Using MetroLER to Diagnose and Remove CD-SEM Metrology Artifacts

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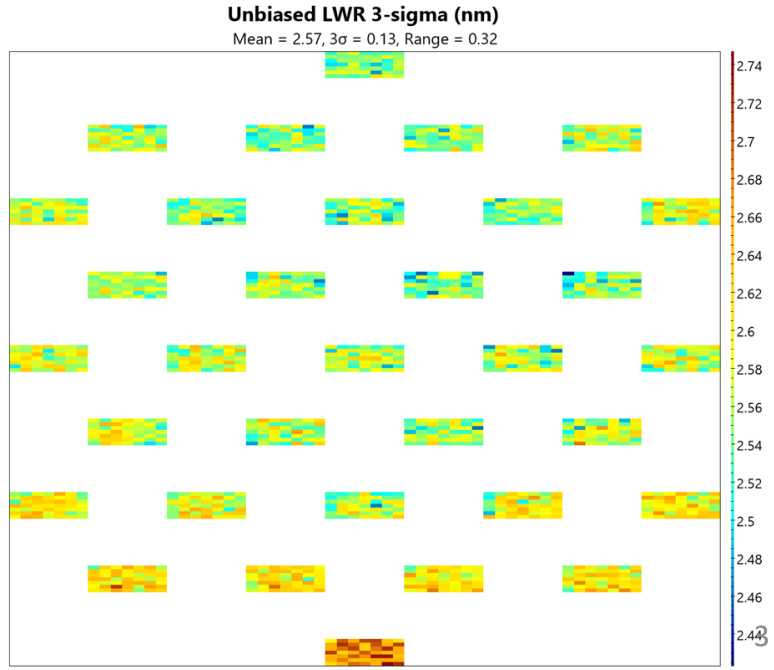
A funny thing happened on the way to a different study…

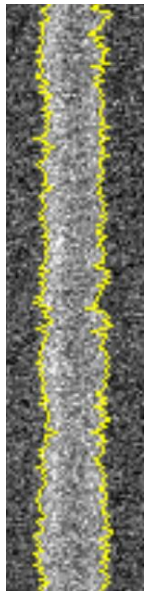
- While collecting high volumes of CD-SEM data for an across-wafer study, we noticed various artifacts in the data as analyzed by MetroLER
- Add-on Goals:
  - Investigate any discovered SEM tool artifacts
  - Mitigate them if possible

Data Collection (May 2019 – February 2020)

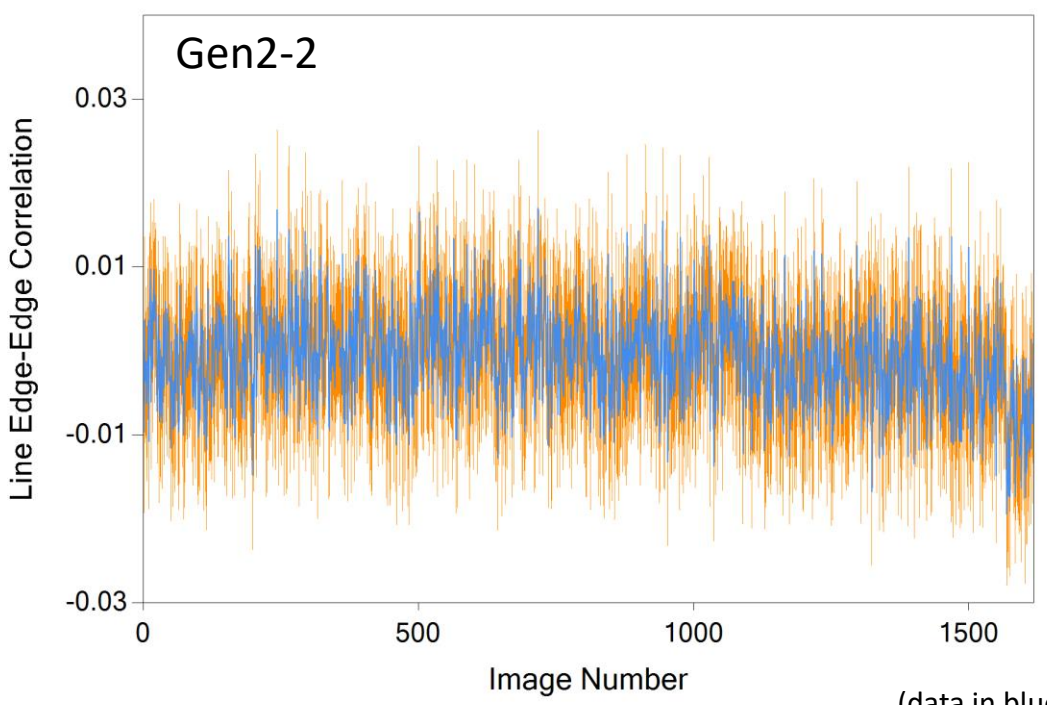
- Wafer processed at imec
  - ADI-wafer (uniform),
  - EUVJ3030 30nm, Organic underlayer
  - Structure V16P32
- Same wafer measured on six different CD-SEM metrology tools (three generations)
  - Gen1-1, Gen1-2, Gen2-1, Gen2-2, Gen3-1, Gen3-2
- Metrology Settings
  - 2048x2048 images, 0.8nm x 0.8nm pixel (Gen1 tools: 0.824nm x 0.824nm pixel)
  - 500V, 16 Frames, 32nm pitch resist features
  - 7x7 sampling per field, 33 fields per wafer
  - 1617 images per wafer per metrology tool
- All measurements made with MetroLER v2.1.2

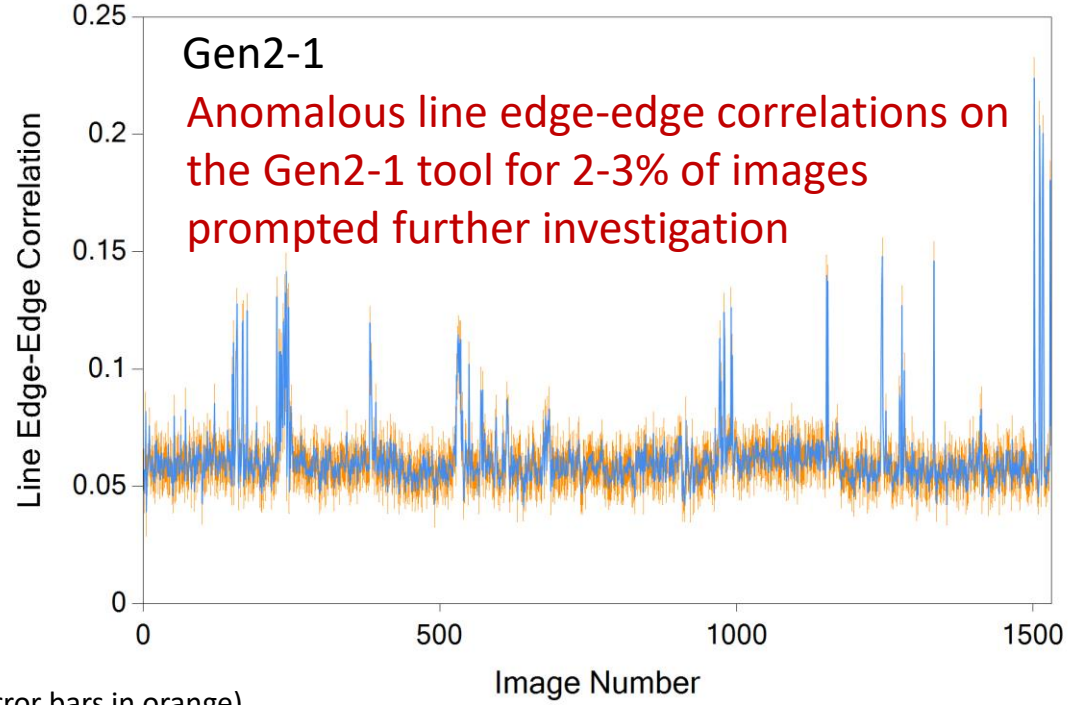


First Artifact – high left/right edge correlations



- While measuring roughness, MetroLER also measures the correlation between left and right edges
  - For litho single exposure, we expect the correlation to be about zero

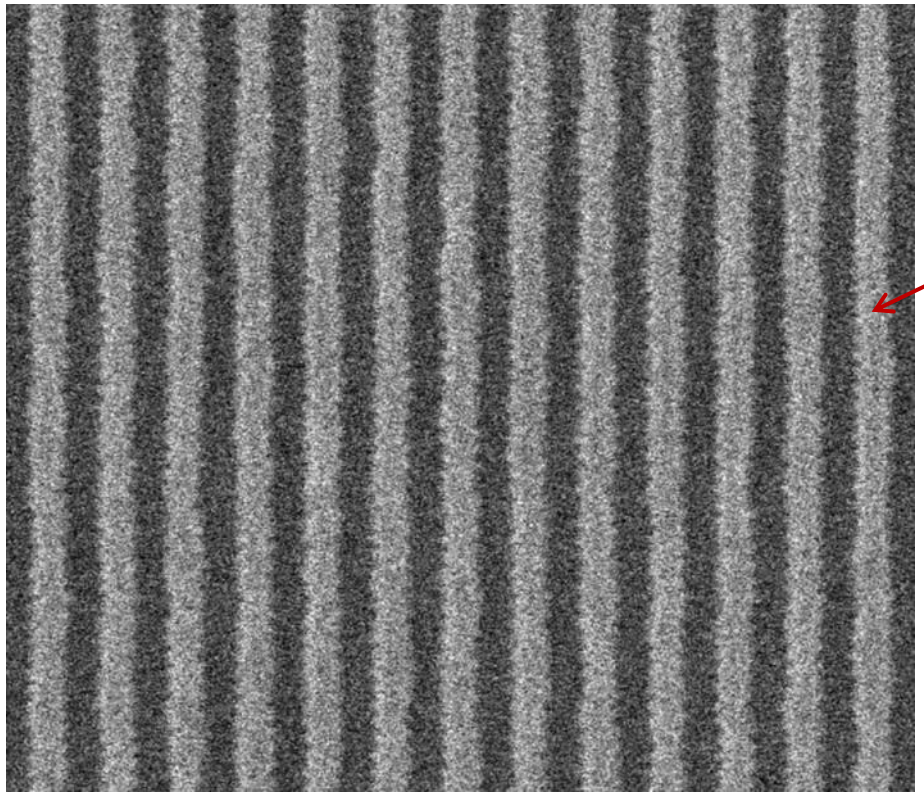




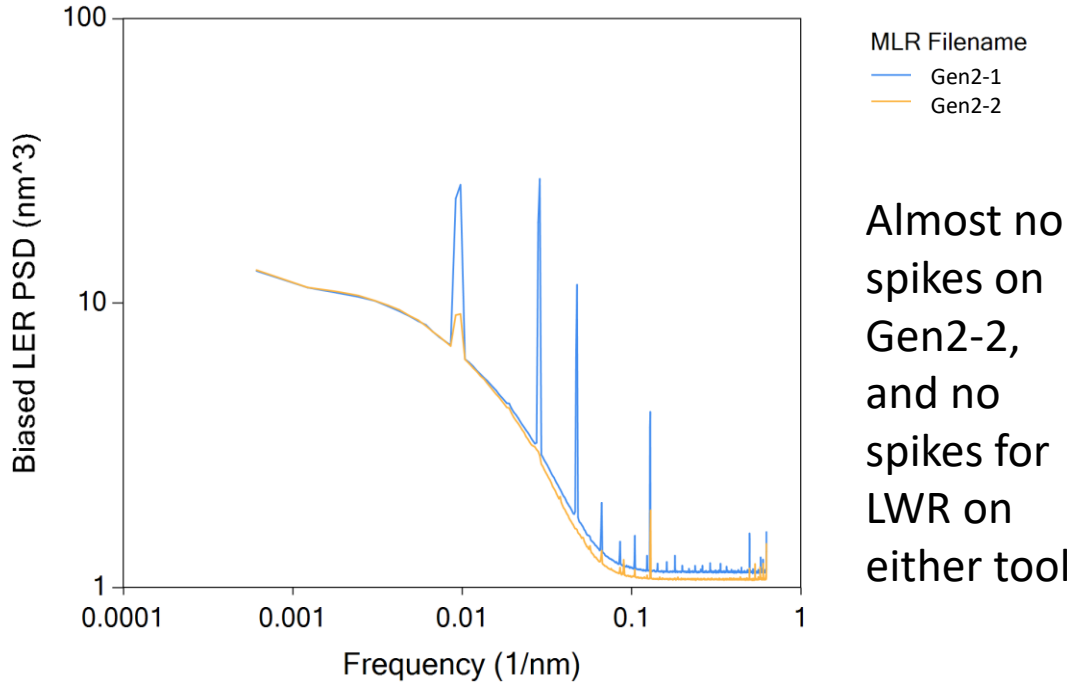
(data in blue, error bars in orange)

SEM Tool Problem: Gen2-1 only

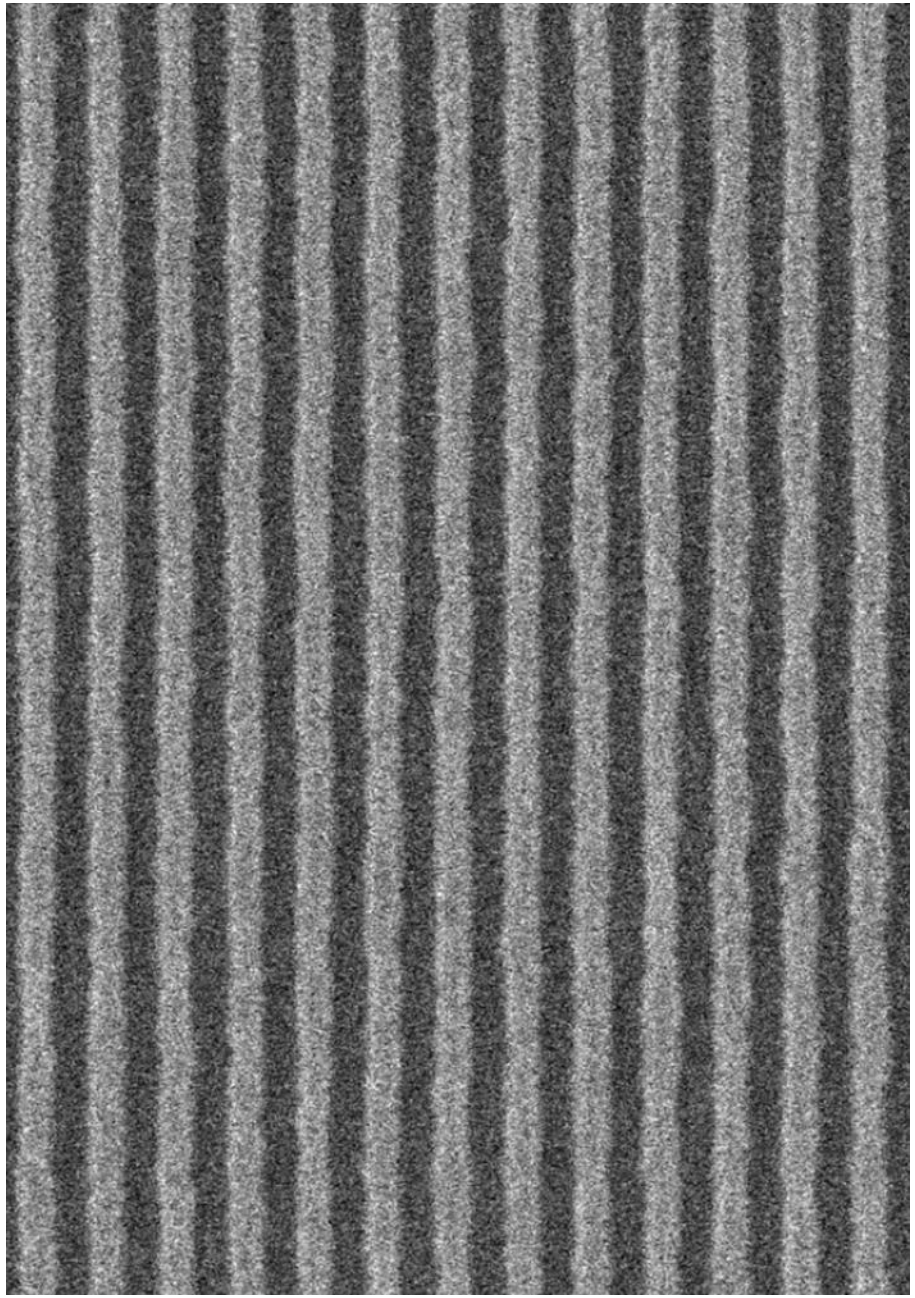
- About 2-3% of images exhibited artificial “zig-zag” edge effect



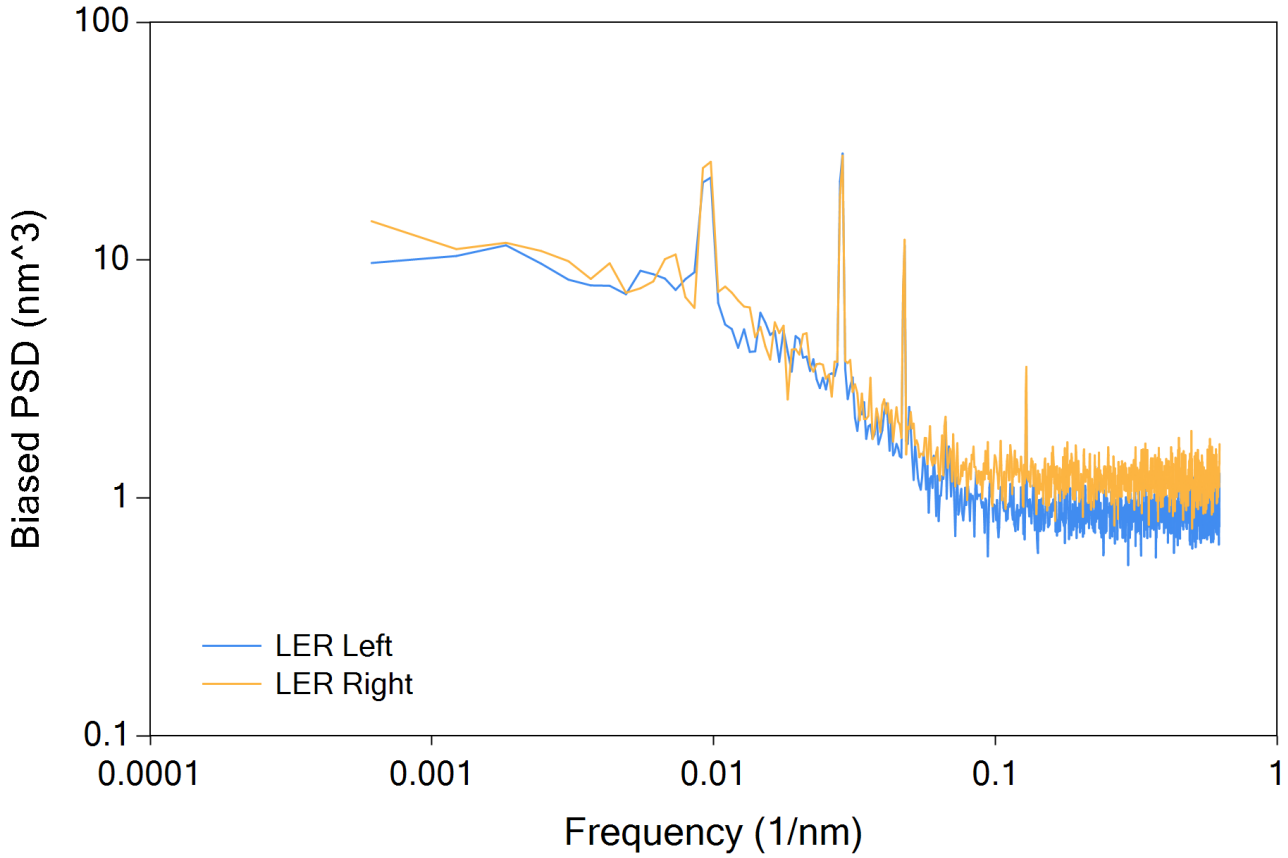
Artificial zig-zag of edge leads to large PSD spike and high line edge-edge correlation (up to 0.23)

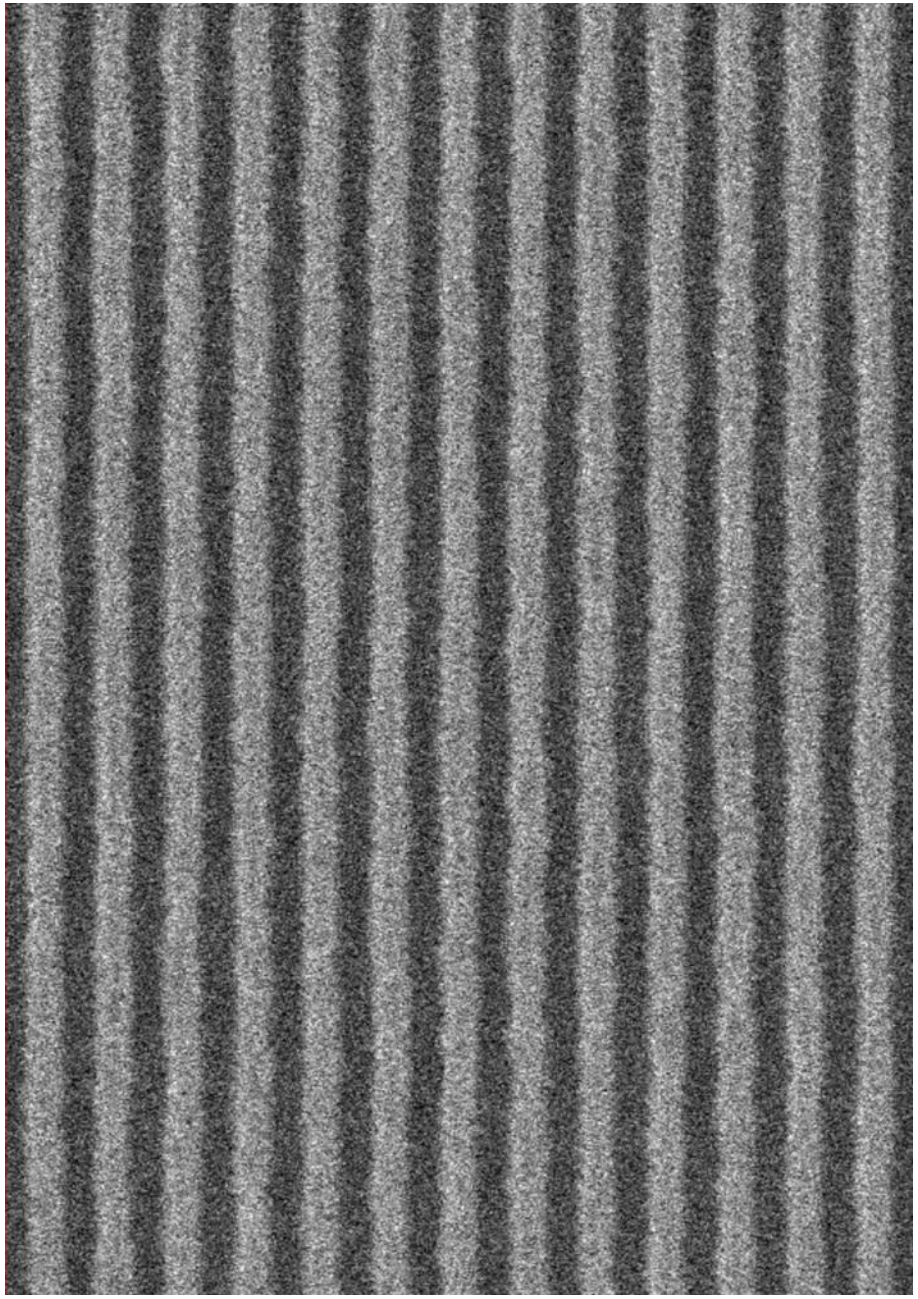


Almost no spikes on Gen2-2, and no spikes for LWR on either tool



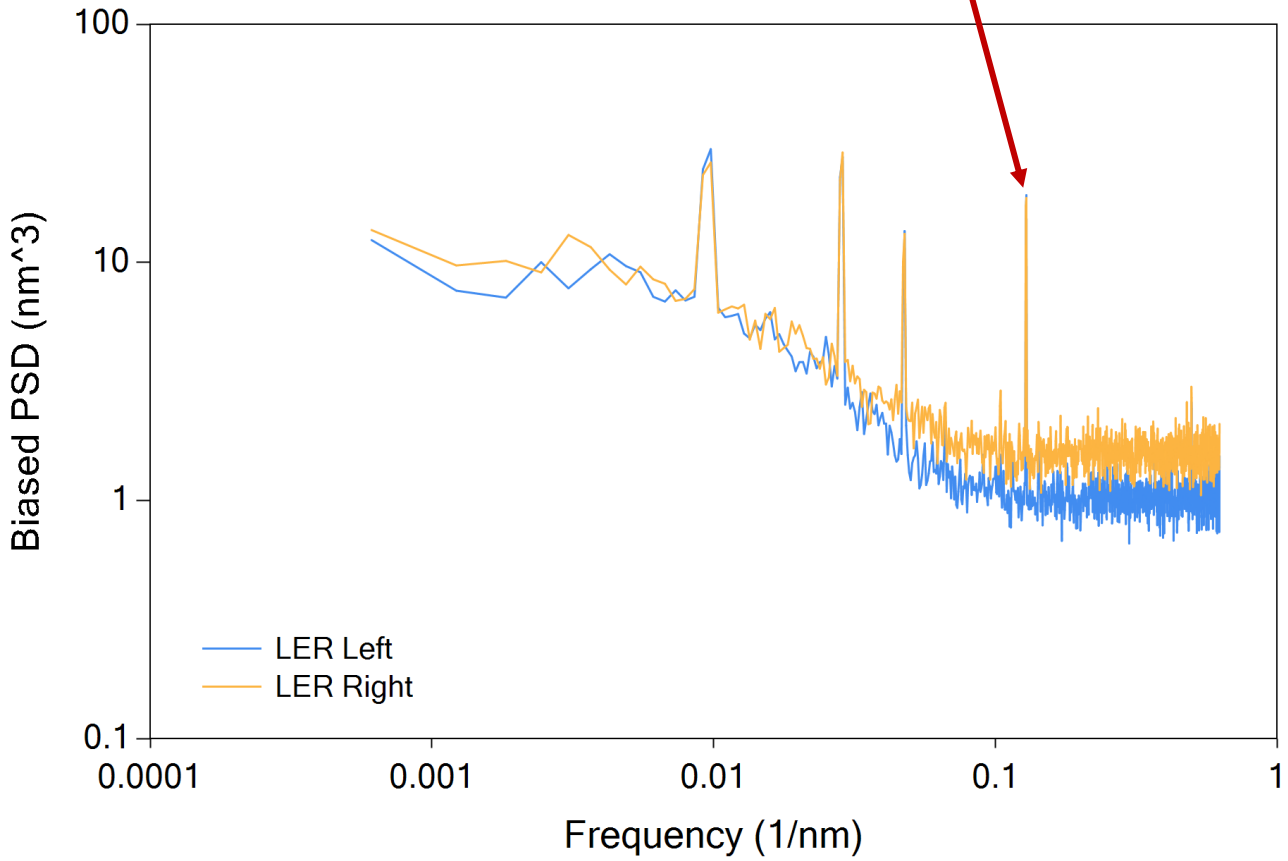
Typical Image in Batch
(line edge-edge correlation = 0.05)

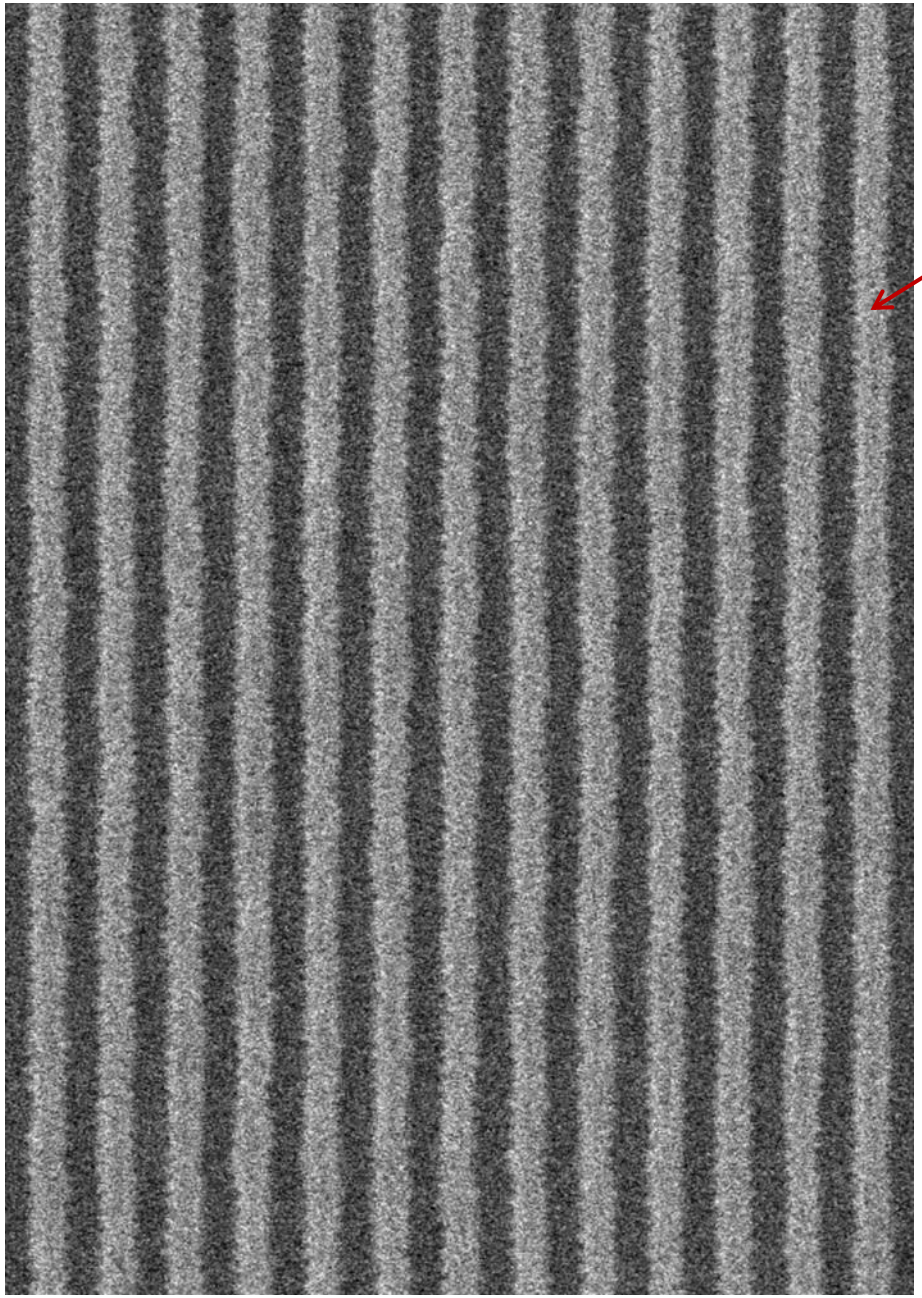




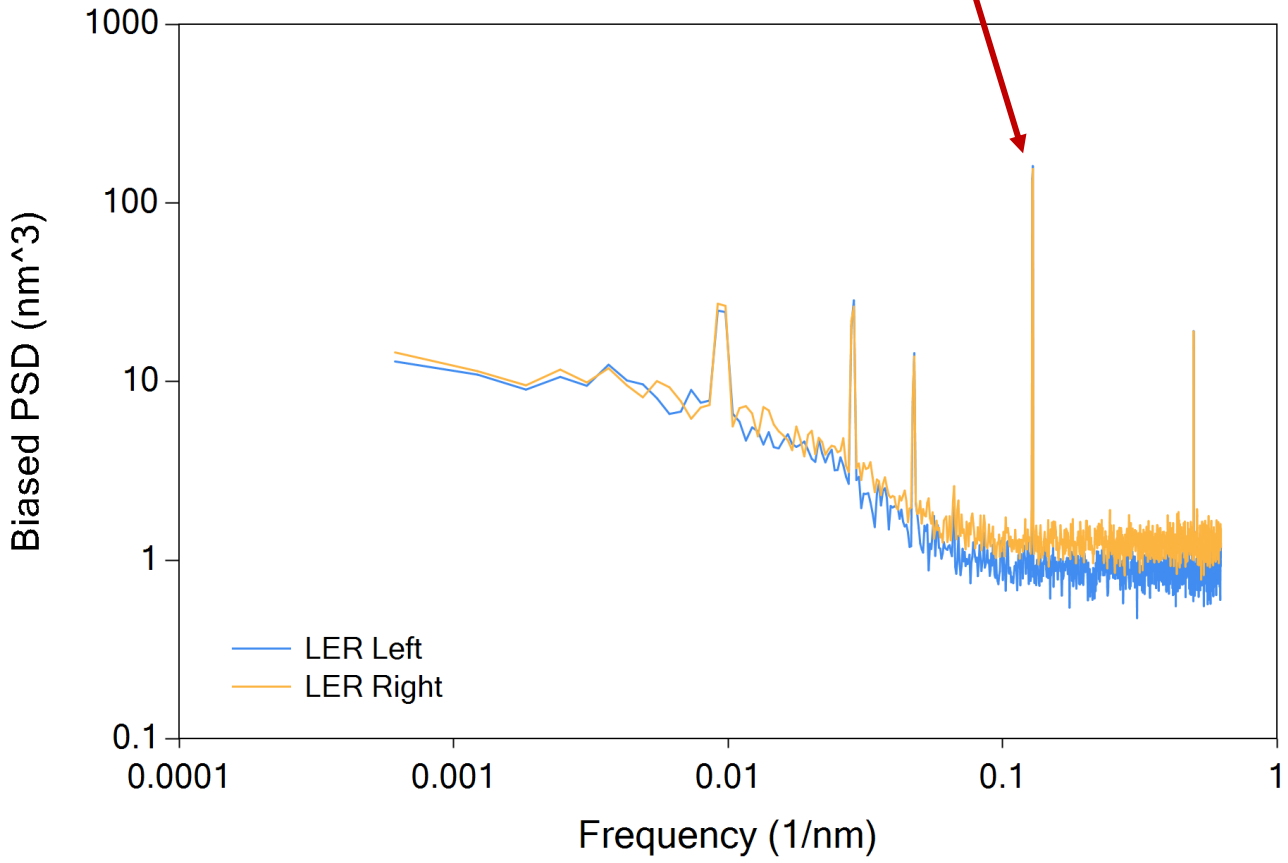
Different Image in Batch
(line edge-edge correlation = 0.08)

Small PSD spike beginning to grow larger



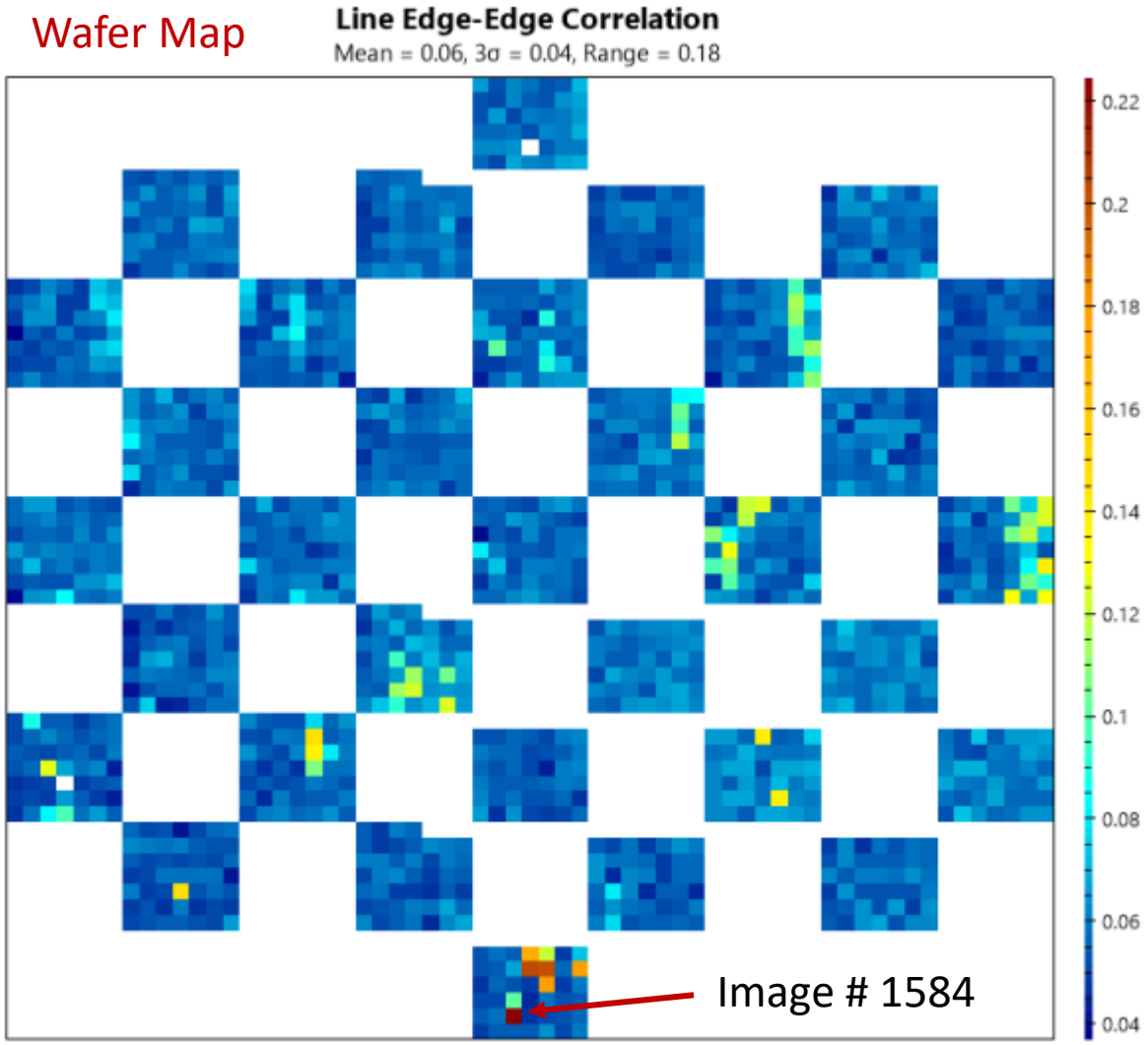


Artificial zig-zag of edge leads to large PSD spike
(period ≈ 8nm, line edge-edge correlation = 0.23)

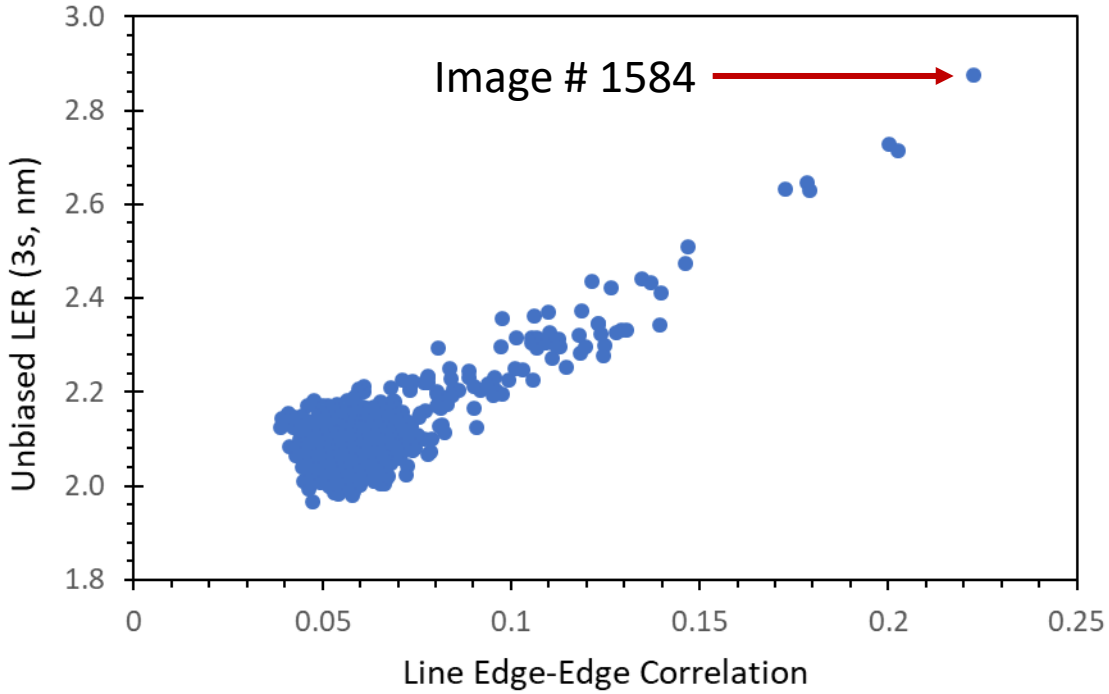


Consequences

Wafer Map



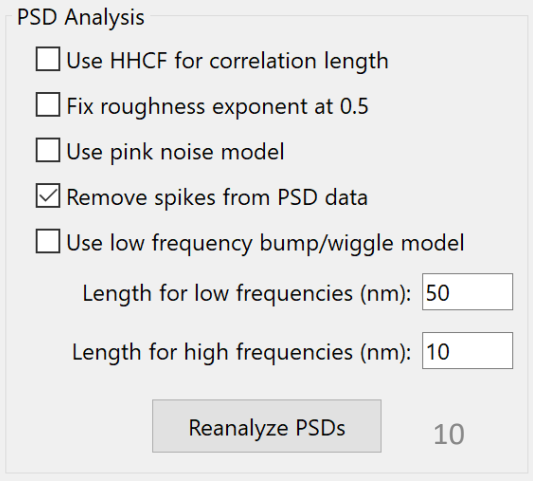
The artificial zig-zag causes an increase in unbiased LER, and correlates the left and right edges



Note: spike removal option is OFF here for unbiased LER calculation

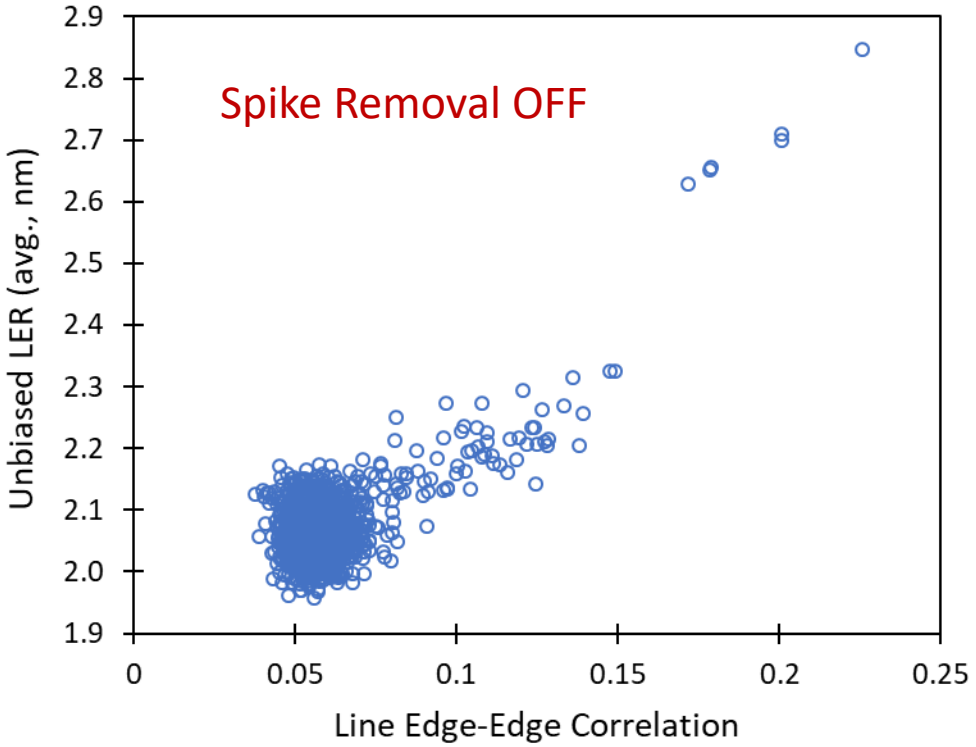
Consequences

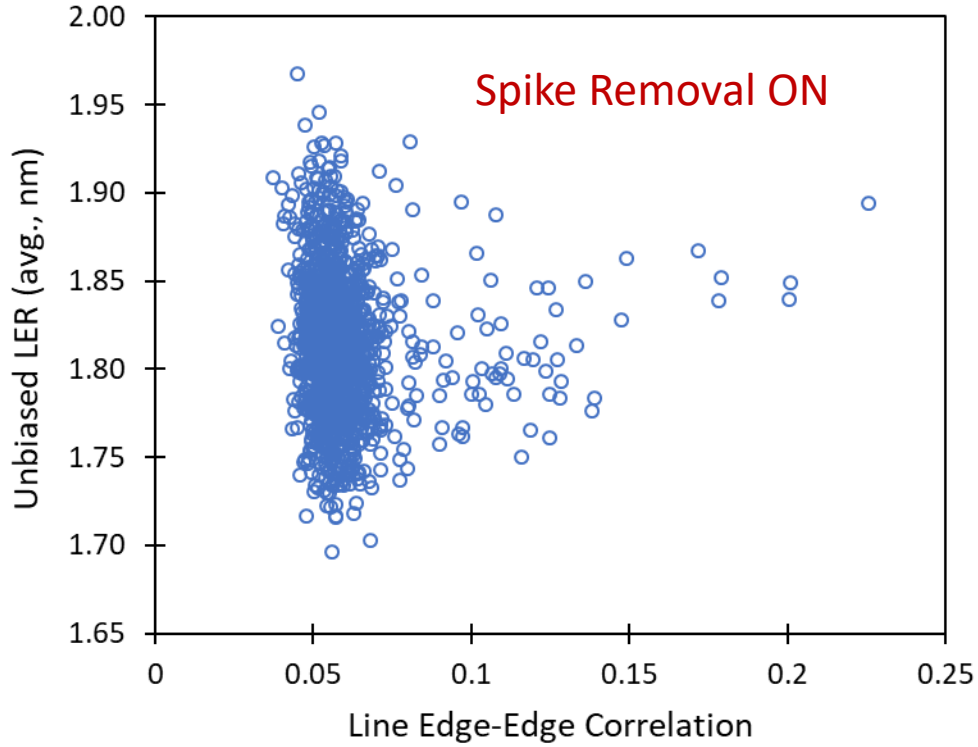
- It appears that 2-3% of the images from the Gen2-1 SEM have a “zig-zag” artifact that is SEM-related, not wafer-related
- These images have a large spike in the LER PSD, large edge-edge correlation (0.1 - 0.23 versus 0.05 for a typical image) and large unbiased LER (up to 1/3 higher)
- PSD spikes (very narrow, very tall) indicate artificial roughness components in the image (probably electronic noise here)
- If spike removal is not turned on, the spike will impact unbiased LER and PSD fitting
- Spike removal option can mitigate these effects



Spike removal is effective at erasing the consequences of this artificial zig-zag effect

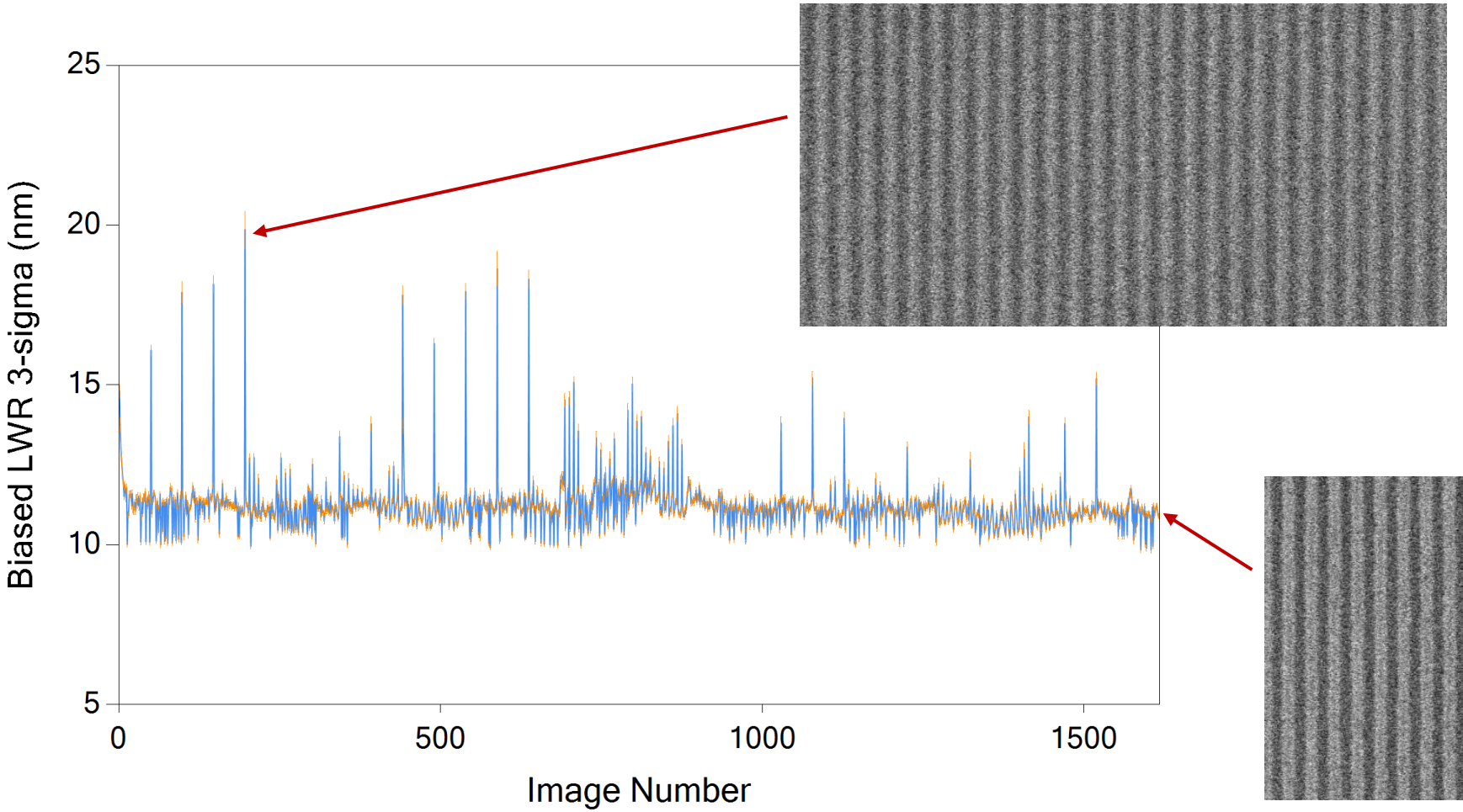
Images with zig-zag have high edge-edge correlation and biased PSD spikes

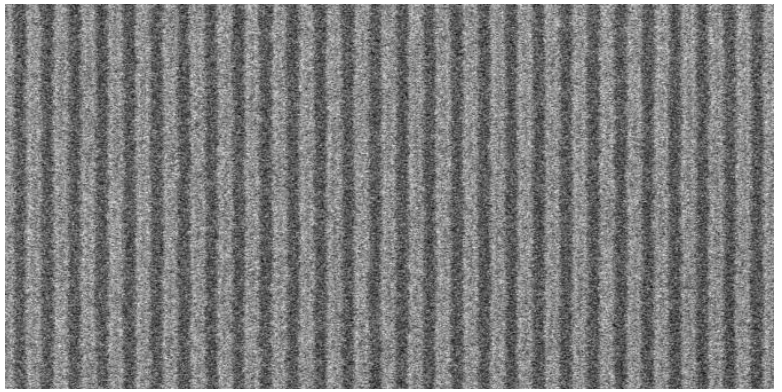




With spike removal turned on, the high unbiased LER caused by zig-zag is eliminated

Second Artifact: Focus issue on Gen1s



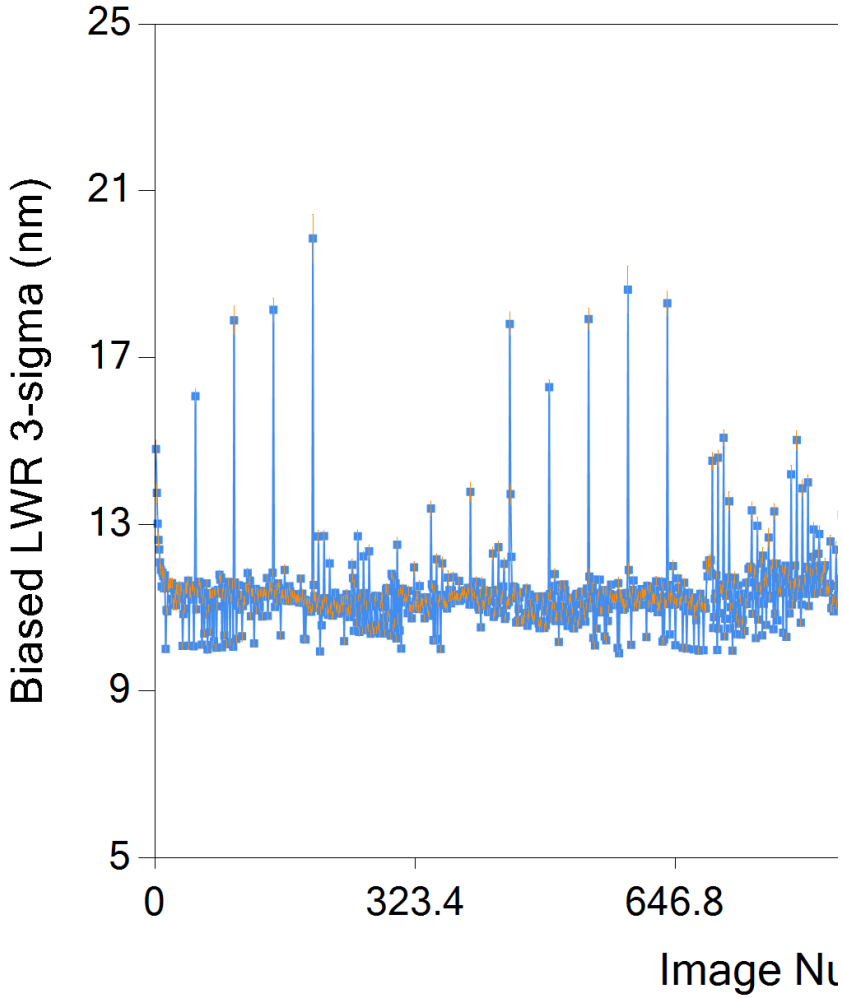


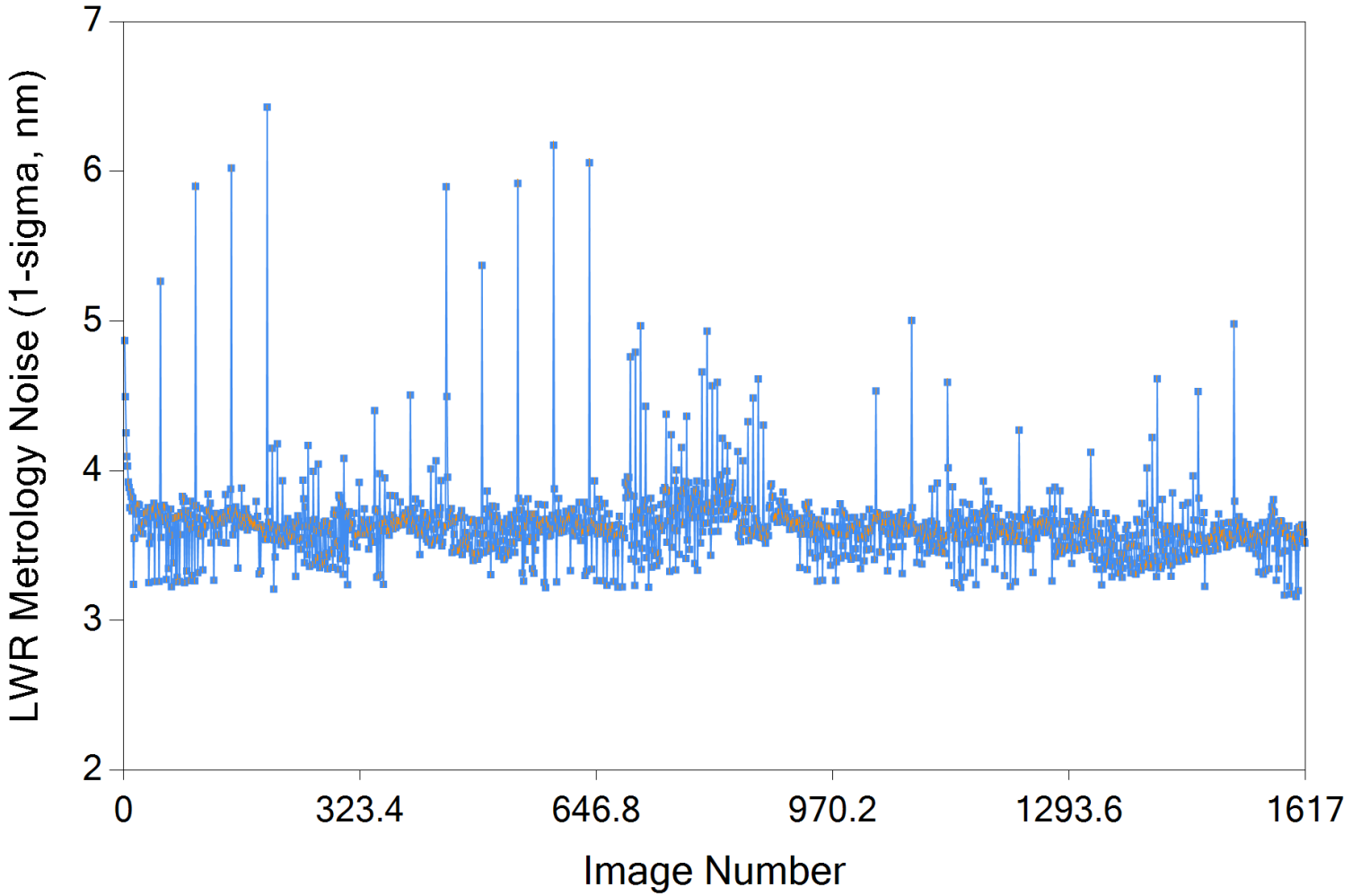
SEM autofocus failure

Gen1-1: 21 bad images
Gen1-2: 47 bad images

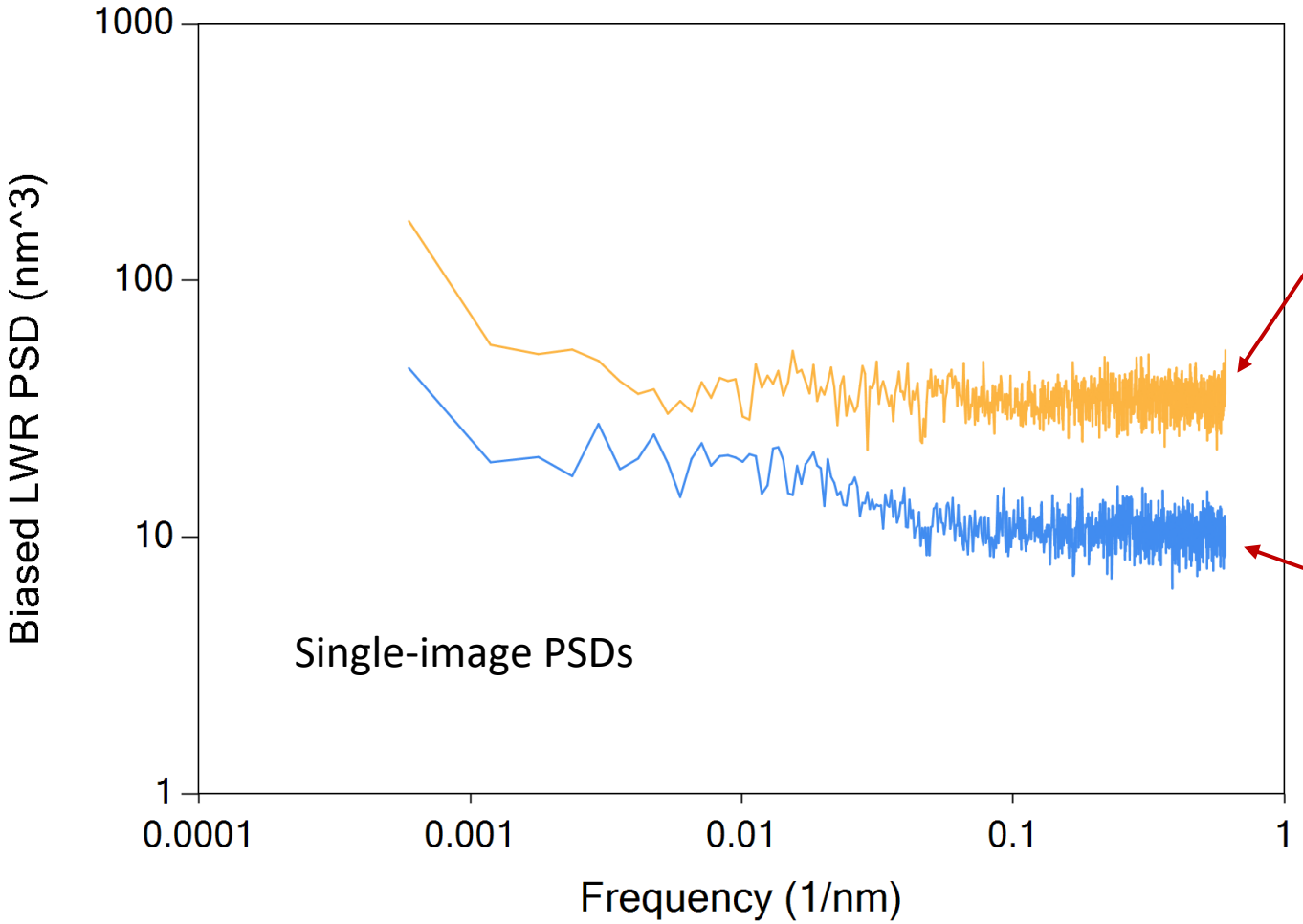
(This data from Gen1-2)

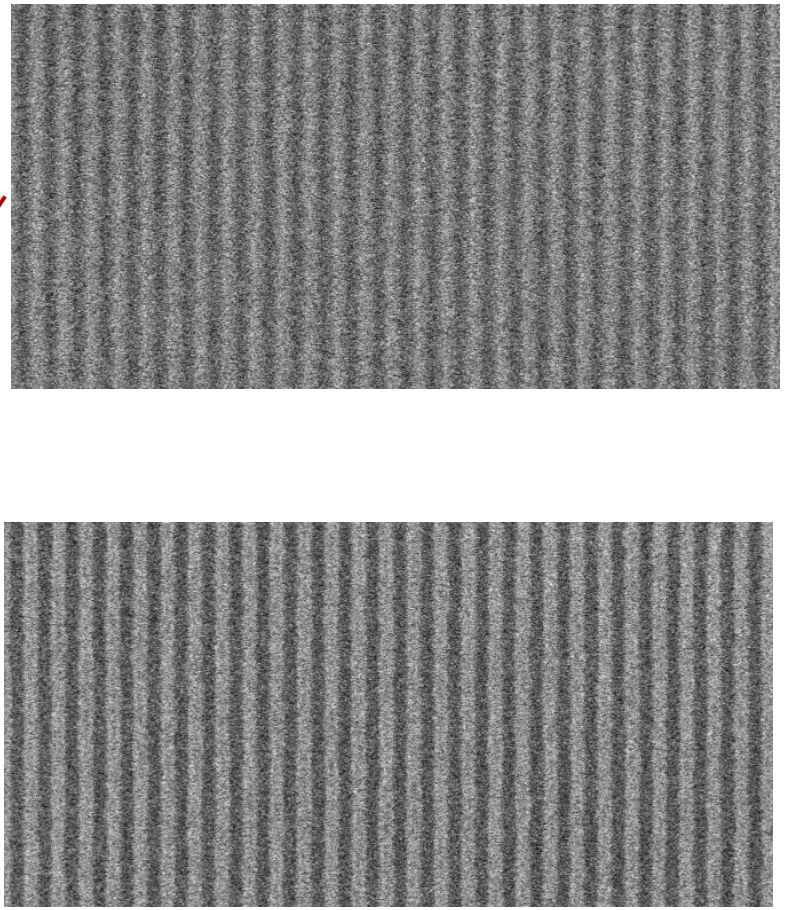
Gen1-2 Data Set: The problem is metrology noise





Comparing two images

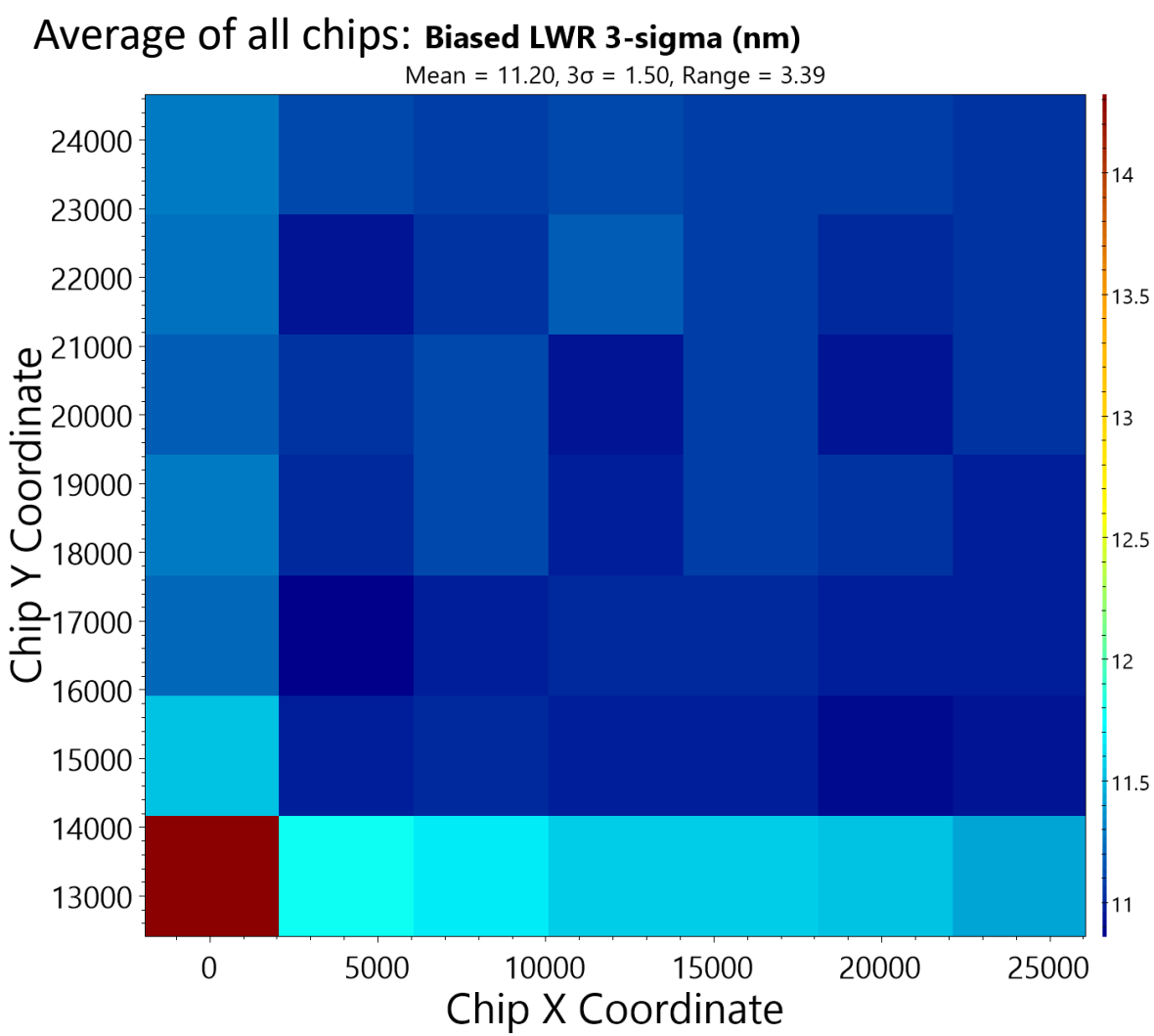


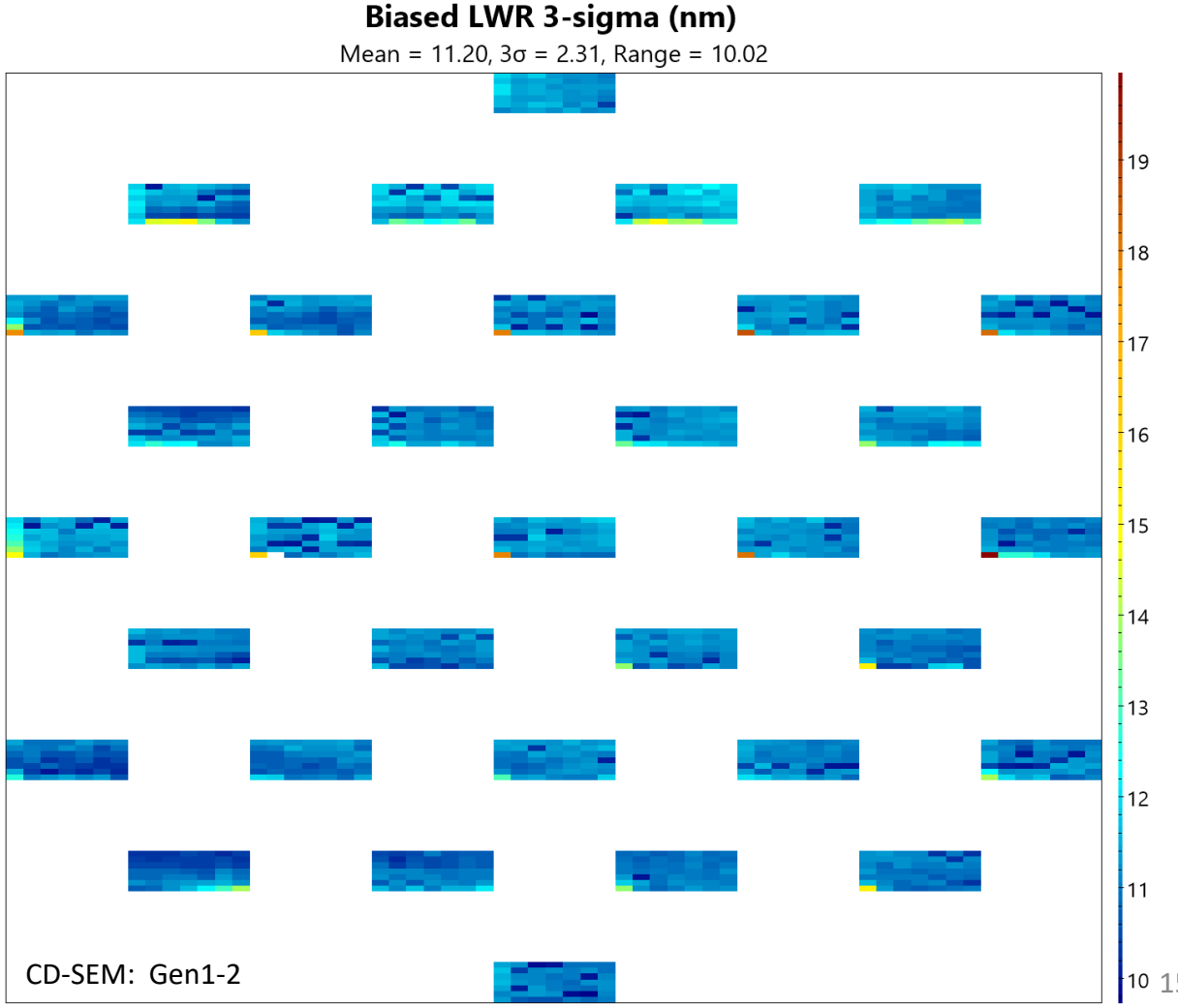


CD-SEM: Gen1-2

Worst case location in field

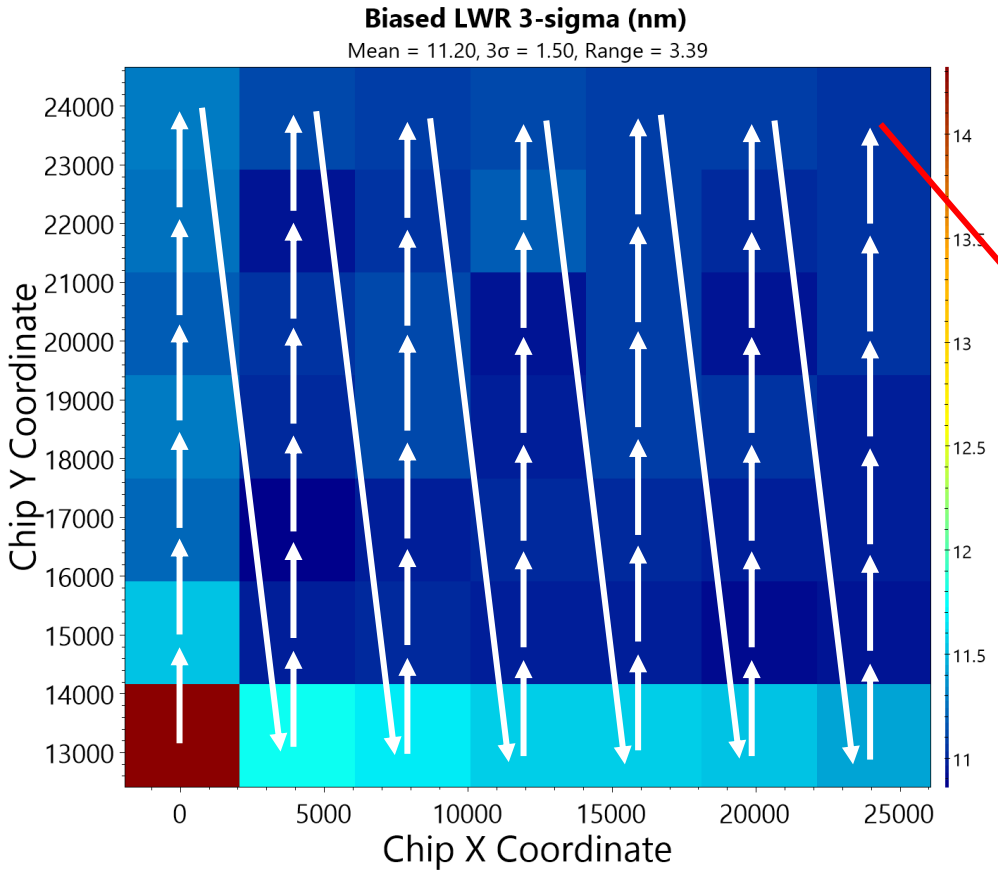
The lower left corner of the field often has 1.5x – 2X higher biased LWR.



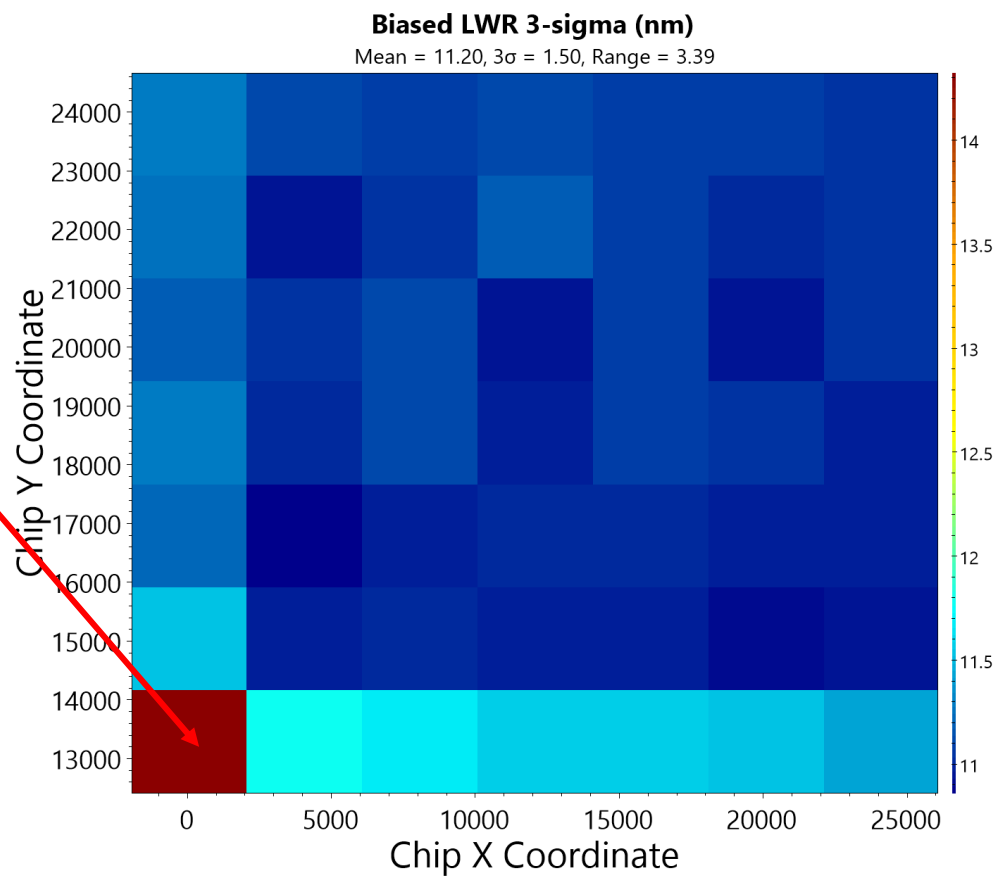


SEM Job Measurement Order

Chip 2

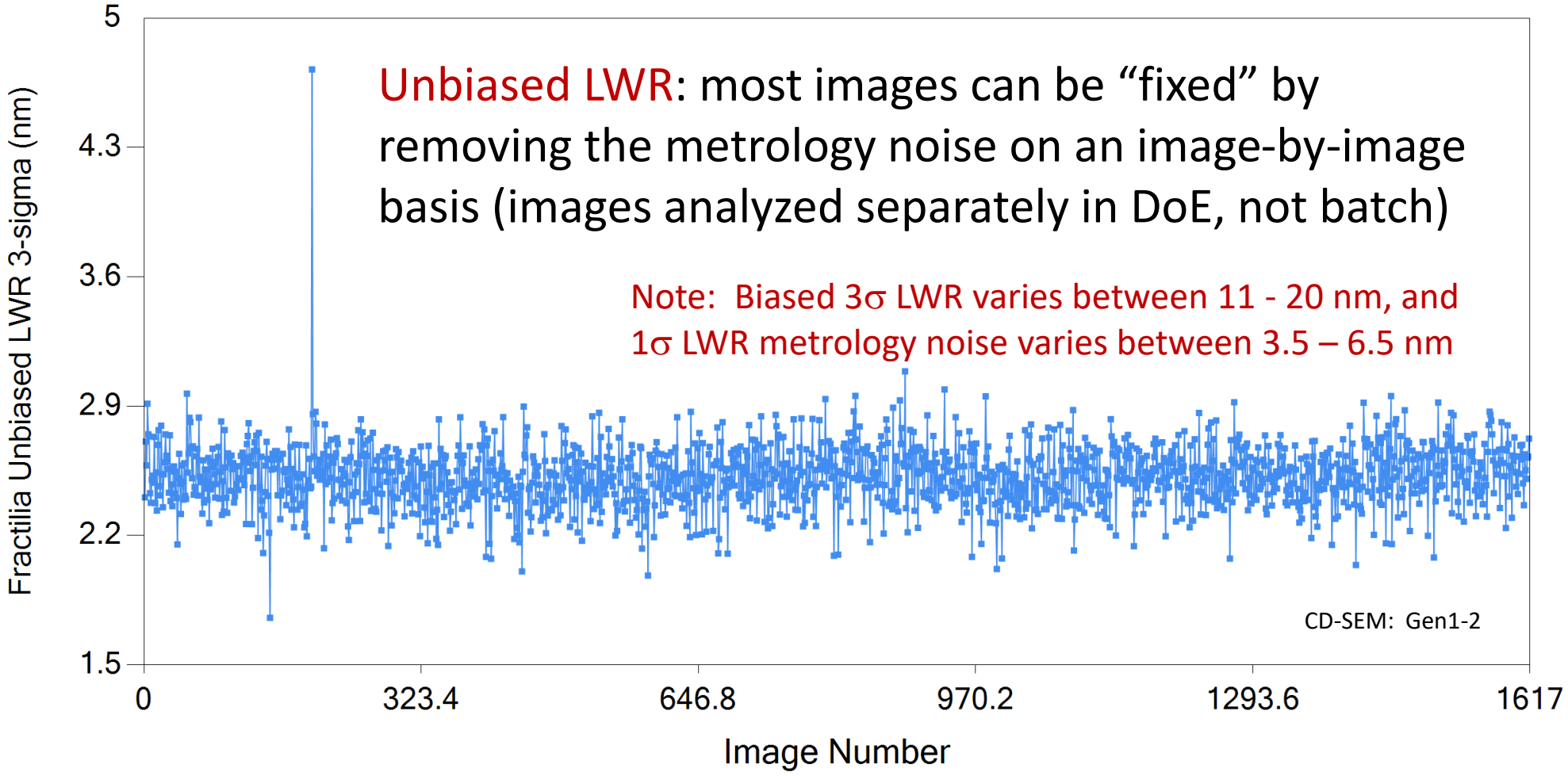


Chip 4

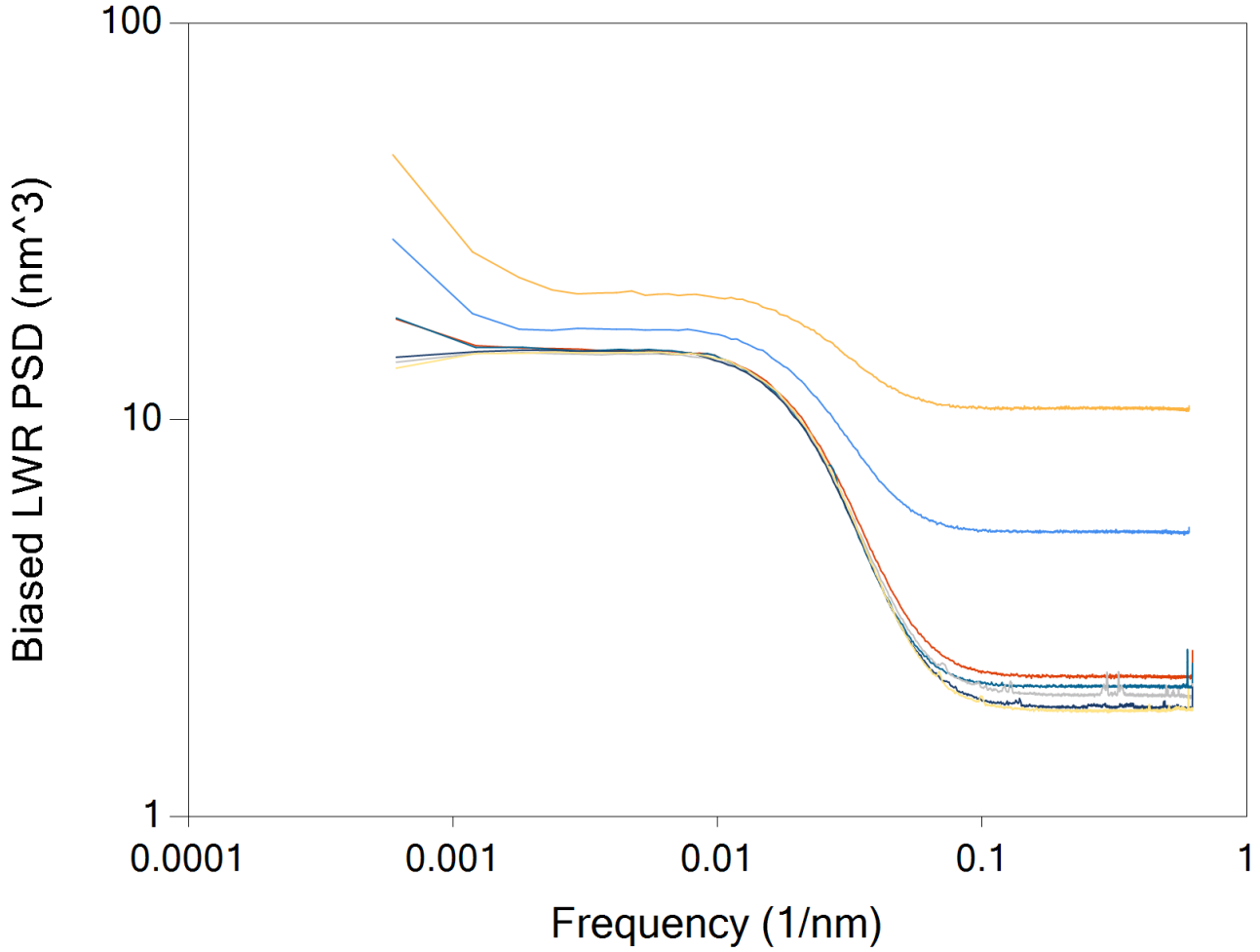


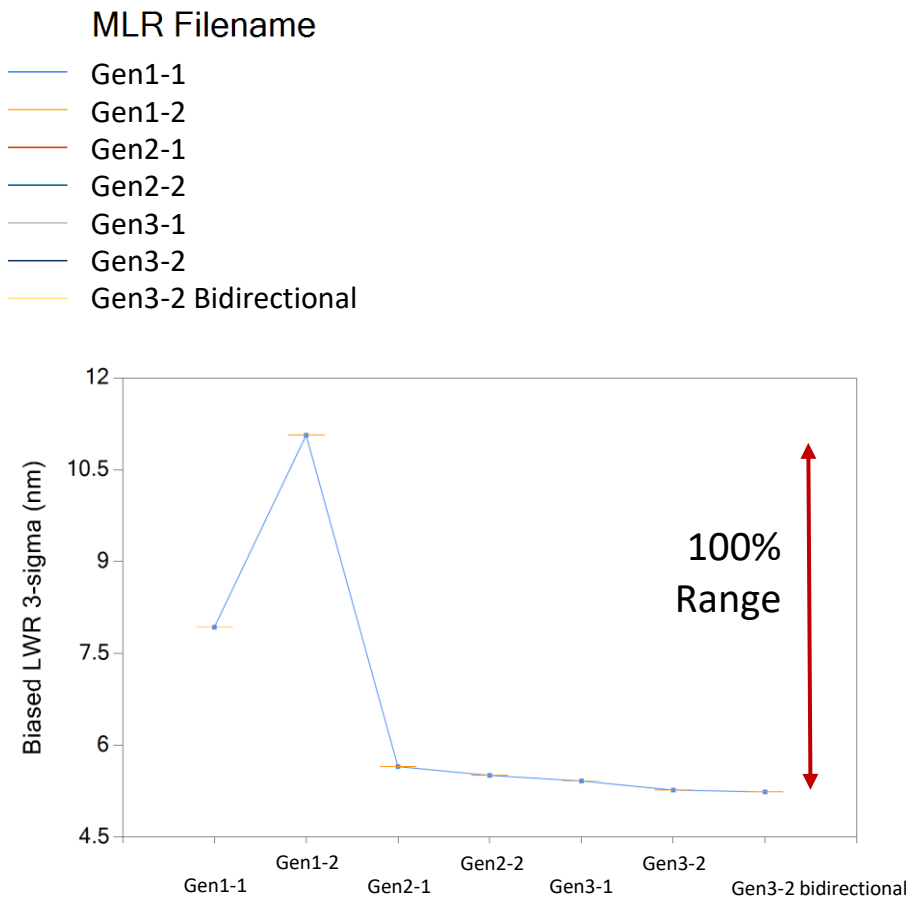
The lower-left corner field position is the first measurement after a long stage movement.

MetroLER can remove metrology noise differences

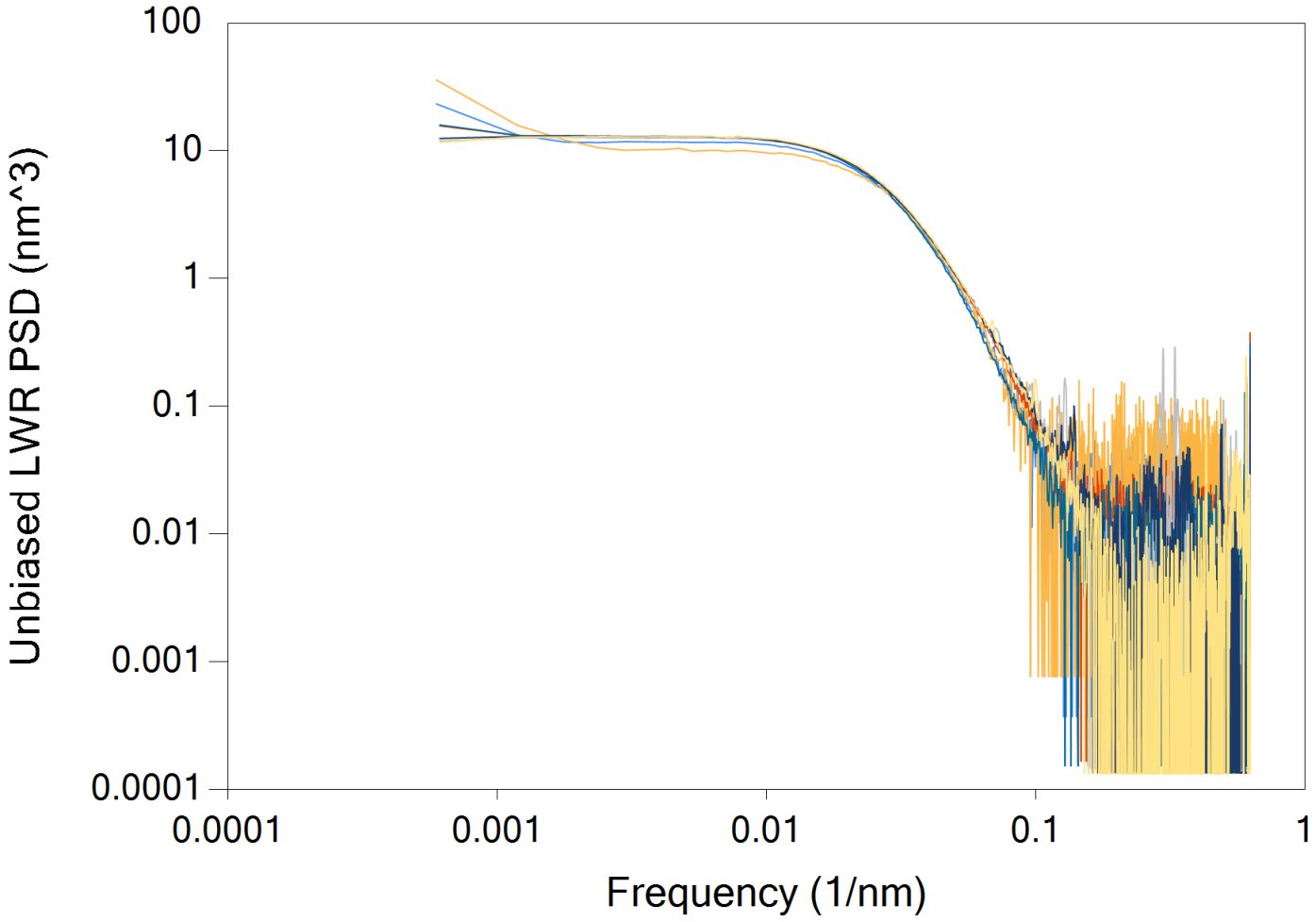


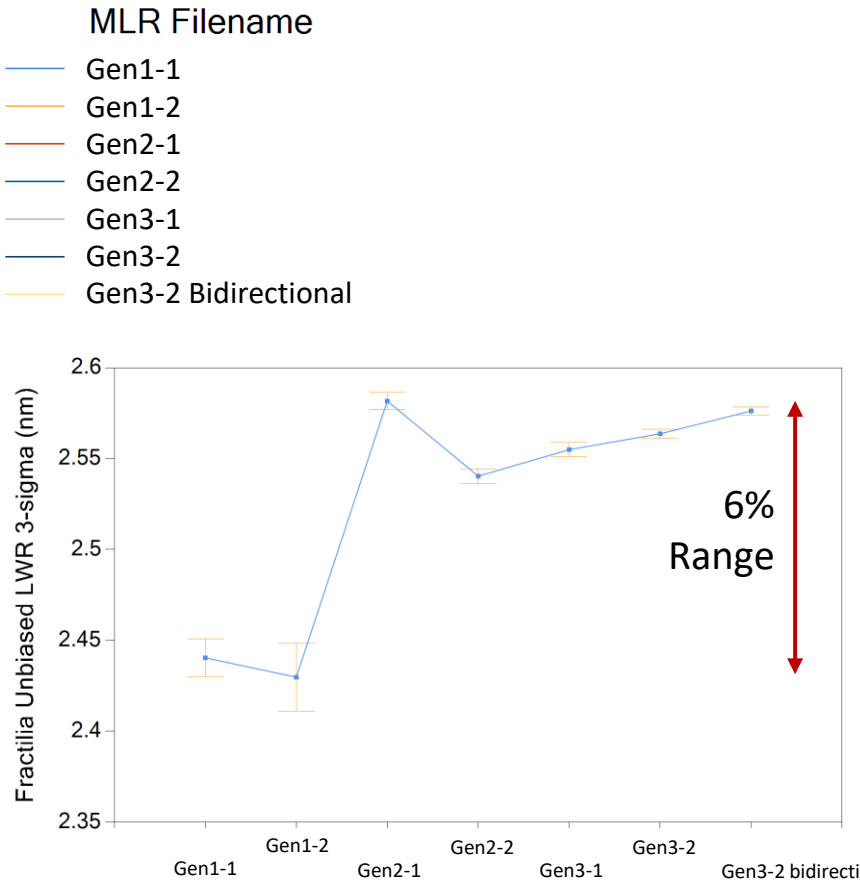
Tool Matching – Biased LWR





Tool Matching – Unbiased LWR





Conclusions

- Goal: Investigate any discovered SEM tool artifacts; Mitigate them if possible

- Conclusions:
  - Two very different problems were identified:
    - “Zig-zag” effect intermittent on Gen2-1 tool (probably electronic noise)
    - Focus problem after long stage travel on Gen1-1 and Gen1-2 tools
  - Both problems caused significant increases in biased LWR and LER
  - MetroLER was successful in removing the impact of these tool errors on the unbiased LWR and LER

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Thank You

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