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MANUFACTURING METROLOGY TEAM

A sensitivity analysis for the measurement of internal additively manufactured surfaces by X-ray computed tomography

Adam Thompson, Nicola Senin, Lars Körner, Ian Maskery, Simon Lawes, Richard Leach


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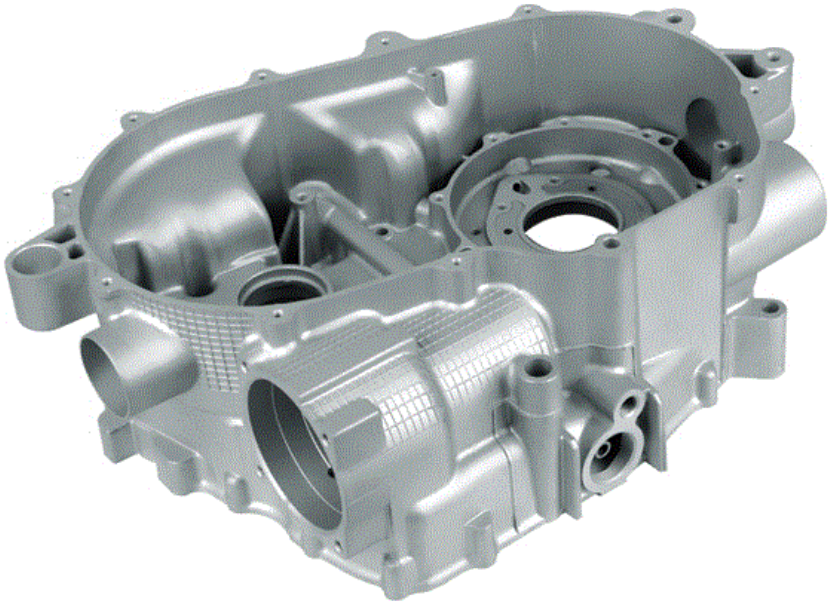
Introduction

Surface measurement

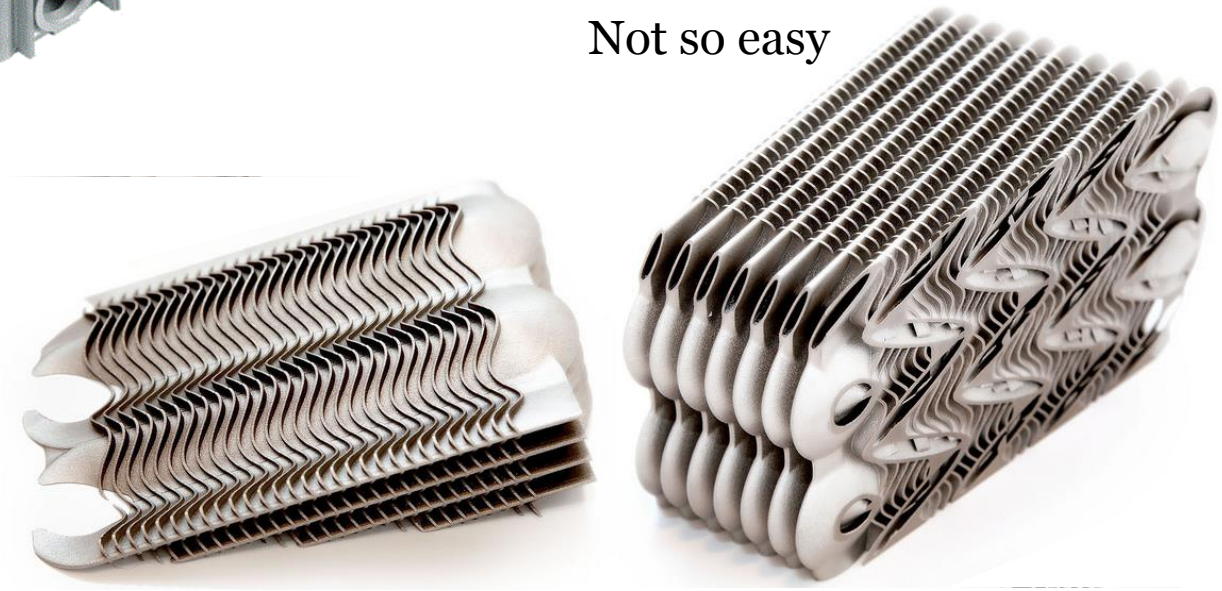
Measure this?



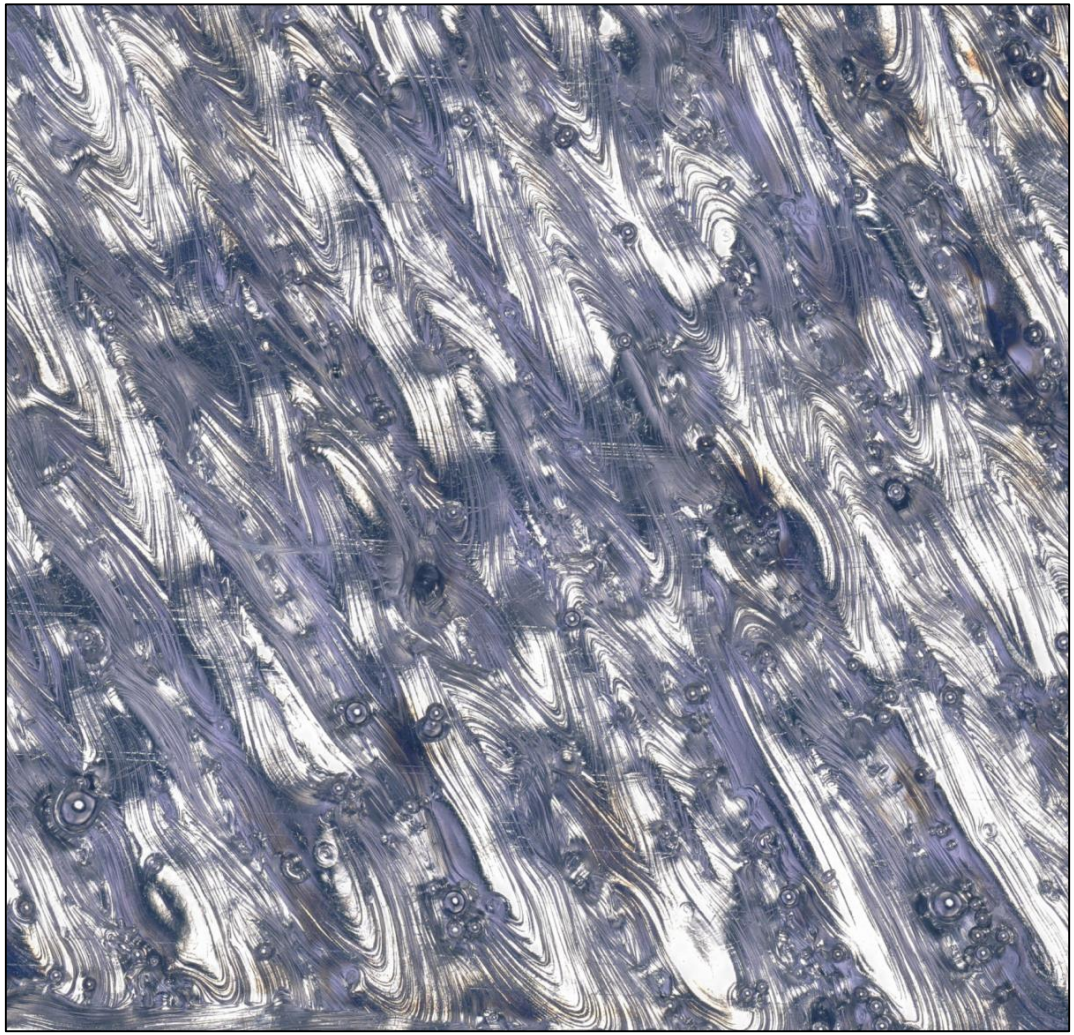
Easy

Measure these?

Not so easy



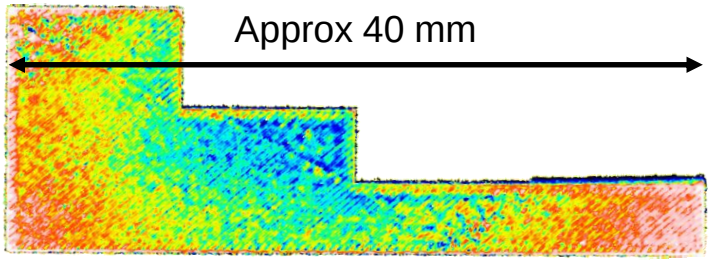
AM surface measurement issues

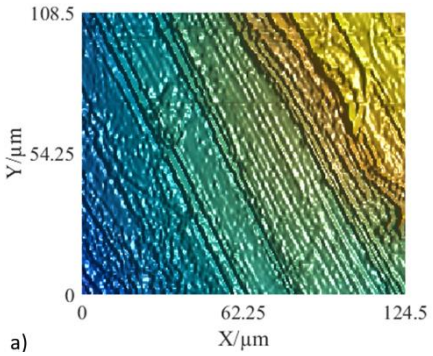


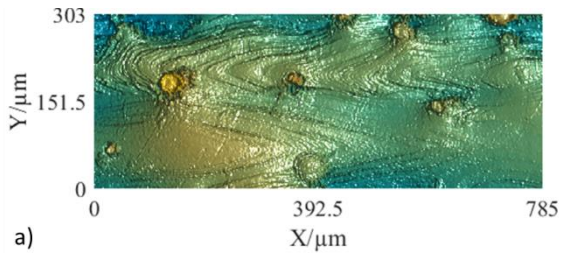
AM surface measurement issues

Large range of relevant scales

- Large scale waviness
- Weld tracks (mid scale)
- Weld ripples (small scale)

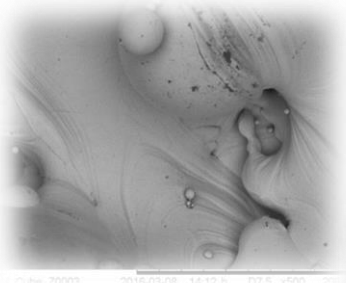




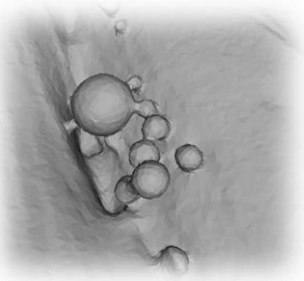


High slopes

Undercuts



Step-like transitions



Non-uniform surface properties

Varying materials, mechanical properties, etc.

Highly reflective and opaque regions

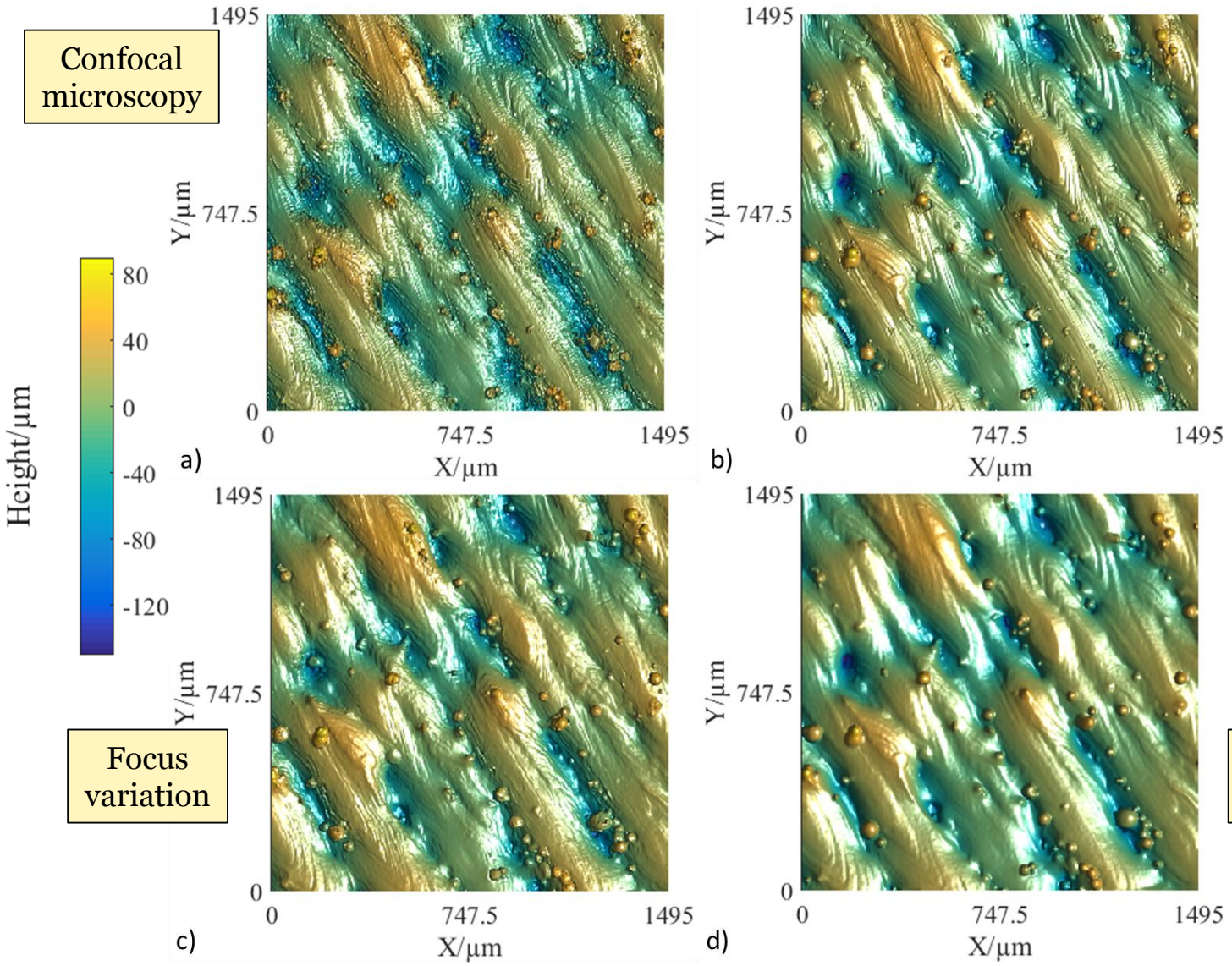
Measurement solutions for AM surfaces

Confocal microscopy

Coherence scanning interferometry

Focus variation

X-ray computed tomography

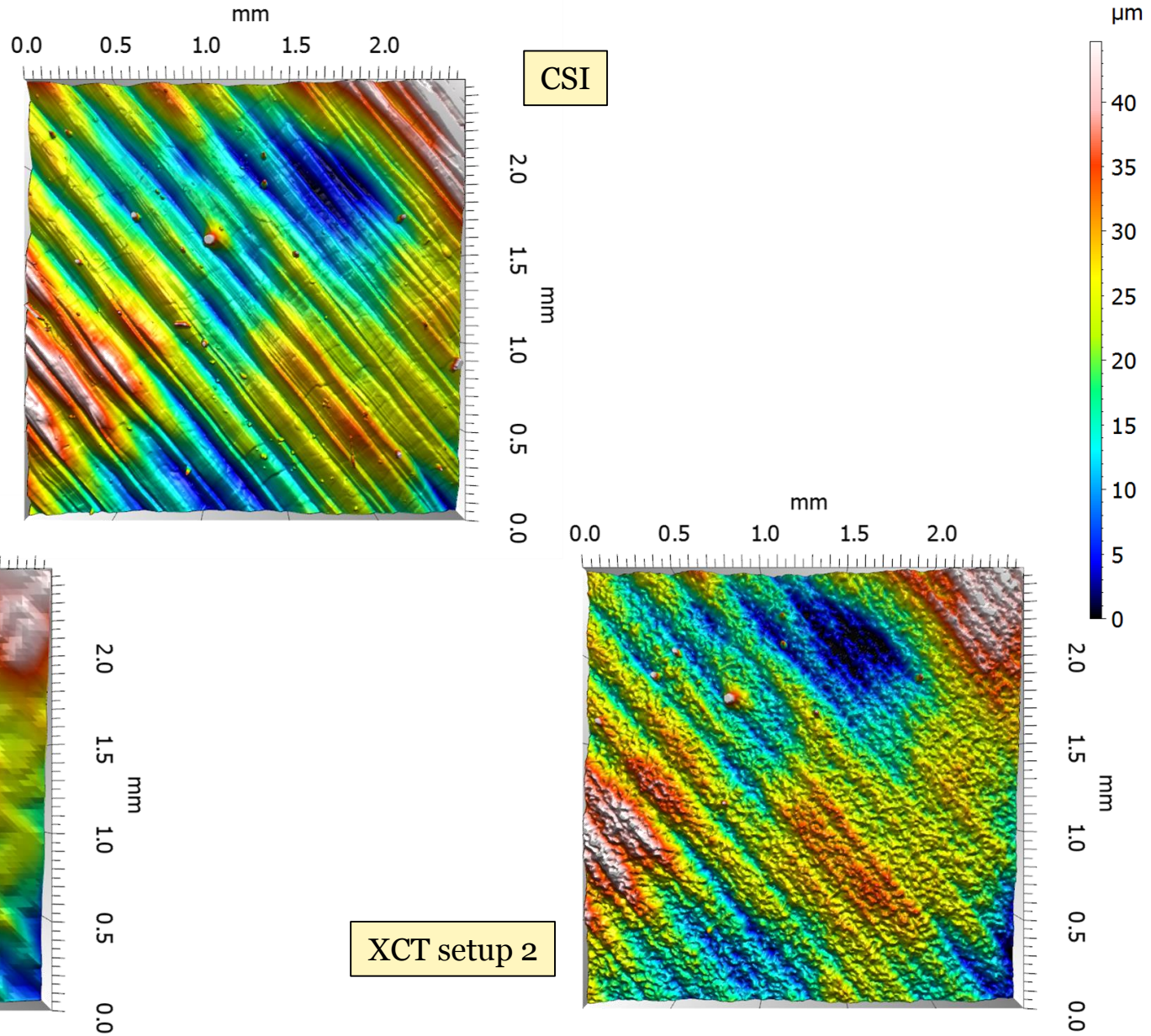


Papers in press
Thompson A, Senin N, Giusca C and Leach R 2017 *Ann. CIRP*
Thompson A, Senin N and Leach R 2017 *Meas. Sci. Technol.*

See also
Townsend A, Pagani L, Scott P and Blunt L 2017 *Prec. Eng.* **48** 254-264
Thompson A, Senin N, Maskery I, Körner L, Lawes S and Leach R 2017 *Add. Man.* **Under review**

Assessment of the metrological performance of XCT surface measurement

Investigation of sensitivity to measurement process parameters



Data approximately aligned and truncated for visualisation

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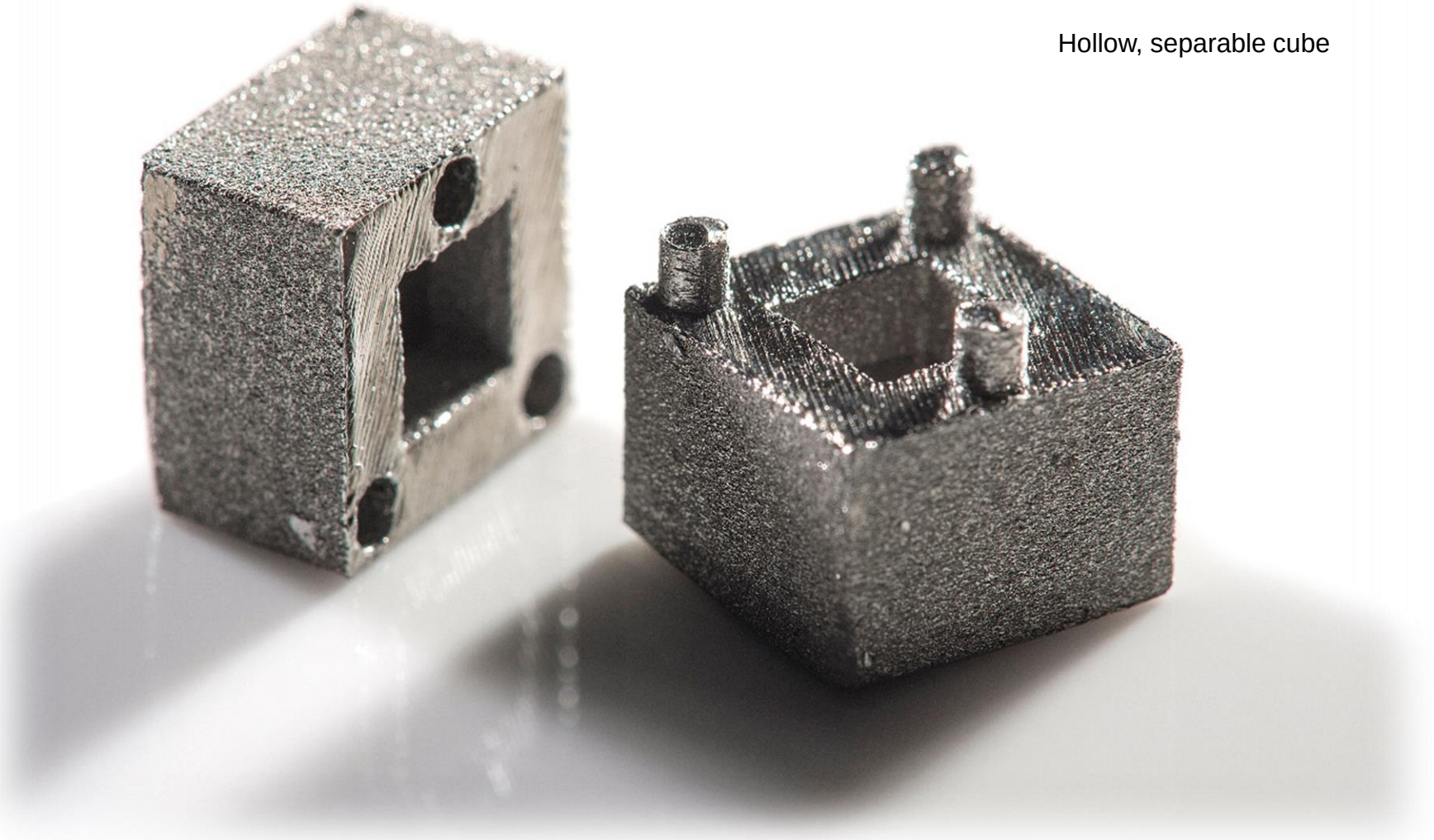
Methods

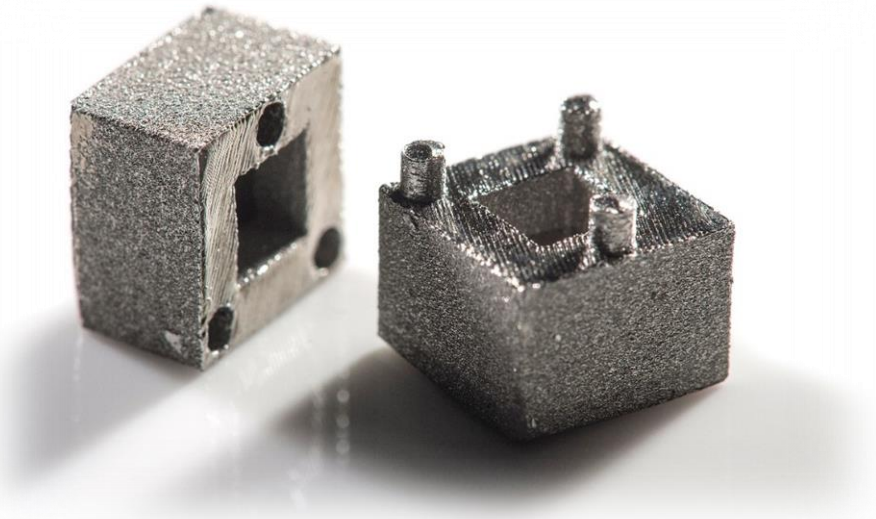
Test case

Metal powder bed fusion

Hollow, separable cube

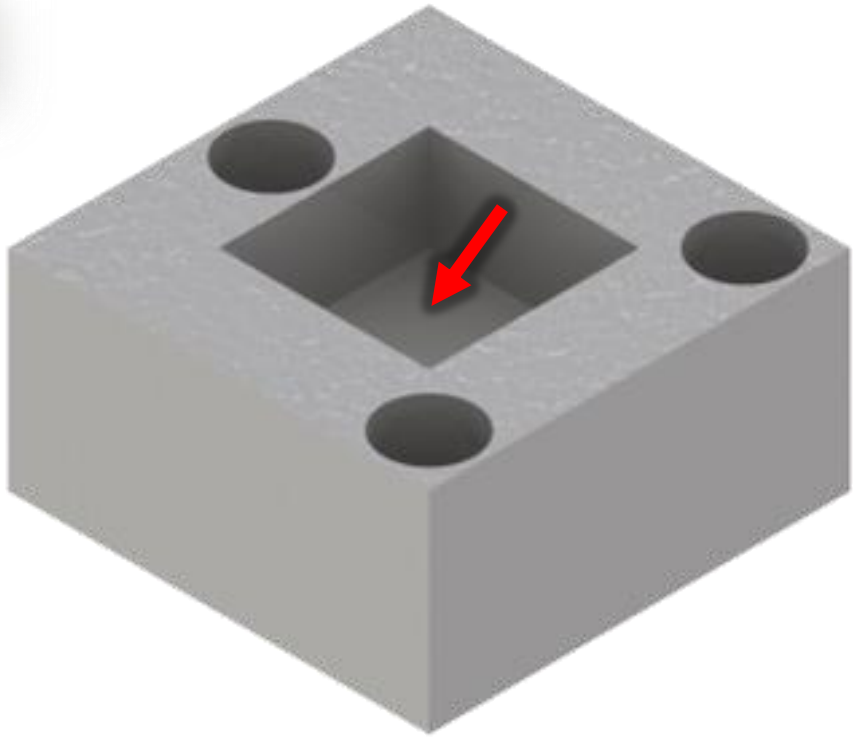


Test case



Metal powder bed fusion

Hollow, separable cube

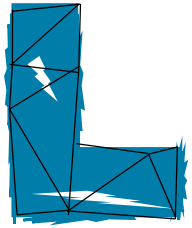


XCT Measurement pipeline

XCT Measurement

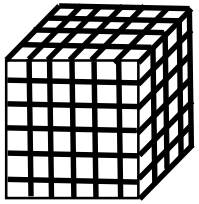
Projection data (2D images)

Reconstruction



Triangulated model

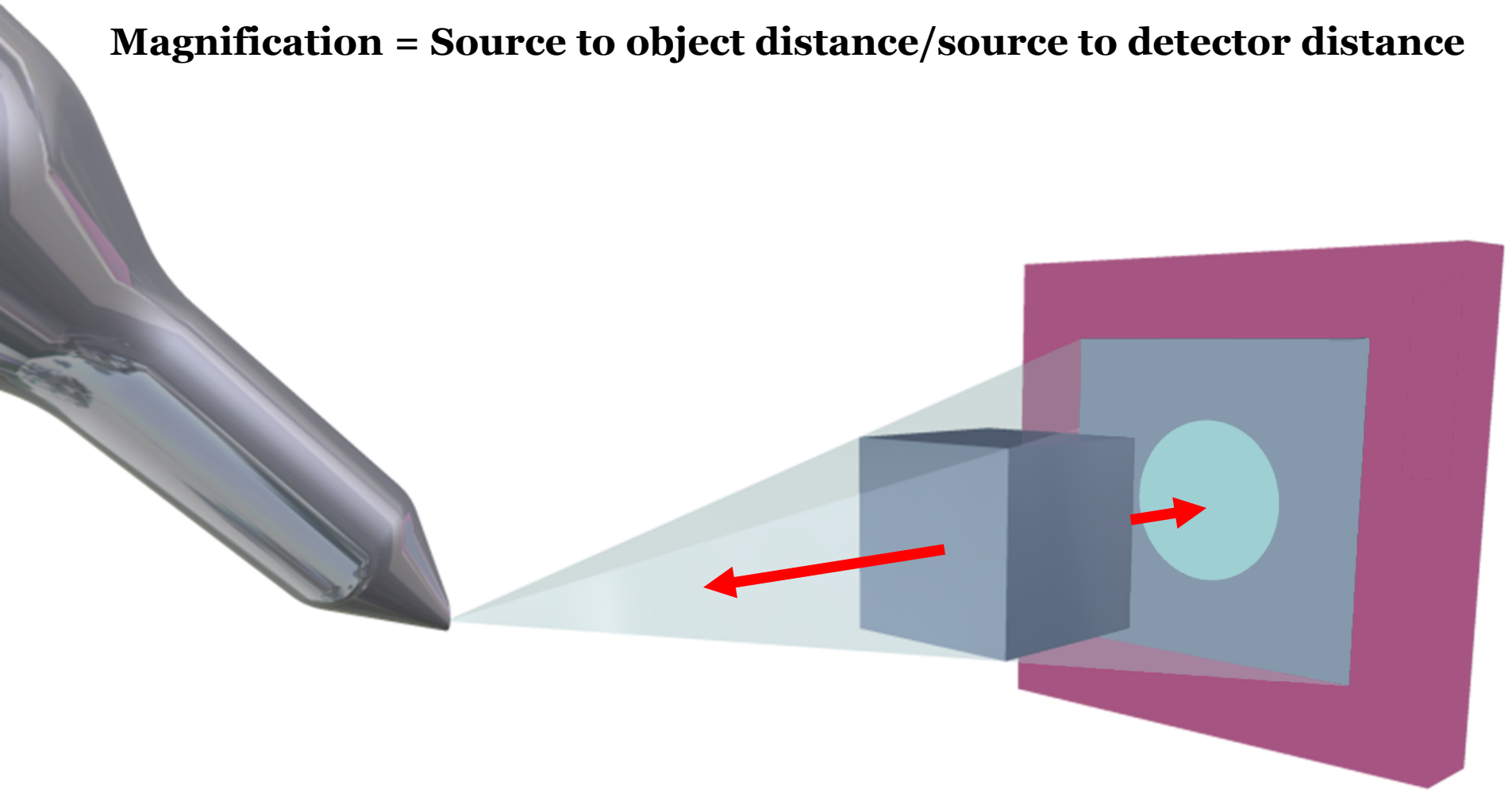
Surface determination



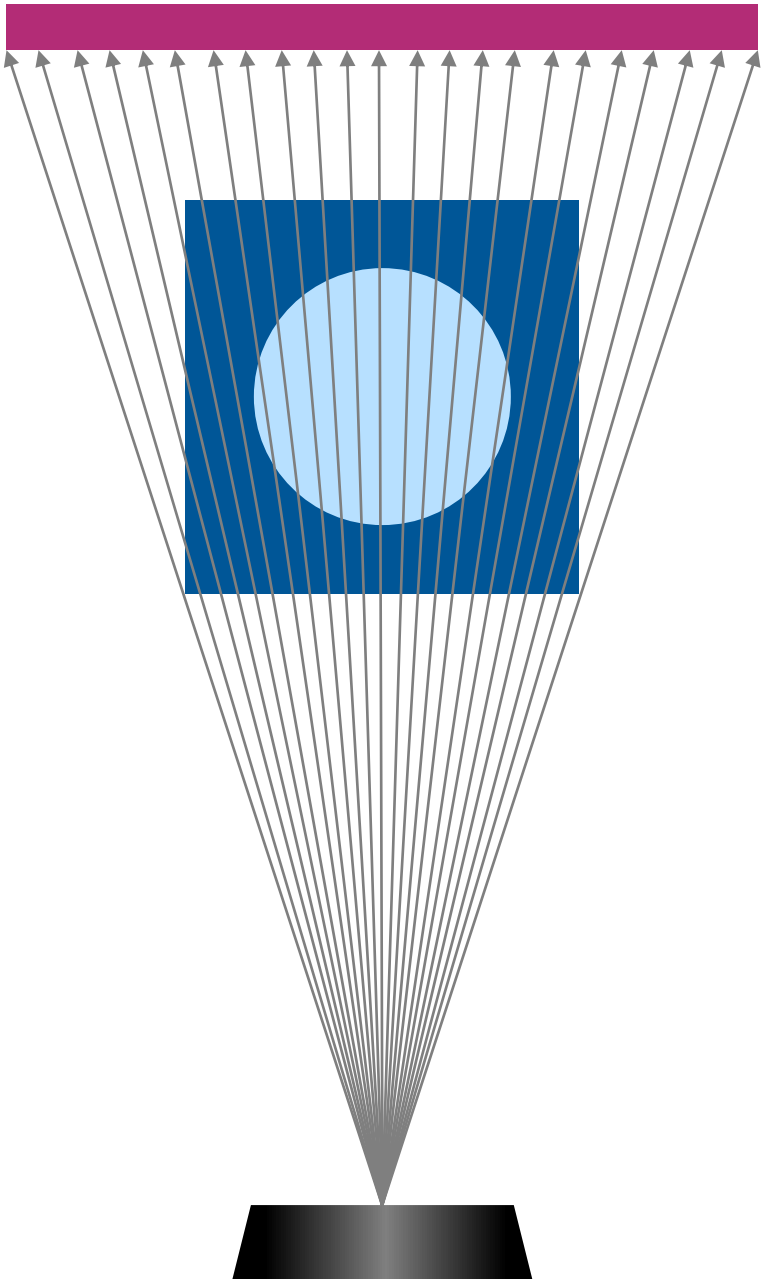
Volume data (3D image)

Selected measurement process parameters: Geometric magnification

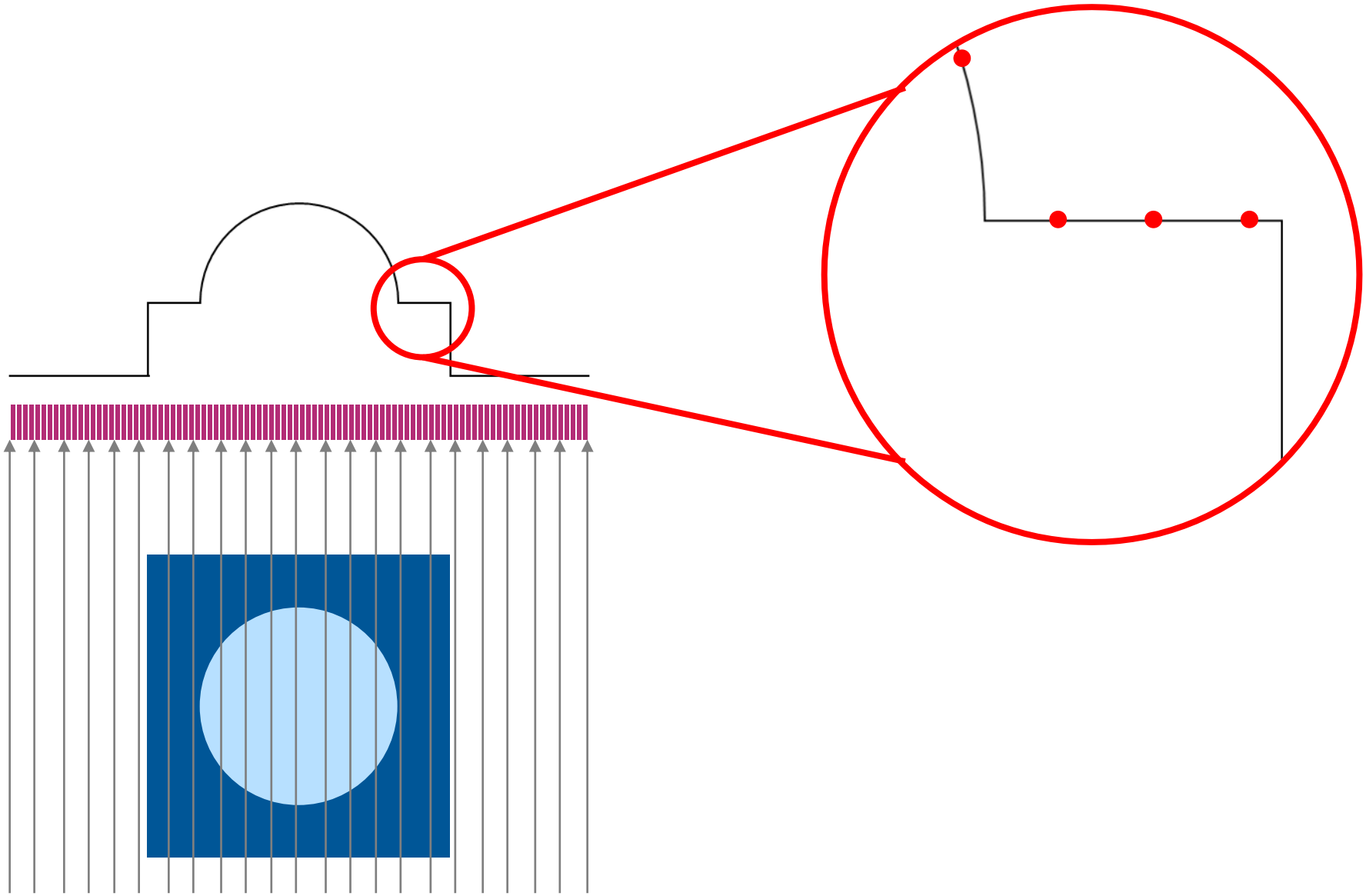
Magnification = Source to object distance/source to detector distance



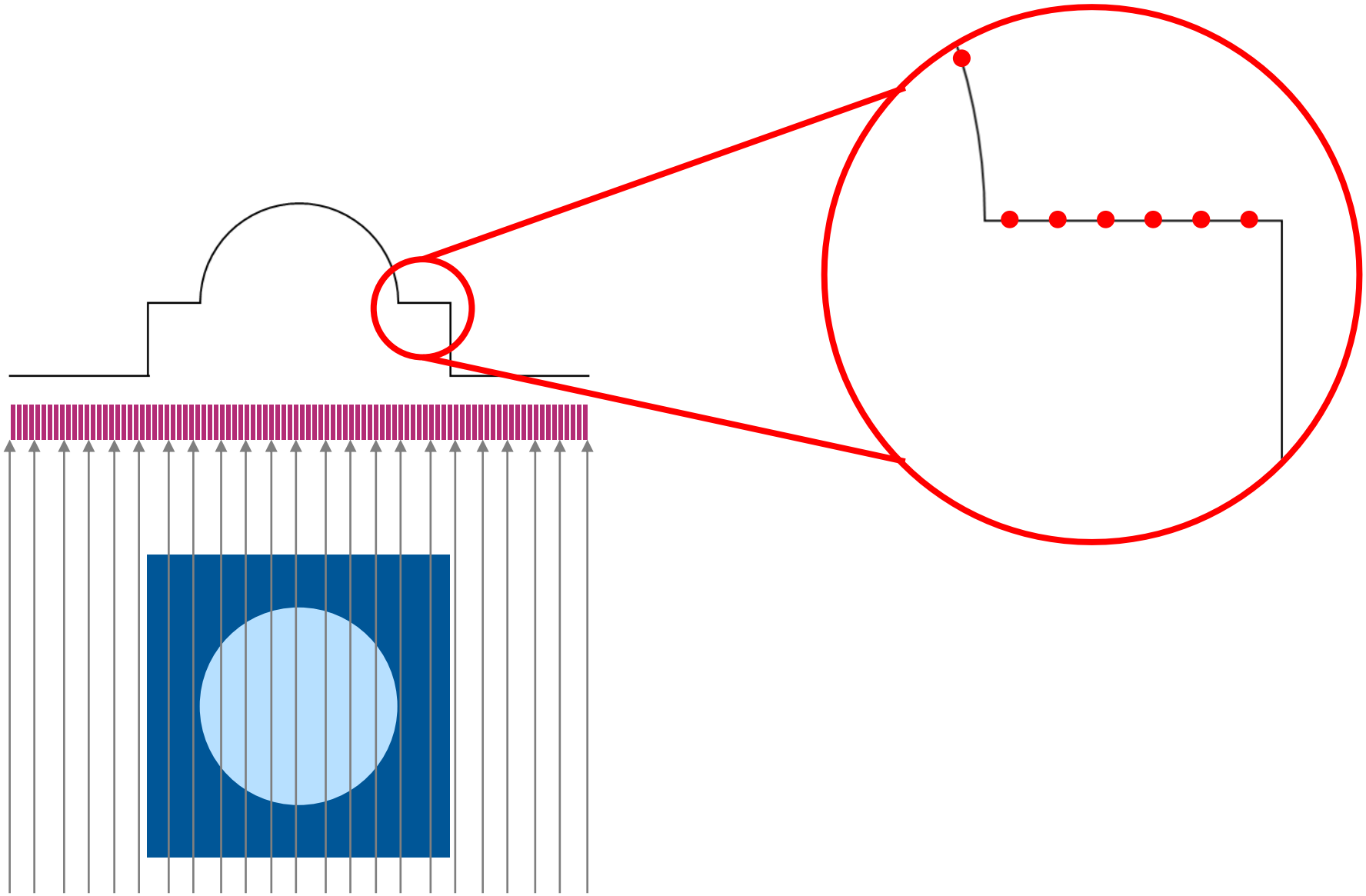
Selected measurement process parameters: Reconstruction sampling



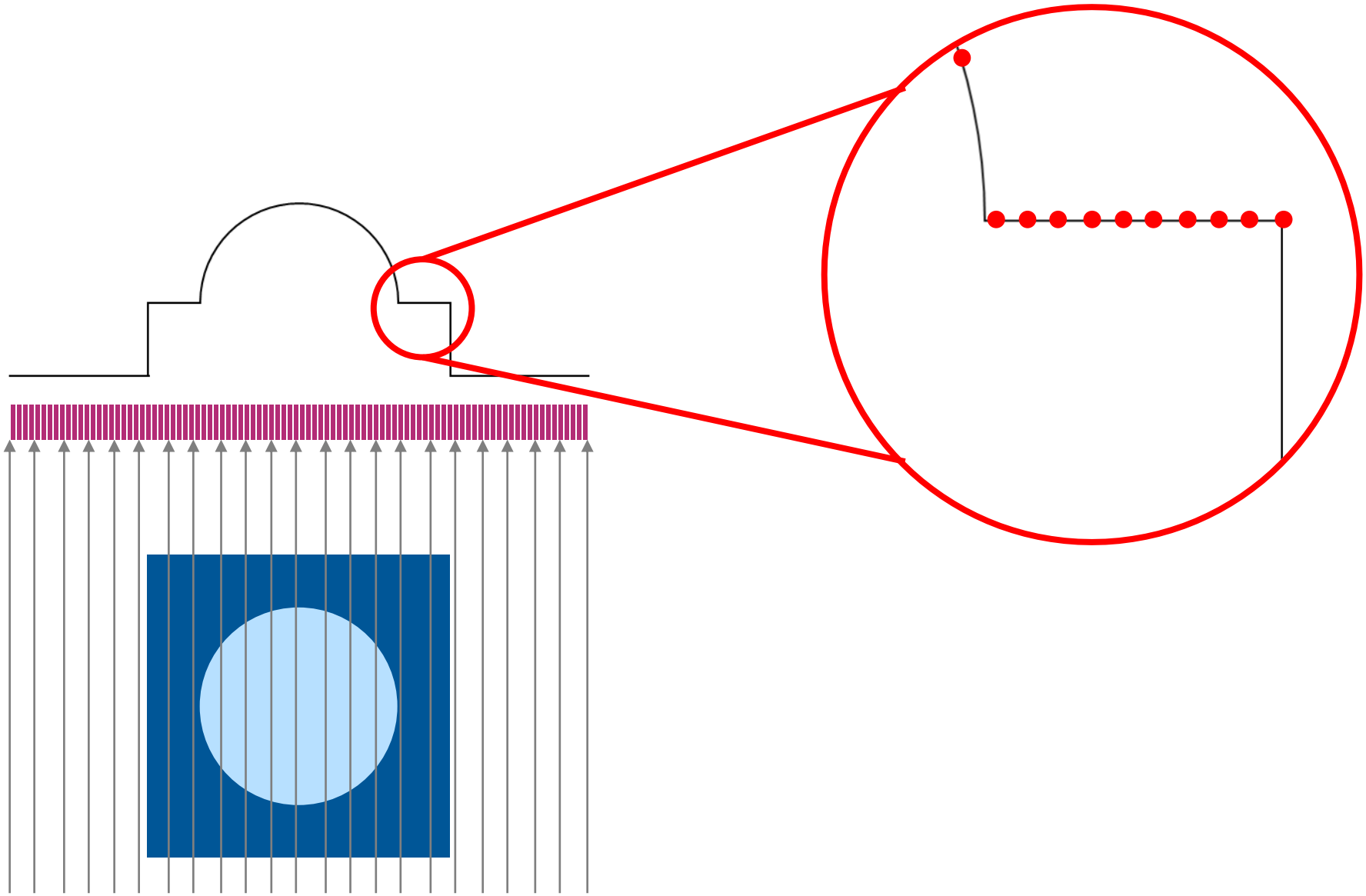
Selected measurement process parameters: Reconstruction sampling



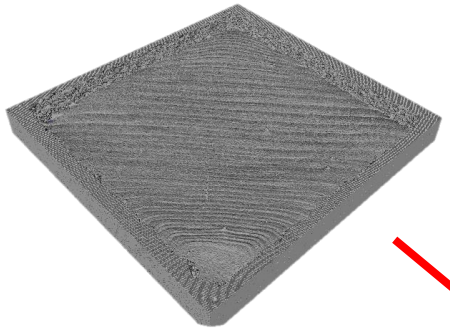
Selected measurement process parameters: Reconstruction sampling



Selected measurement process parameters: Reconstruction sampling

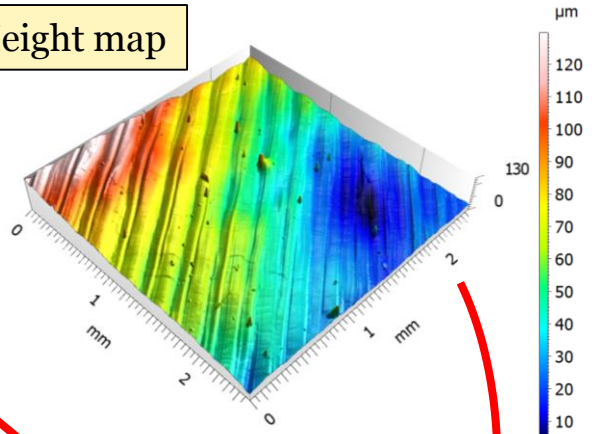


XCT Surface measurement pipeline

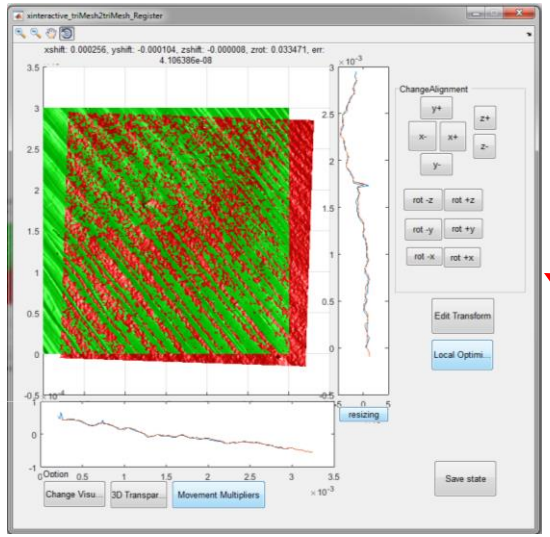


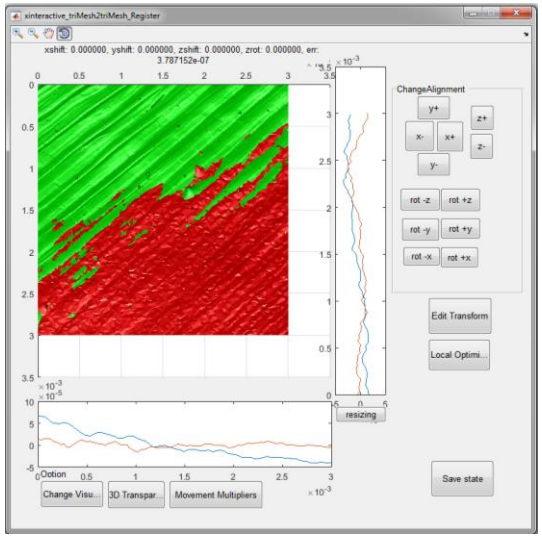
XCT triangulated model

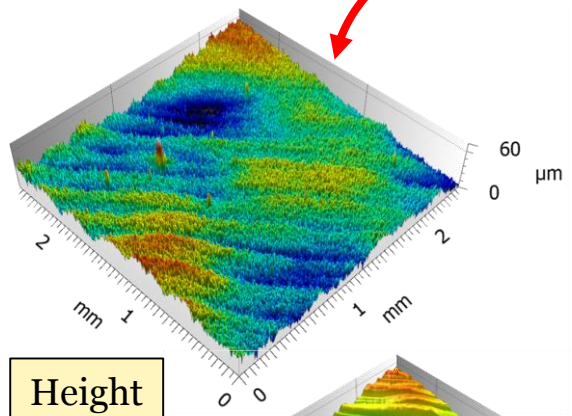
CSI Height map



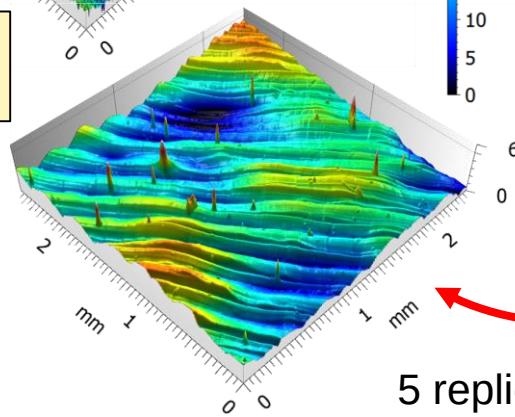
Triangulation







Height maps



Raster scanning

5 replicates taken for each measurement, of the same region of interest

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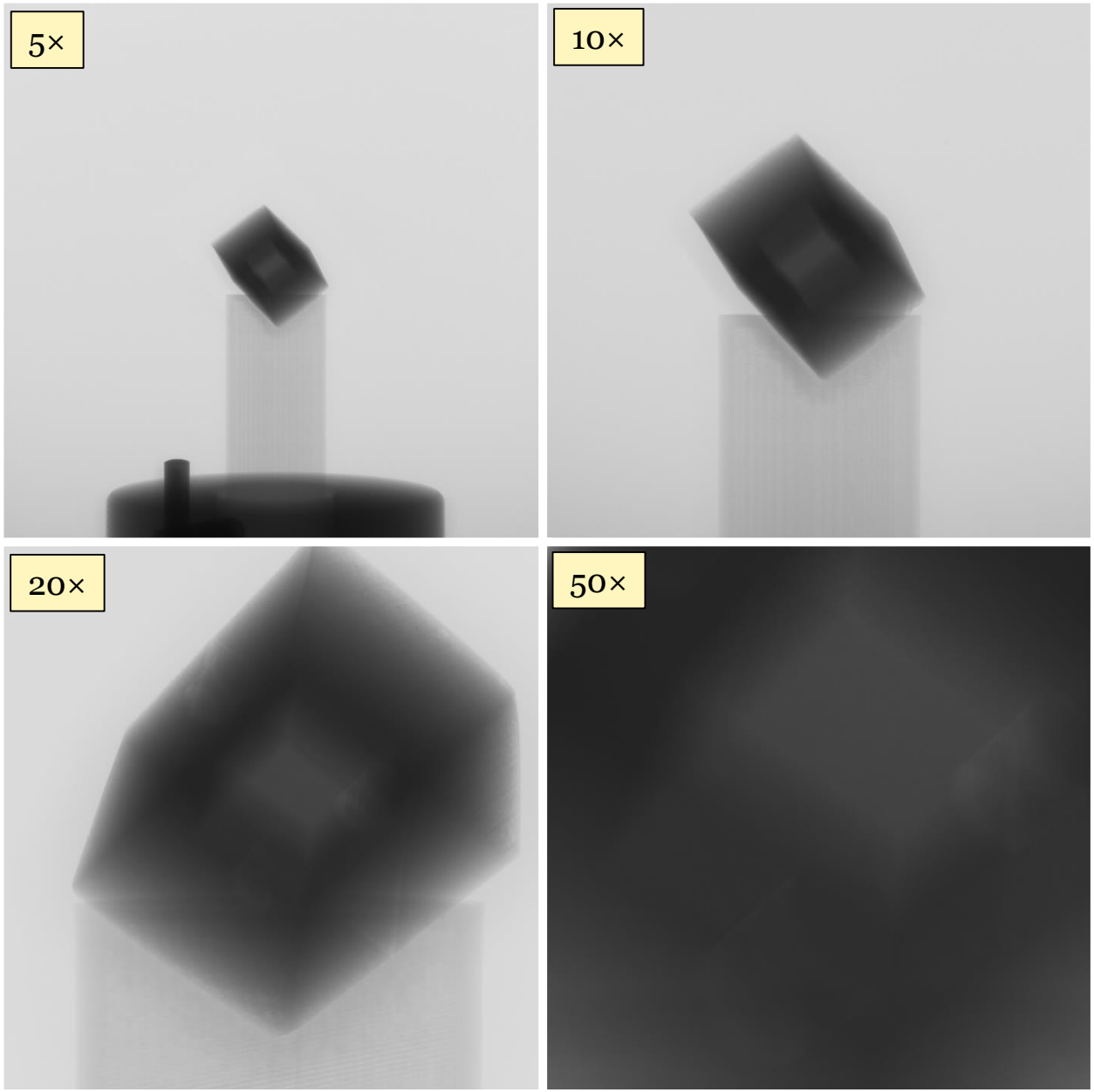
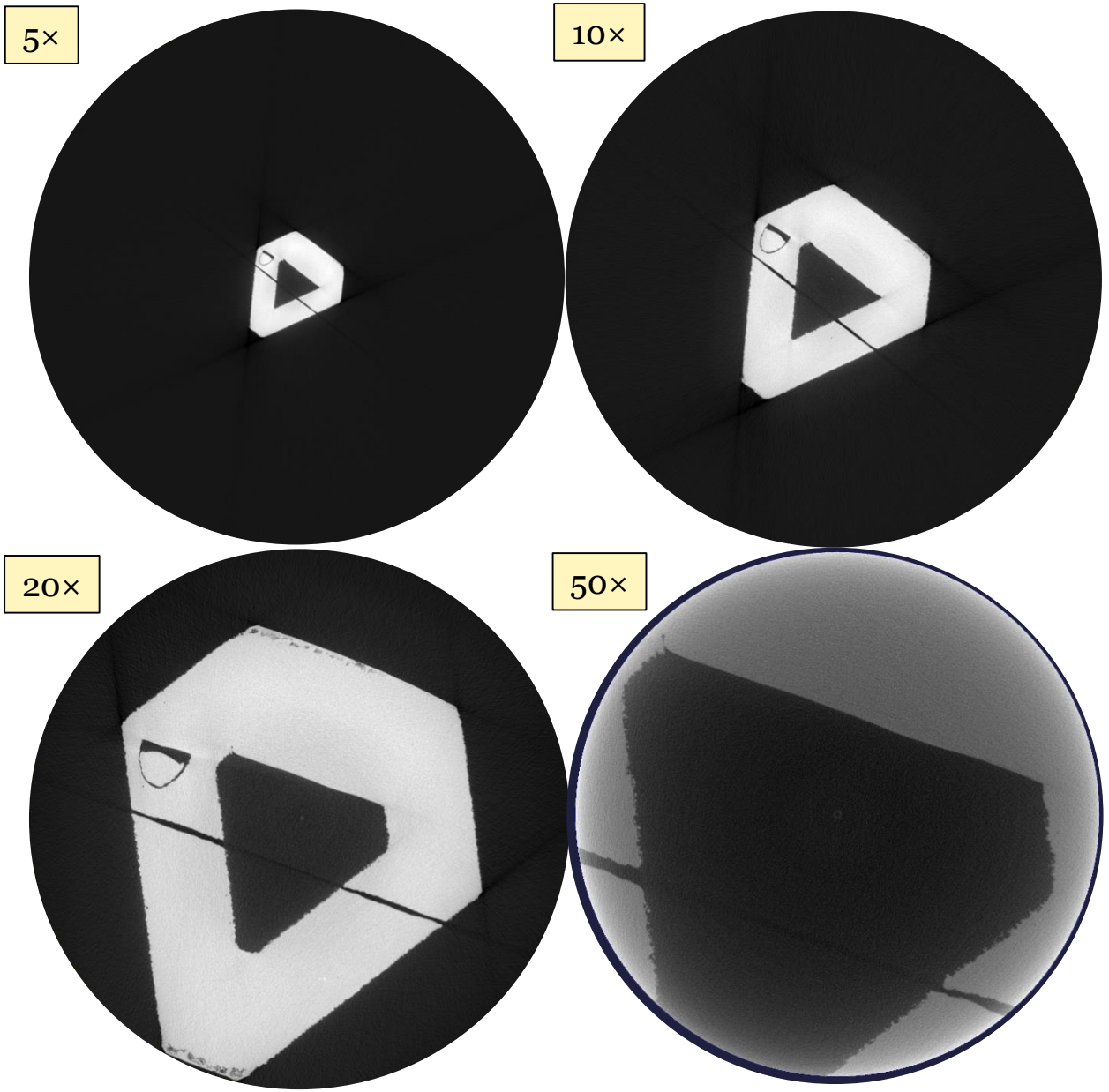
Results

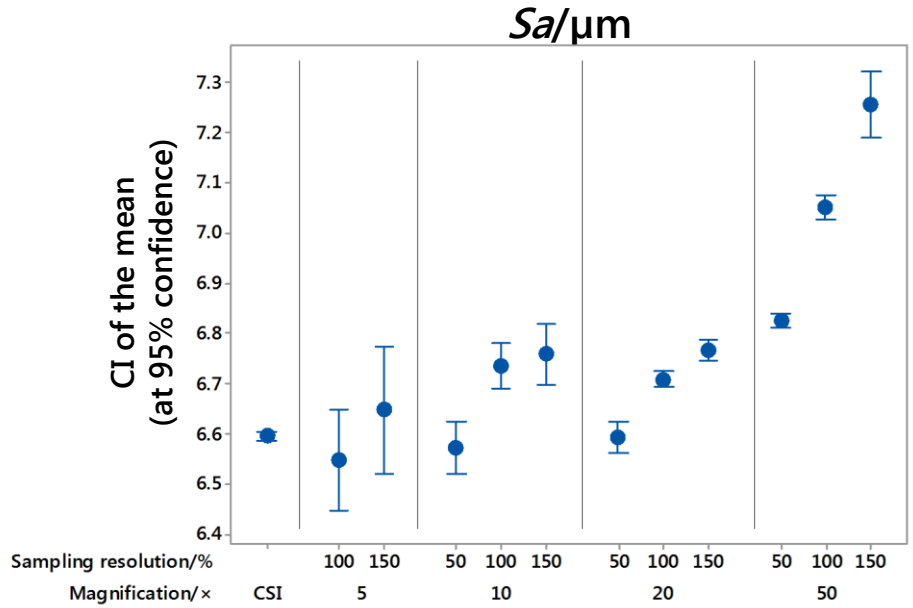
XCT projections & reconstruction slices

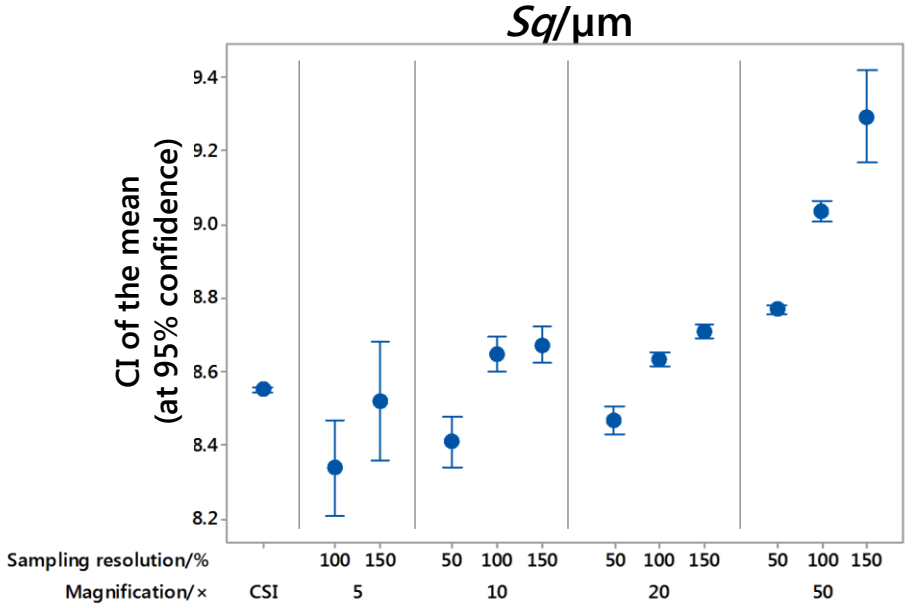


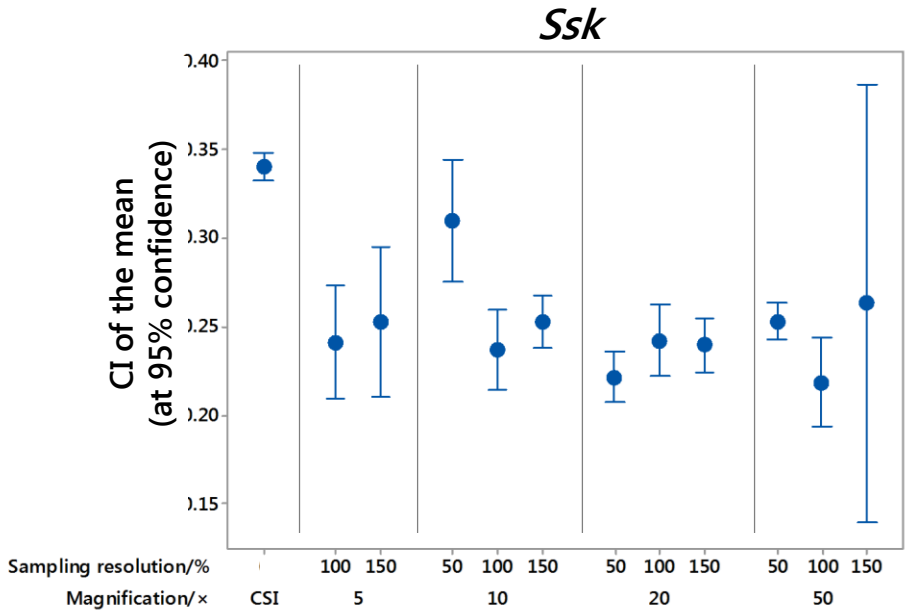
XCT projections & reconstruction slices

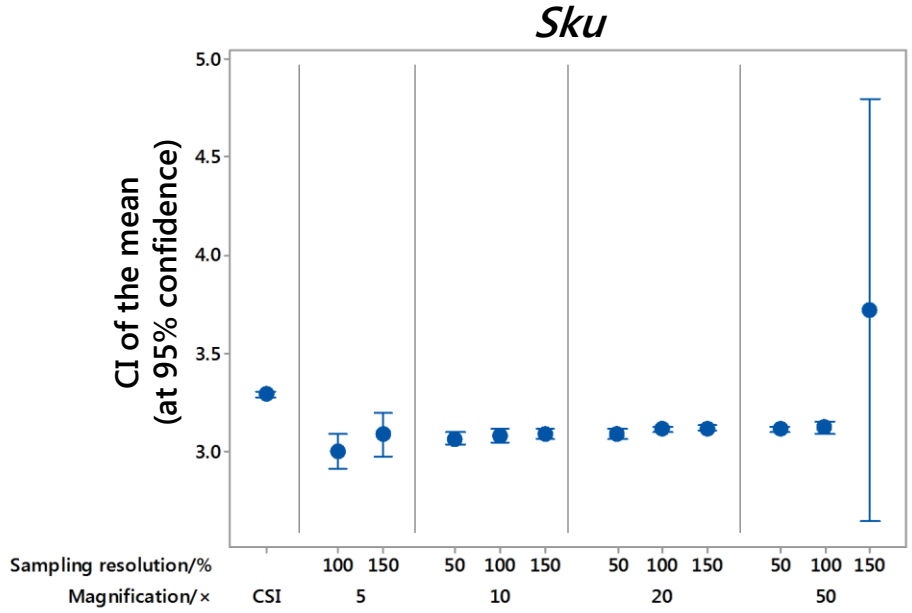


Areal texture parameters









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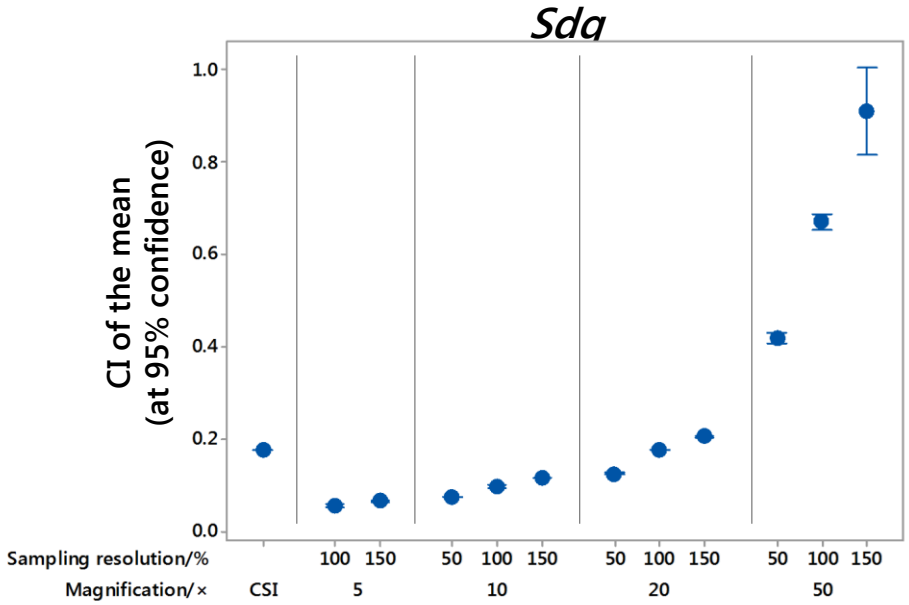
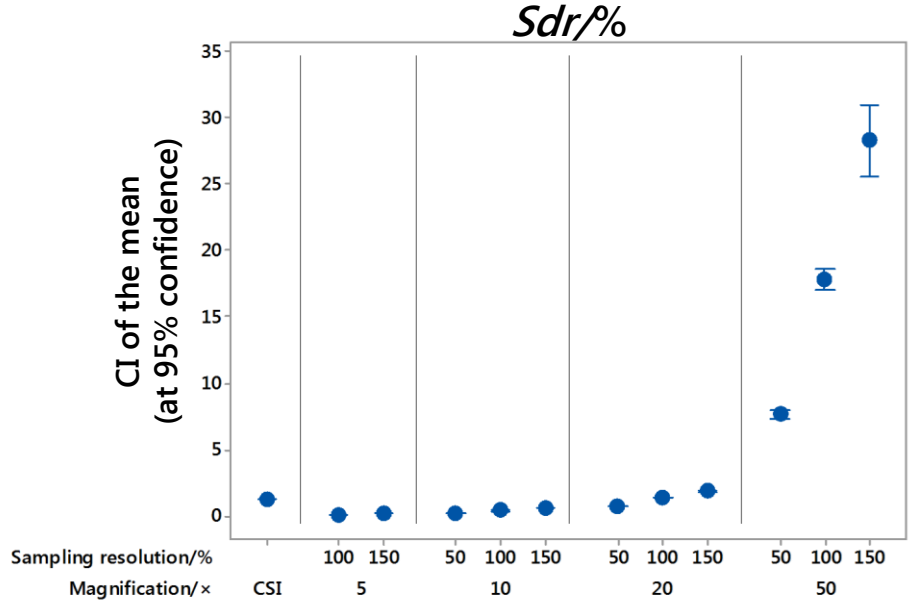
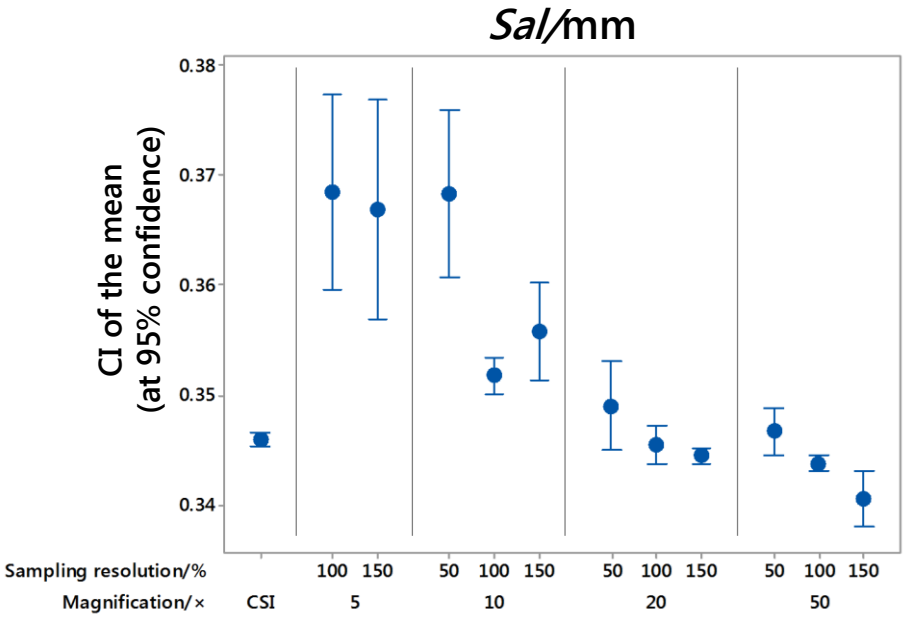
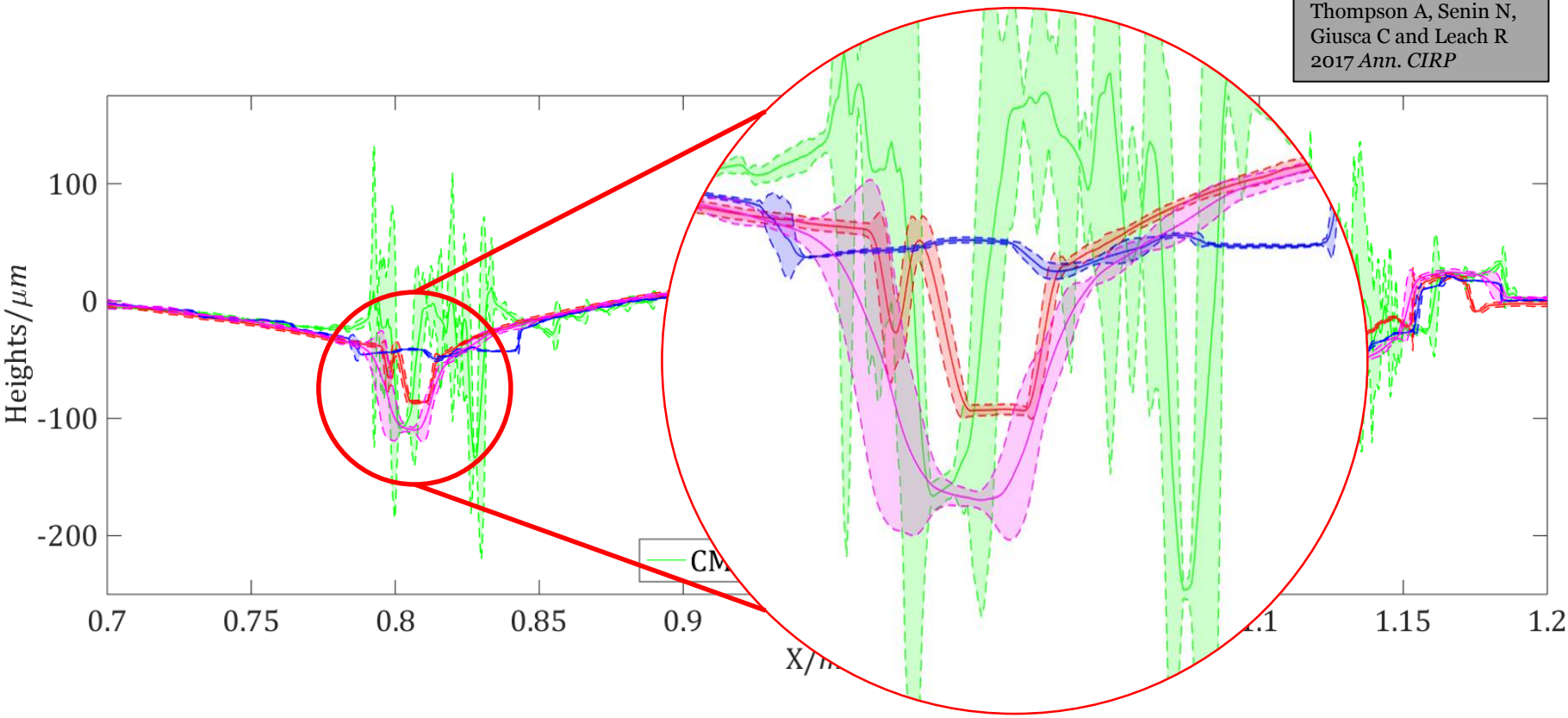




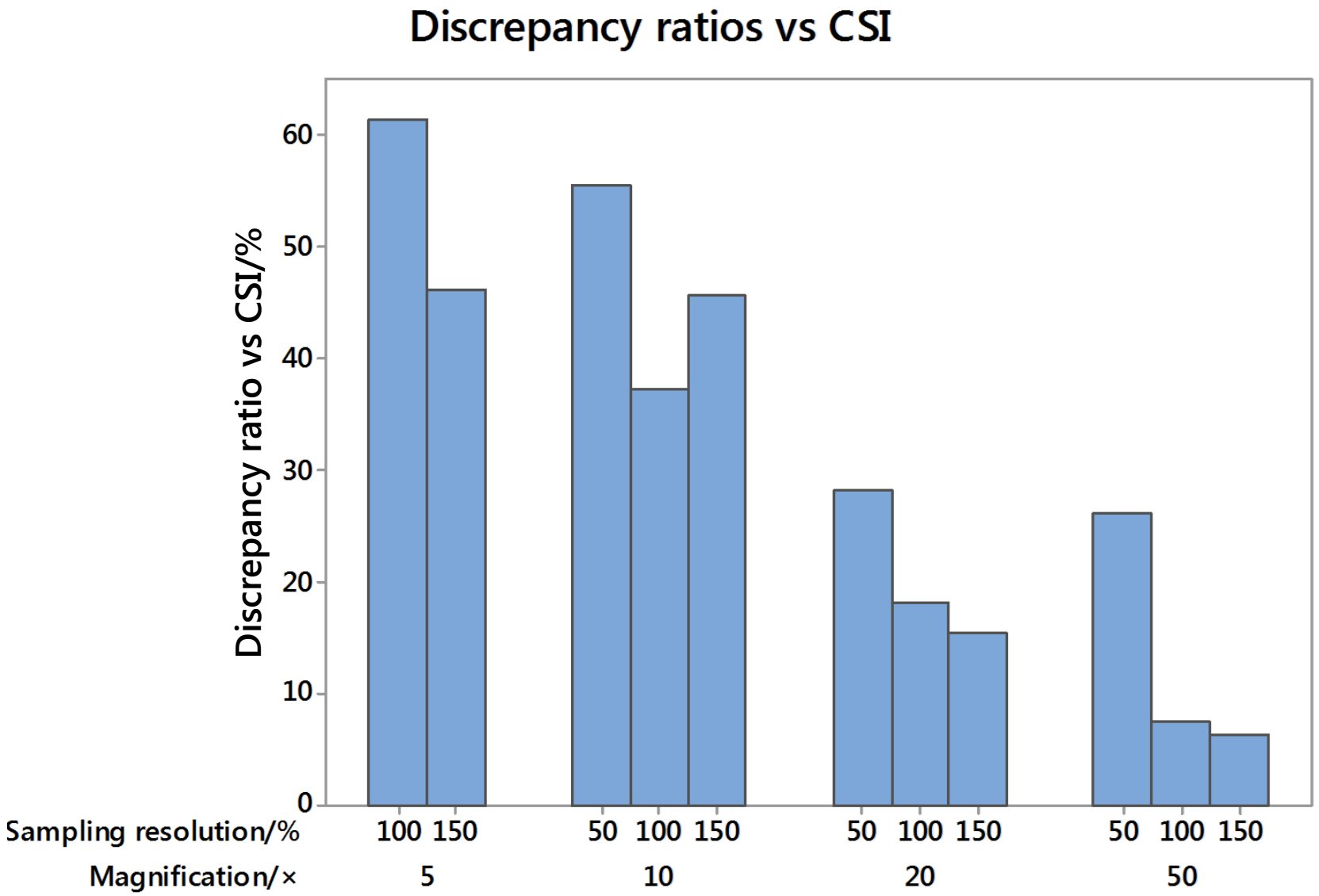


Statistical modelling of topography

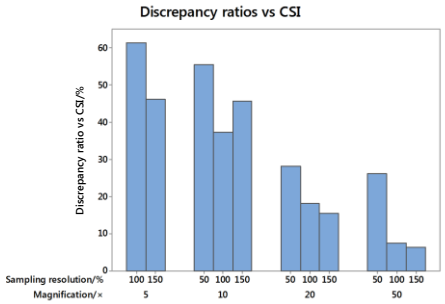
Paper in press
Thompson A, Senin N, Giusca C and Leach R 2017 *Ann. CIRP*



Statistical modelling of topography



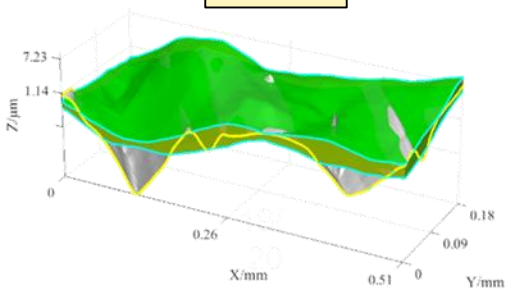
Statistical modelling of topography

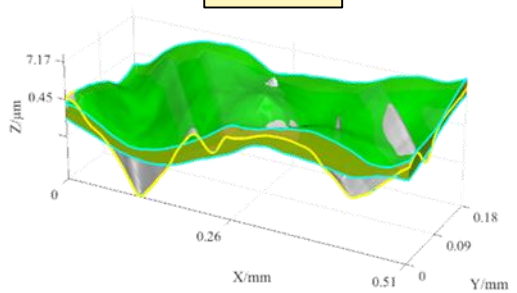


100 %

150 %

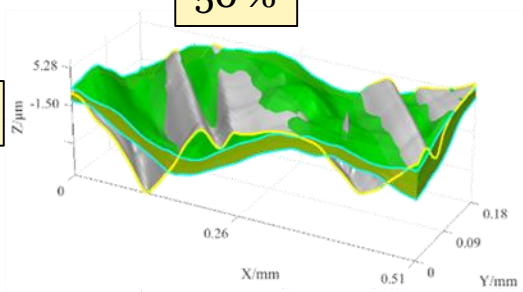
5×

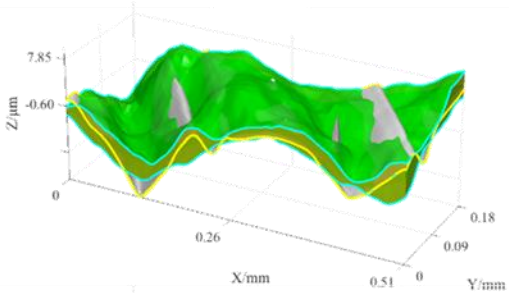


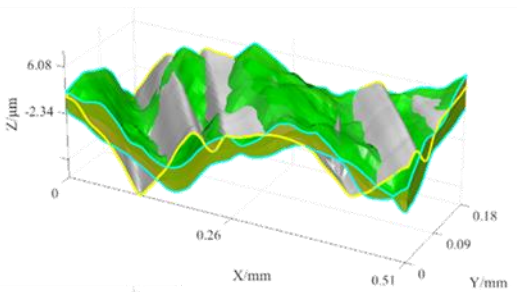


50 %

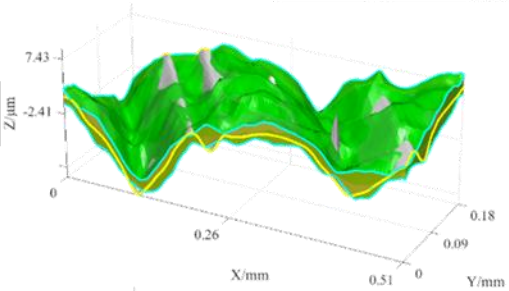
10×

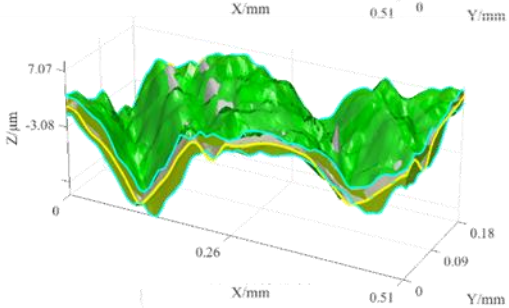


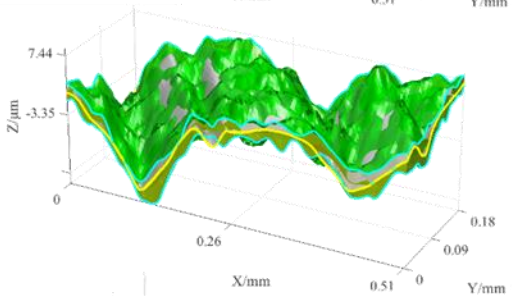




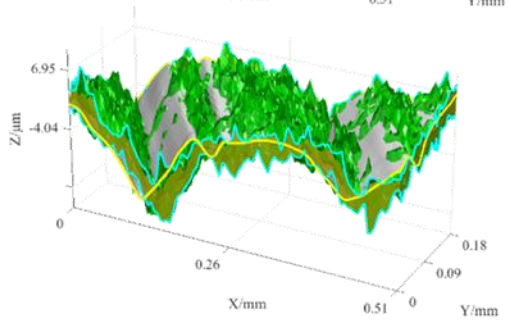
20×

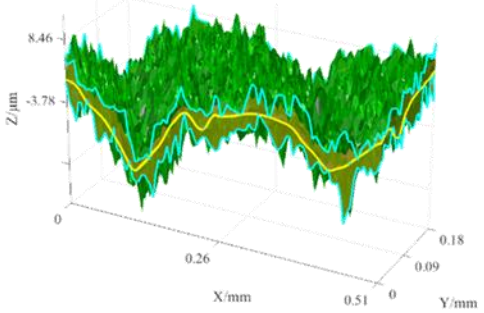


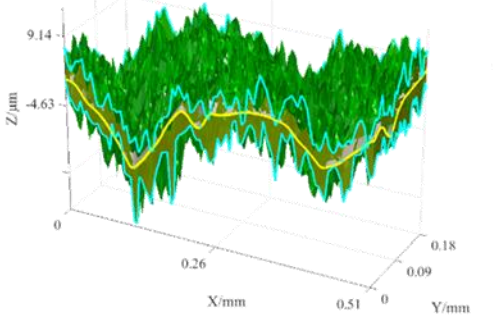




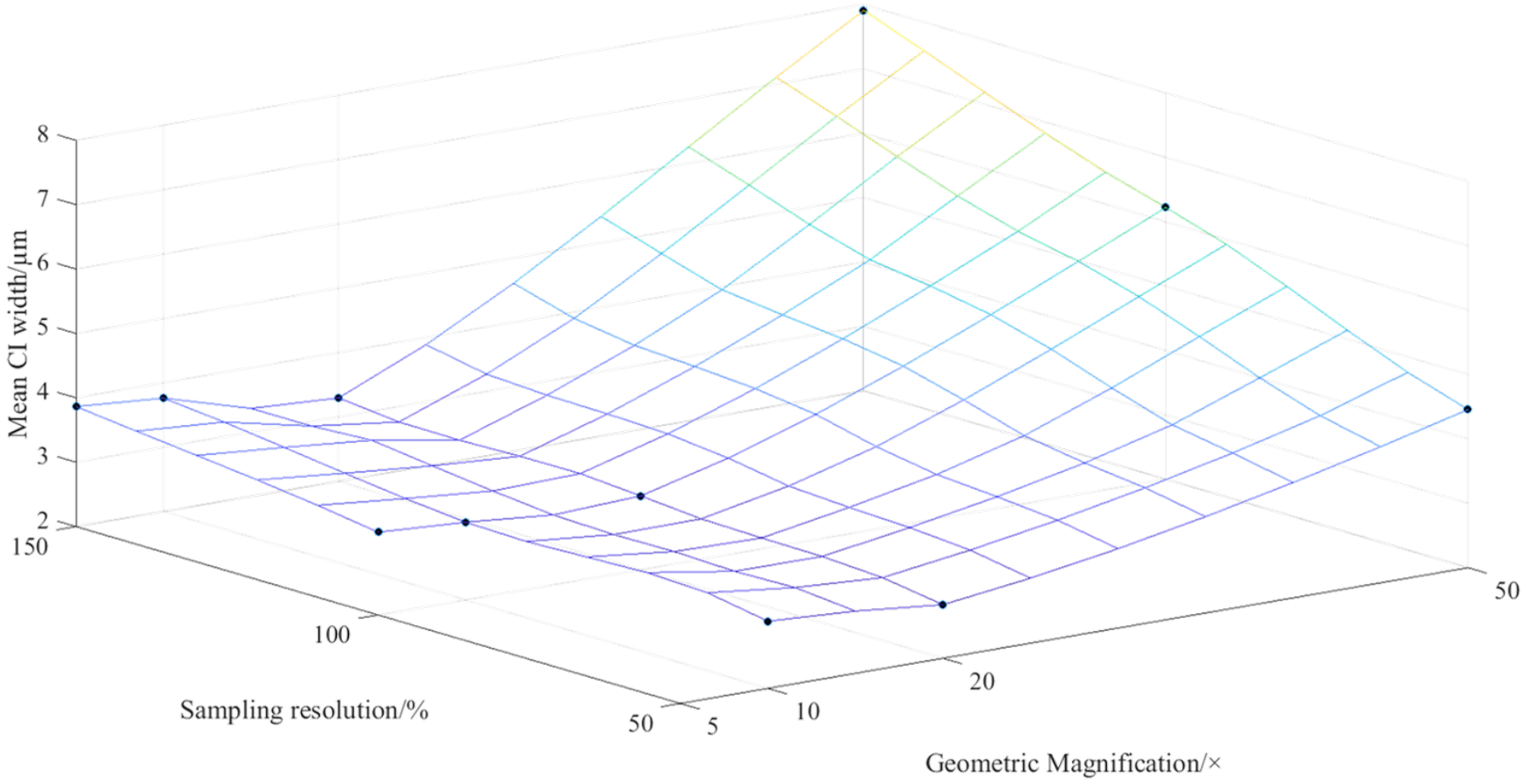
50×







Repeatability error (mean CI width)



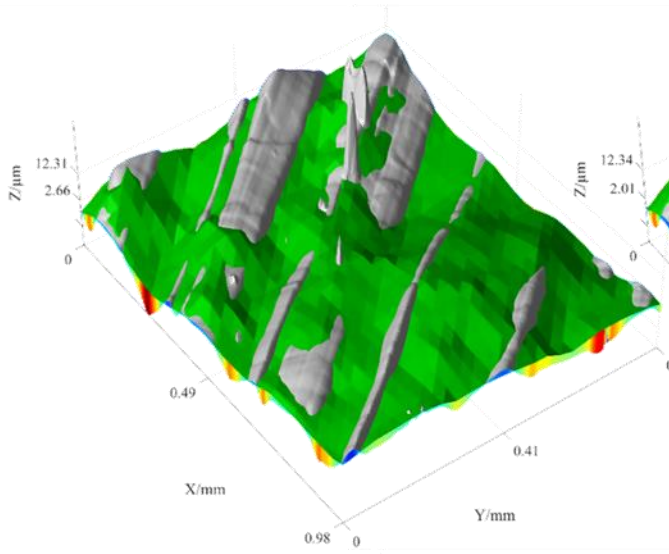
Volumetric difference between paired single instances (XCT vs CSI)

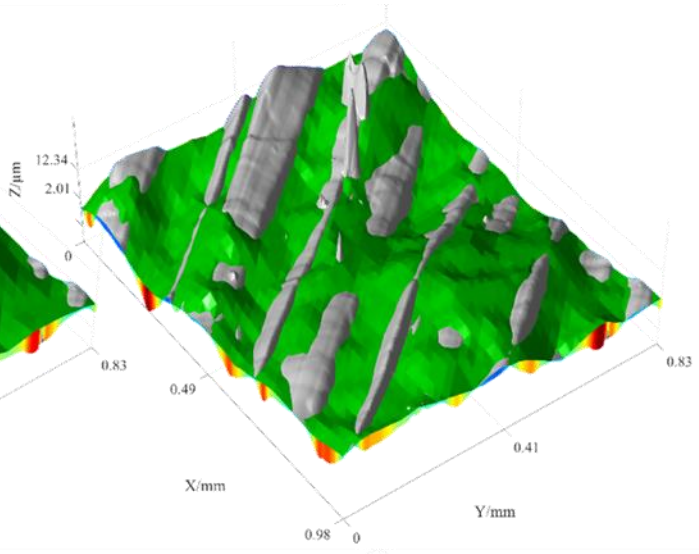
50 %

100 %

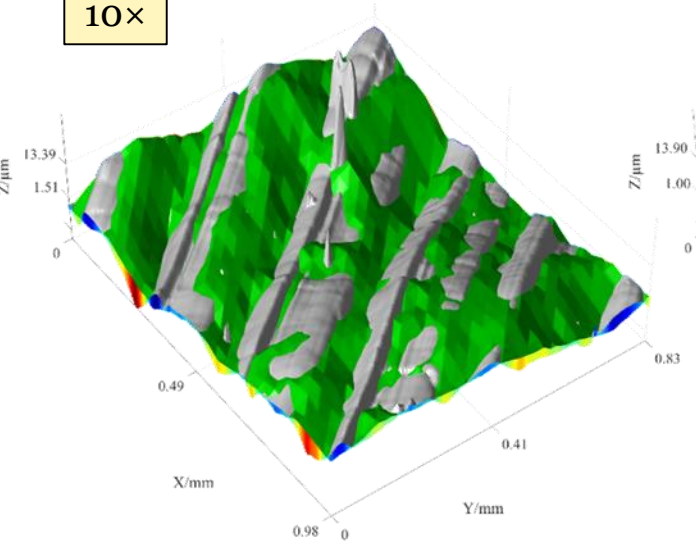
150 %

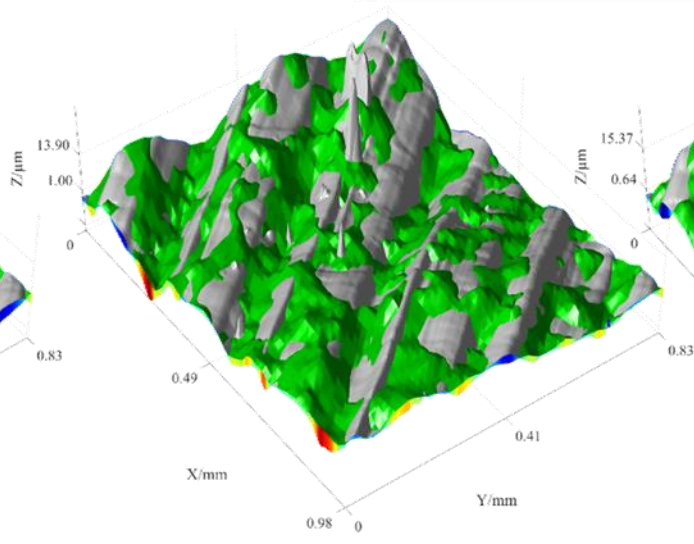
5×

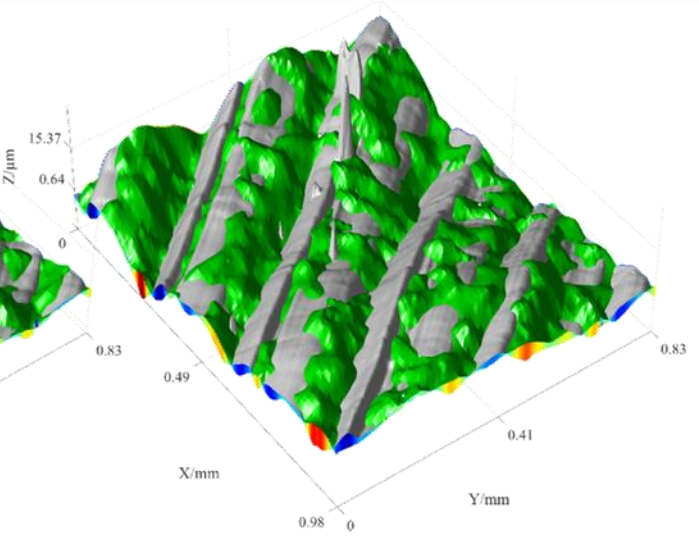




10×







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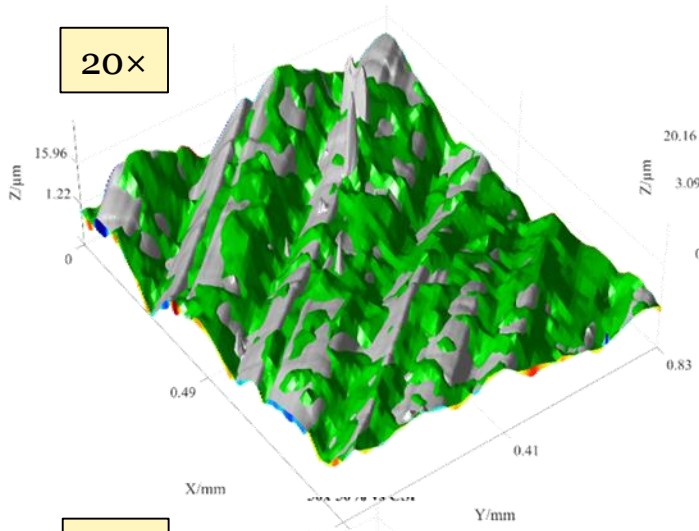
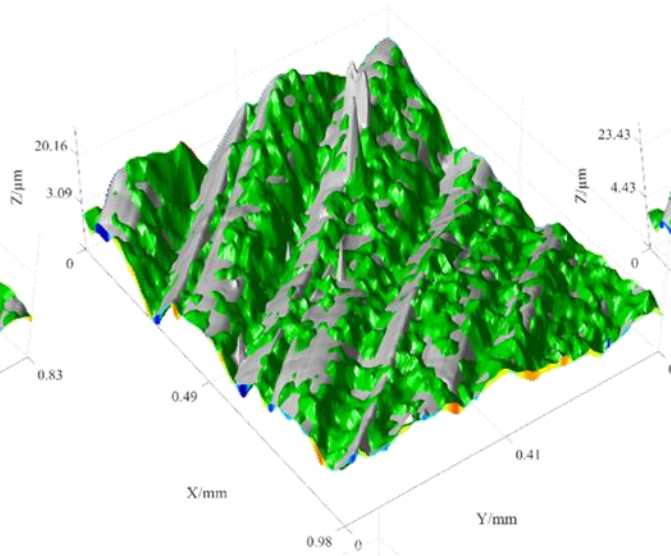
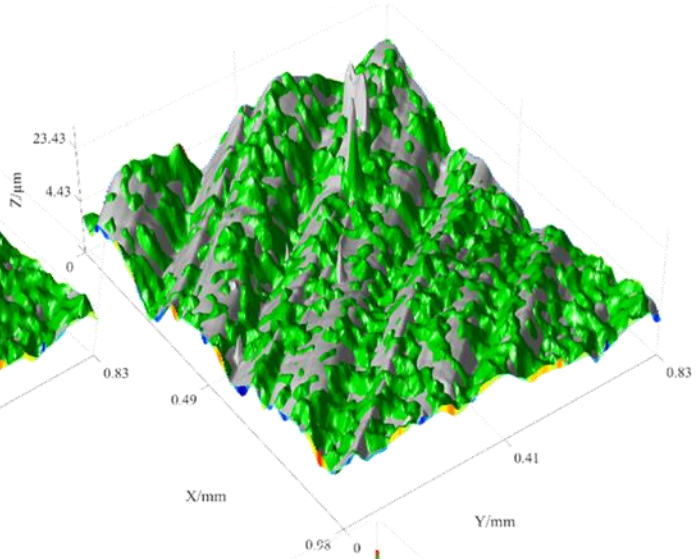
150 %

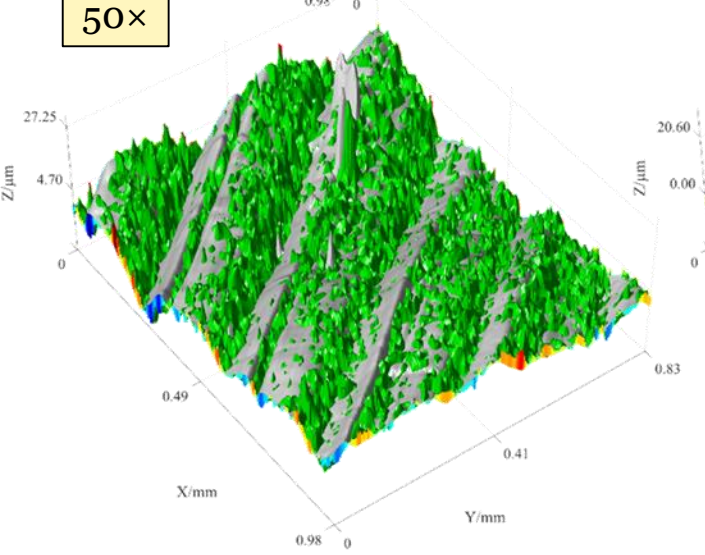
20×

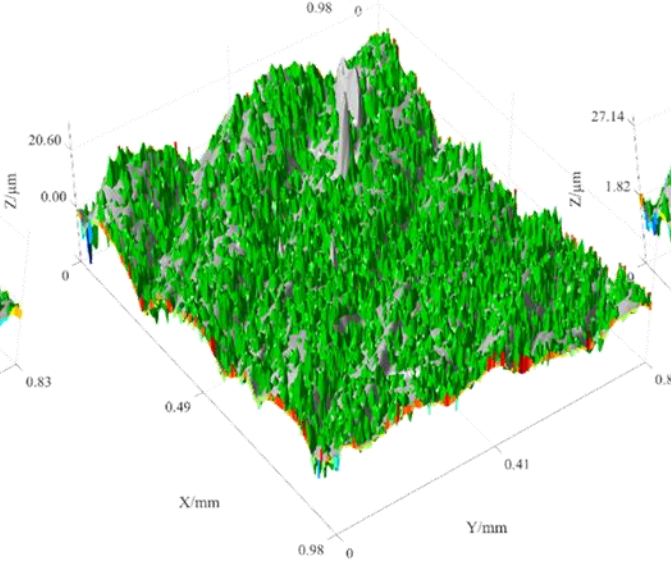


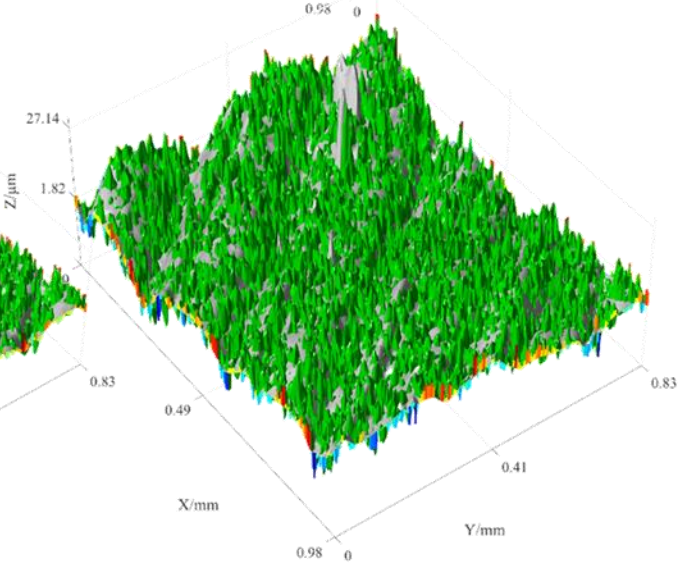




50×

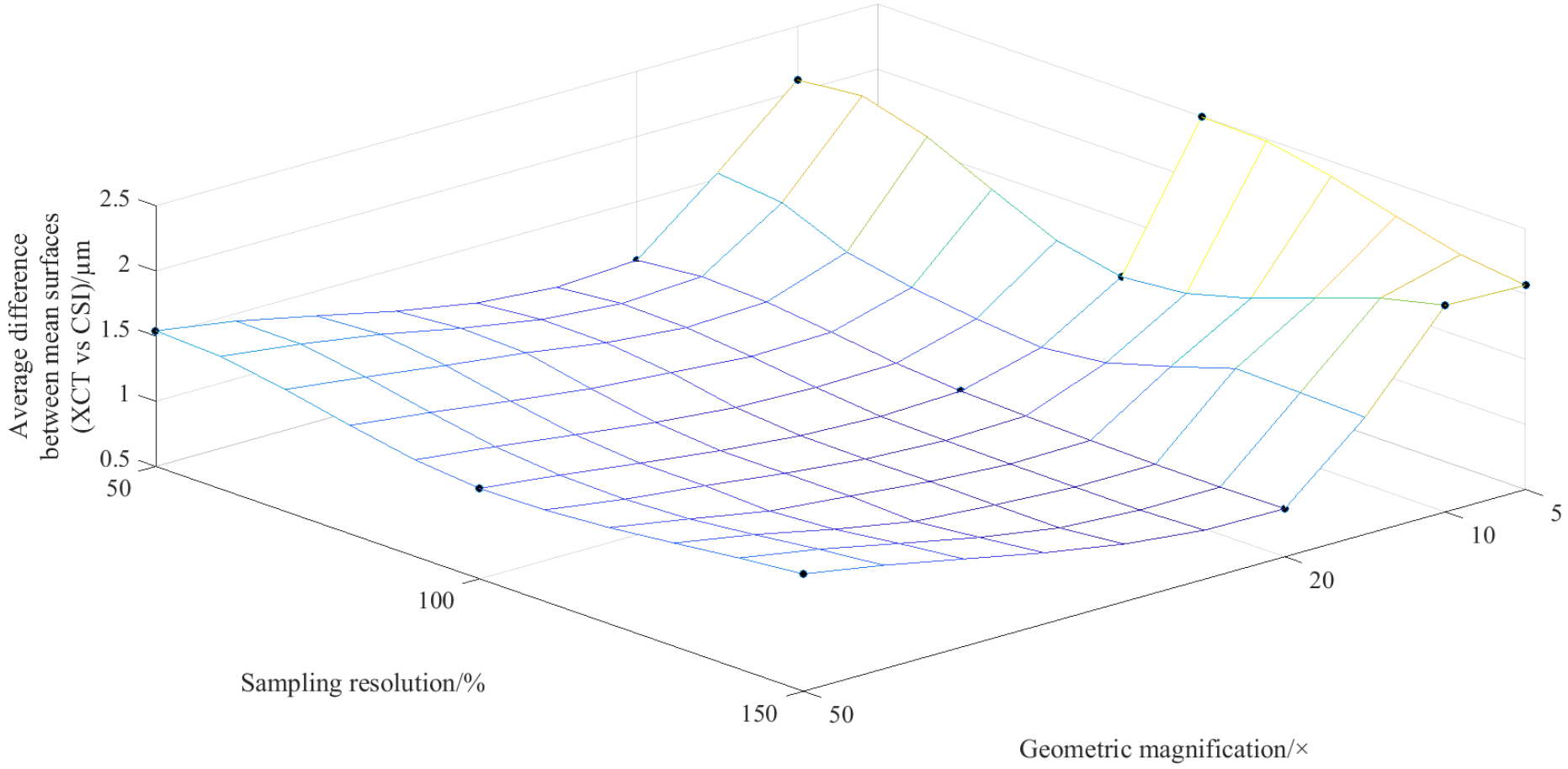






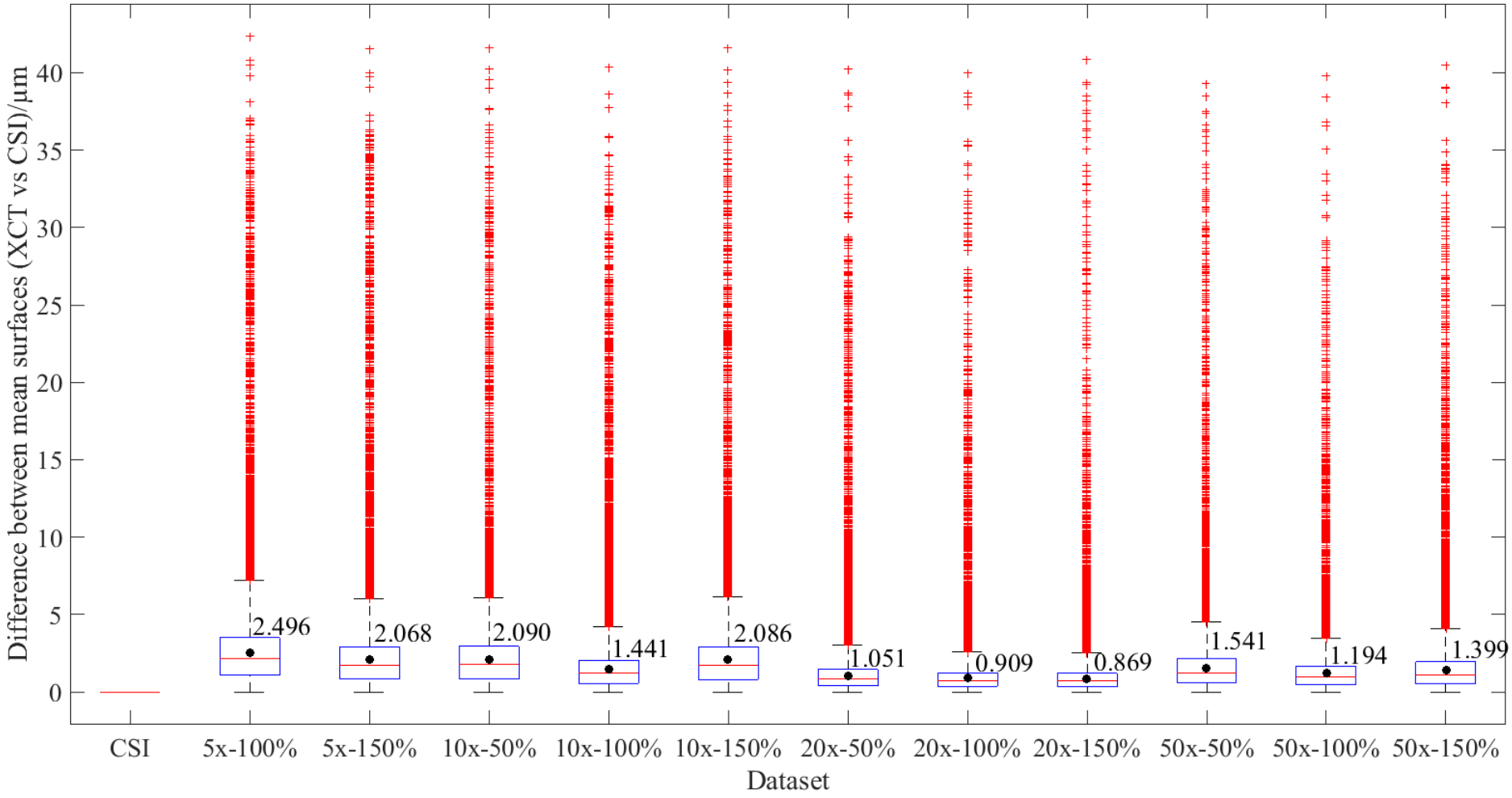
Average distance between paired mean topographies (XCT vs CSI)

Average local difference between means



Distribution of distances between paired mean topographies (XCT vs CSI)

Distribution of local differences between means

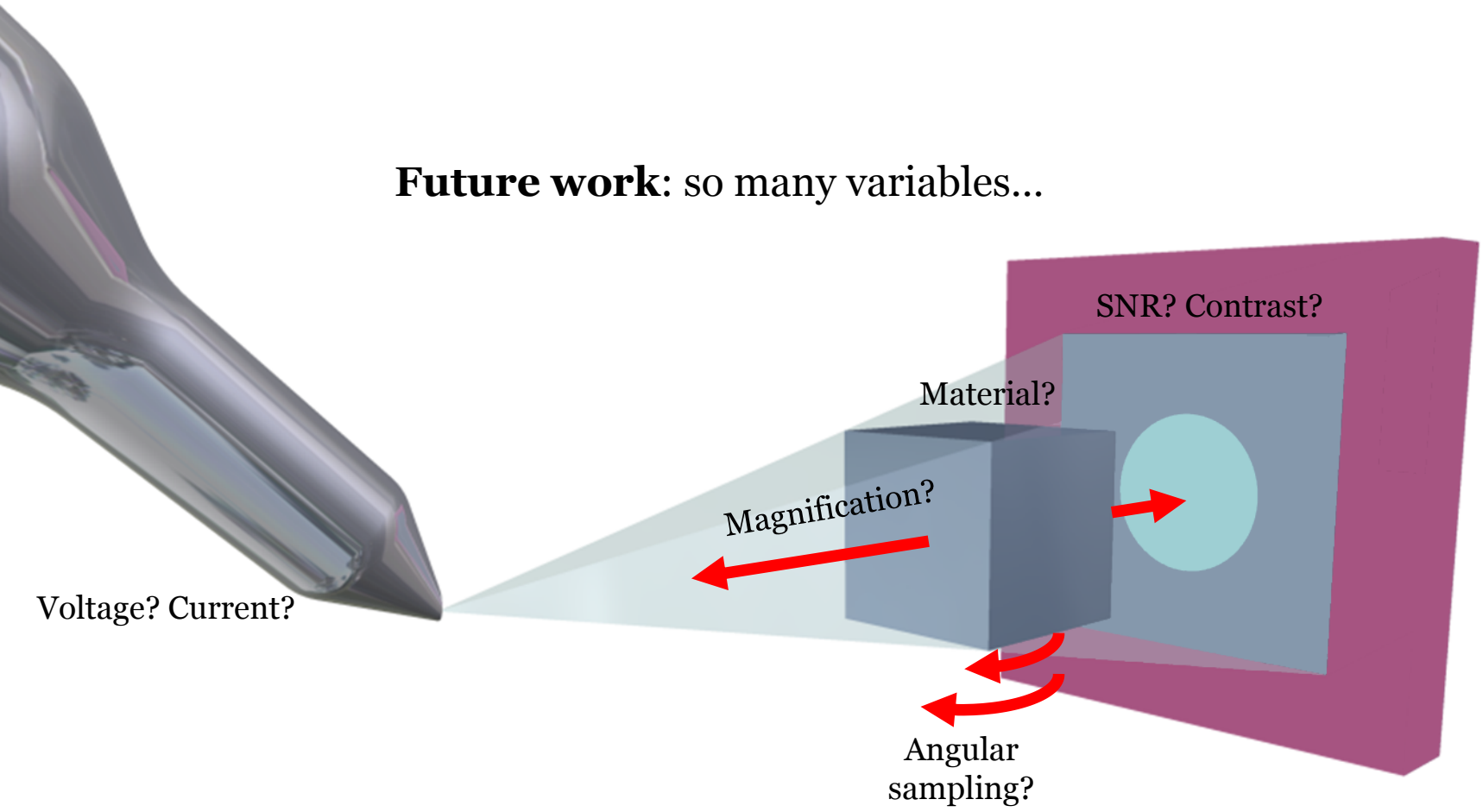


Conclusions and future work

Minimum requirements

XCT topography measurement possible, but sensitivity to measurement process parameters needs to be further explored, as results vary significantly

Future work: so many variables…



Many thanks for your attention