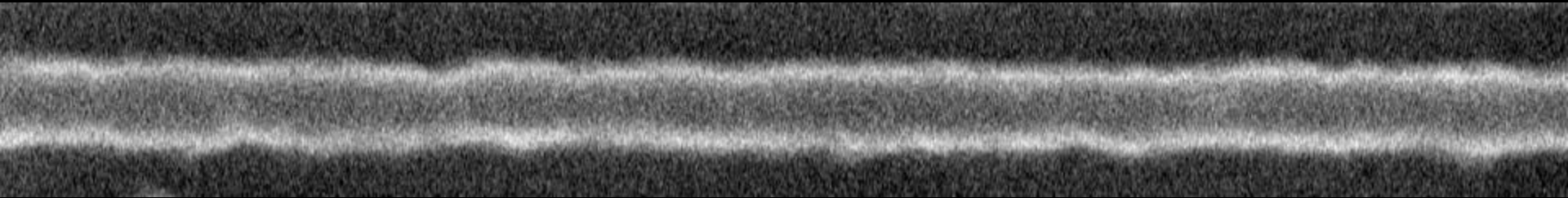


LER Metrology: Can we trust the numbers?

Patrick Naulleau and Brittany McClinton

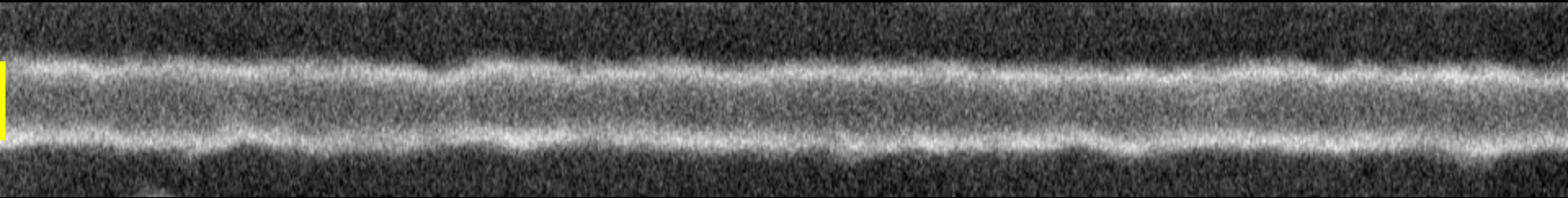
Line-edge roughness (LER)



$\uparrow h$

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (h - \mu)^2} \quad LER = 3\sigma$$

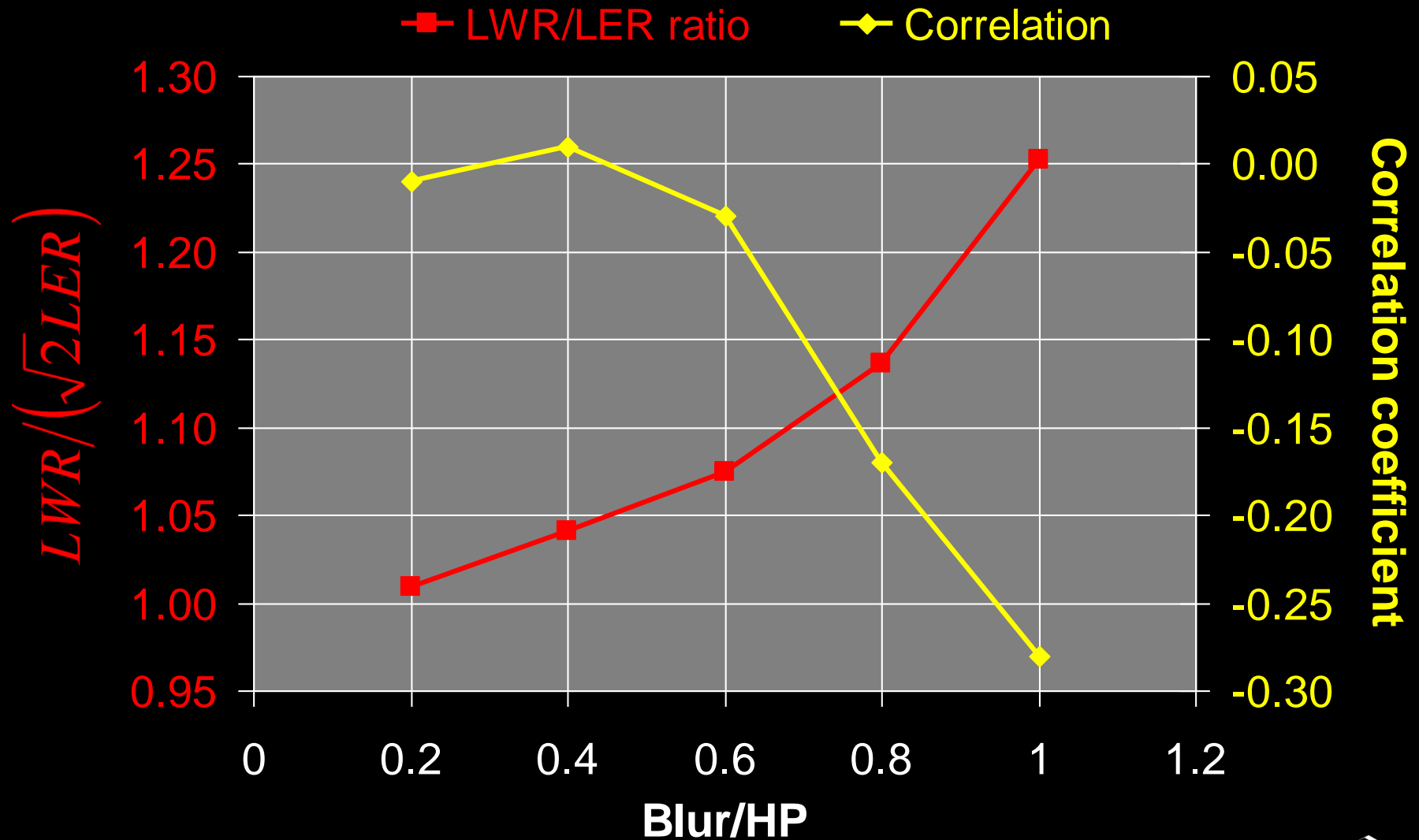
Line-width roughness (LWR)



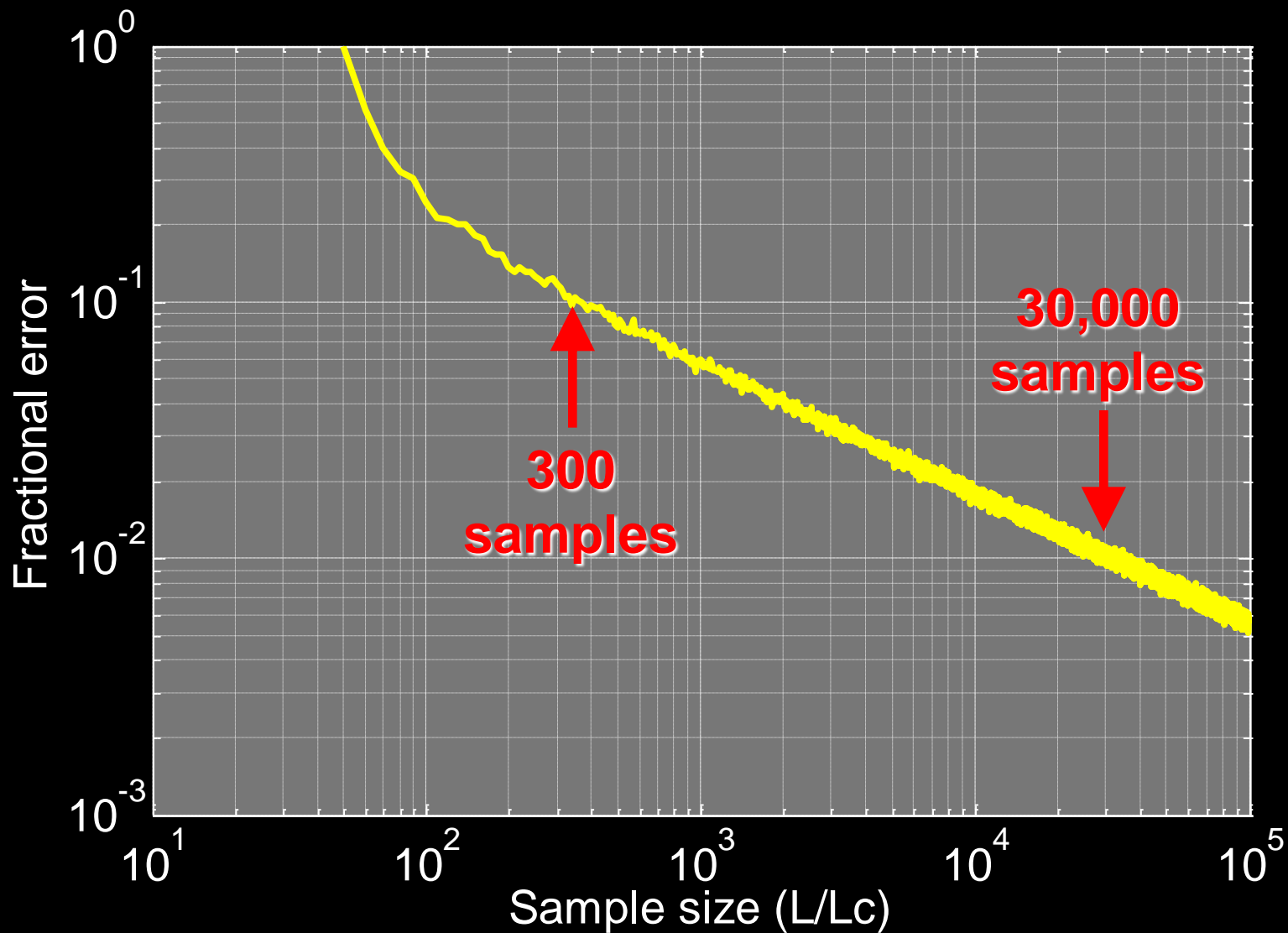
$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (W - \mu)^2}$$

$$LWR = 3\sigma$$

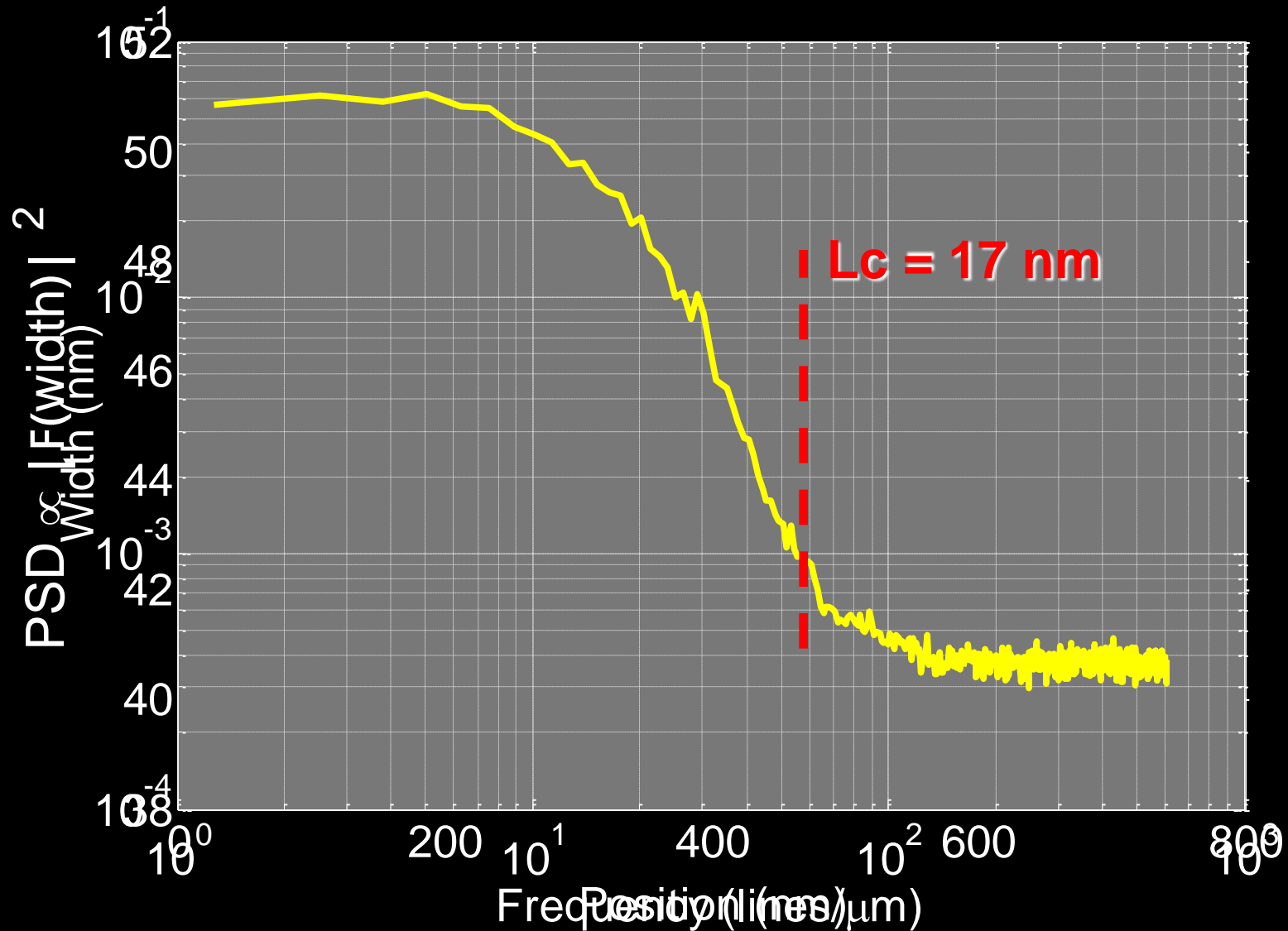
LER and LWR: are they interchangeable?



Error in determining statistics from finite data

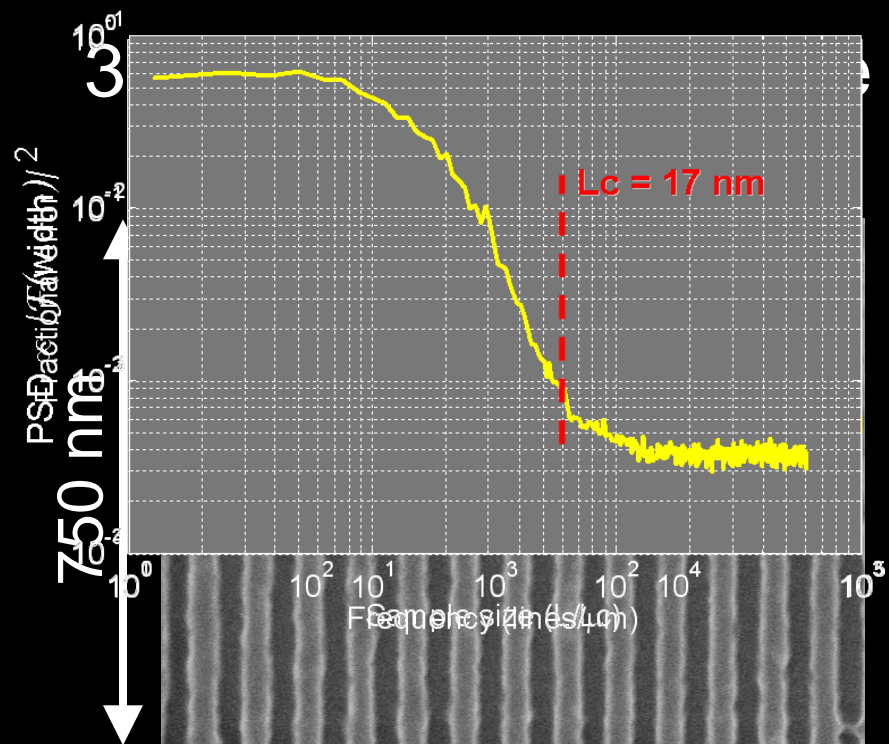


Determining the correlation length



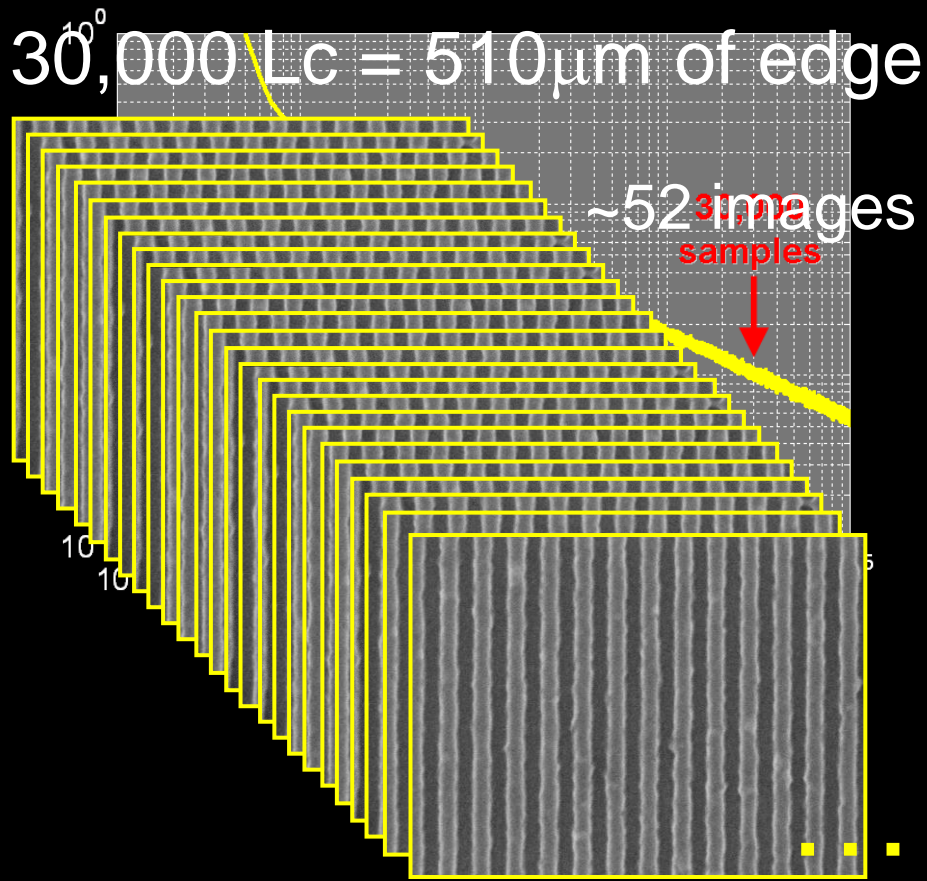
How many images do we need?

10% uncertainty

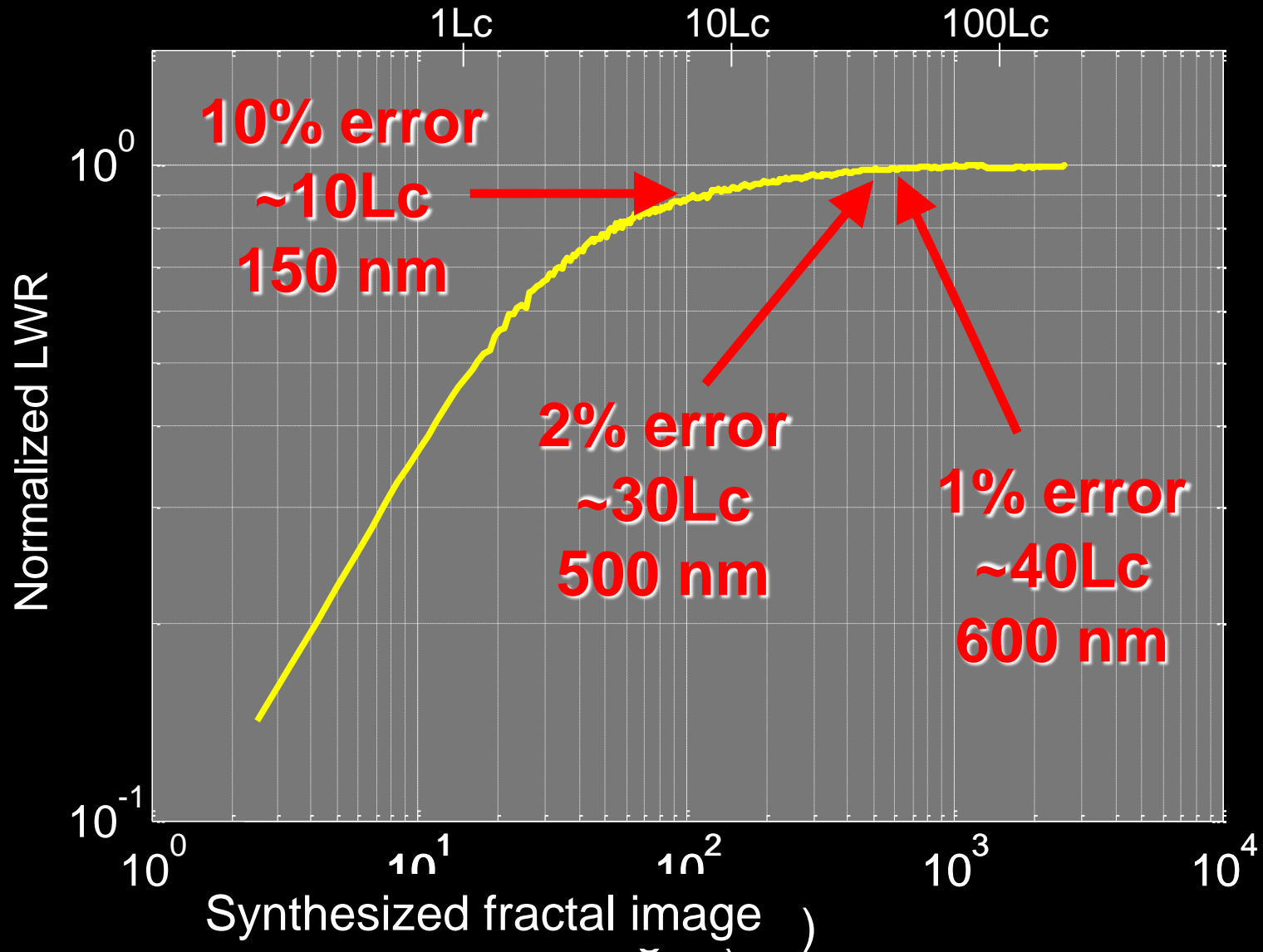


$\sim 10 \mu\text{m}$ of edge data

1% uncertainty

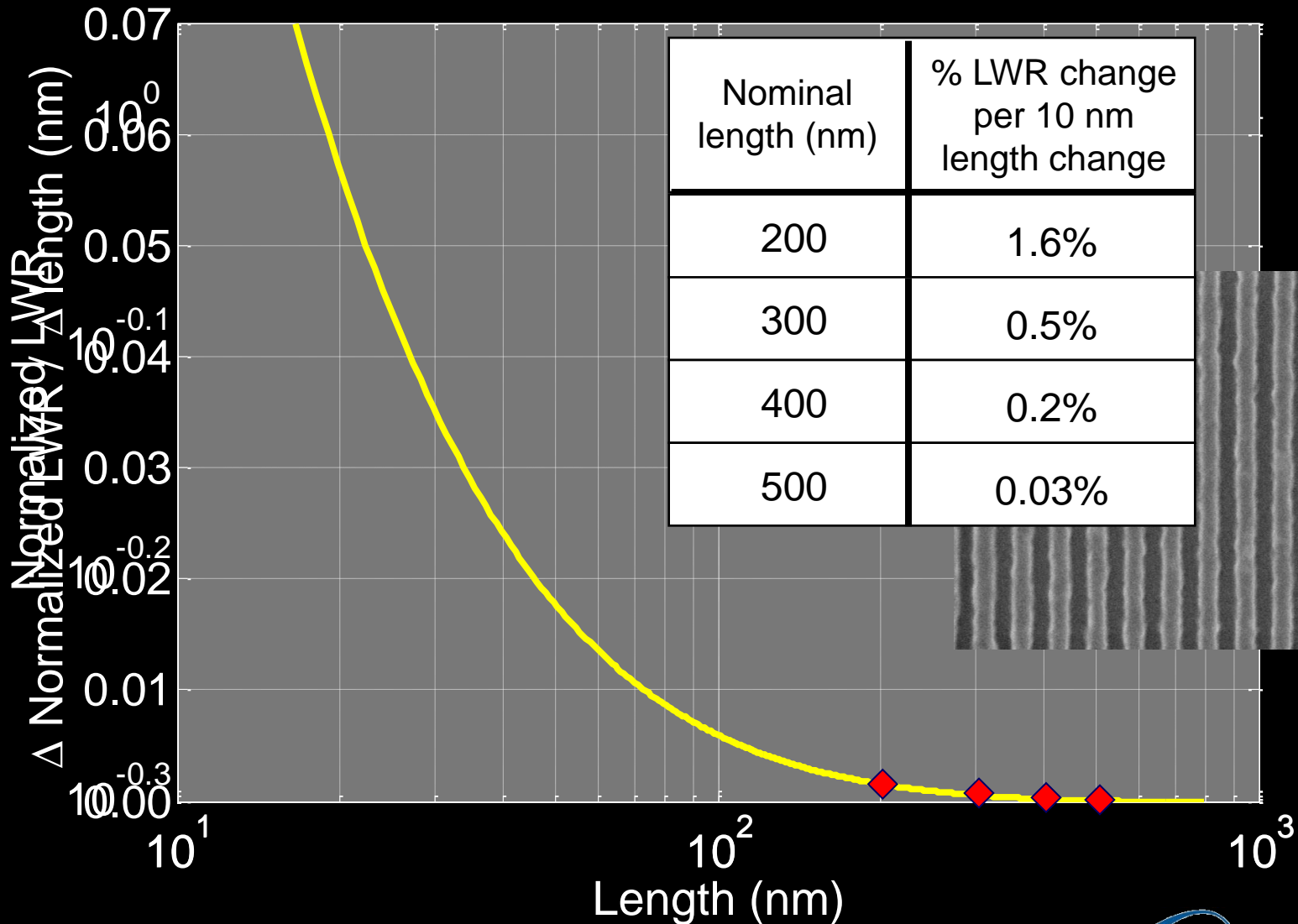


The importance of analysis length

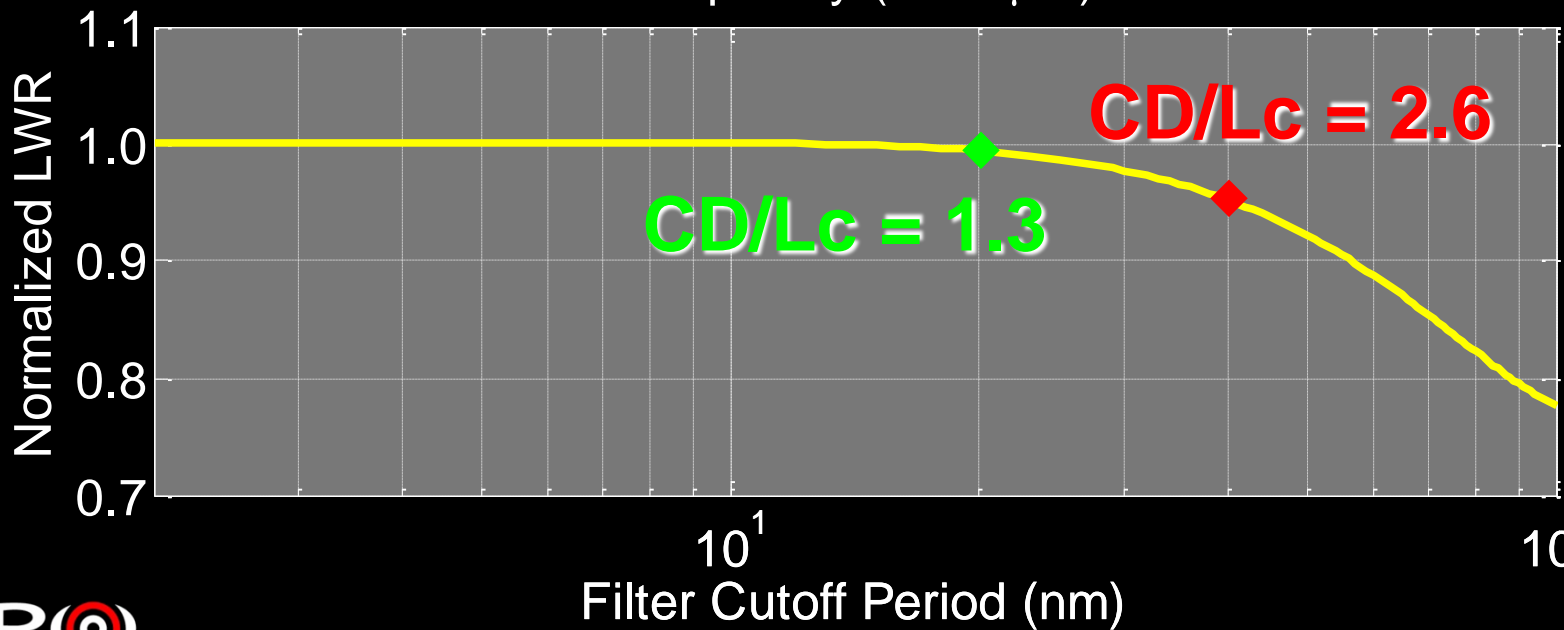
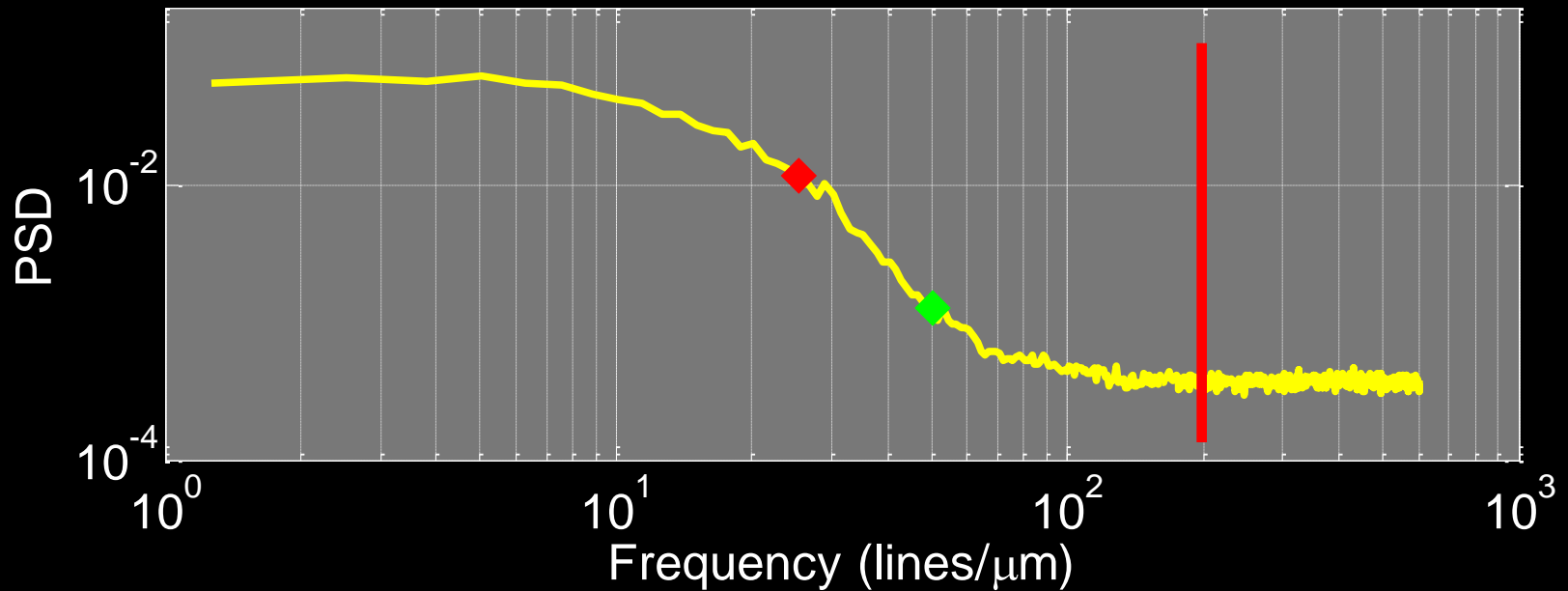


Sensitivity to changes in analysis length

Experimental data from champion CA resist with 17-nm correlation length

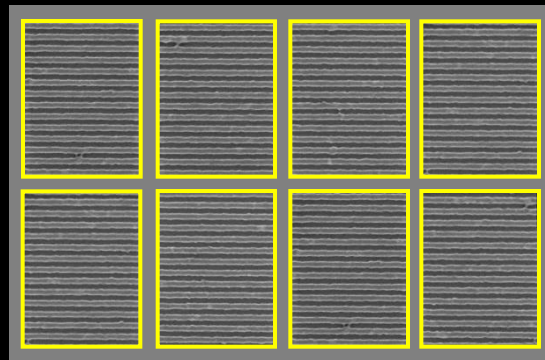


ITRS defines LWR cutoff period as $T_c = HP$

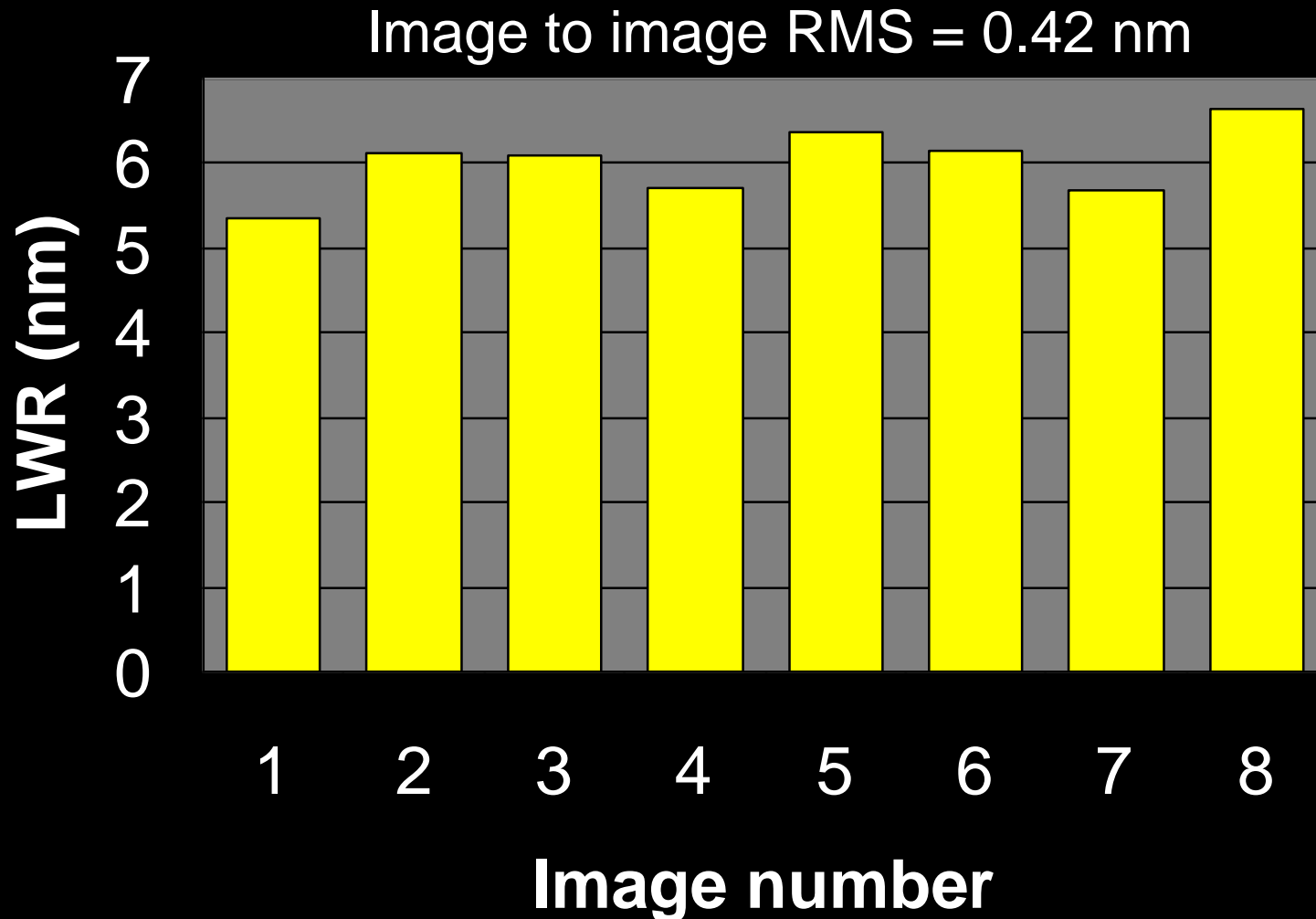


Now what about actual measurement
uncertainties?

Measurement variations within one set of lines on wafer



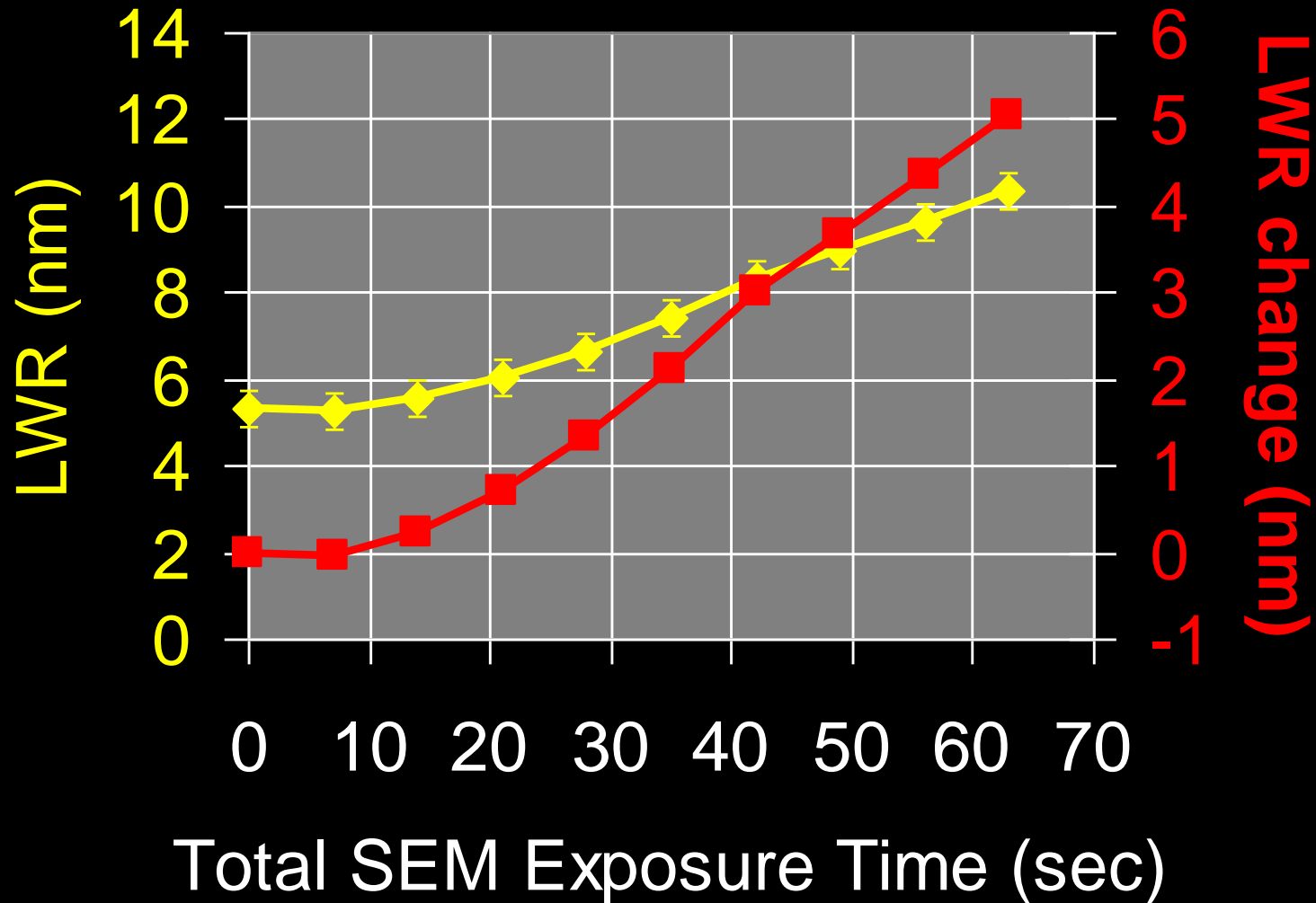
Average of 16 images required to achieve 0.1-nm precision



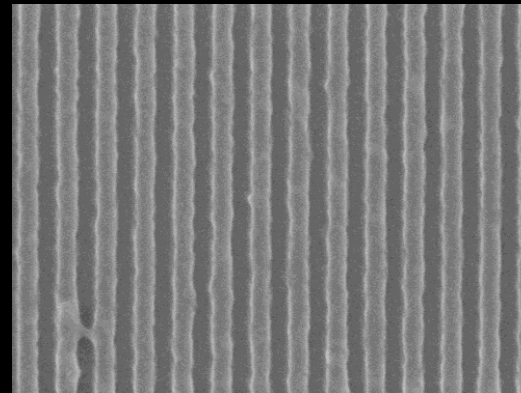
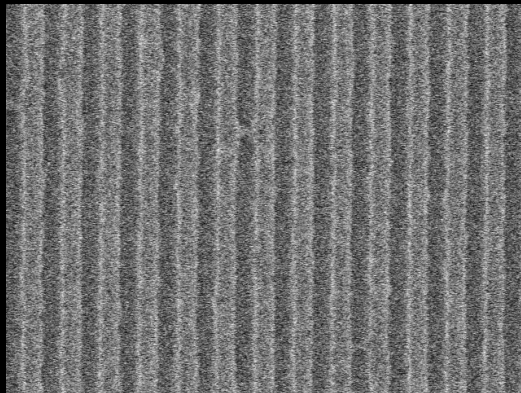
Repeated measurements at a single point



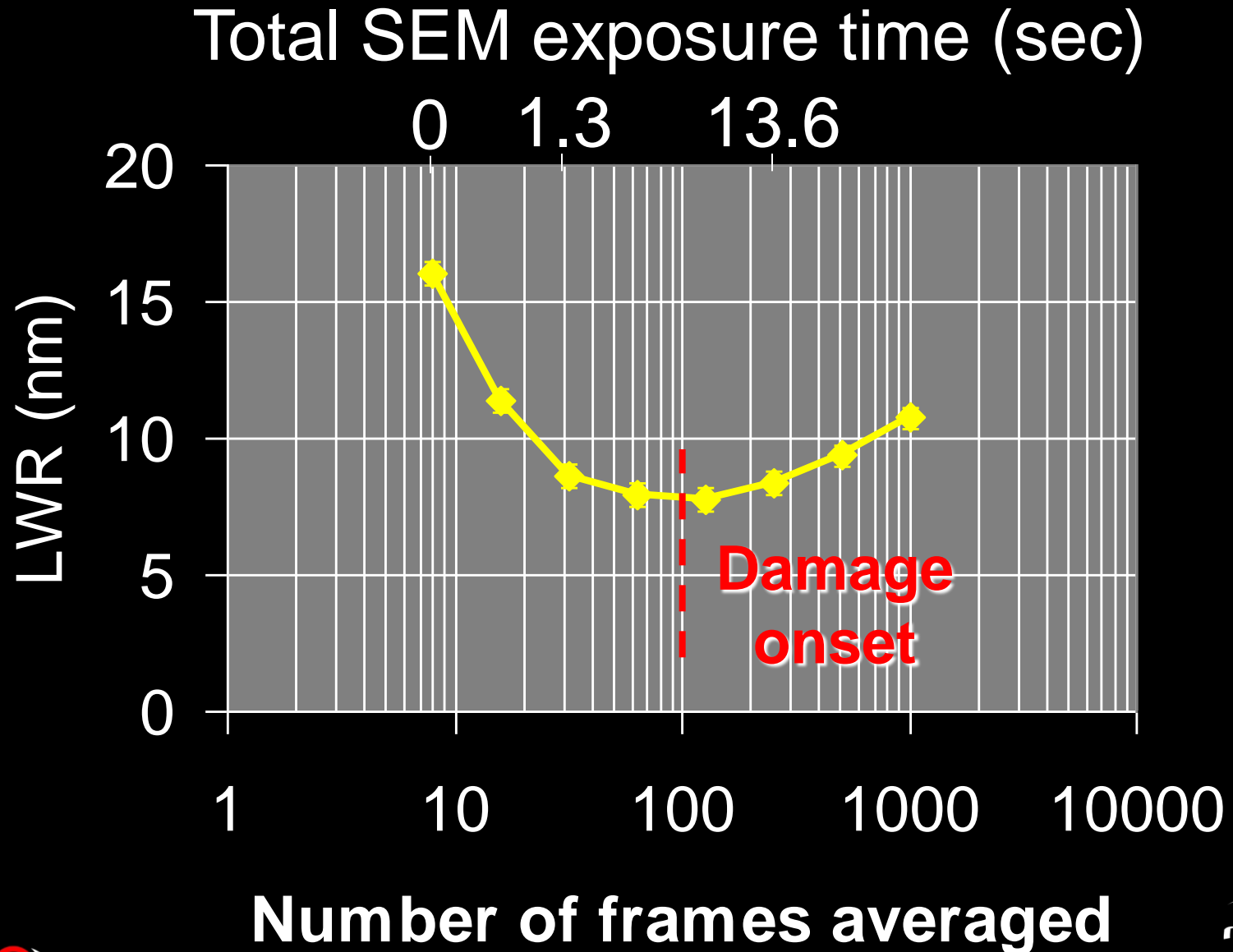
Care must be taken to ensure that region is not damaged by SEM



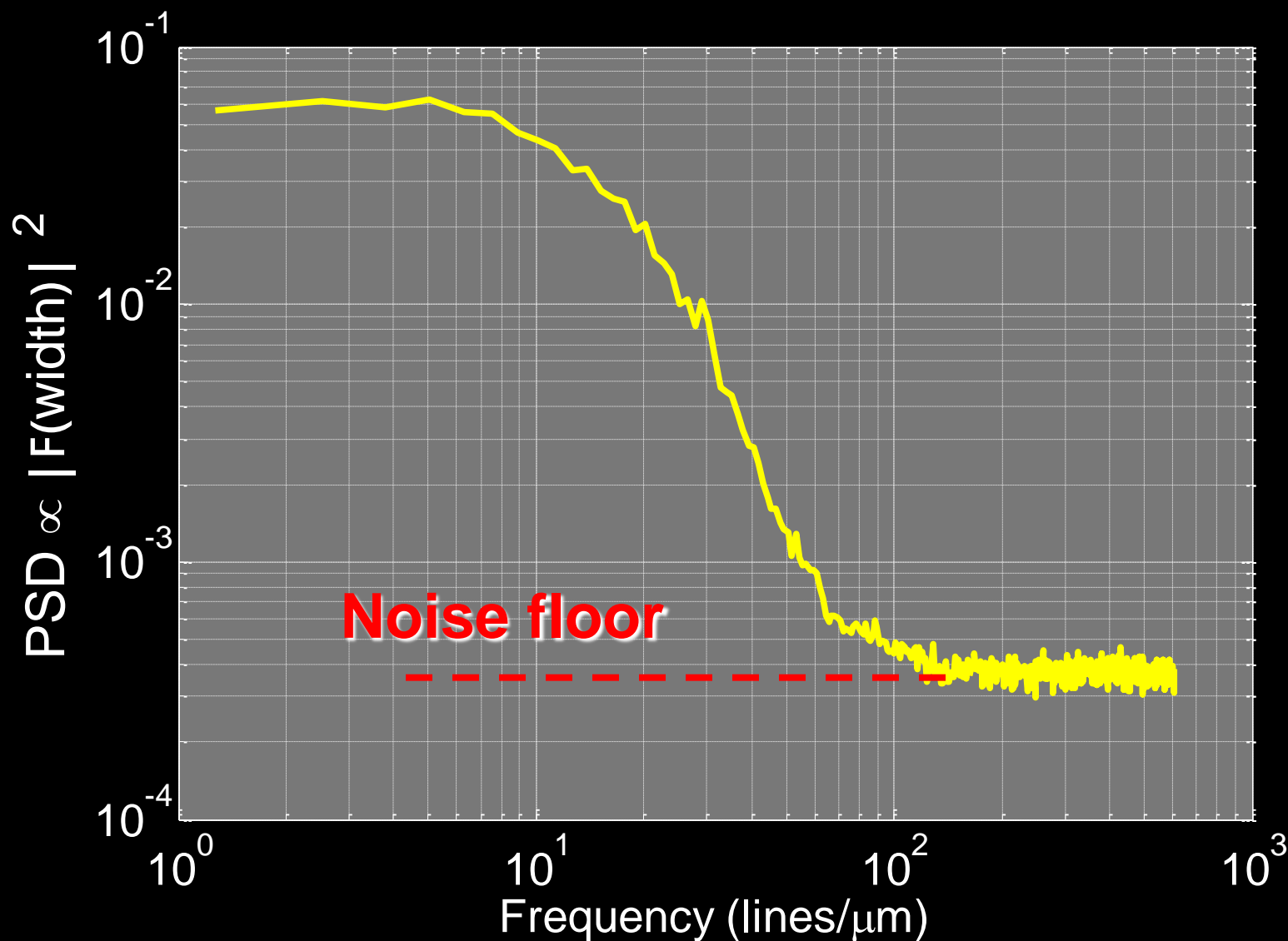
SEM Noise



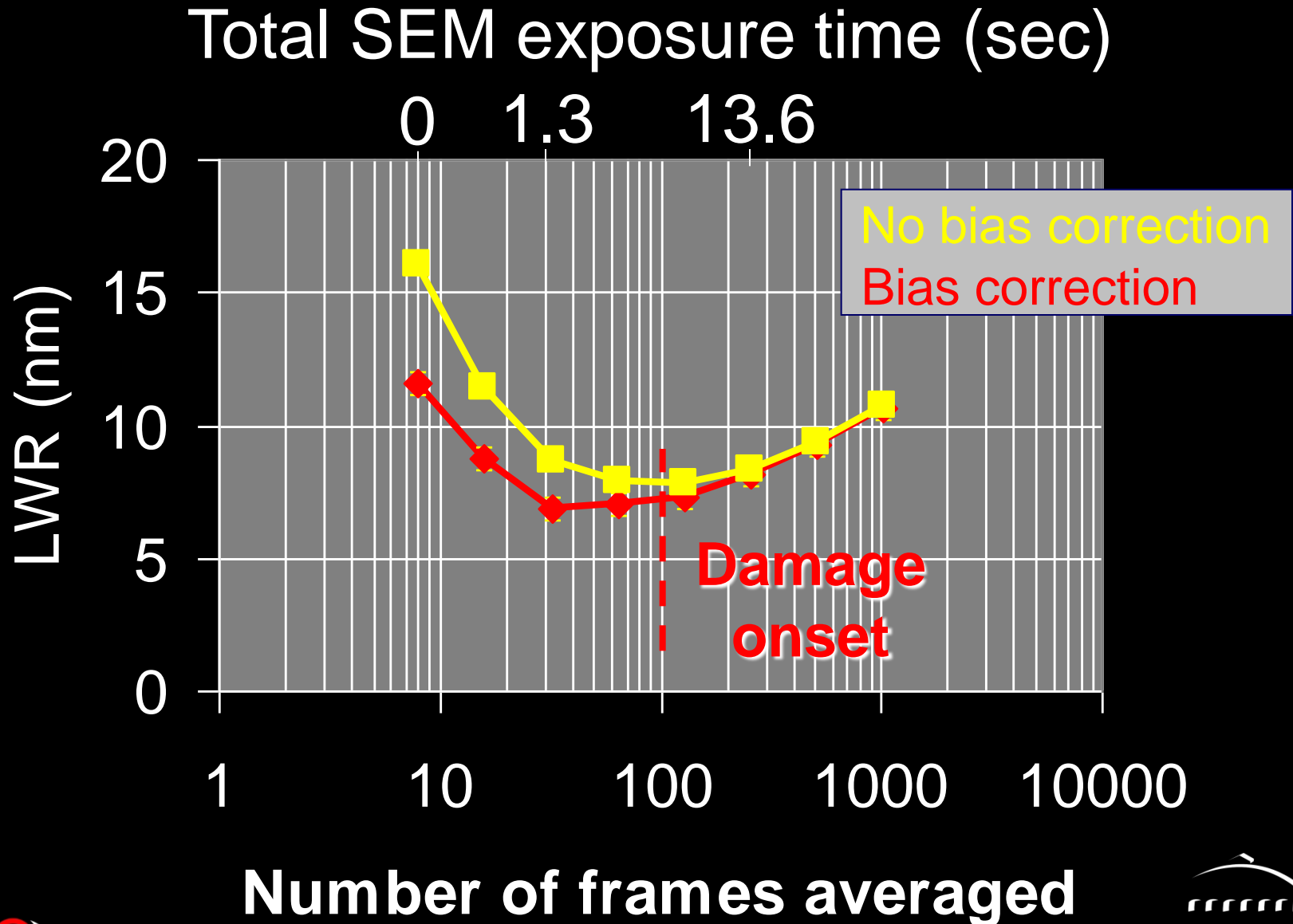
SEM noise has large effect



Noise floor can be estimated from PSD



SEM noise has large effect



Filtering out SEM Noise

Ideal test image

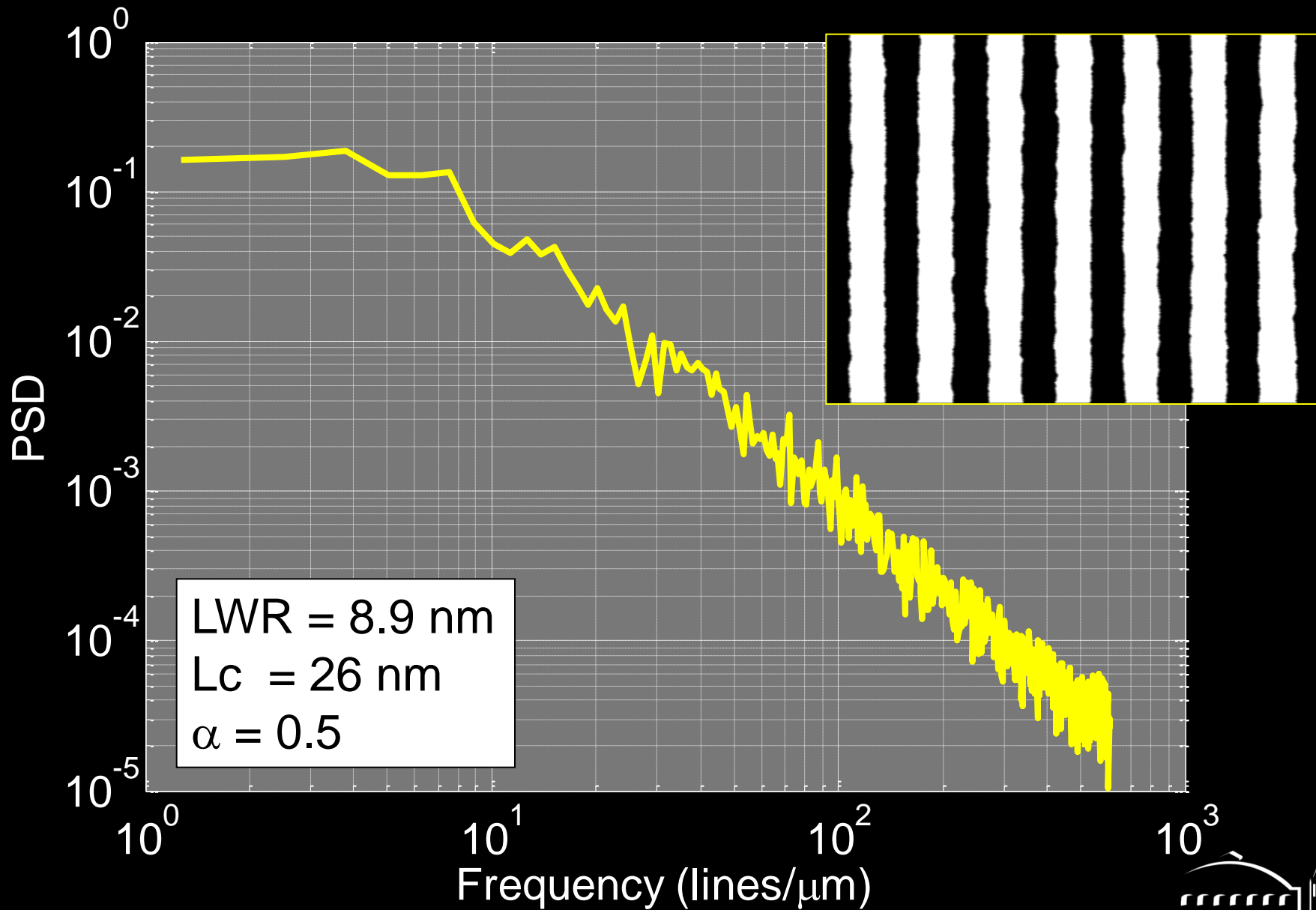
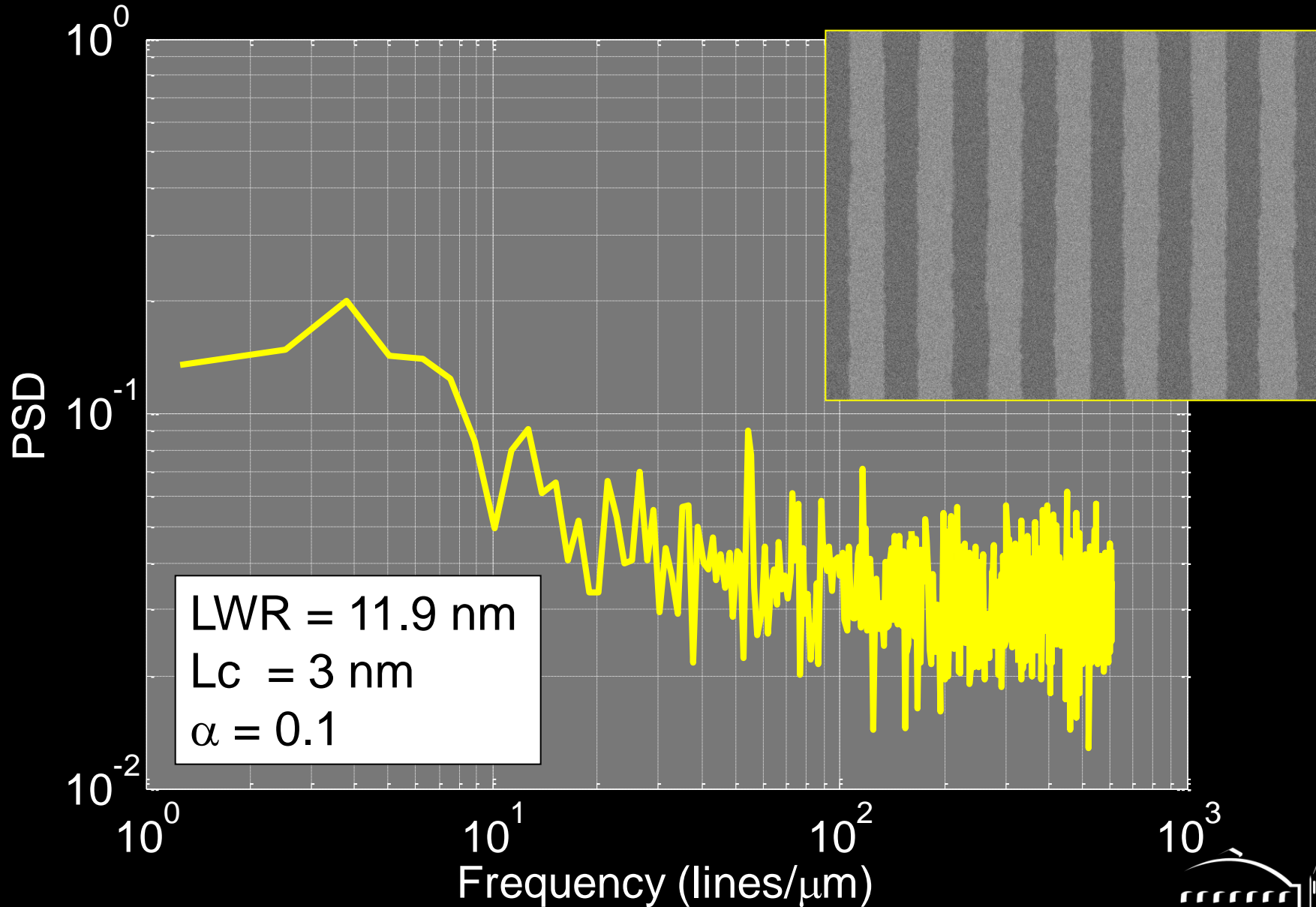
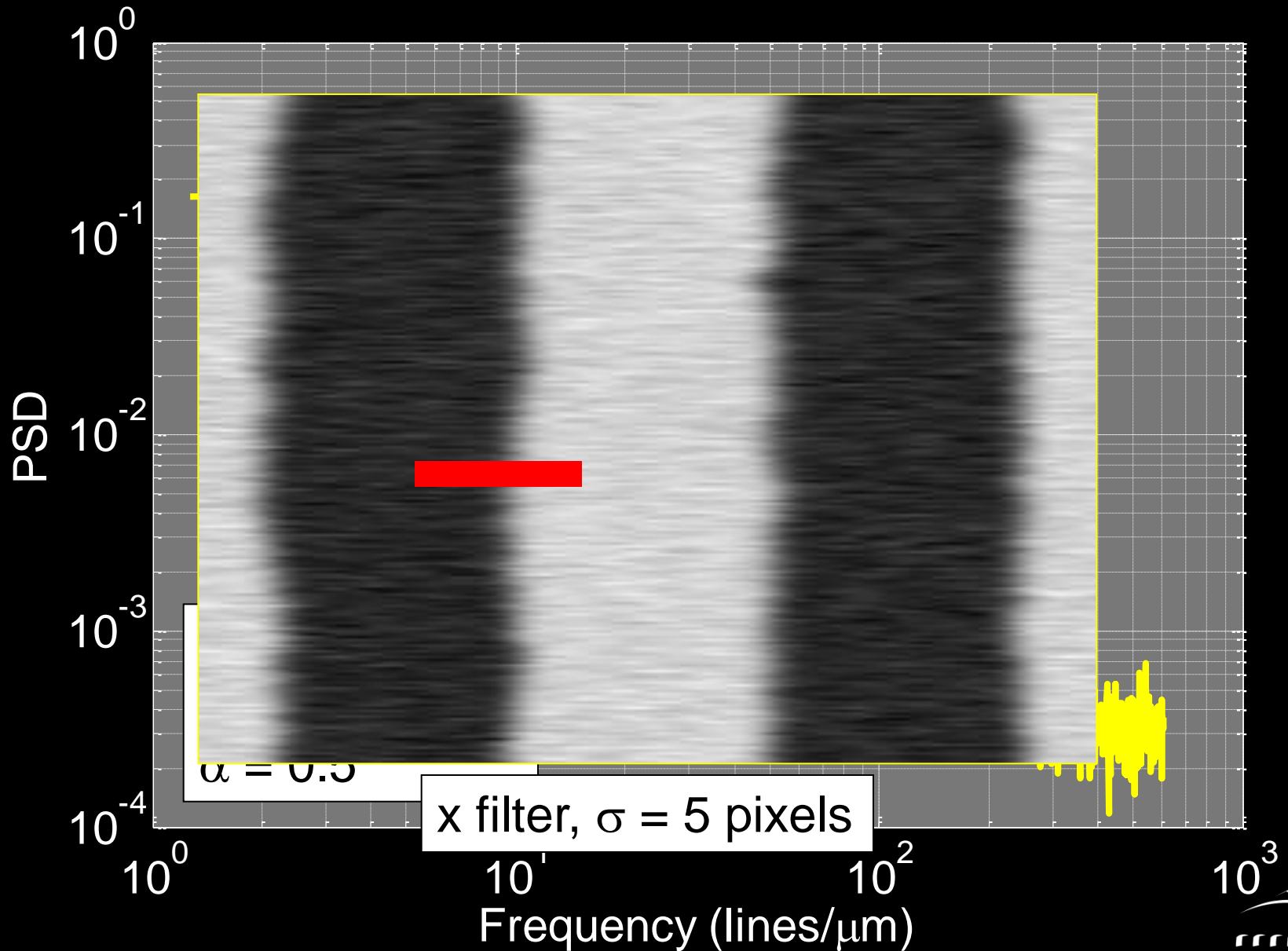


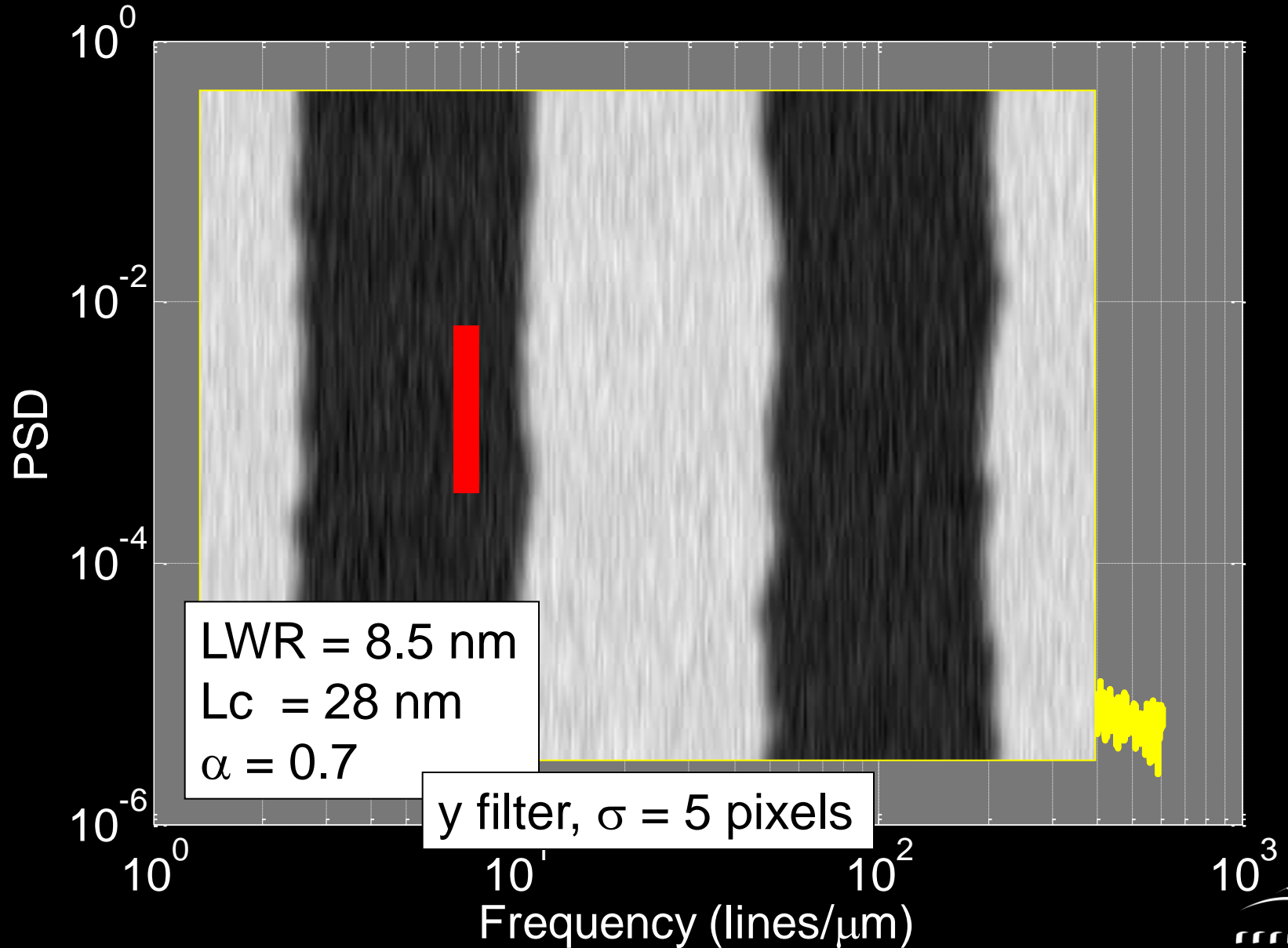
Image with added noise



Critical metrics recovered with x-filtering



Y-filtering does not perform as well



Summary

- Be Skeptical-Make sure you are comparing apples to apples
- Multiple image averaging required to achieve target precisions
- Beware of SEM damage
- Be careful when filtering out noise

Thank You