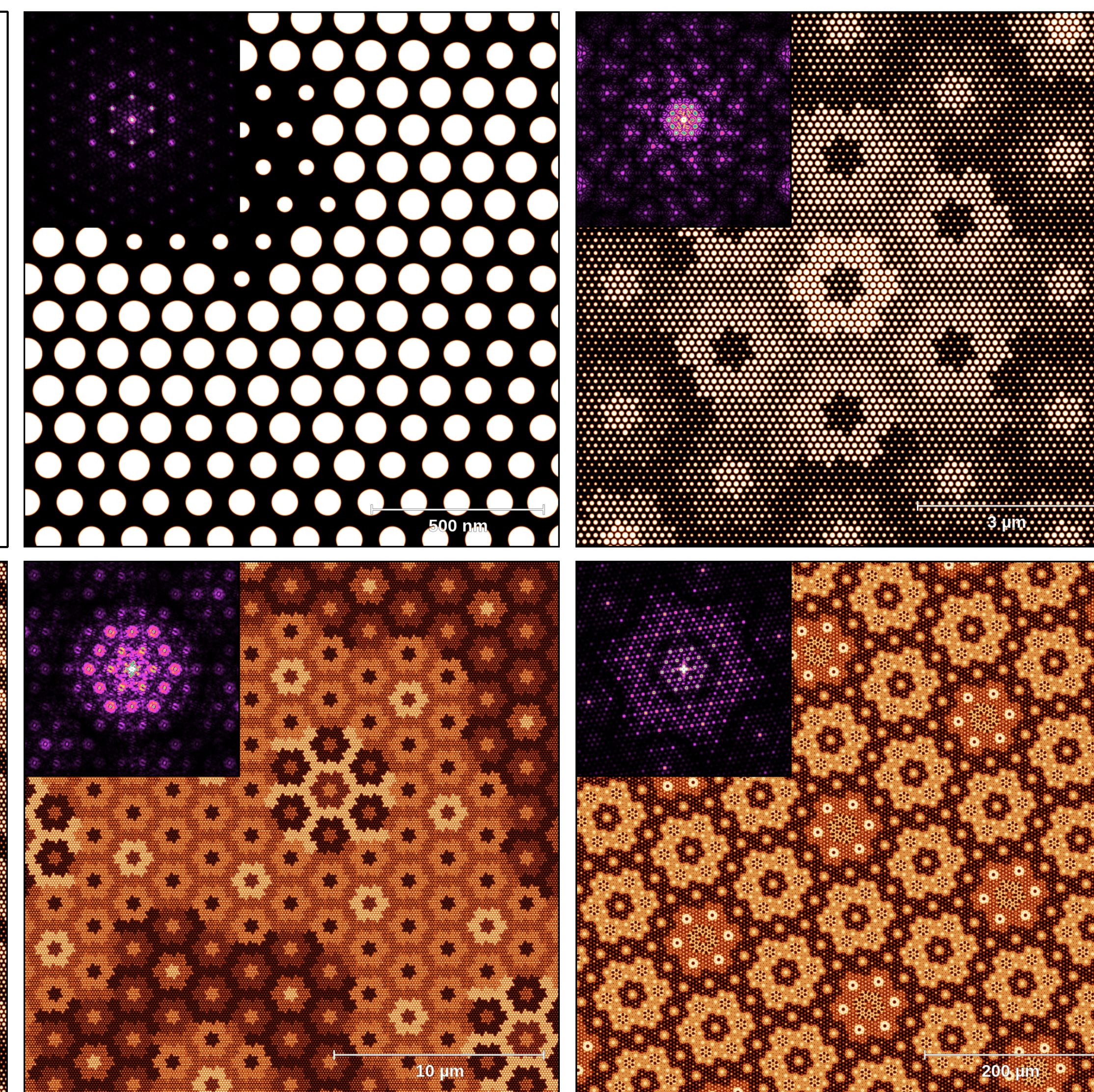


250 μm border
find me marker
see by naked eye
height standard
flatness?

Simulation

Spectral density (FFT)
Topography or material density

Images generated from the same (x, y, r) data as used to make GDSII files for manufacturing.

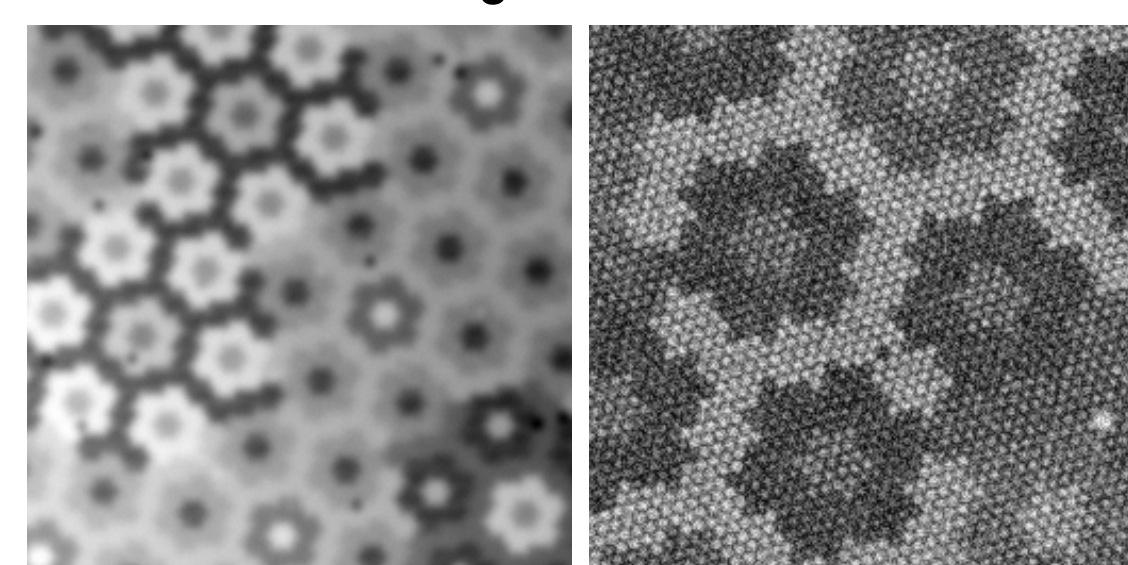


Blind size estimation

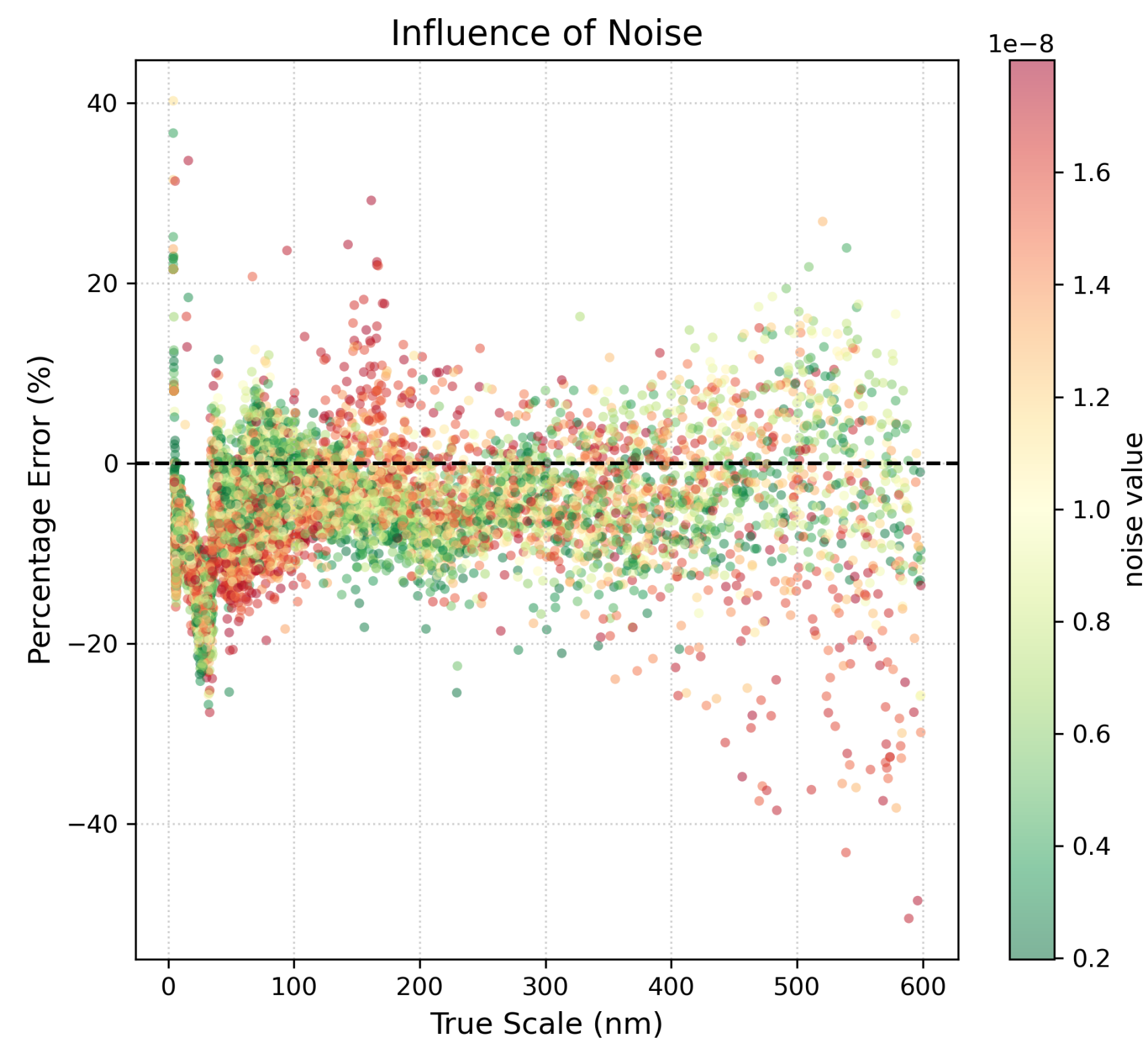
Blind size estimation just from images
Embeddable – simple & fast

Convolutional Neural Network

5 convolutional layers
256 \times 256 input images (crop)
100k image dataset with artefacts
noise, blur, background & local defects



Trained in PyTorch, ONNX translated to C.
Compiled to ~1.6 MB standalone executable.
Inference time ~0.4 s.



In different instruments

Testing behaviour in different instrument types

Optical instruments

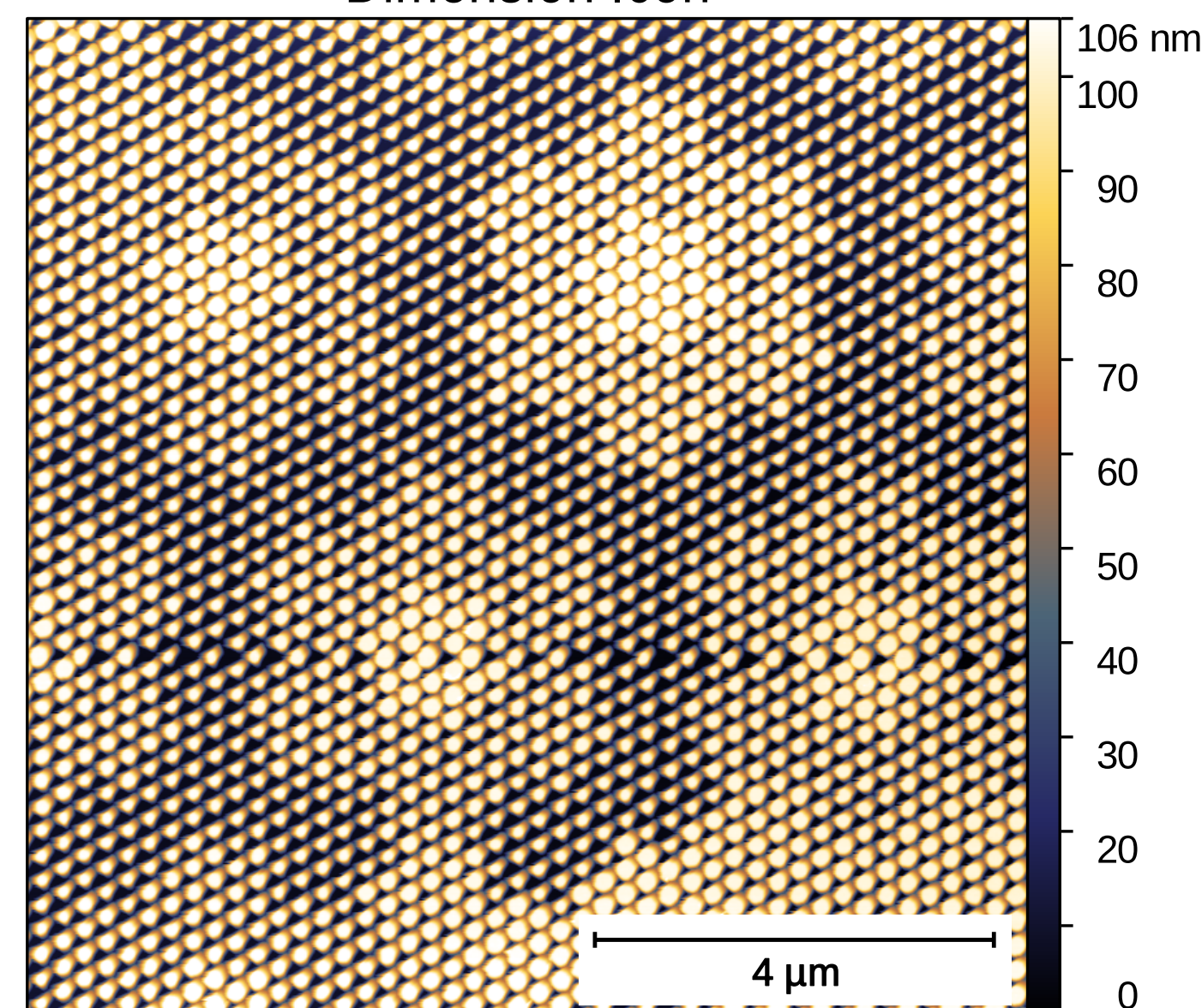
Nice intensity contrast everywhere
Height measurement confused
(Use flat find-me bars)

Atomic force microscopy

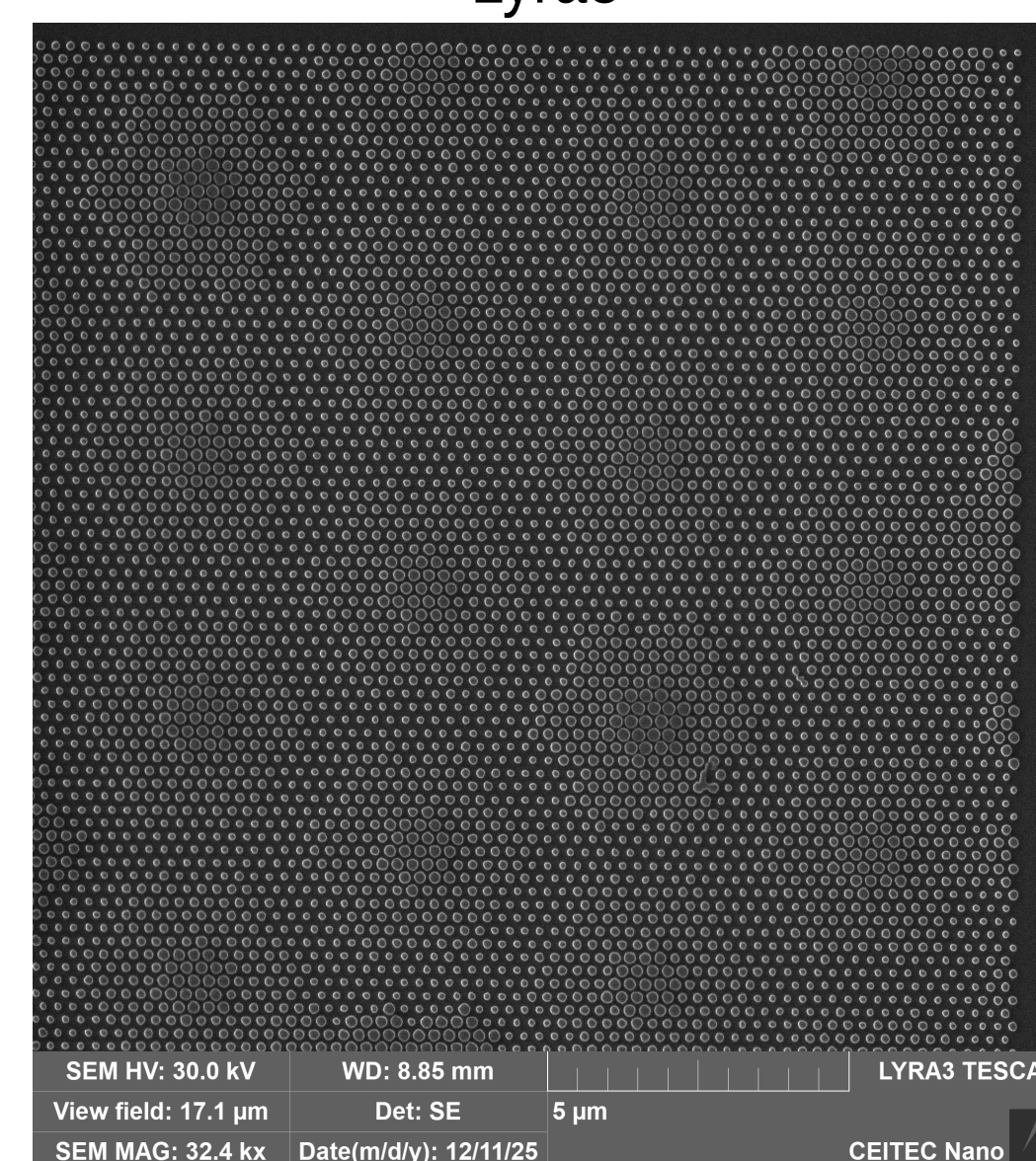
Prototype OK for pitch
Not great for height
Aspect ratio too high

SEM – features a bit too wide
Corrected in final design

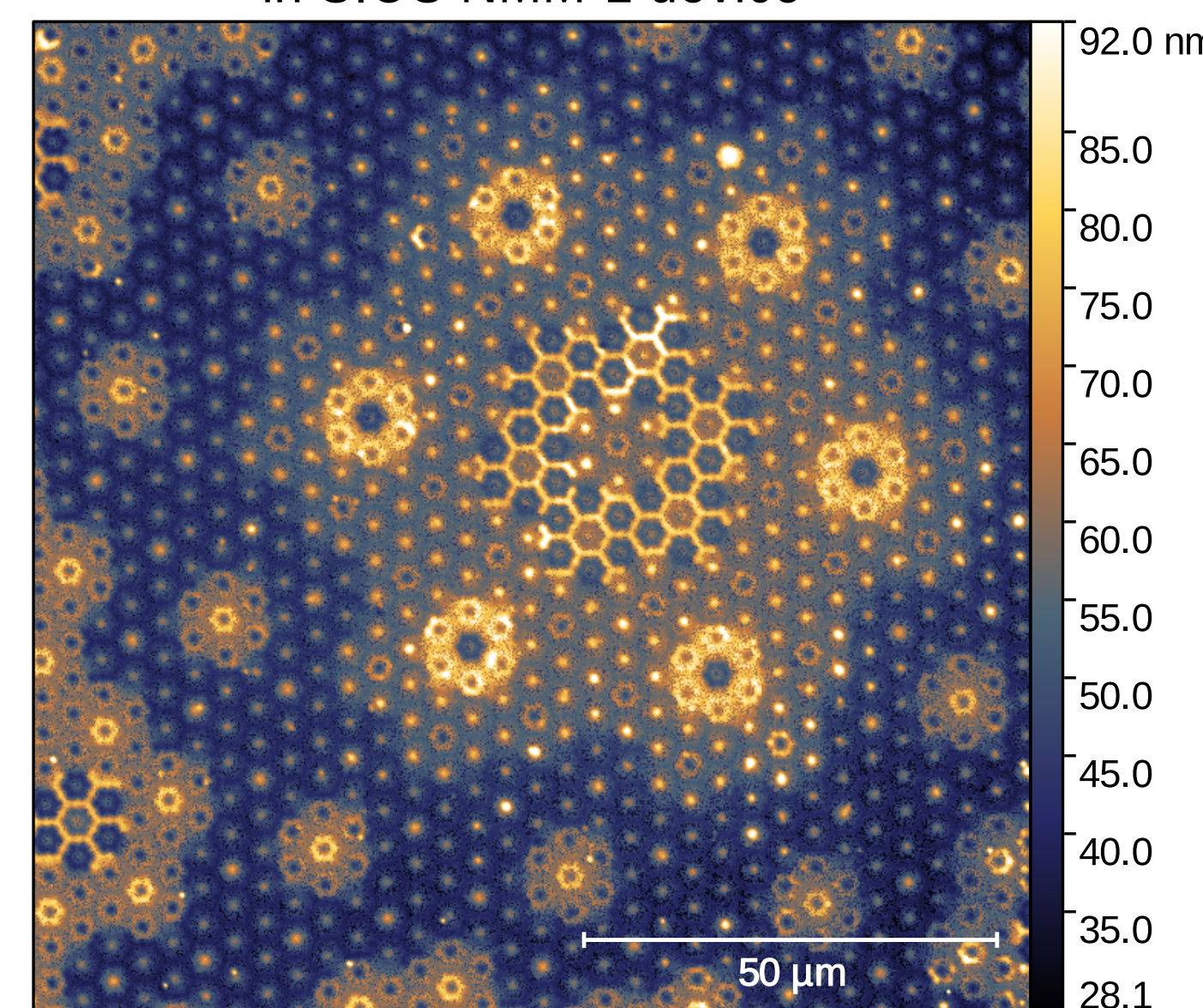
Atomic force microscopy
Dimension Icon



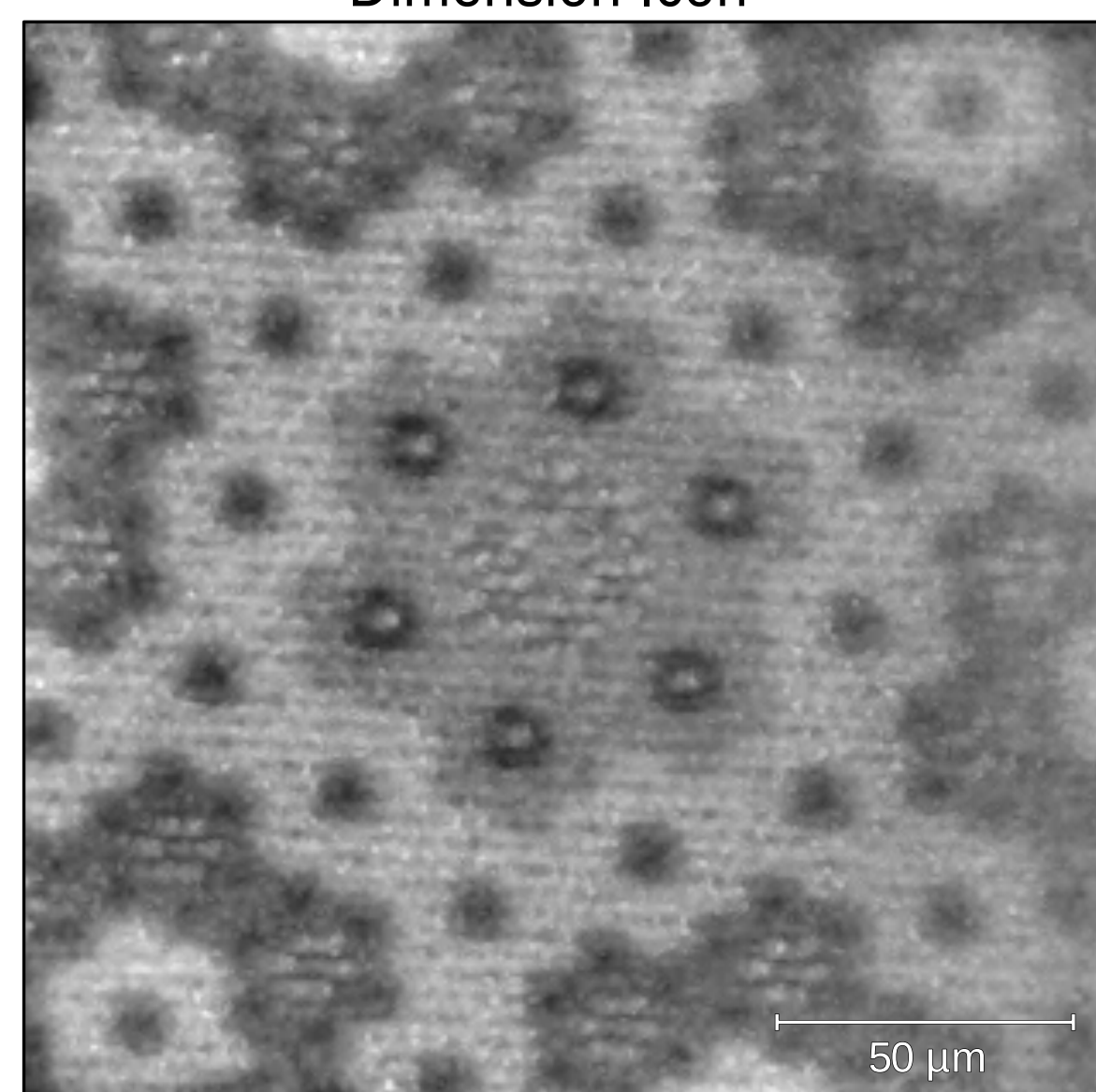
Scanning Electron Microscopy
Lyra3



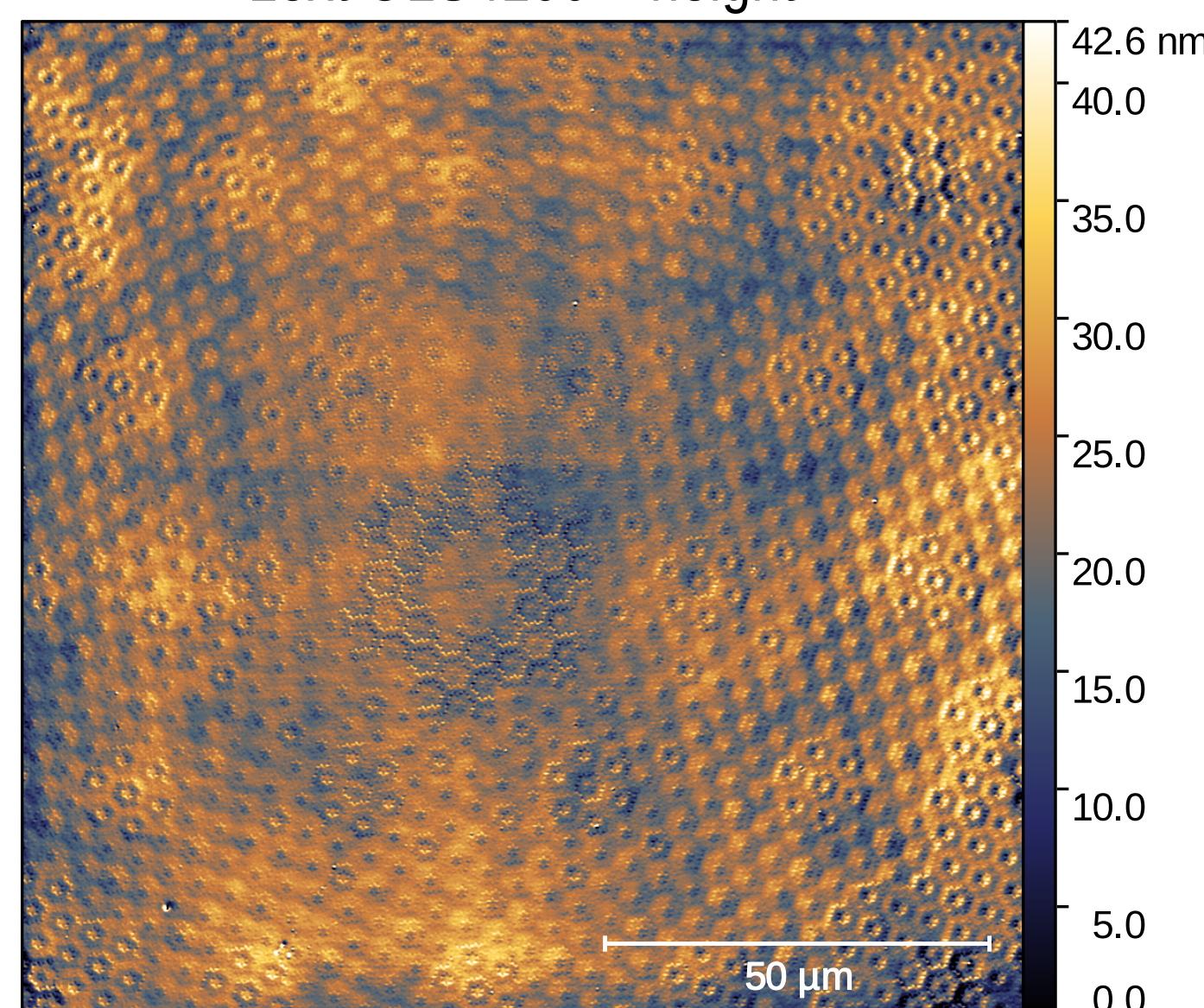
White light interferometry
in SIOS NMM-1 device



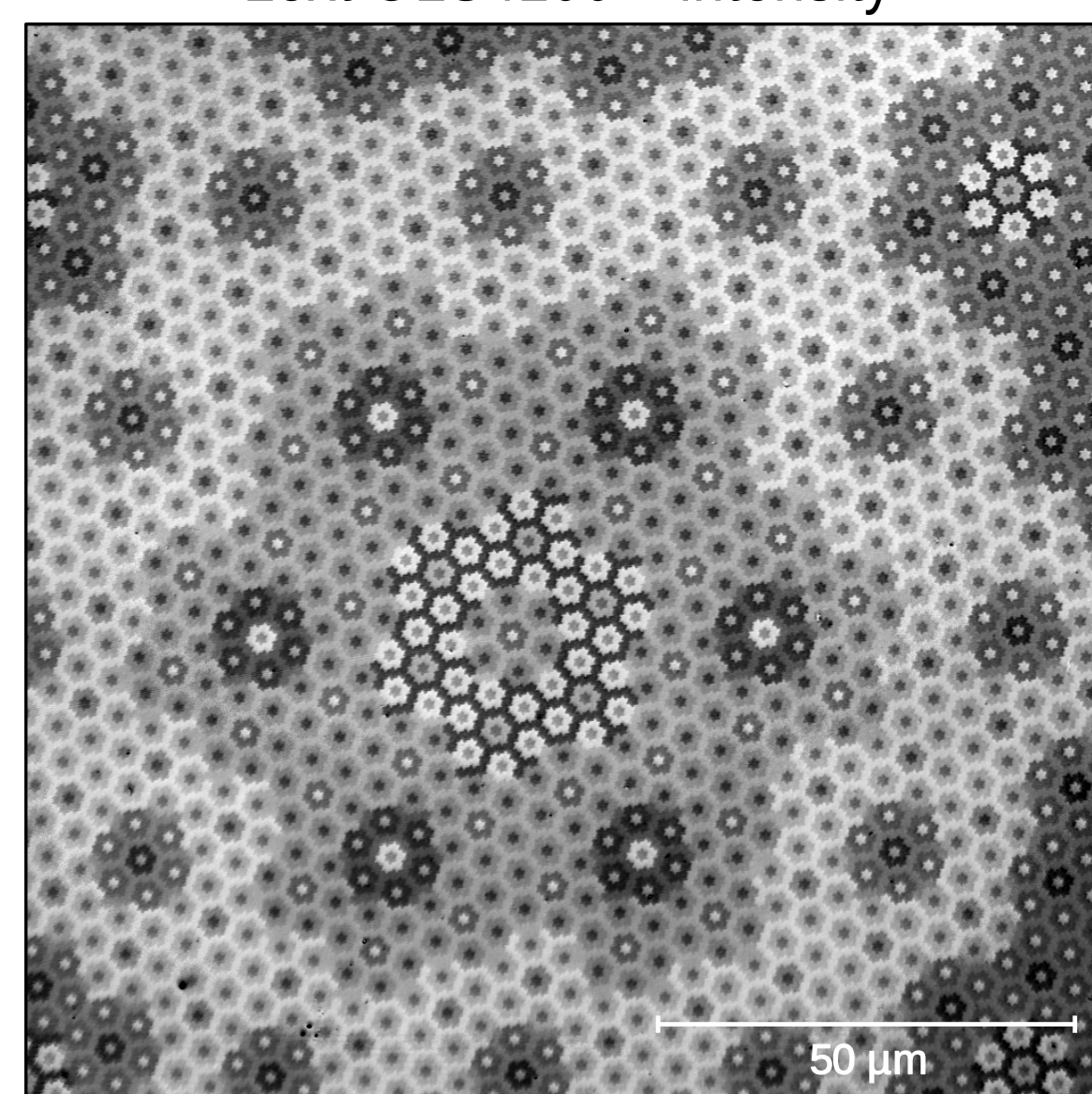
Optical preview
Dimension Icon



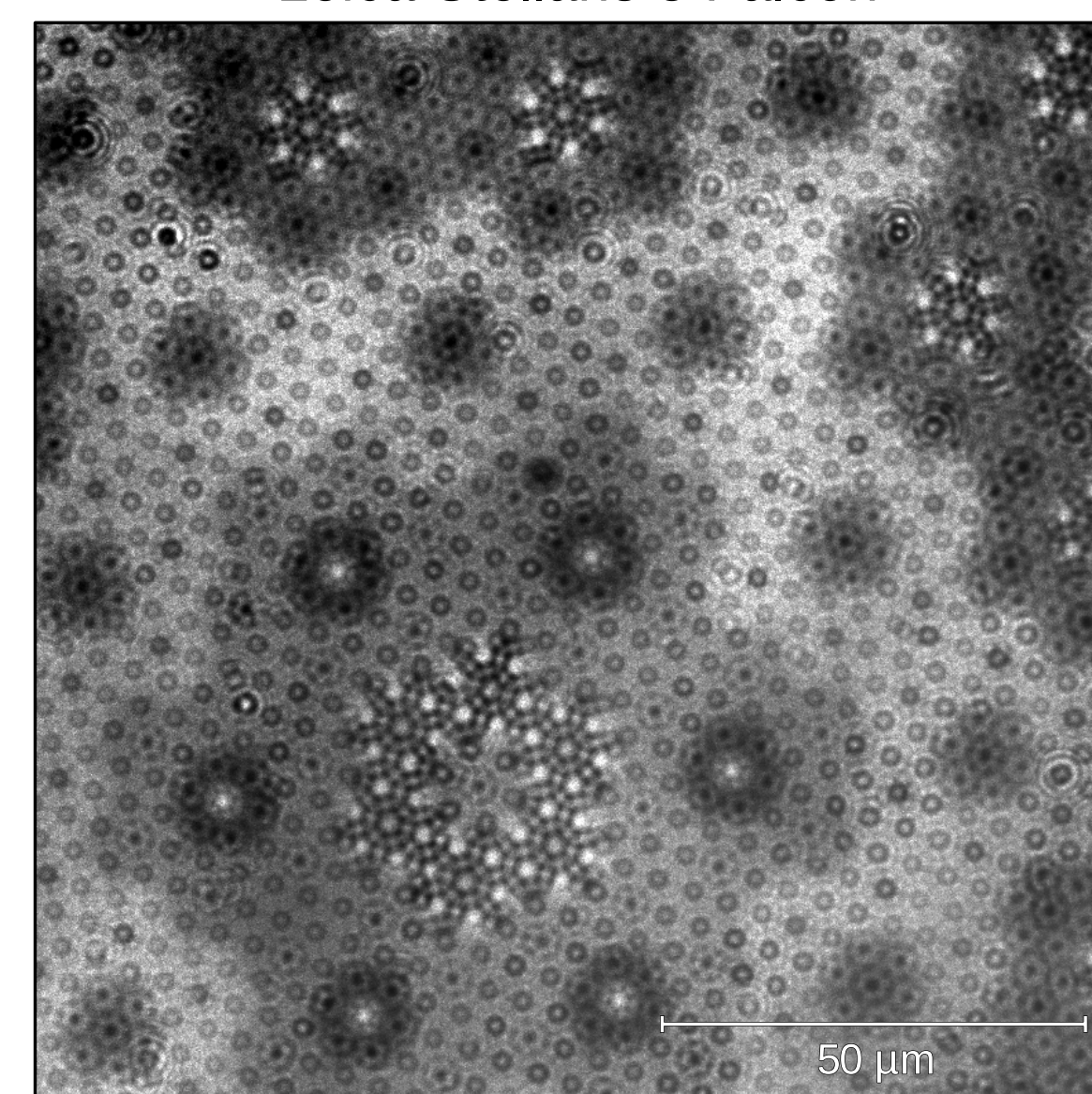
Laser Scanning Confocal Microscope
Lext OLS4100 – height



Laser Scanning Confocal Microscope
Lext OLS4100 – intensity



Laser Scanning Confocal Microscope
Leica Stellaris 8 Falcon



Prototype

Earlier version of the design
~100 nm SiO_2 on Si (antireflection condition)
Made by etching an existing layer

Area 300 μm \times 300 μm
Pitch 250 nm
5 different fill ratios

Shown experimental data – this prototype

Acknowledgements

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