

# Localization microscopy for nanoelectronic manufacturing

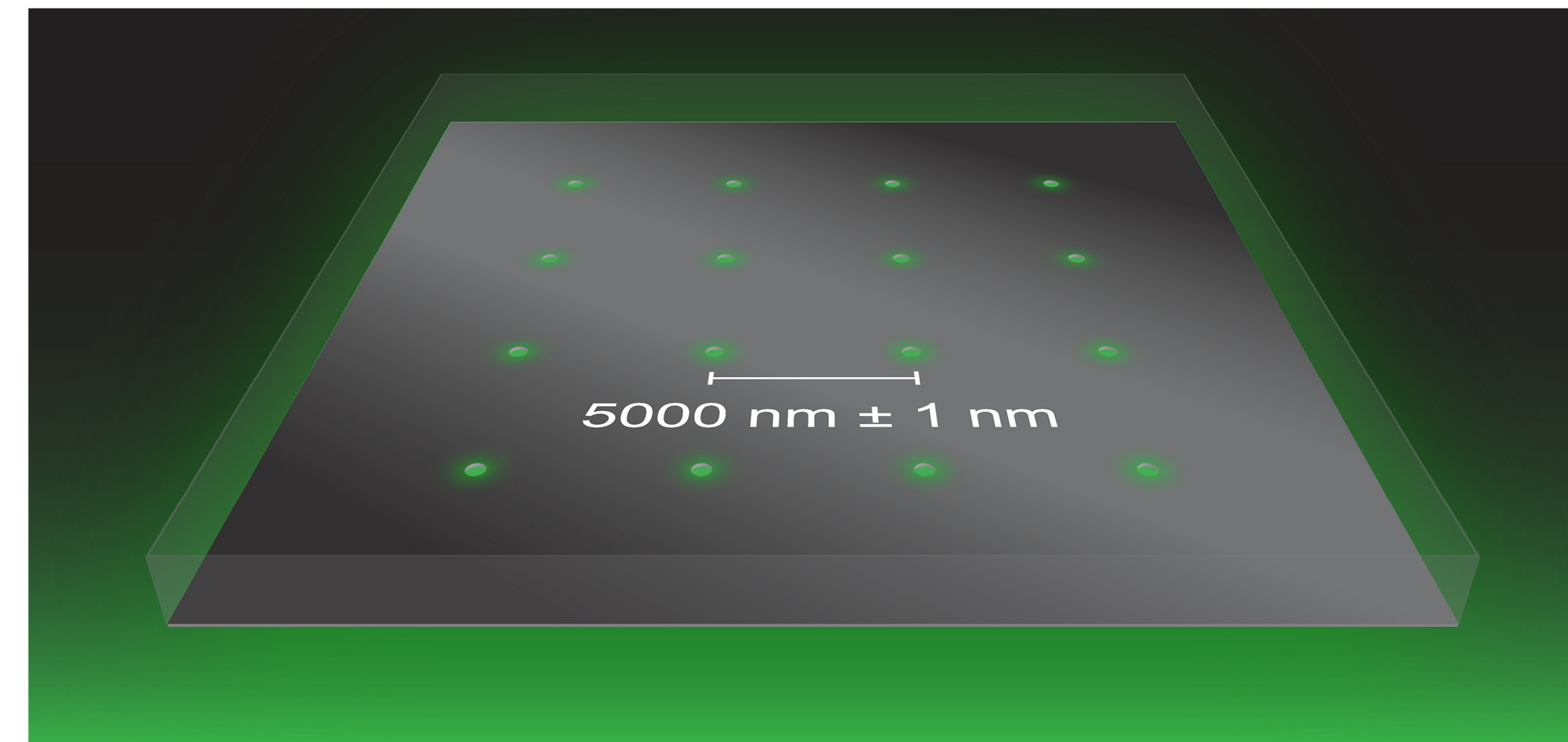
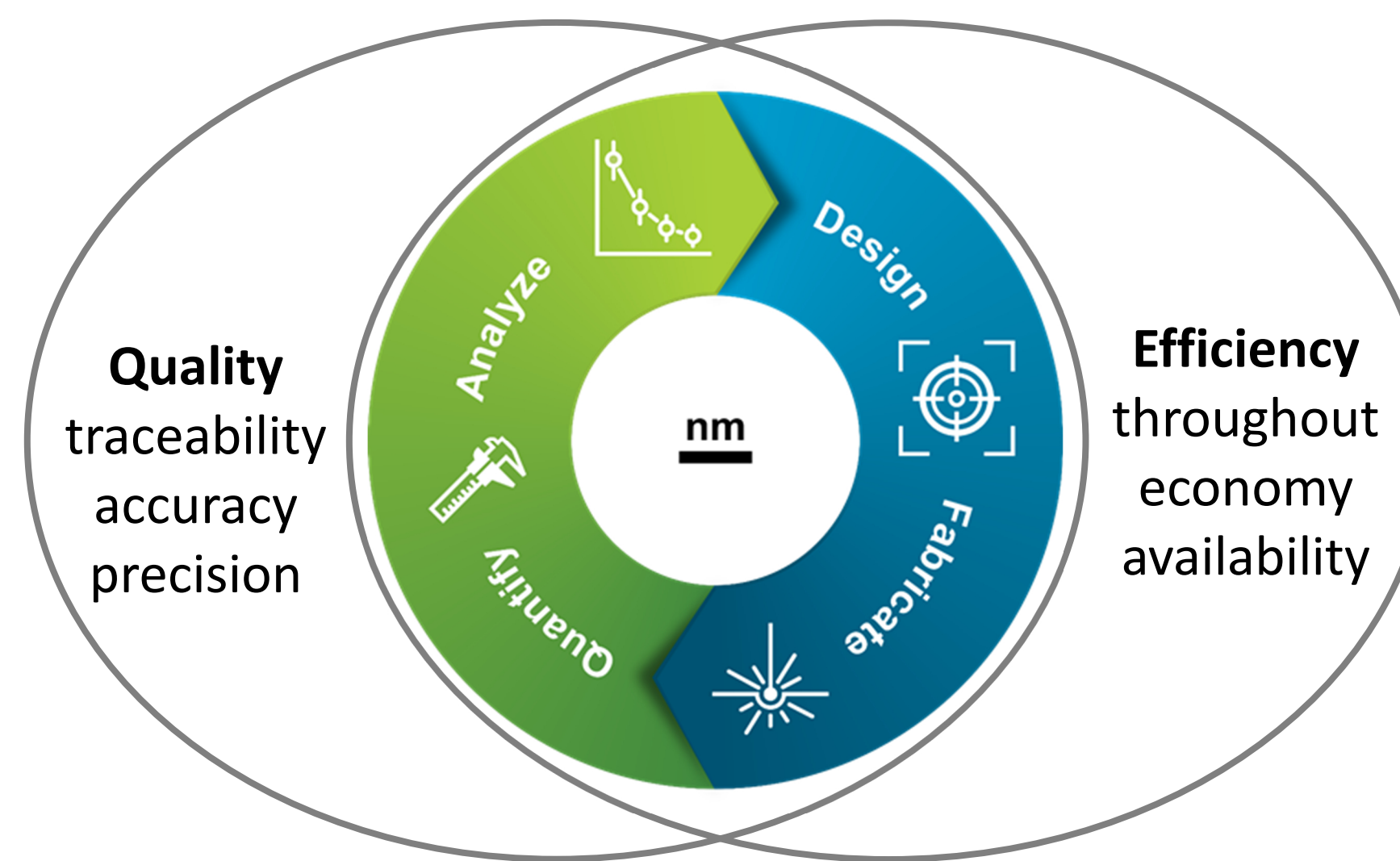
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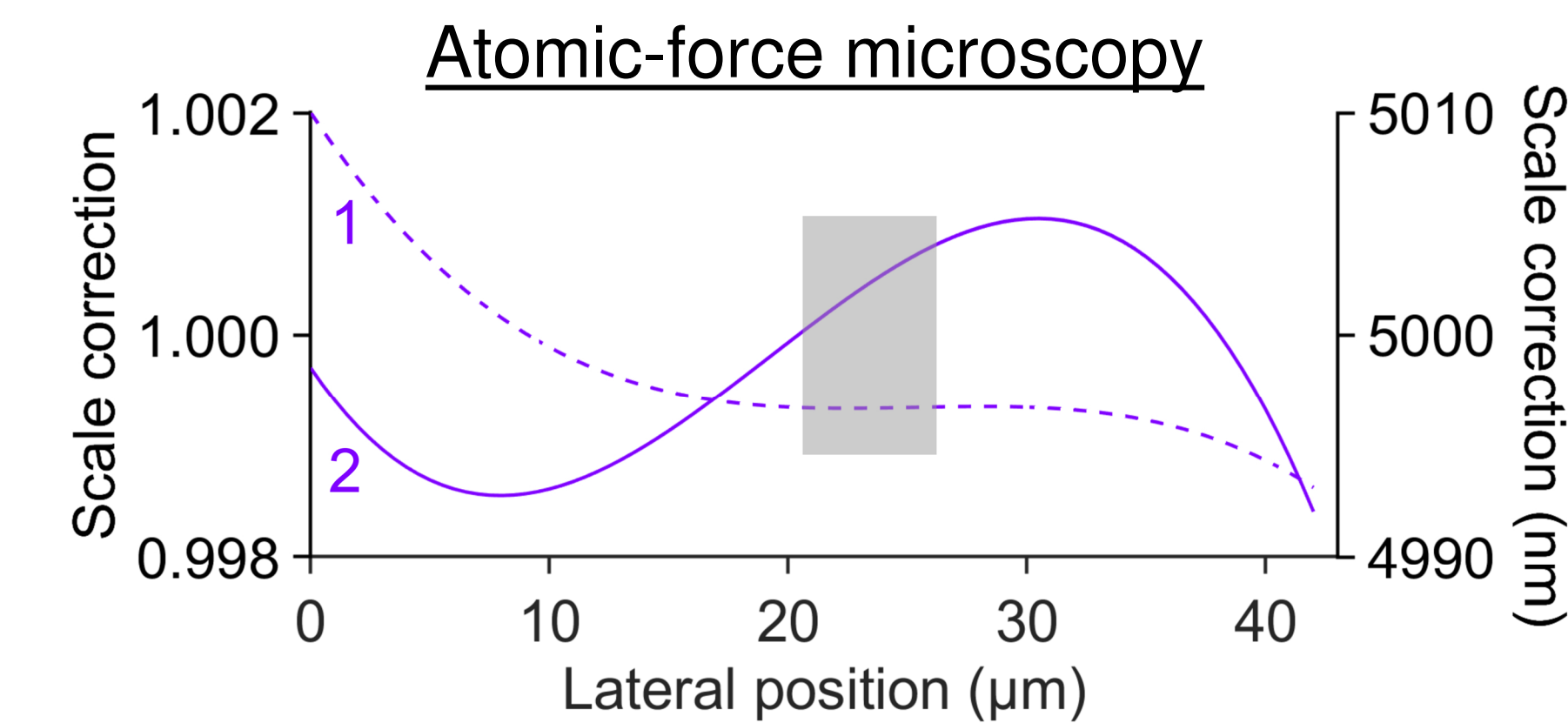
## Deployable standards

A virtuous cycle of making and measuring nanostructures

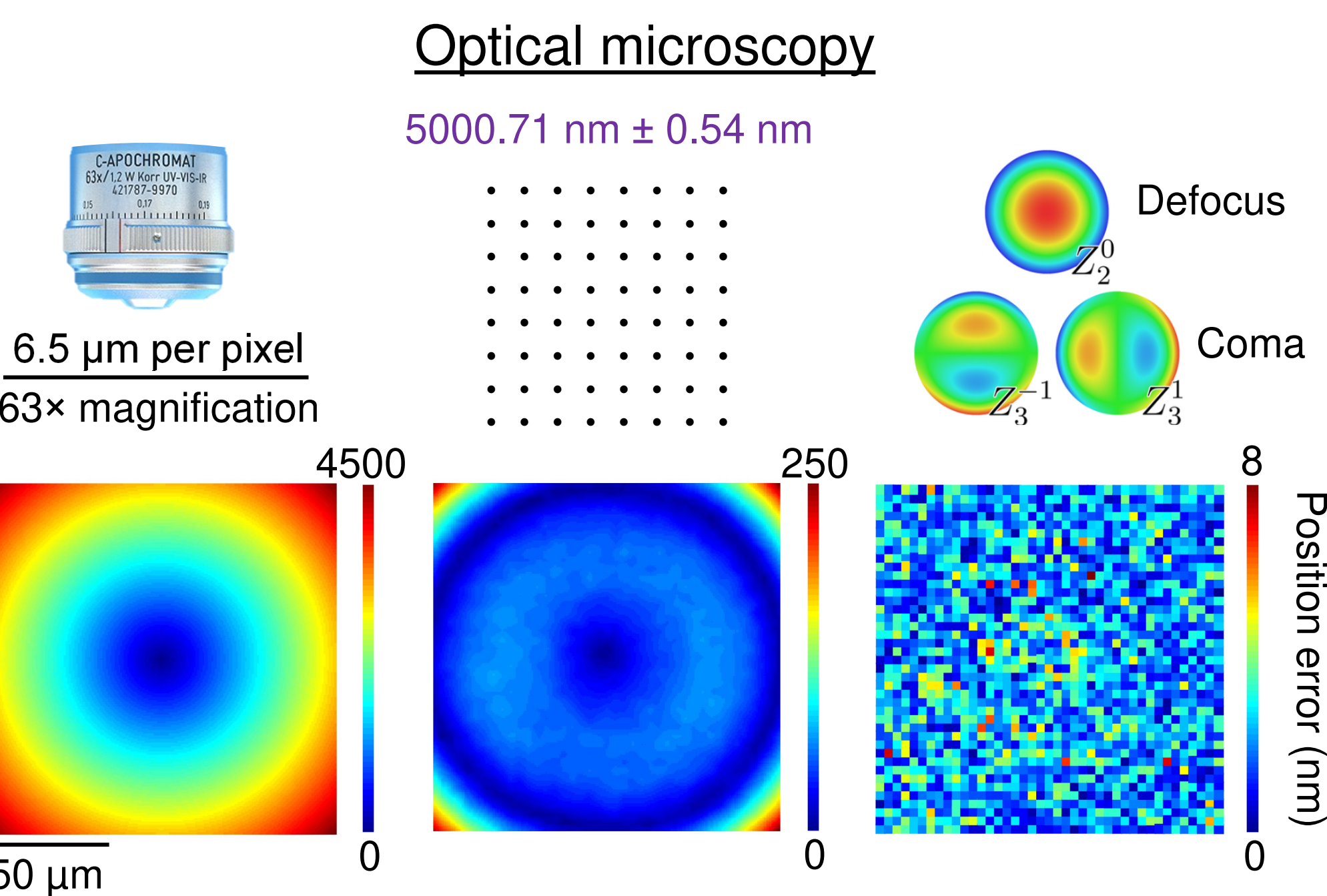


Arrays of nanoscale apertures as position standards for localization microscopy

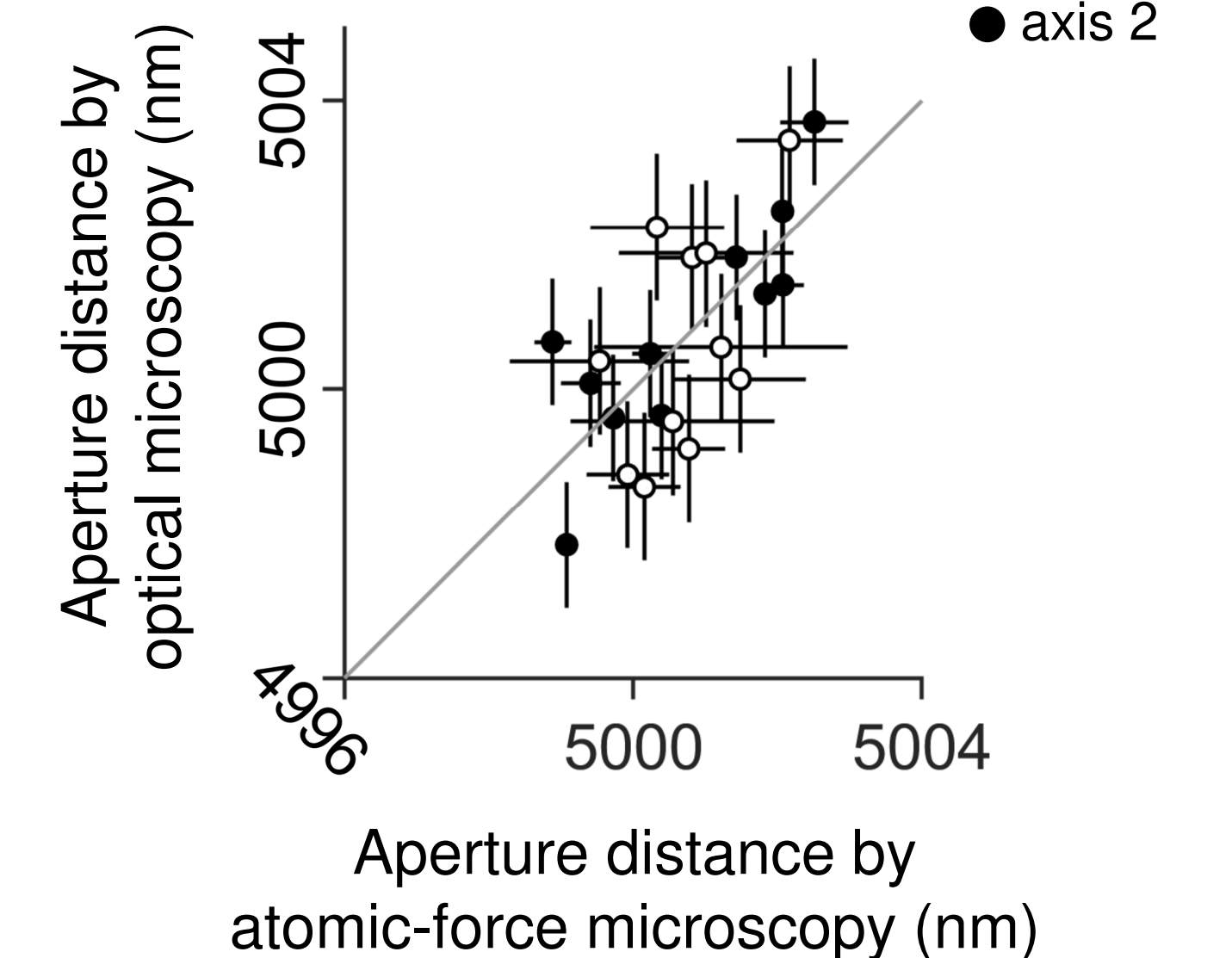
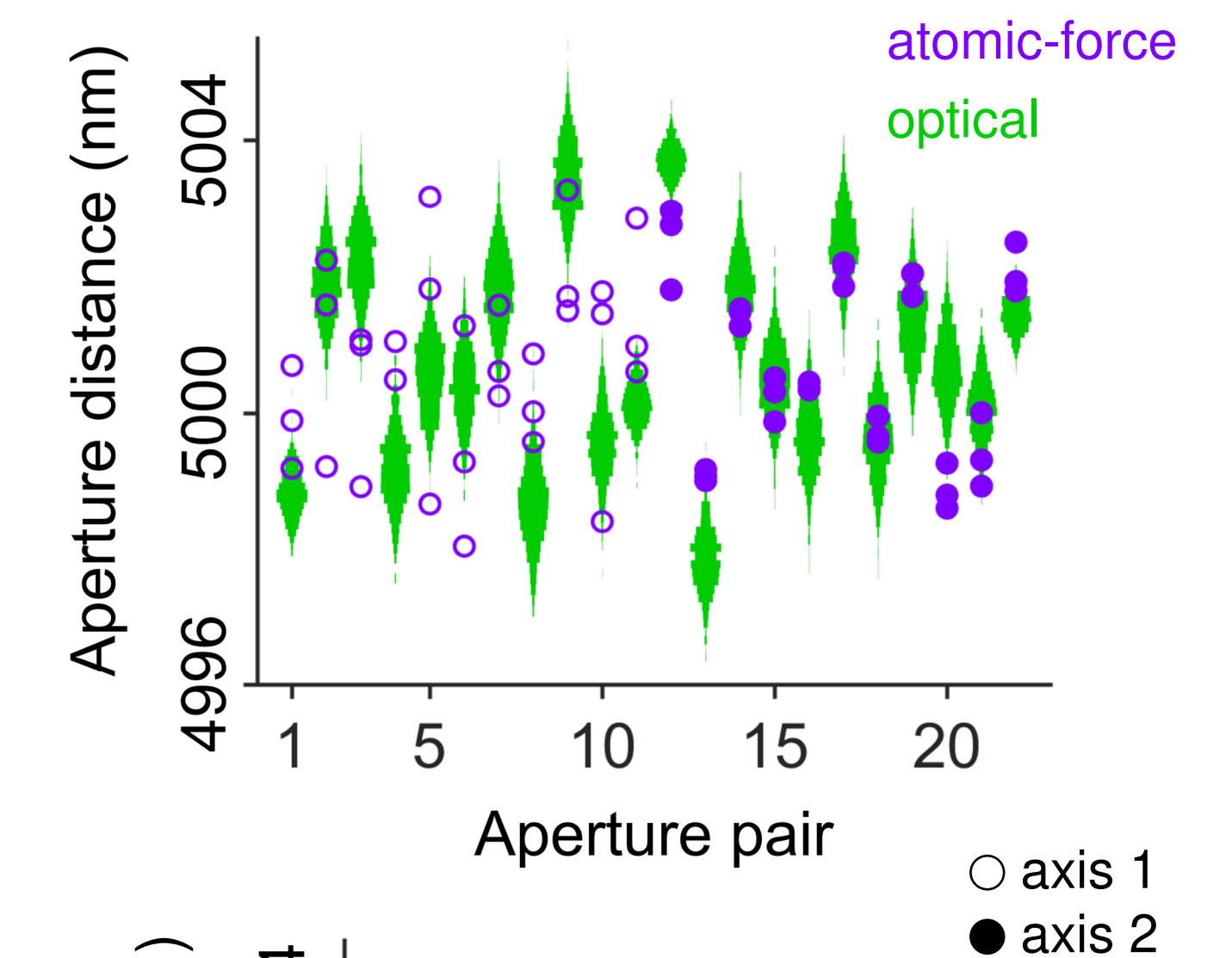
## Scale calibration



Target pitch	5000 nm
Actual pitch	5000.71 nm ± 0.54 nm

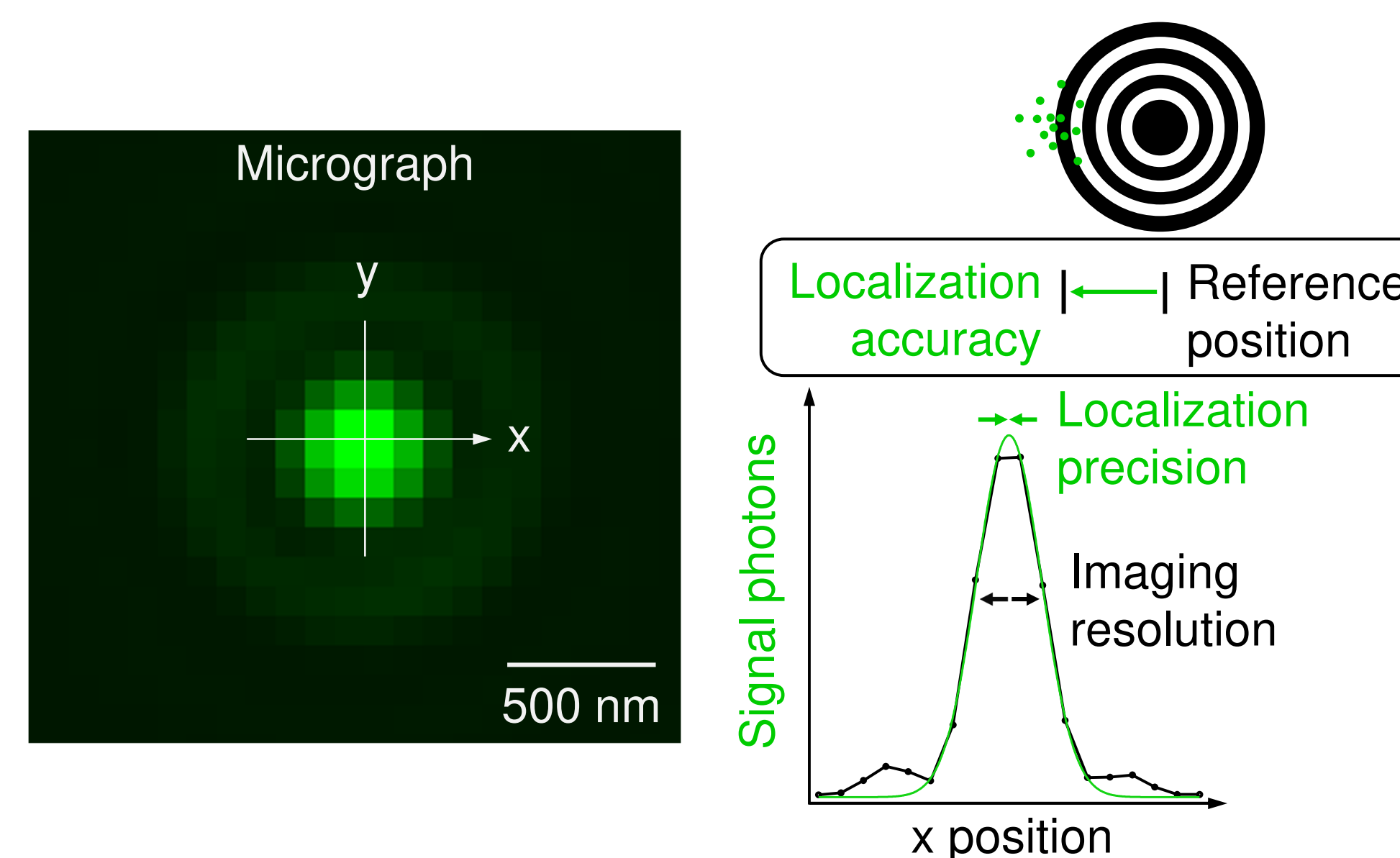


## Distance measurements

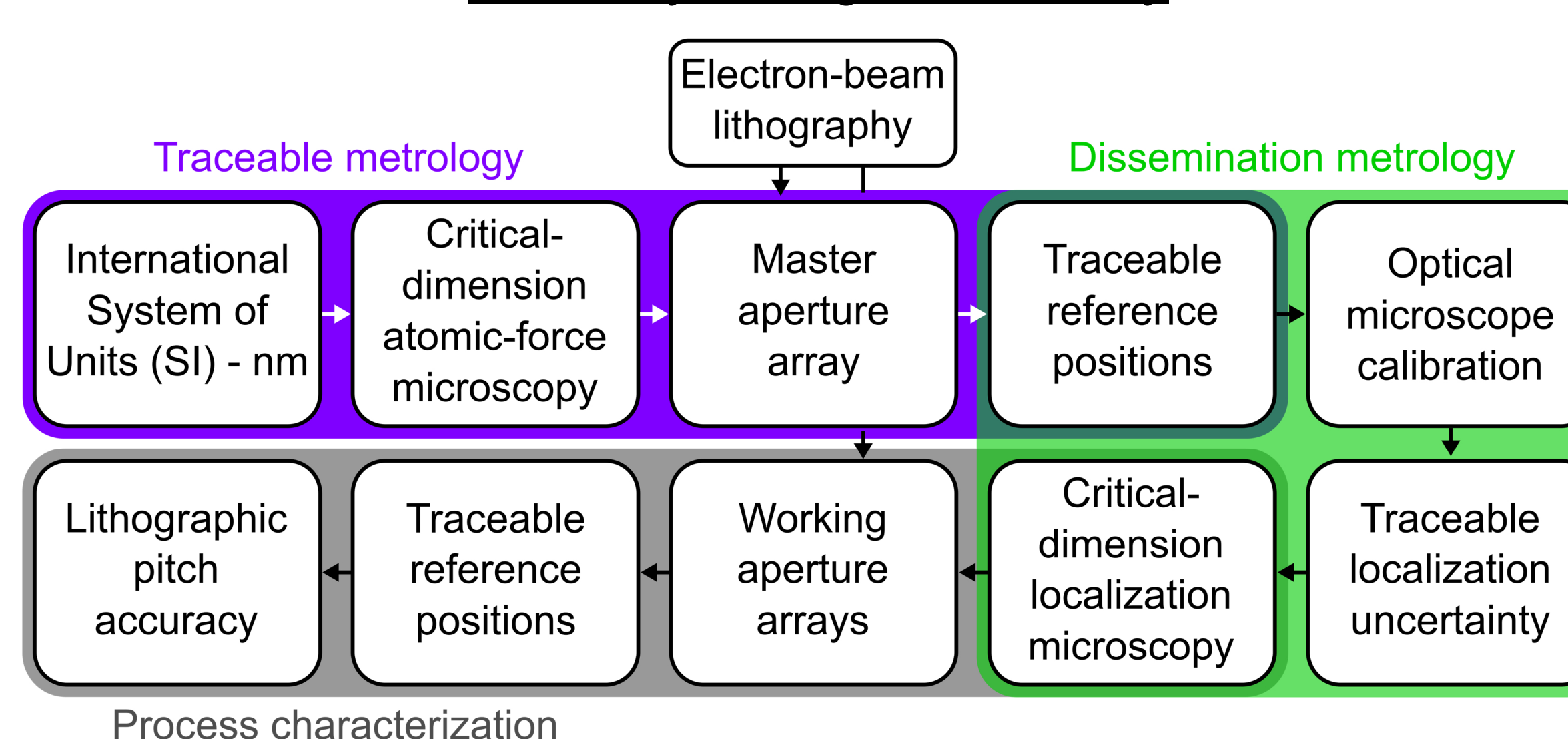


Distance deviations facilitate uncertainty evaluation

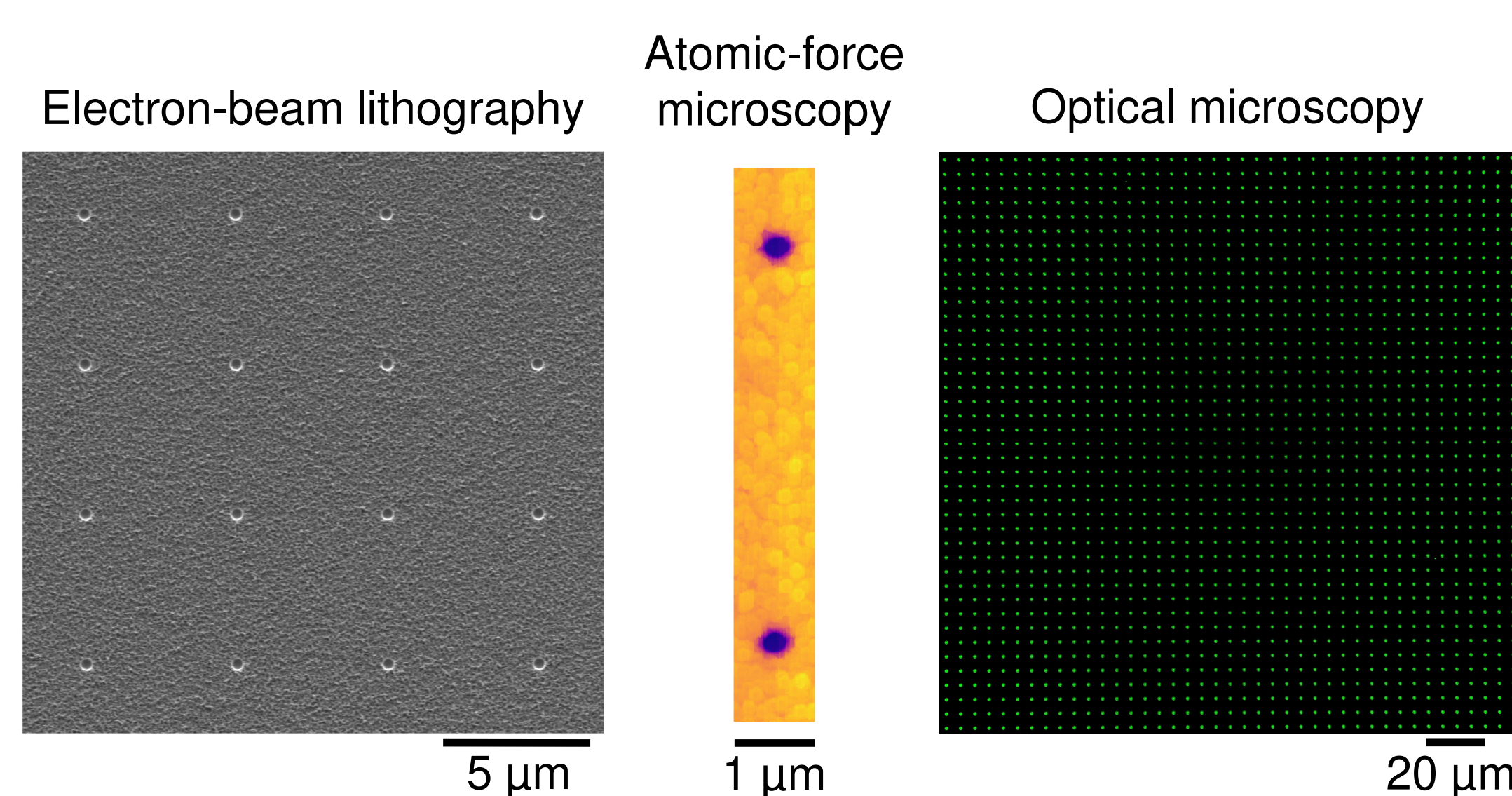
## Localization microscopy



Accuracy through traceability

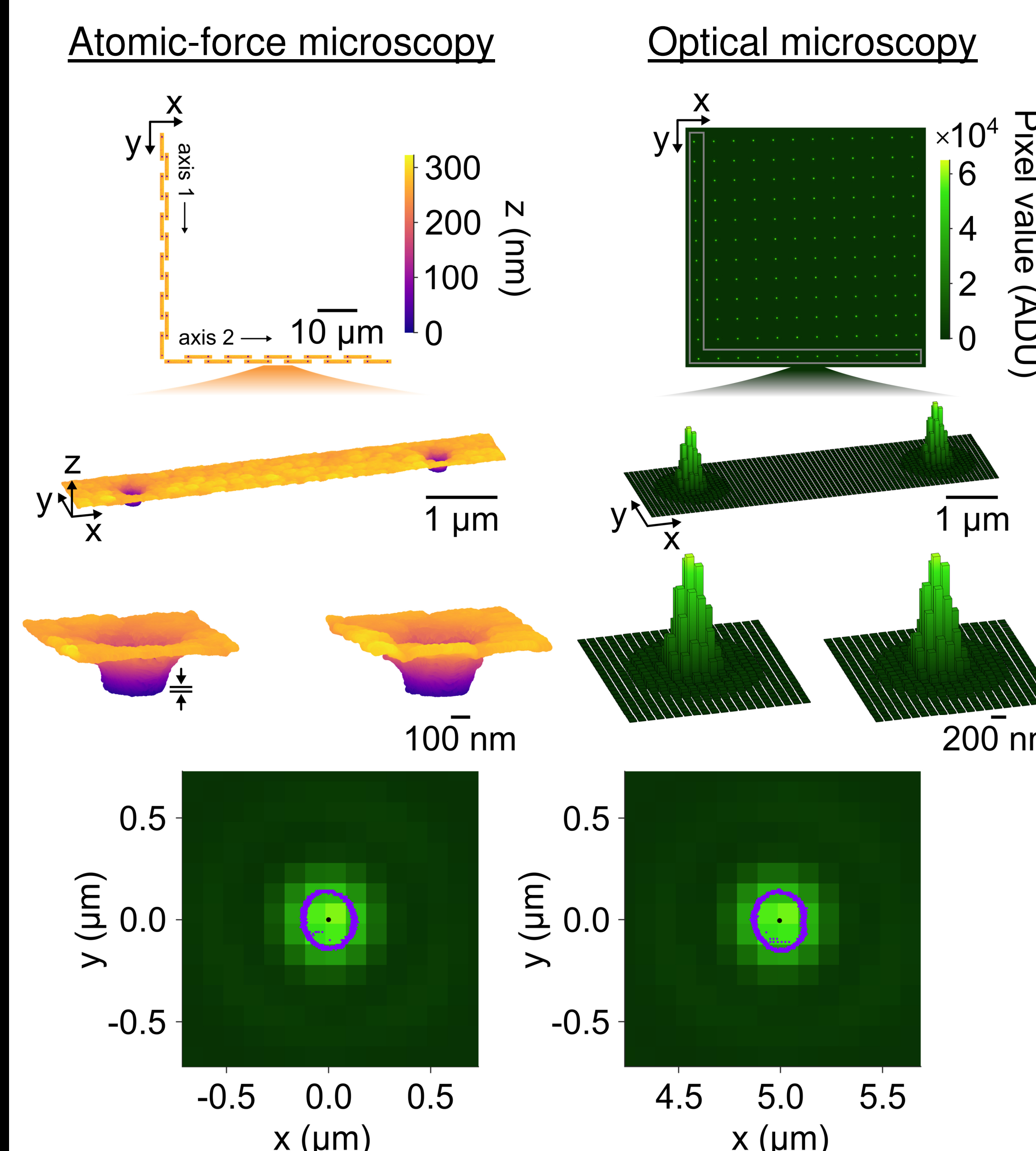


## Aperture array

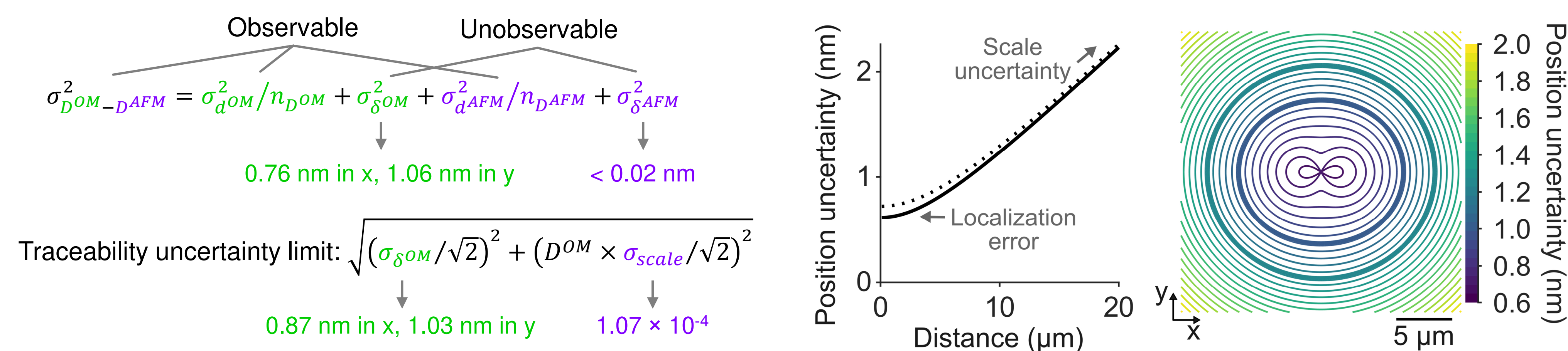


- Fabricate position standard by electron-beam lithography
- Estimate pitch by critical-dimension atomic-force microscopy
- Calibrate optical microscopy using traceable value of pitch
- Characterize traceable uncertainty of optical microscopy
- Apply traceable optical microscopy to rapidly characterize new standards, devices, and fabrication processes

## Correlative microscopy



## Traceable localization uncertainty



## Feedback to fabrication

### Electron-beam lithography

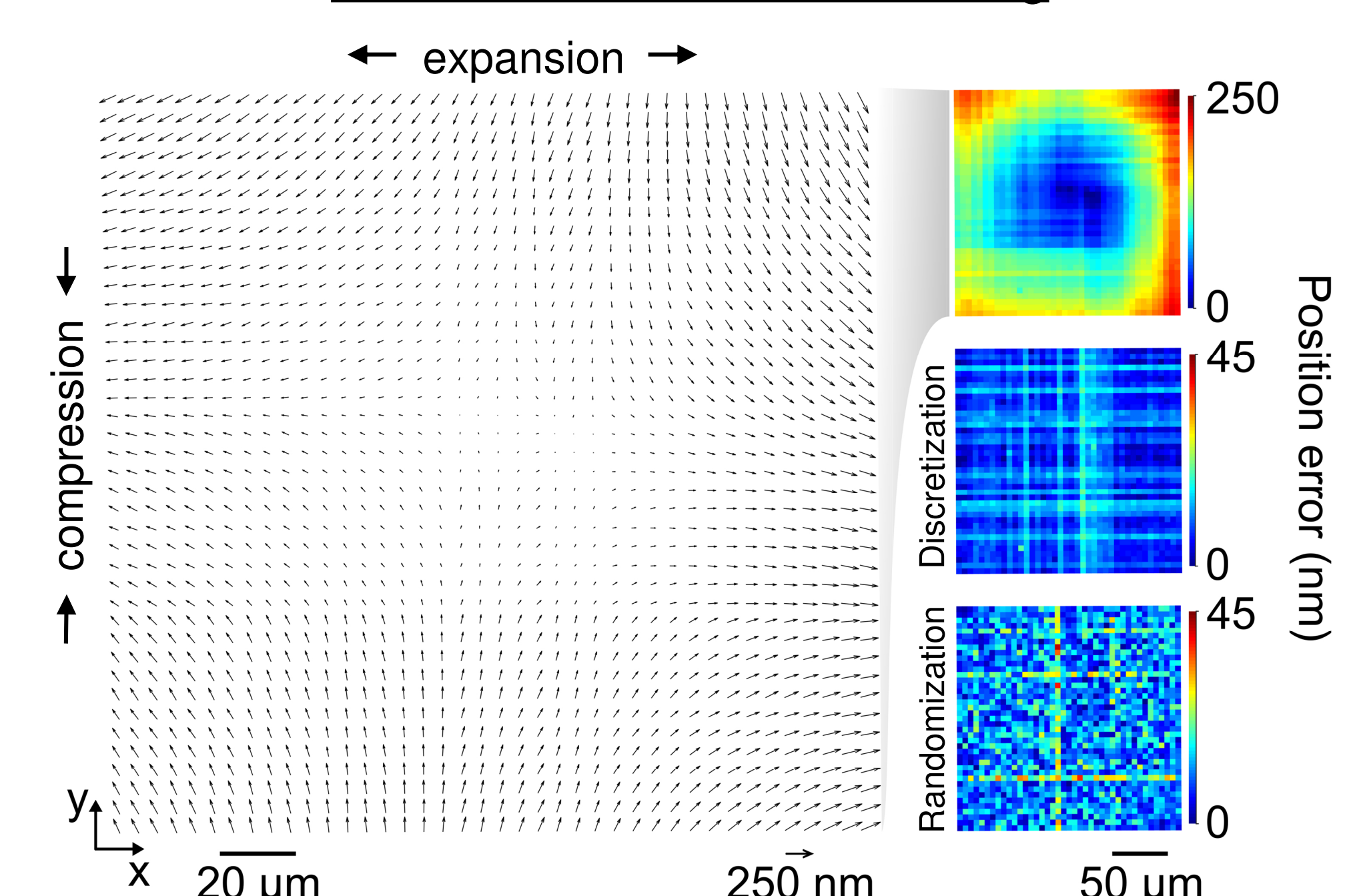
Traceable characterization of fabrication accuracy

Array	Pitch (nm)	Standard Error (nm)	Uncertainty (nm)
1	5000.71	0.13	0.54
2	4999.90	0.03	0.54
3	5000.30	0.01	0.54
4	5001.45	0.03	0.54
5	4997.30	0.08	0.54
6	4996.44	0.08	0.54

Consensus mean pitch: 4999.34 nm ± 1.00 nm

Prediction interval: 4999.40 nm ± 2.34 nm

### Focused-ion-beam machining



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Prior work



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