Quantum Dot Localization

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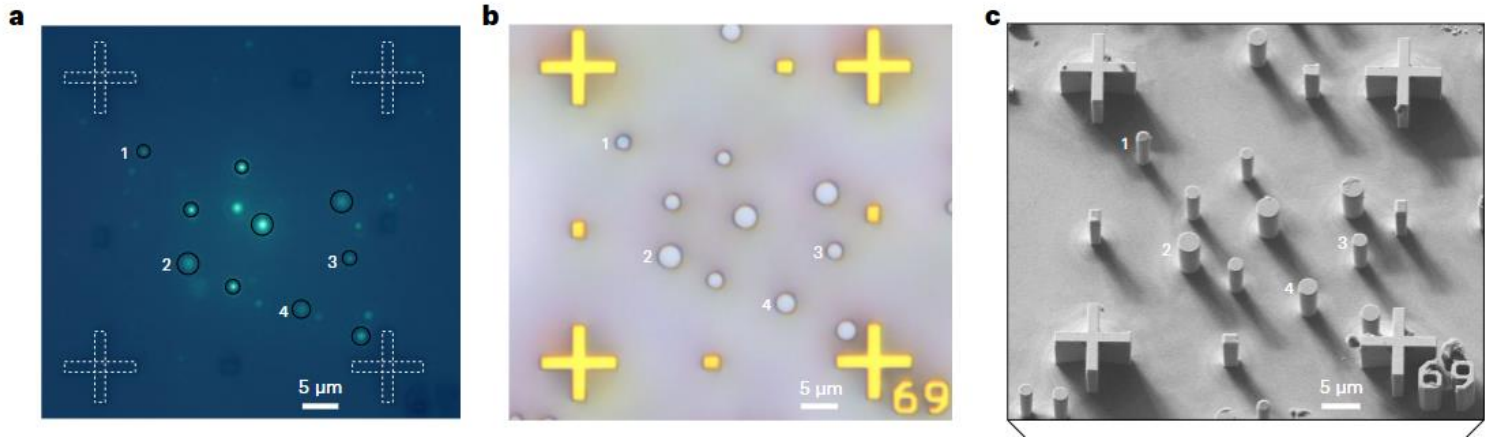
Quantum Dot Localization: Motivation

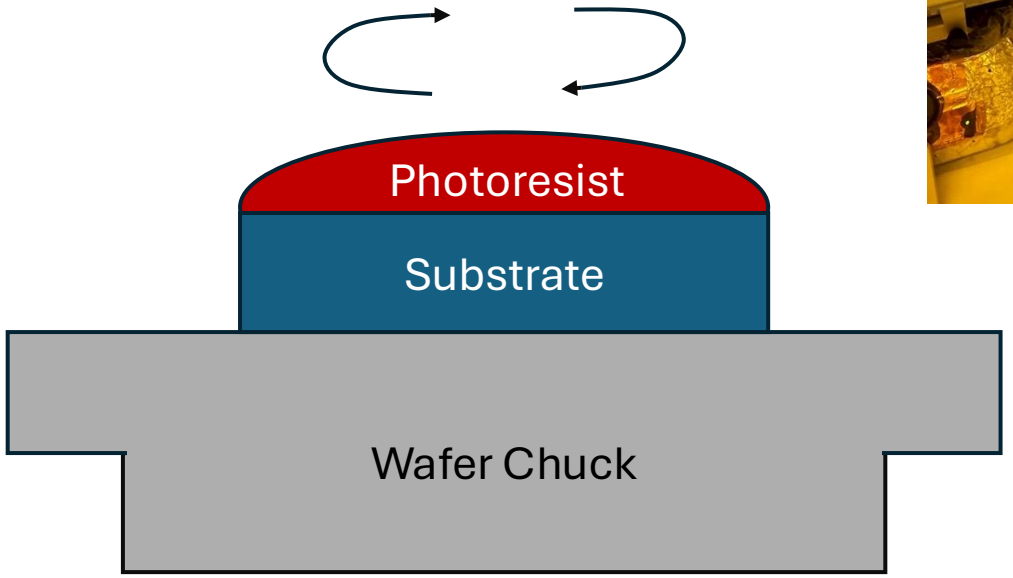
- Potential applications in optical quantum computing, quantum communications
- Localization required to “map” quantum dots
  → Reliably couple photonic devices with quantum dots
- Previous works utilized fluorescent optical microscopes
- Can AFM correlate surface features to embedded quantum dots?

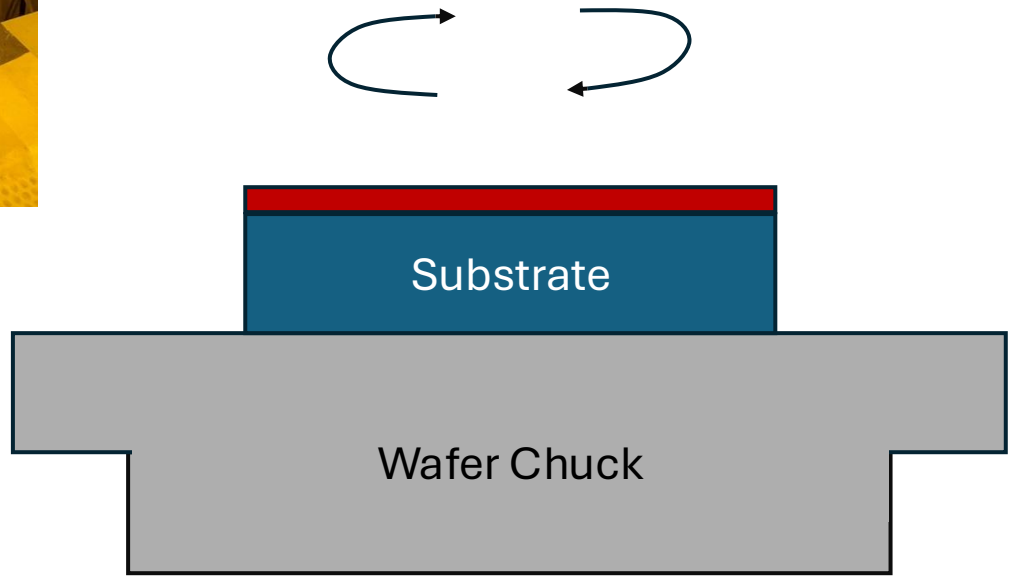


Quantum Dot Localization Process: Spin Coating (1/5)

Steps required for quantum dot localization:

- Spin coating

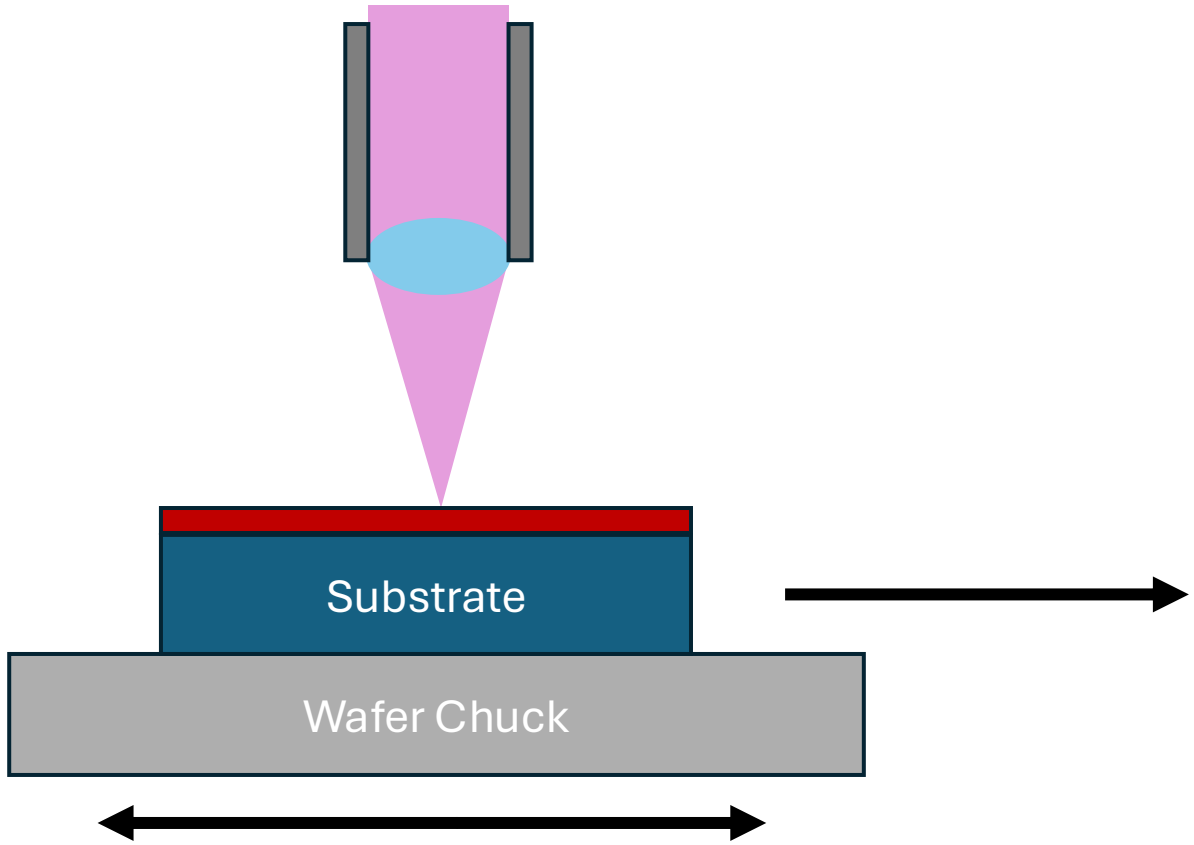


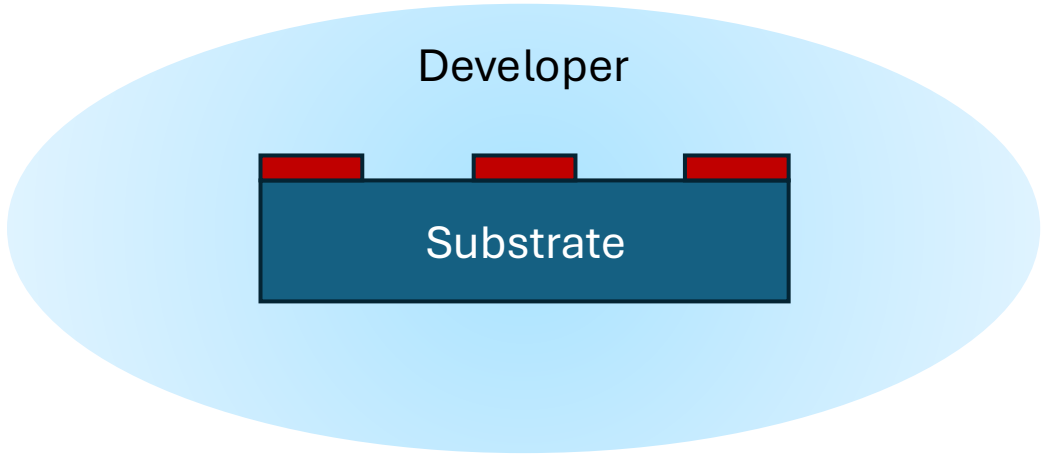


Quantum Dot Localization Process: Photolithography (2/5)

Steps required for quantum dot localization:

- Spin coating
- Photolithography

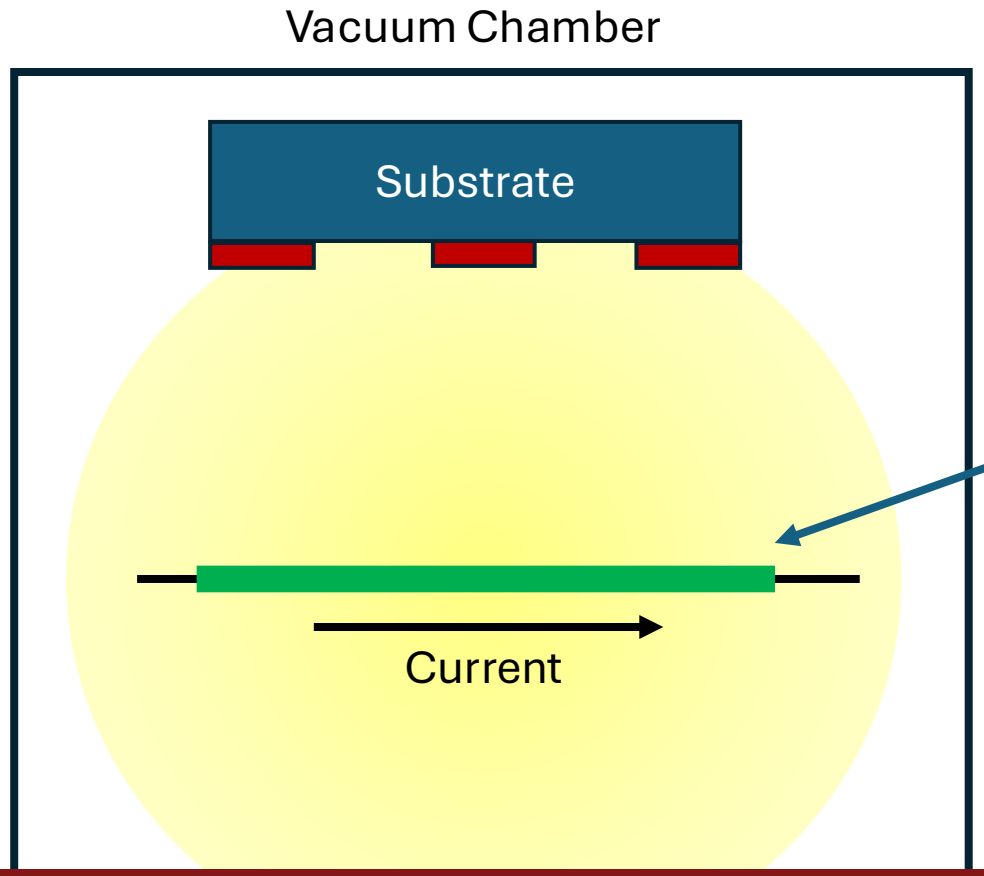




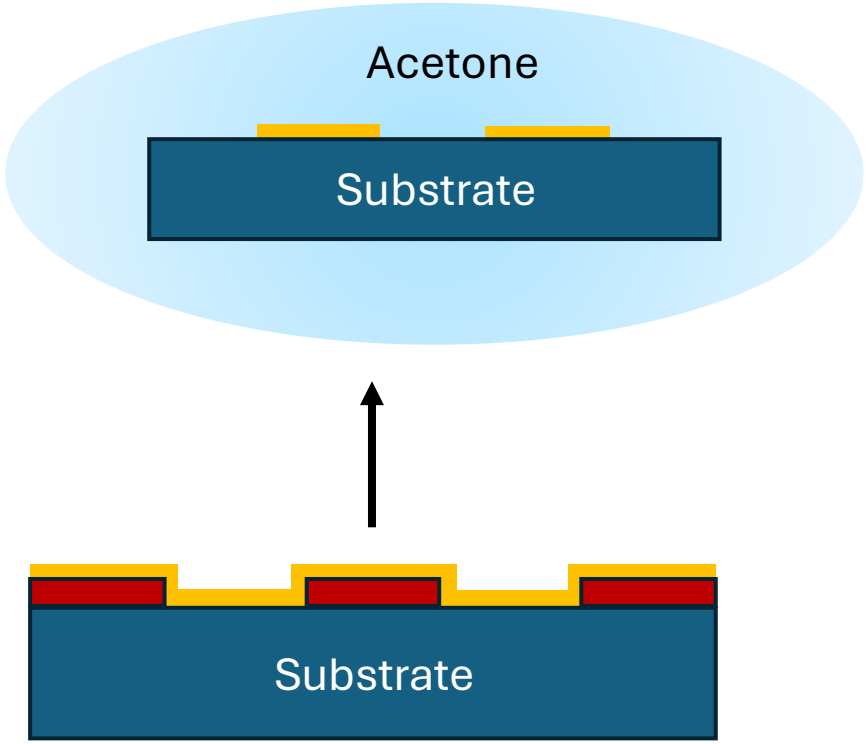
Quantum Dot Localization Process: Metal Deposition(3/5)

Steps required for quantum dot localization:

- Spin coating
- Photolithography
- Metal Deposition/Thermal Evaporator



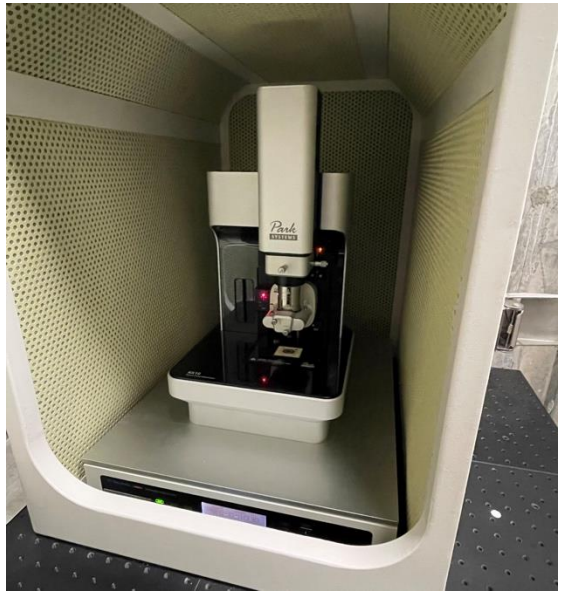
Chromium on Tungsten Wire

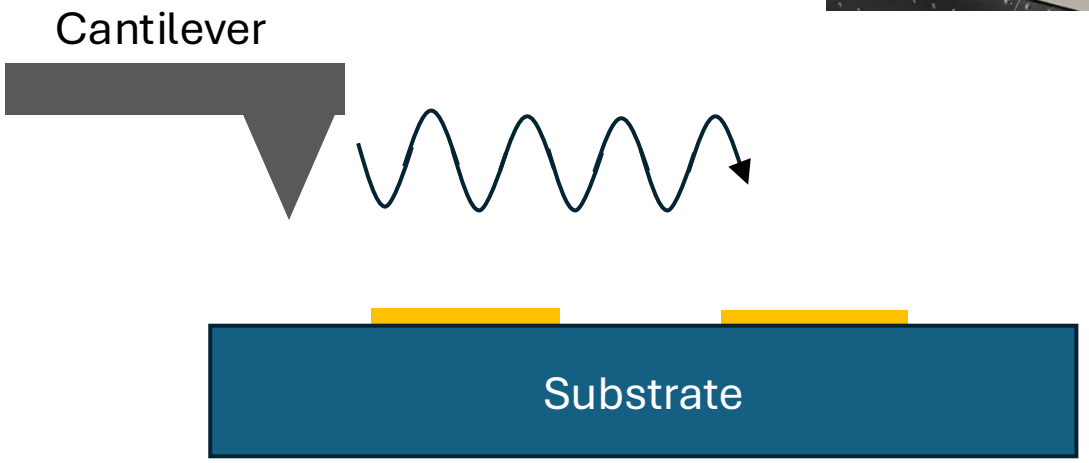


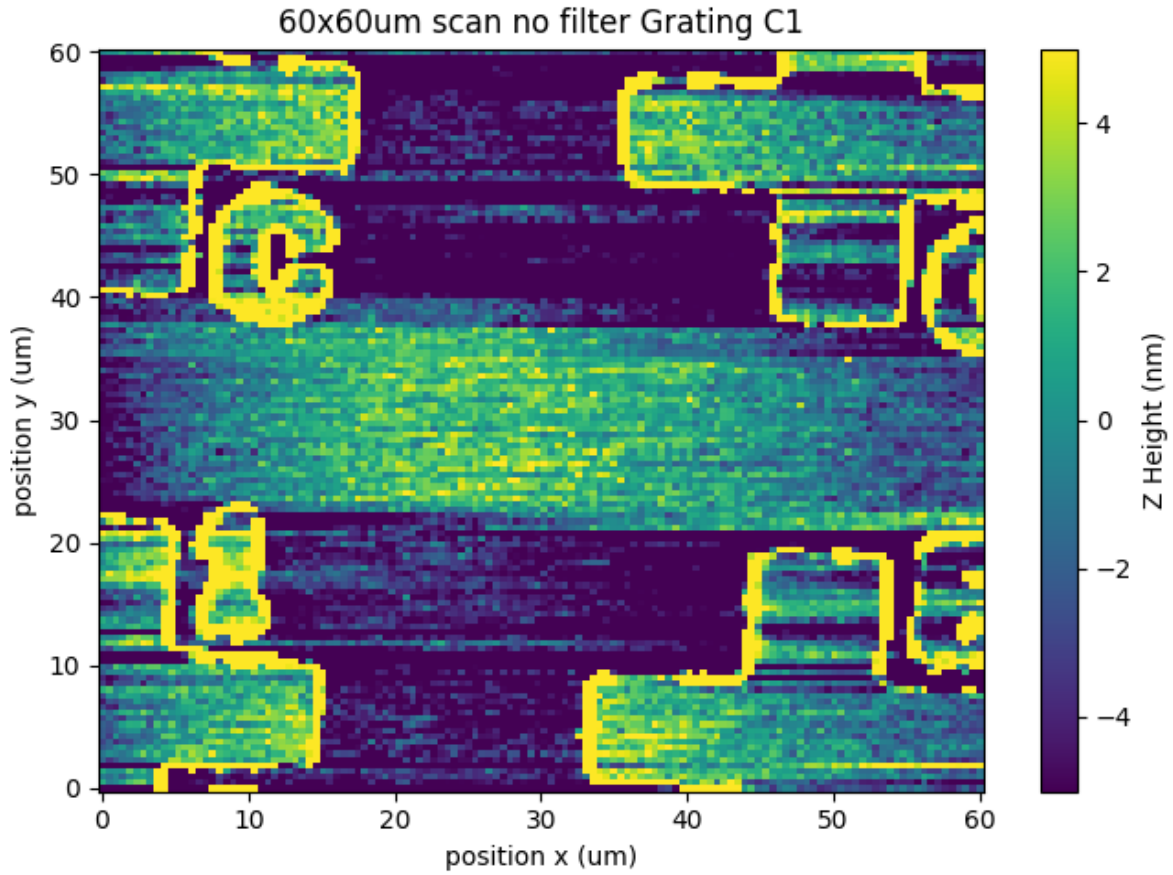
Quantum Dot Localization Process: Atomic Force Microscopy (4/5)

Steps required for quantum dot localization:

- Spin coating
- Photolithography
- Metal Deposition
- Atomic Force Microscopy (AFM)



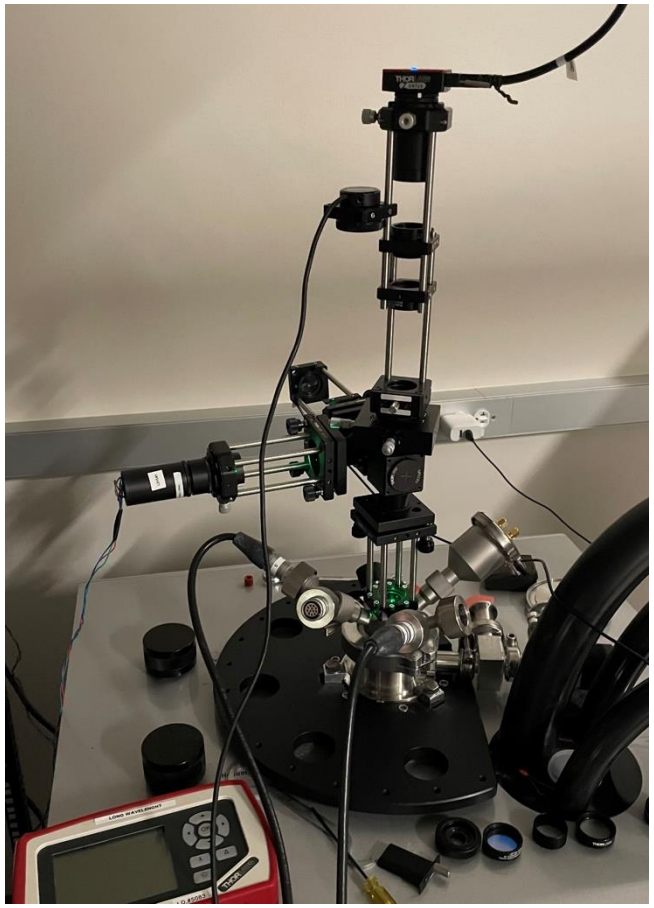


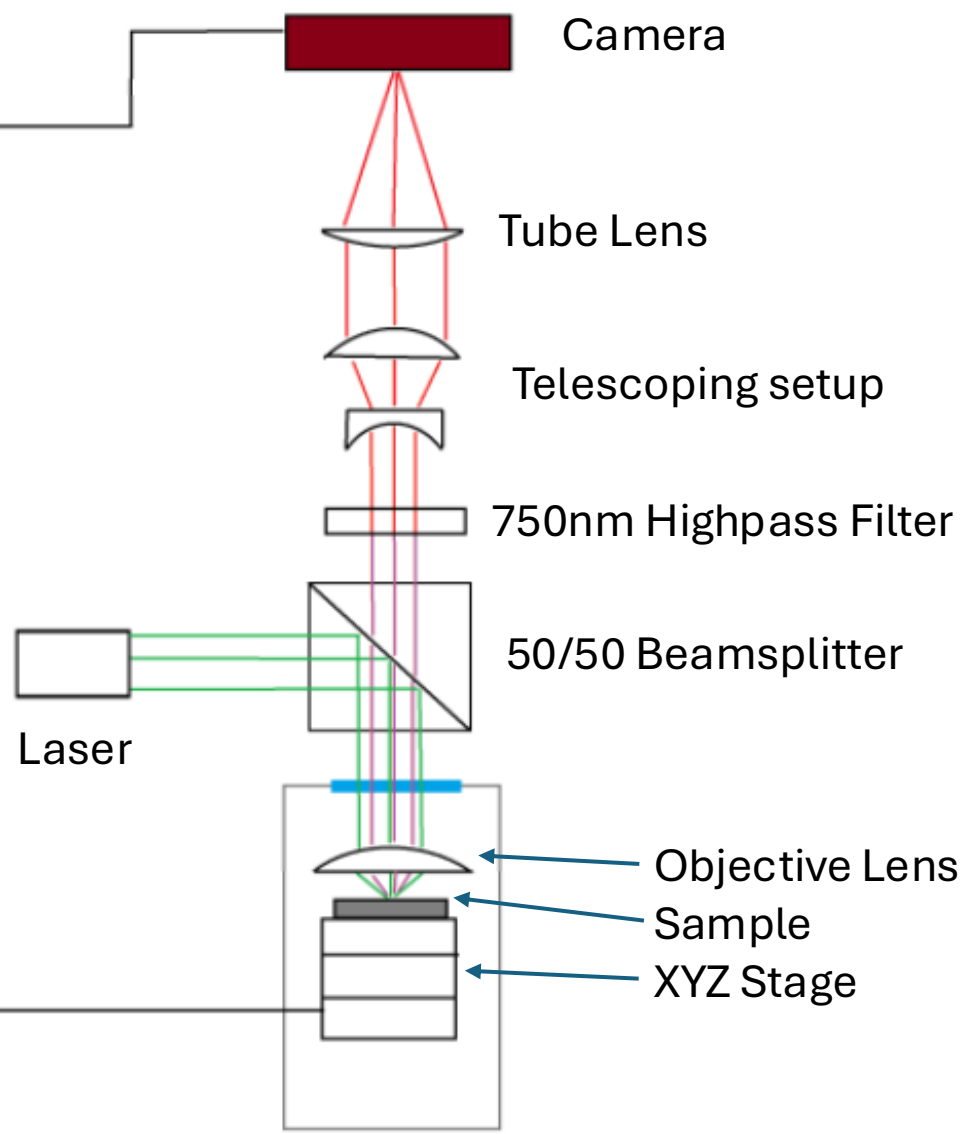


Verifying our results: Optical Microscopy (5/5)

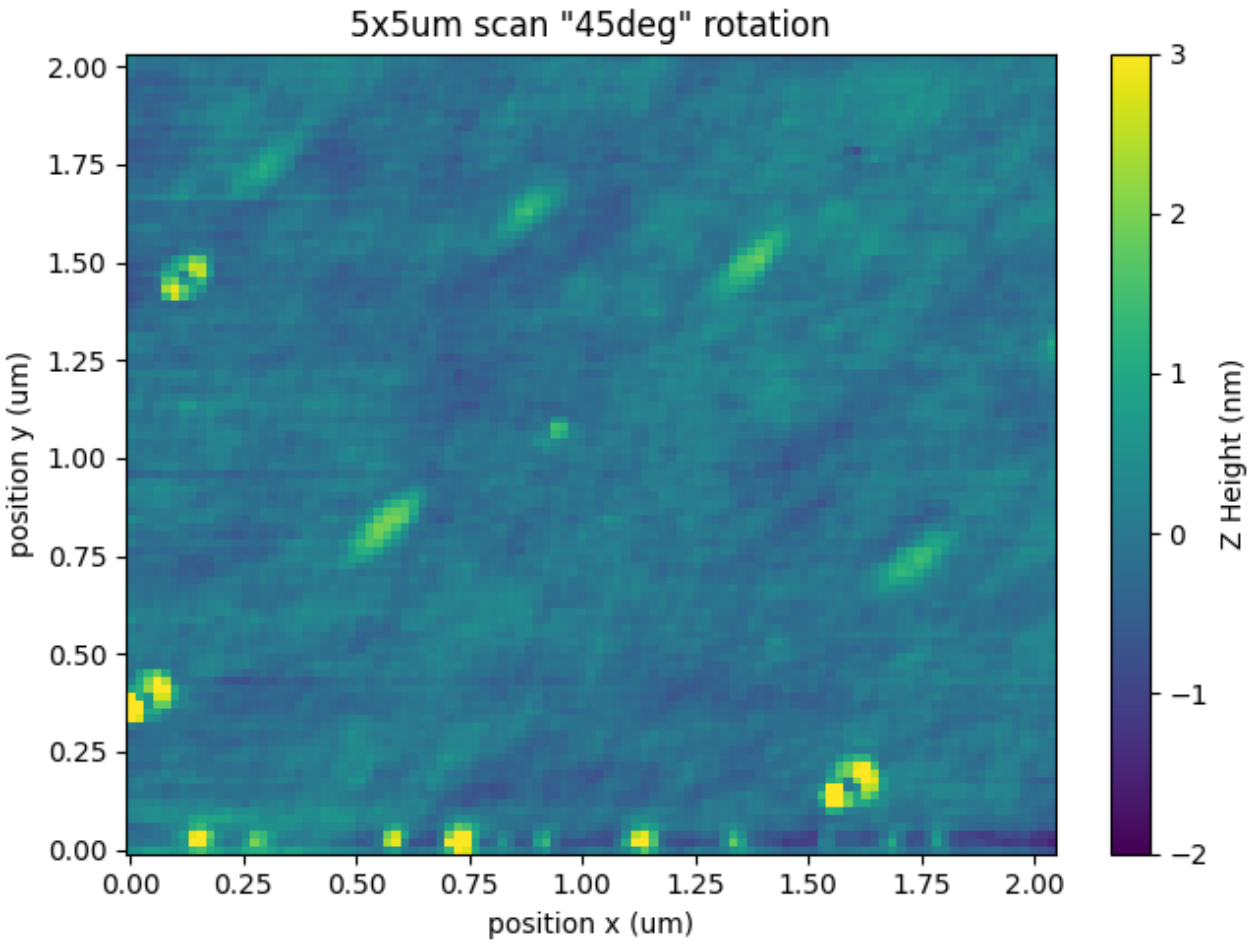
Steps required for quantum dot localization:

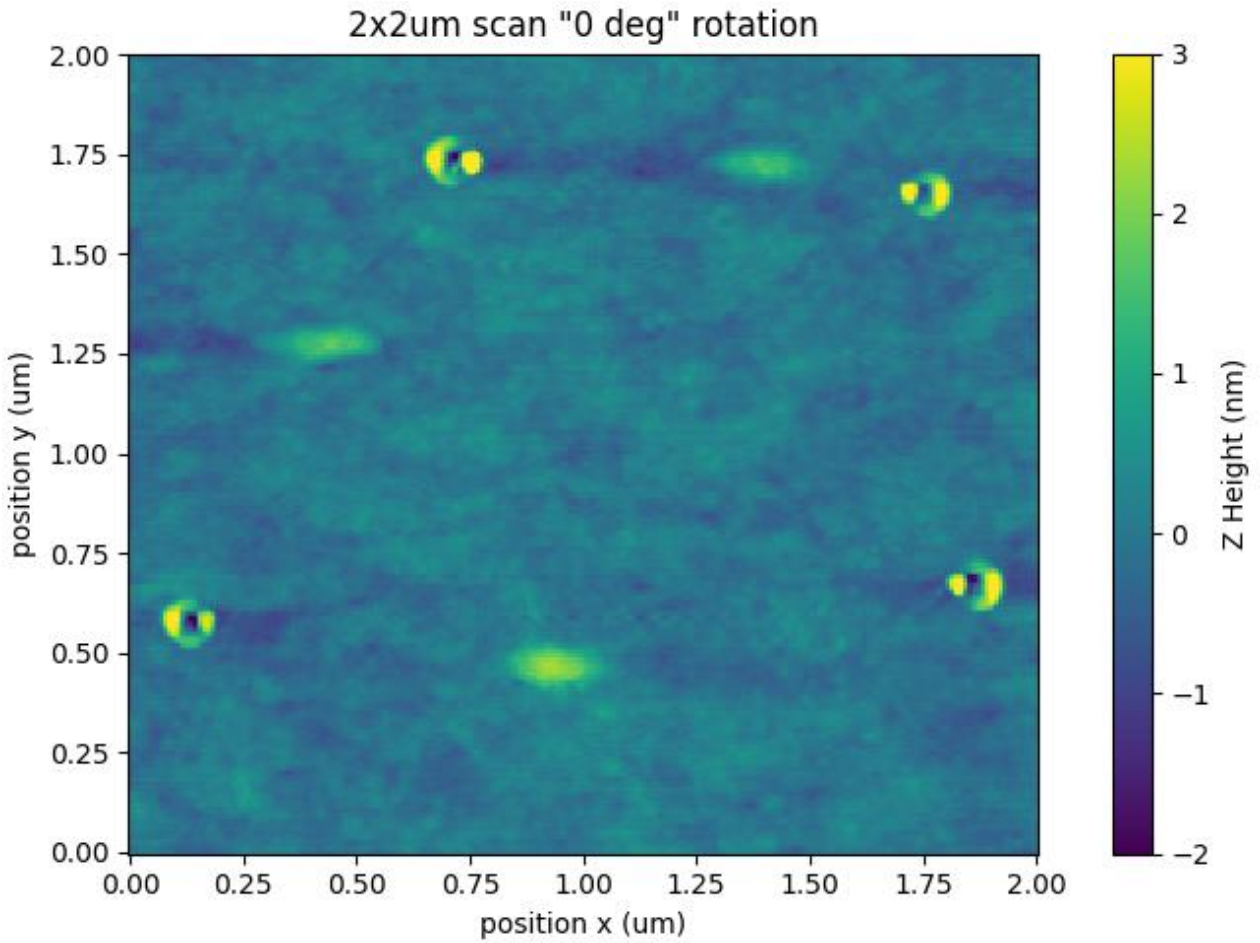
- Spin coating
- Photolithography
- Metal Deposition
- Atomic Force Microscopy (AFM)
- Cryogenic Fluorescent Microscopy





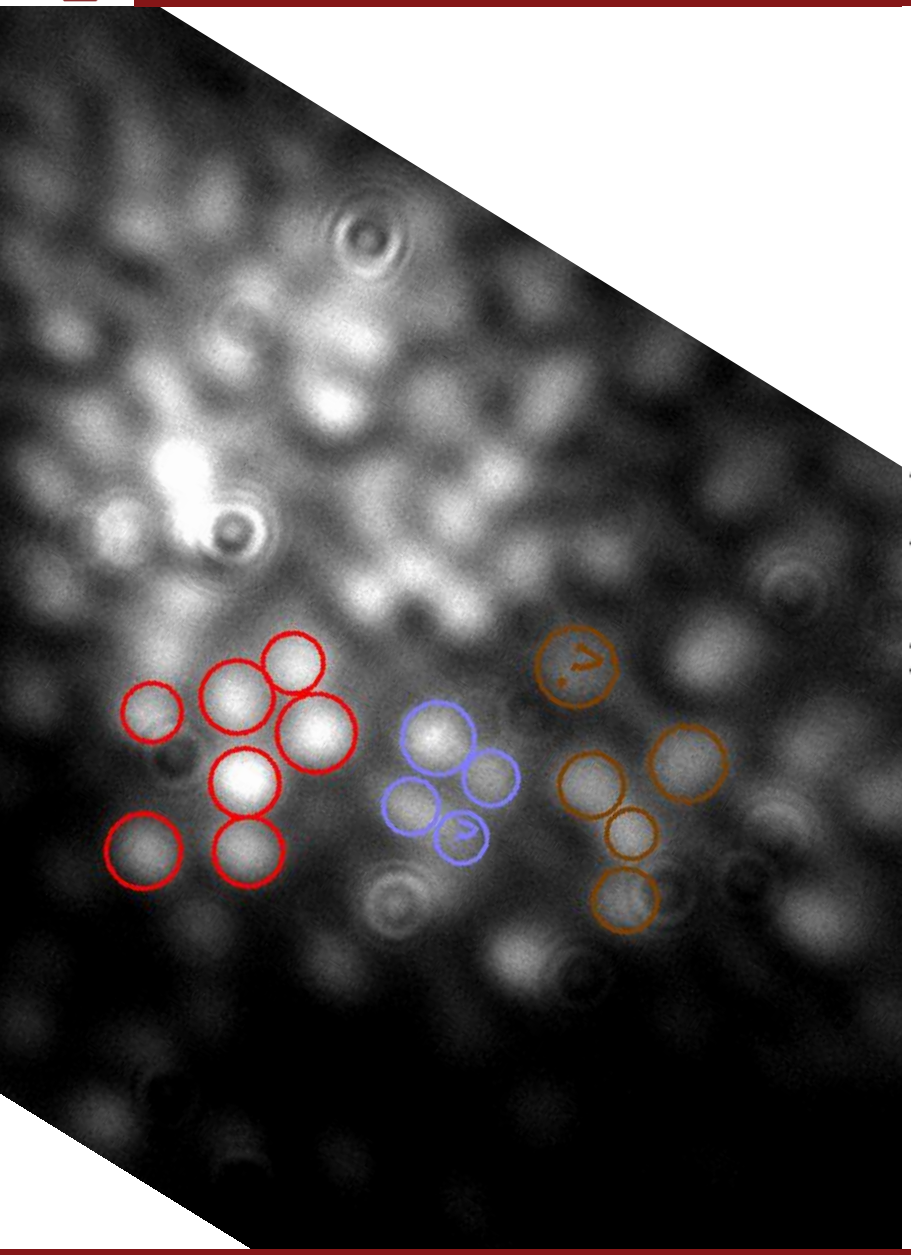
AFM Early Results and Feature Orientation

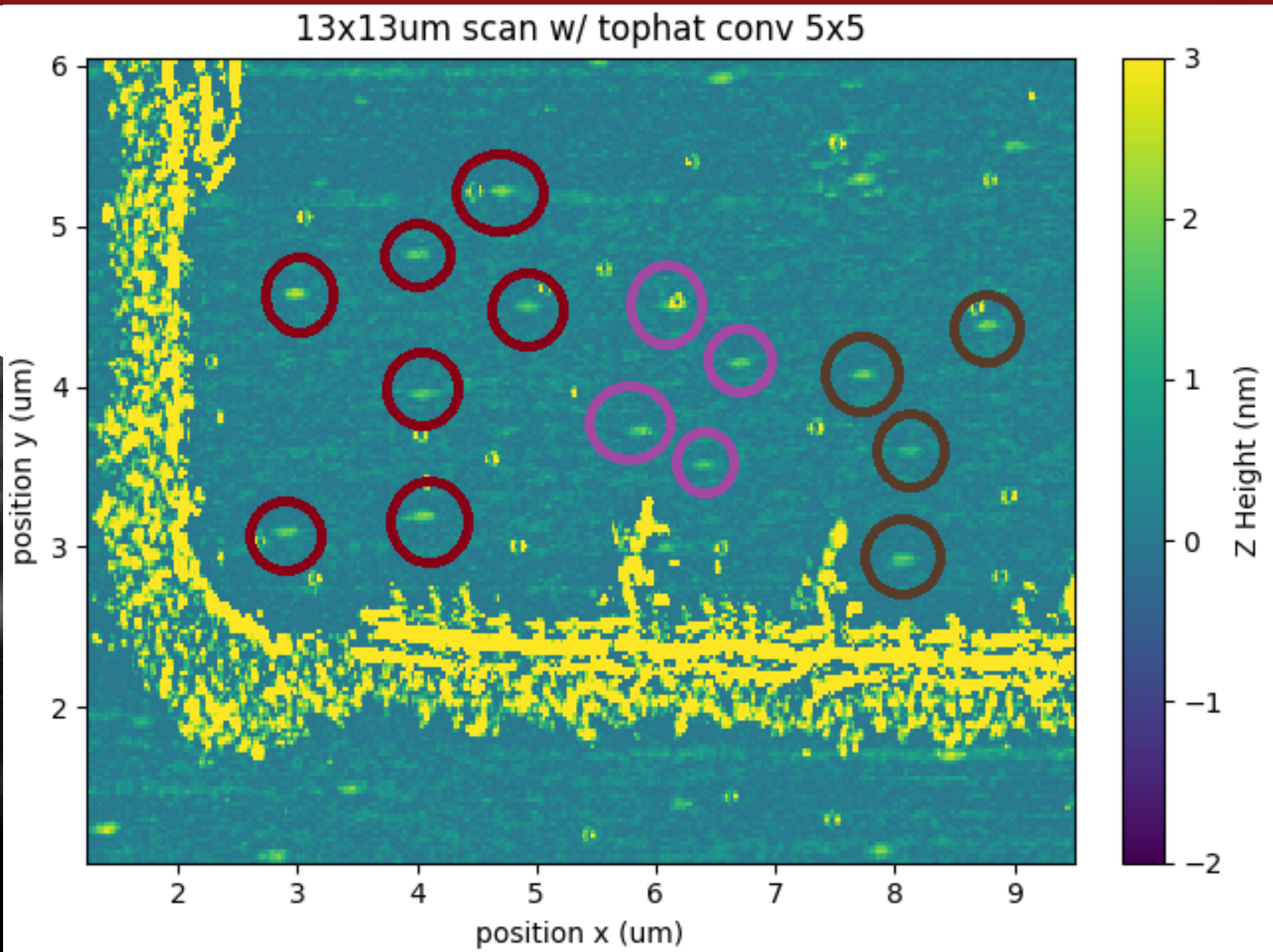




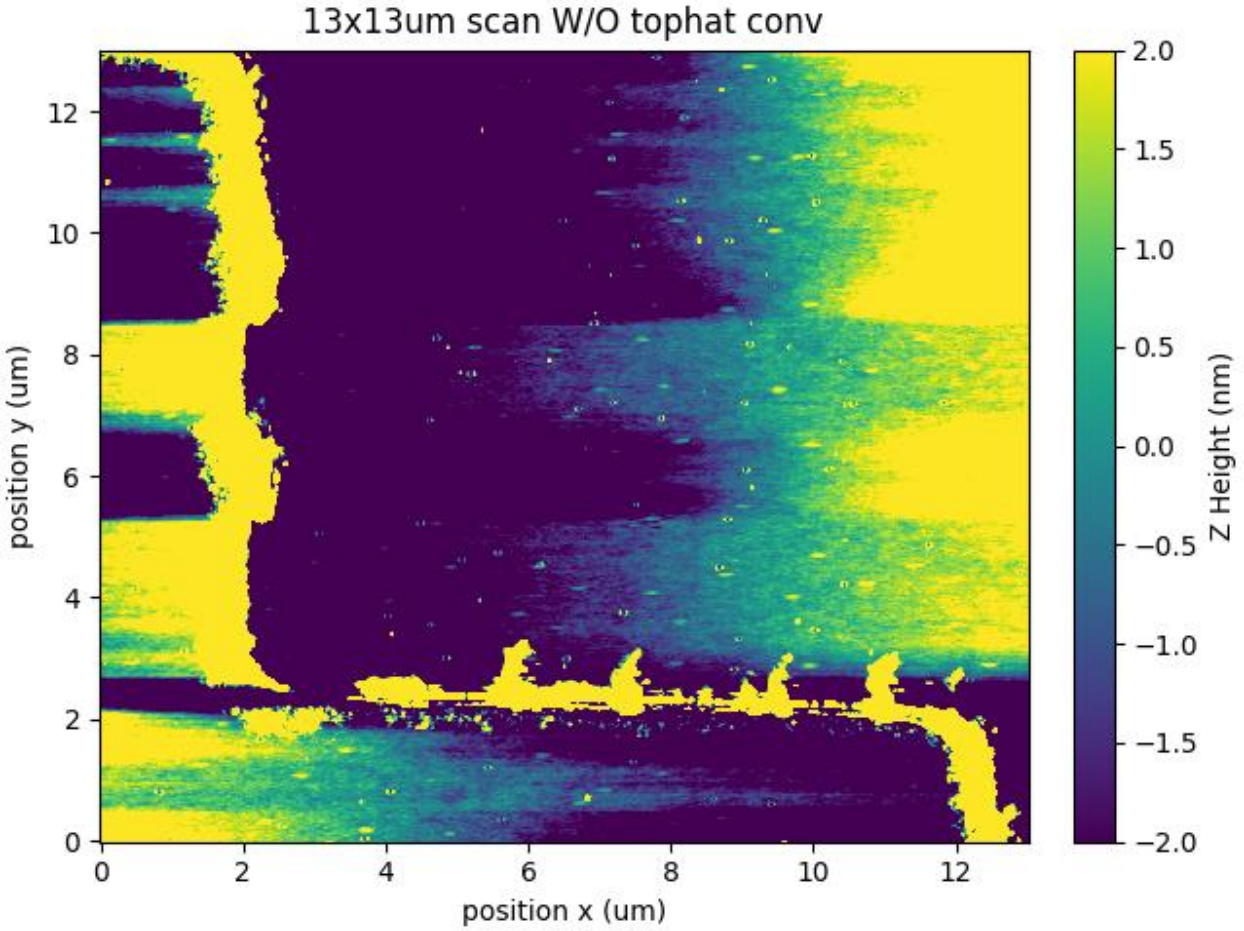
Bumps corresponding to embedded quantum dots are “stretched” in a direction

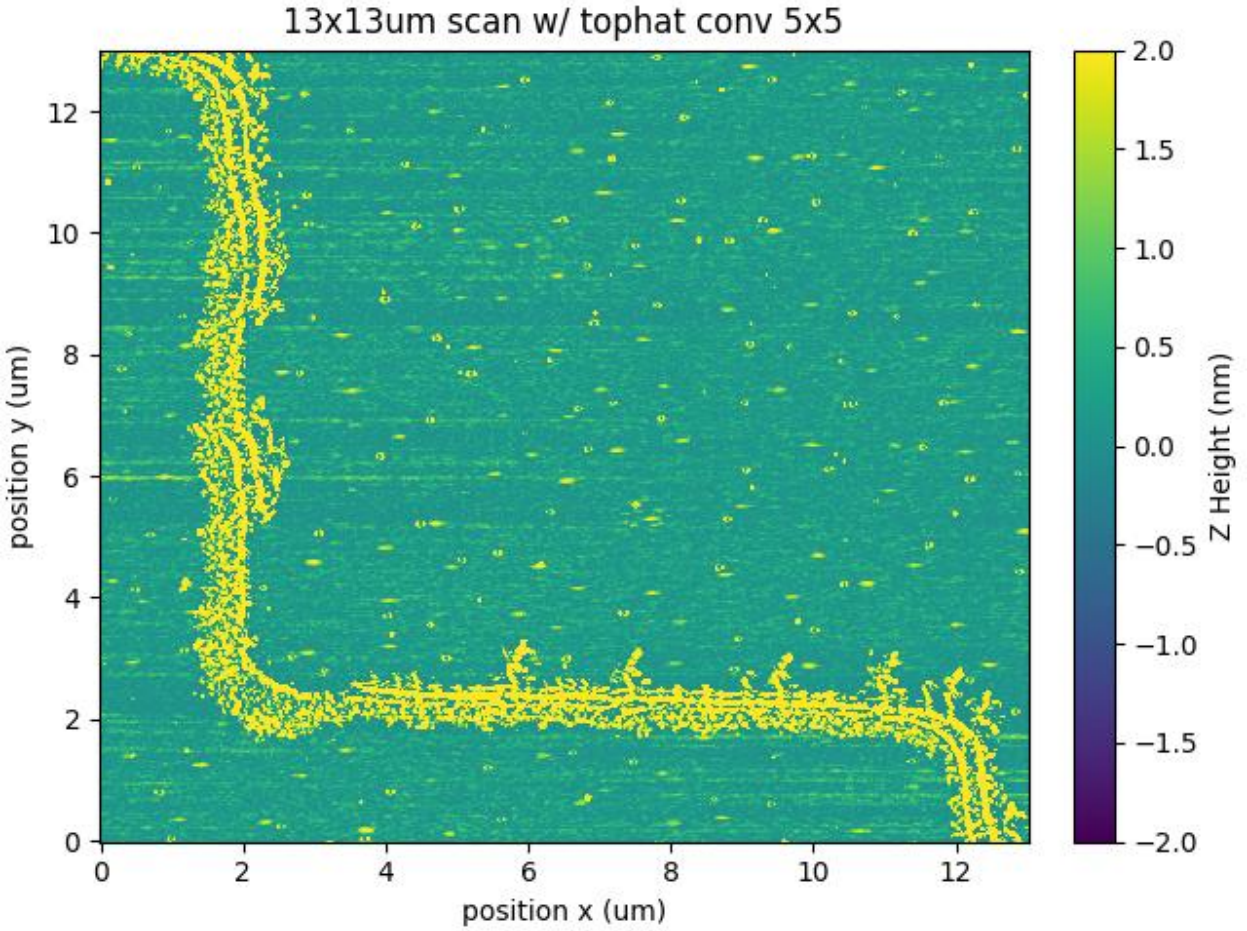
QD AFM vs Fluorescent Microscopy Image





AFM – Image Processing



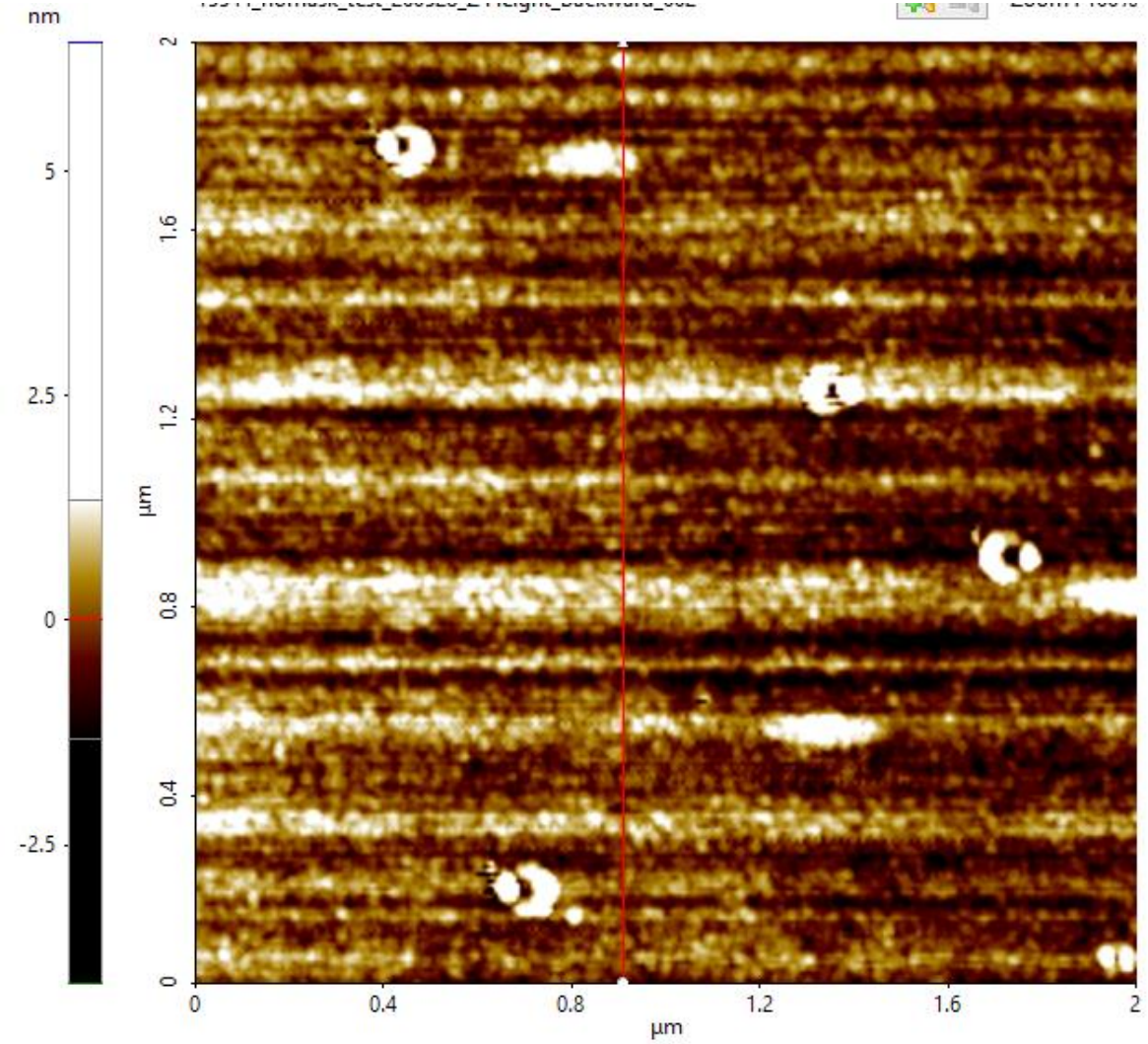


Large structures with “drastic” changes in height => aberrations in afm scan

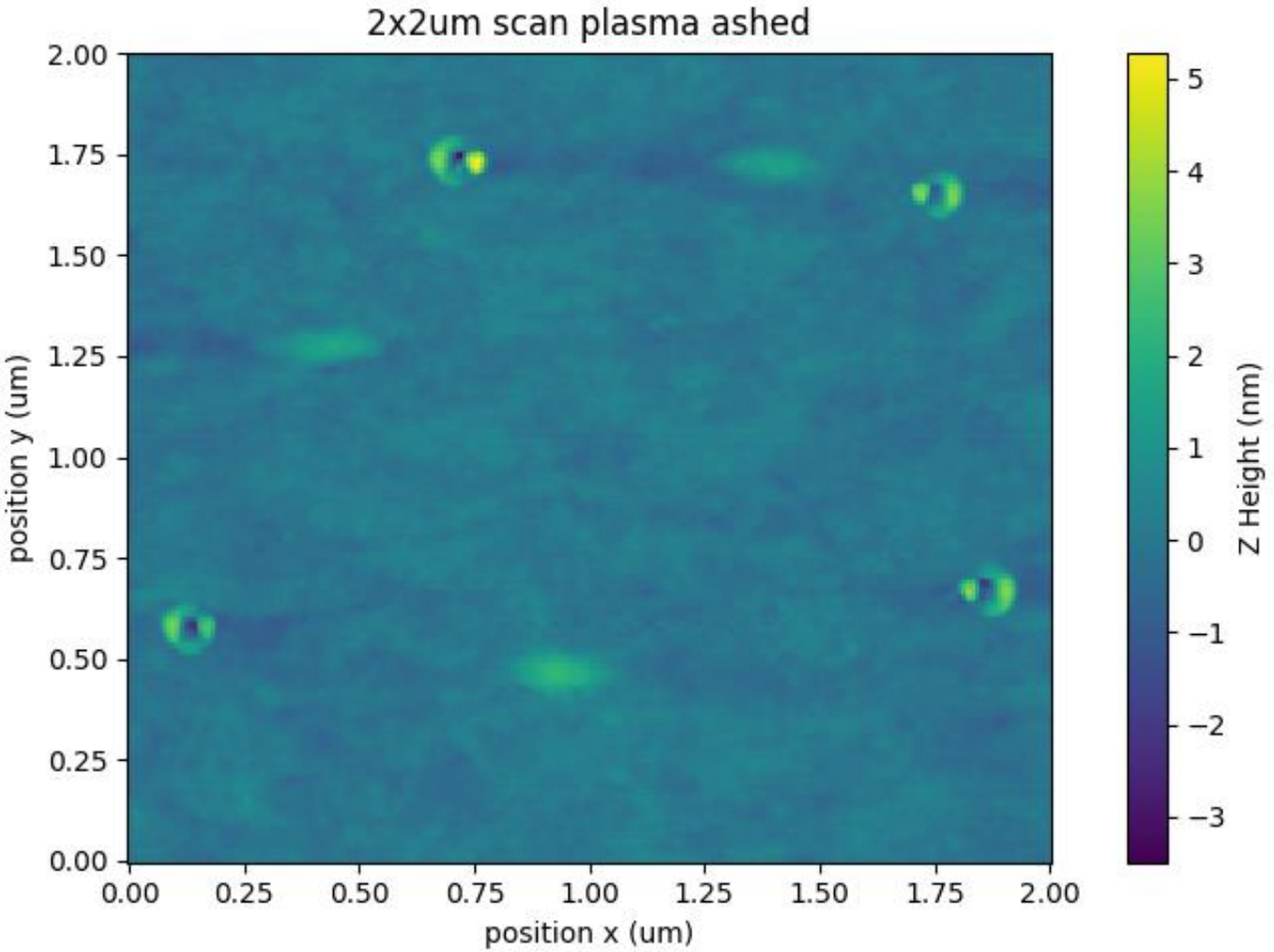
Still some “tearing”/aberrations post-tophat convolution

Aside: Post-Liftoff Cleaning

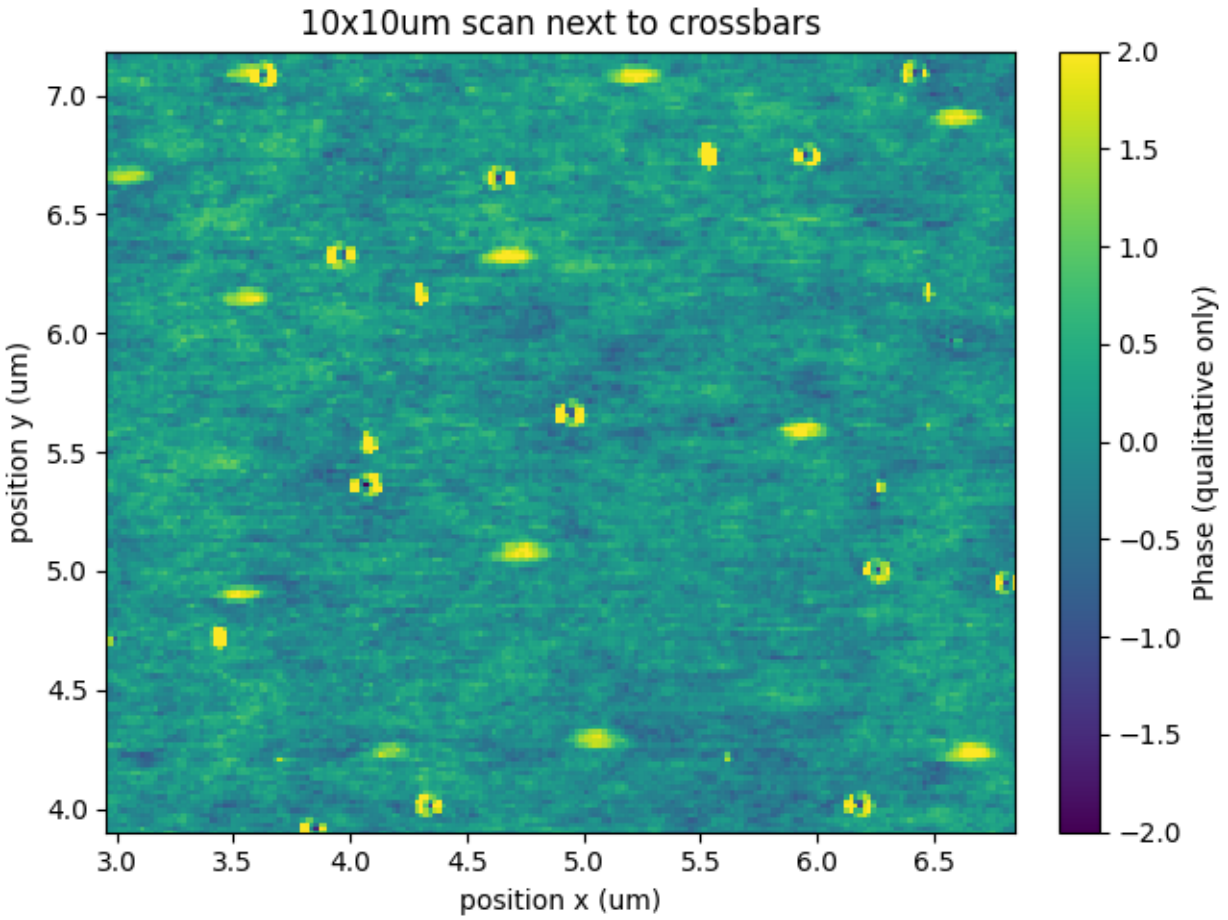
Photoresist cleaned via acetone only

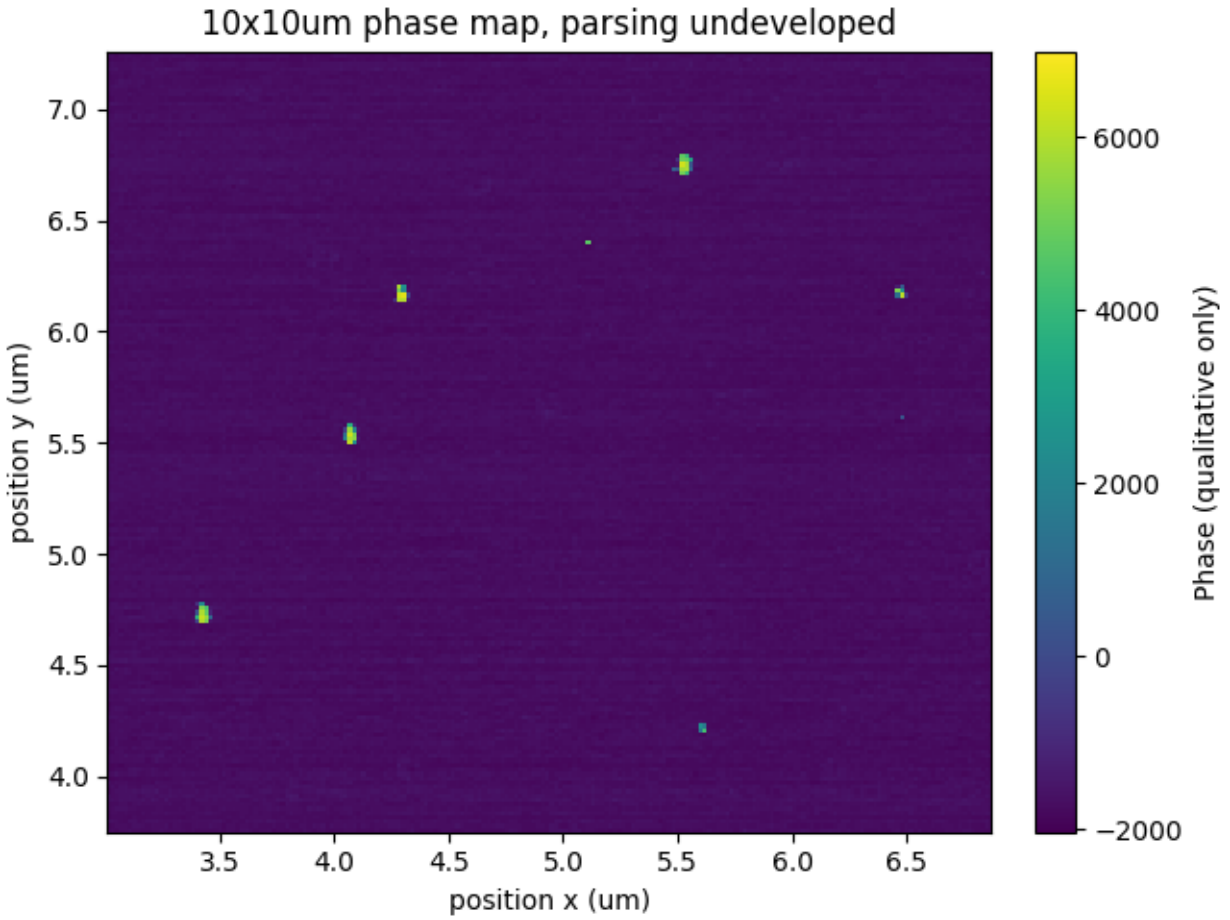


Photoresist cleaned via acetone then plasma ashed 10min



Future Work (1/2)





Future Work (2/2)

Implement computer vision to gather position of quantum dots relative to reference grating
- i.e. OpenCV

Finish building a ex-situ parser for Park Systems' NX10 AFM

Can we place a QD within a structure?

Confusion matrix and benchmarking our analysis – how precise is our python model?

Can a ~10nm layer of chromium under ~400nm of E-Beam Resist be seen via SEM?

How accurate is AFM vs. optical microscopy methods
- Purcell factor of some set of structures

Conclusion

Quantum dots have applications in photonics, but developing reliable localization methods is critical

Quantum dots' positions correlate to a fluorescent microscope image and bumps seen in AFM

Reference structures provide a way to relate these bumps to something (hopefully) visible

Thank You!

Dr. Alisa Javadi

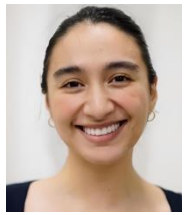
Dr. Pralay Paul
Postdoc

Dr. Nazli Rasouli
Postdoc

Dr. Arne Ludwig

RUHR UNIVERSITÄT BOCHUM RUB

PhD Students:



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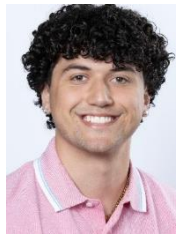
Sujoy Bhattacharjee

Kusal Abeywickrama

Undergraduate Researchers:



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QUANTUM PHOTONIC INTEGRATED DESIGN CENTER

Group Website:

References

[1] Liu, S., Li, X., Liu, H. *et al*. Super-resolved snapshot hyperspectral imaging of solid-state quantum emitters for high-throughput integrated quantum technologies. *Nat. Photon.* **18**, 967–974 (2024). https://doi.org/10.1038/s41566-024-01449-4

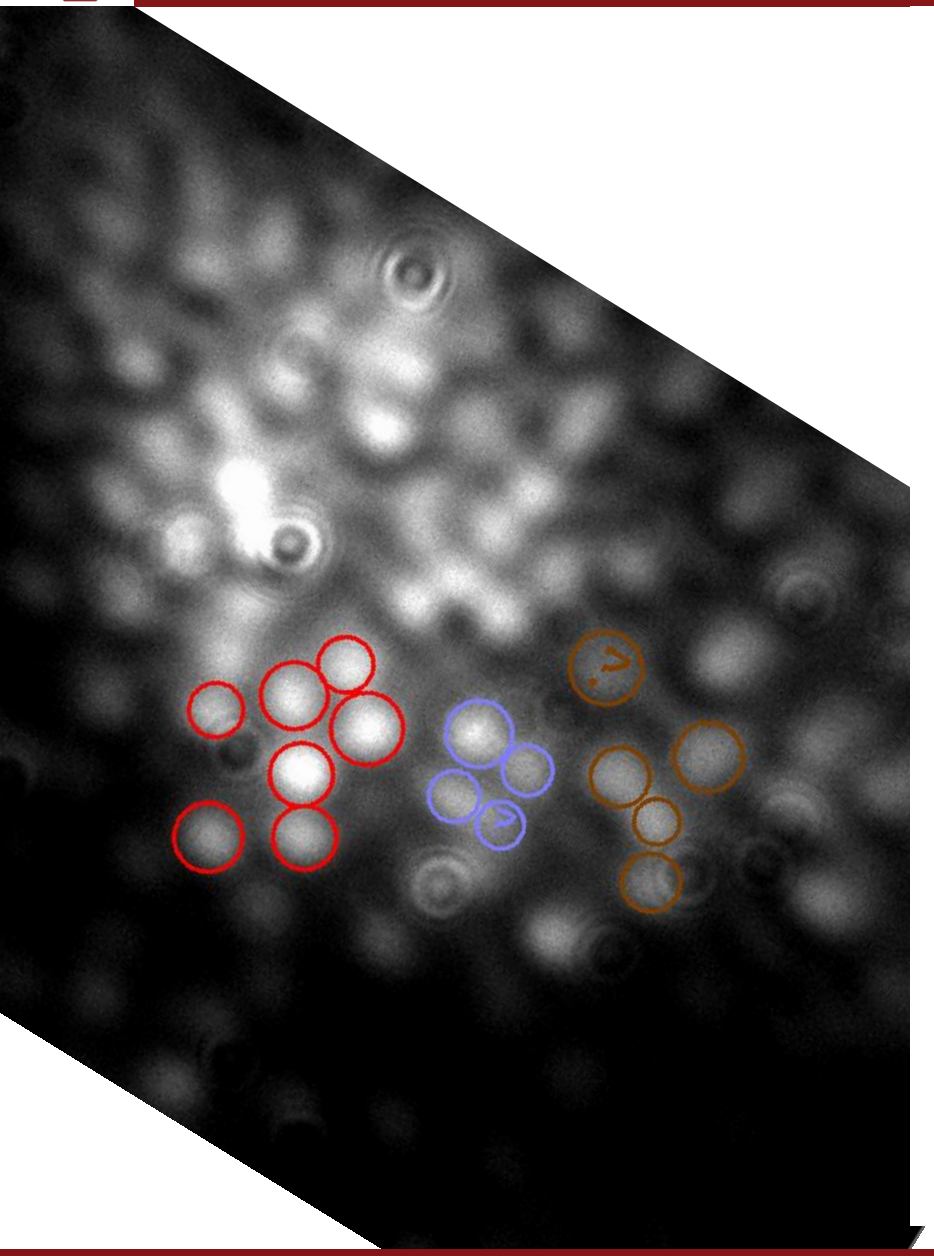
AFM Reverse Engineering

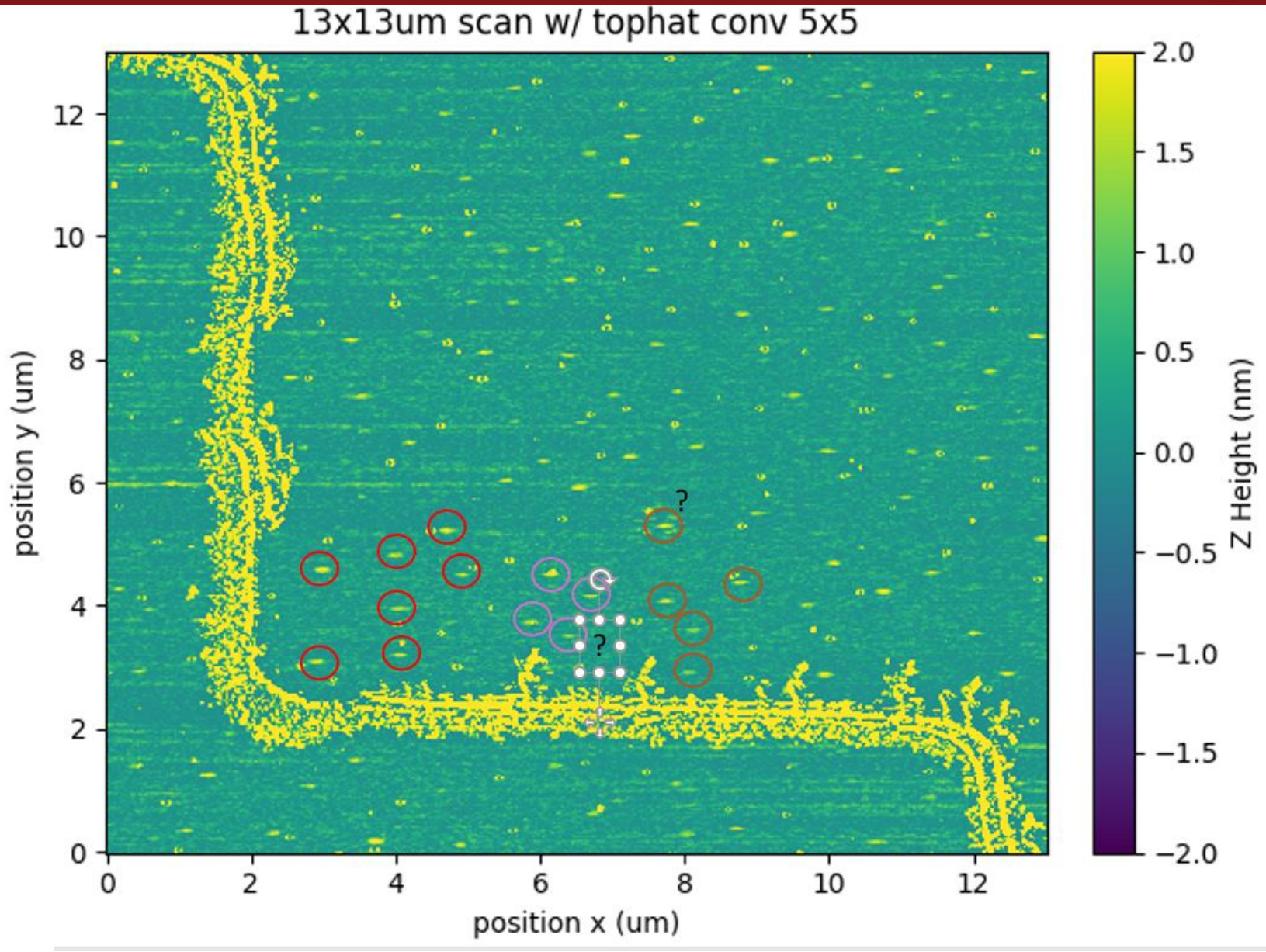
- Stage position (“coarse movement”)
- Stage position (Scanning stage?)
- Parsing (accurately):
  - NCM Phase
  - NCM Amplitude
  - Error
- Scanning parameters:
  - What type of scan (i.e. NCM Phase)
  - Scan size
  - Scan resolution (num pixels in x/y)
  - Scan rate (Hz, how fast we fast scan)
  - Z-Gain (?)
  - Set point (?)

Might not be possible outside of file naming or powerscript (stage pos registers as [0,0] in XEI)

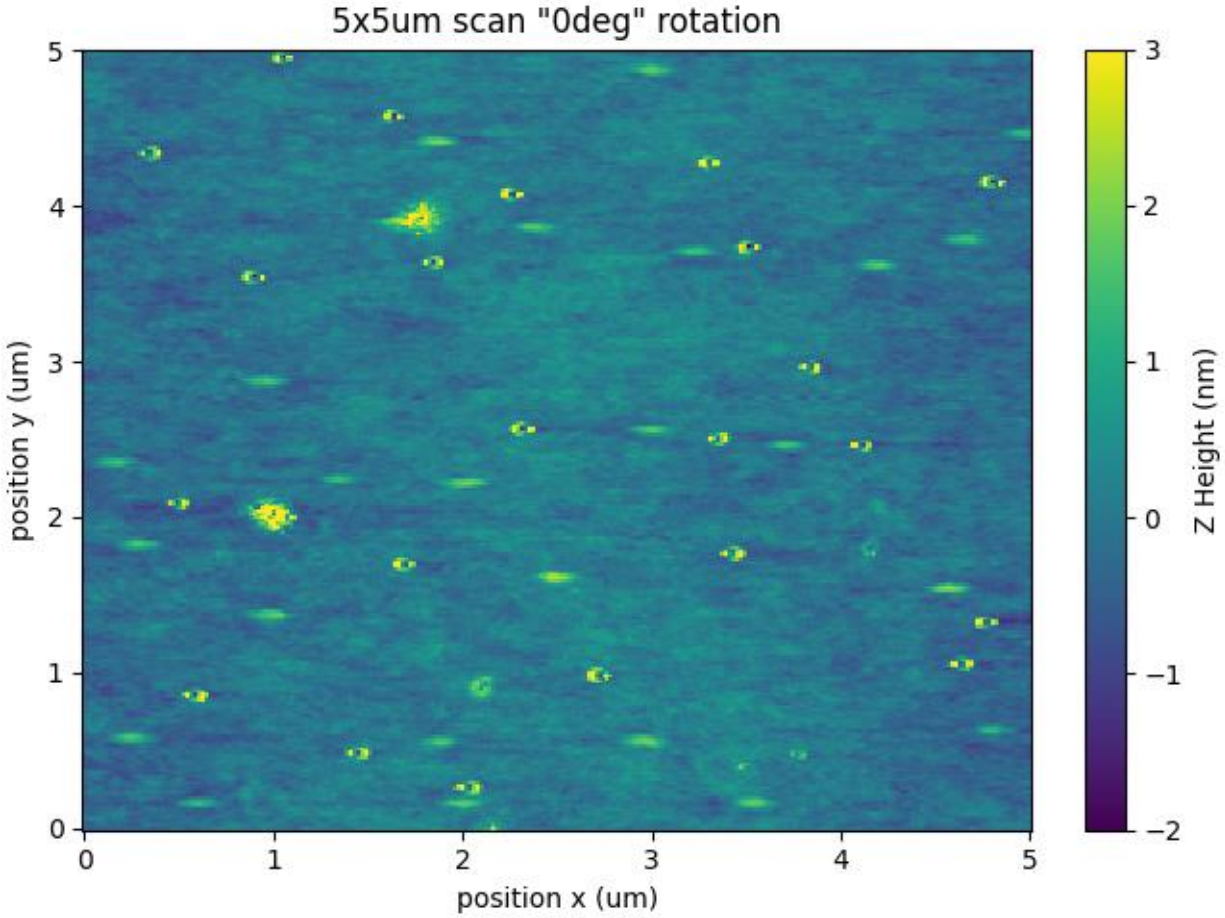
High priority
Medium priority
Funzies

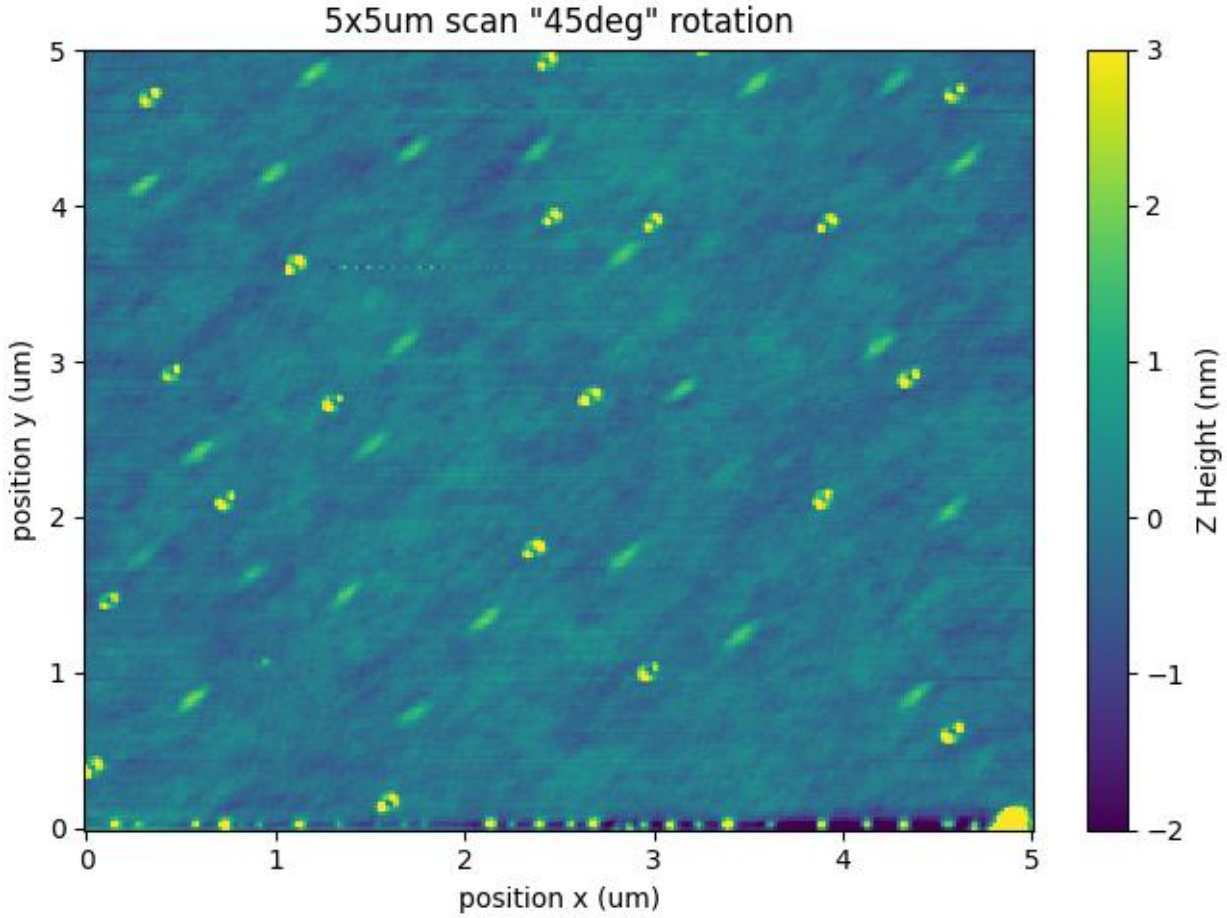
QD AFM vs Fluorescent Microscopy Image





Aside: Feature Orientation (5x5um scans)





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