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# Impact of Tool Design on Phase Defect Detection Sensitivity for EUV Actinic Blank Inspection

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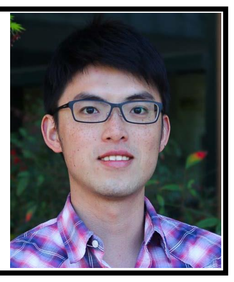
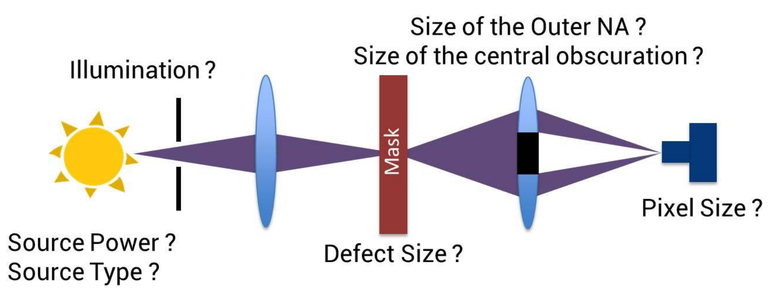


## EUV Actinic Blank Inspection: How to achieve high inspection efficiency?

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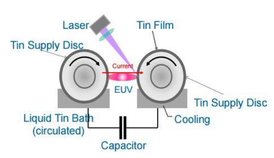
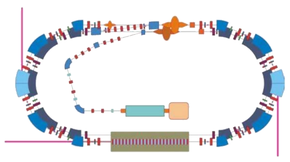
## EUV Source & Camera Settings

- Source Type:
  - Plasma-Discharged Source: source power ∝ illumination NA.
  - Synchrotron-based source: Source power ∝̸ illumination NA.



- Pixel Size: 100 ~ 500 nm (in mask scale).
- Photon Levels:
  - Photons/nm$^2$ : 0.1 ~ 62.5 photons/nm$^2$.

(10 photons/nm$^2$ on a pixel size at 100 nm:
= 1×10$^5$ photons/pixel at "bright field")

Ref.: 1.High radiance LDP source: clean, reliable and stable EUV source for mask inspection. (USHIO)
2.Compact synchrotron source (PSI/AAT)

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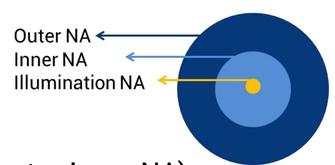
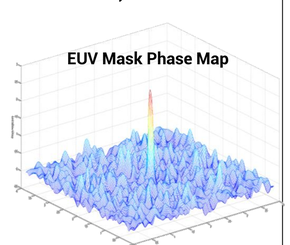
## Defect & Roughness Settings

- Optics & illumination:
  - Outer NA : 0.15 ~ 0.5.
  - Inner NA : 0.025 ~ 0.25
  - Illumination NA : Disk (Coherent ~ Inner NA)




- Defect (Gaussian):
  - H = 0.5 / 1.0 nm, FWHM = 60 nm.




- Mask Roughness:
  - RMS = 61 pm, correlation length = 100 nm.

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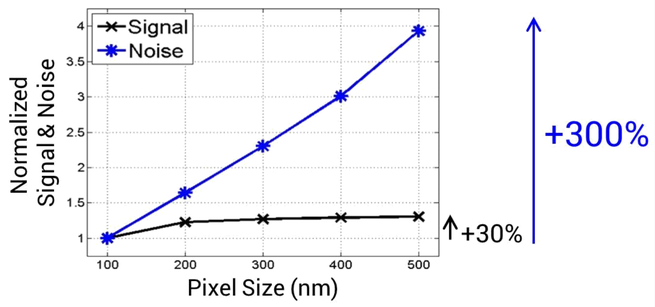
## Impact of pixel size on defect SNR




Larger pixel size reduces the inspection time but also increases the noise more than the defect signal.

H=1.0nm R=61pm, PD=5.6 photons/nm$^2$. NA = 0.25/0.075. Pixel Size= 100-500 nm.

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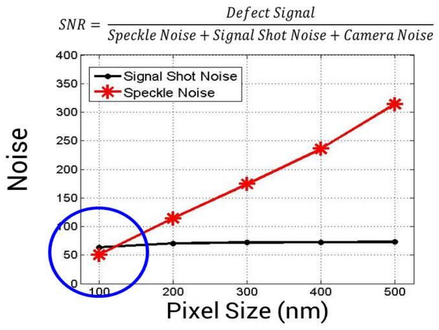
## Impact of pixel size on dominant noise source




1. As pixel size increases, dominant noise source changes from signal shot noise to speckle noise.
2. Signal shot noise dominates at 100 nm pixel size:
   Increase source power (photons) = Increase signal = Increase SNR!!!

H=1.0nm R=61pm, PD=5.6 photons/nm$^2$. NA = 0.25/0.075. Pixel Size= 100-500 nm.

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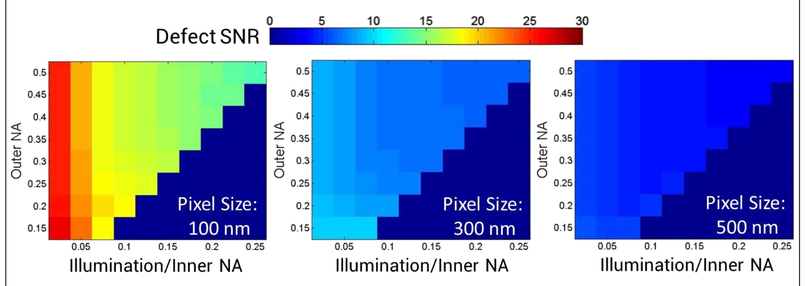
## Impact of pixel size on different NA settings




Pixel size is the dominant factor on defect SNR compare to NA of the optics under fixed photon density.

H=0.5nm R=61pm, PD=10 photons/nm$^2$. Pixel Size= 100-500 nm.

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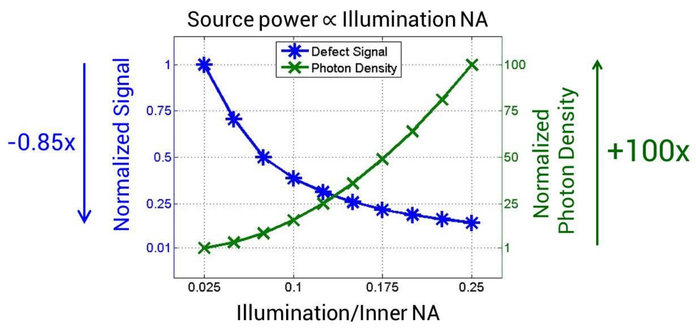
## Impact of illumination (inner) NA on photon density & signal




Increased source power compensates the loss by larger partial coherence and increases the signal strength in abs. number of photons.

H=1.0nm, Outer NA = 0.5. Pixel Size= 100 nm.

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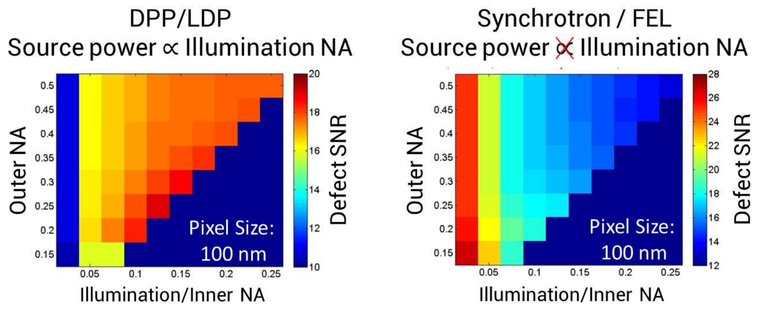
## Impact of EUV source type on different NA settings




At signal shot noise dominated situation (pixel size = 100 nm), larger illumination NA (partial coherence) improves the defect SNR by more photons for DPP/LDP source.

H=0.5nm R=61pm, PD=0.1-62.5 photons/nm$^2$. Pixel Size= 100 nm.

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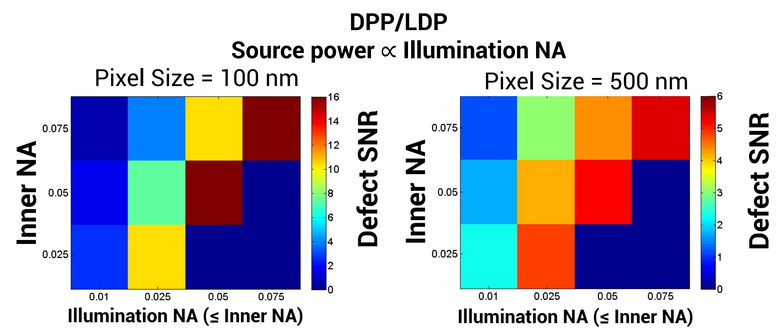
## Impact of illumination & inner NA on defect signal




Illumination NA = Inner NA has max. defect SNR.
Larger partial coherent illumination (more photons) is better.

H=0.5 nm R=61pm, Outer NA=0.15, PD=0.1-5.6 photons/nm$^2$. Pixel Size= 100, 500 nm.

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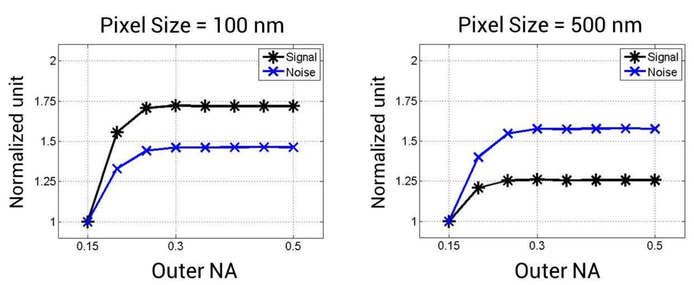
## Impact of outer NA at different pixel sizes on signal & noise




Increasing photon collection efficiency by larger outer NA doesn't necessarily increase defect SNR. It is pixel size dependent and the impact saturates at NA > 0.3.

H=1nm R=61pm, PD=5.6 photons/nm$^2$. Illumination/Inner NA = 0.075. Pixel Size= 100, 500 nm.

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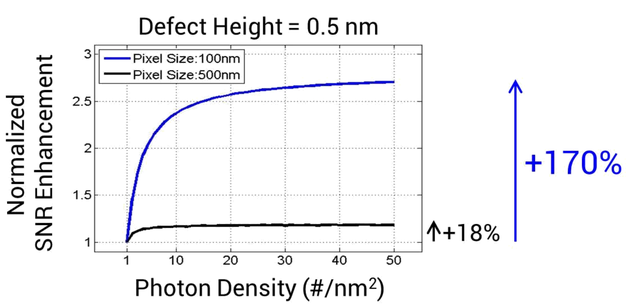
## Impact of source power on defect SNR




SNR enhancement by increasing source power saturates faster and the enhancement is smaller at larger pixel size.

H=0.5nm R=61pm, NA = 0.25/0.1/0.1. Pixel Size= 100, 500 nm.

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## Summary

- Pixel size has a larger impact on defect SNR than NA.
- With DPP/LDP source, more photons by larger partial coherent illumination improves the defect signal, while for synchrotron / FEL source, coherent illumination has higher defect signal.
- Increase outer NA at fixed inner NA doesn't always increases the defect SNR. The impact saturates as outer NA ≥ 0.3.
- Illumination NA = Inner NA to maximize the defect SNR.

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