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Improving OPC Accuracy Using Nikon Scanner Signature File (NSSF)

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Introduction

- OPC model accuracy is critical for advanced nodes.
- Including the information in the Nikon Scanner Signature File (NSSF) in a lithography model makes the model more predictive.
- We show that including the NSSF information directly in the imaging model provides a more accurate imaging model than a model capturing the scanner signature indirectly, through calibration.

Scope

- The benefit of including the pupil Jones matrix and Stokes vector of the illumination in the OPC model is quantified
- The metrics used to quantify the benefit are: edge placement and CD differences between target dimensions and simulated resist contours of OPCed masks.
- No measurements are used in this study. This enables isolation of the effect of NSSF without the confusion of metrology noise.
- OPC is performed on a portion of the gate layer of a generic NAND-flash memory.
- NSSF version 1.5 for NSR-S610C (NA max = 1.3) is used.
- The signature used is the average signature over scanners of the same model, and across the image field.

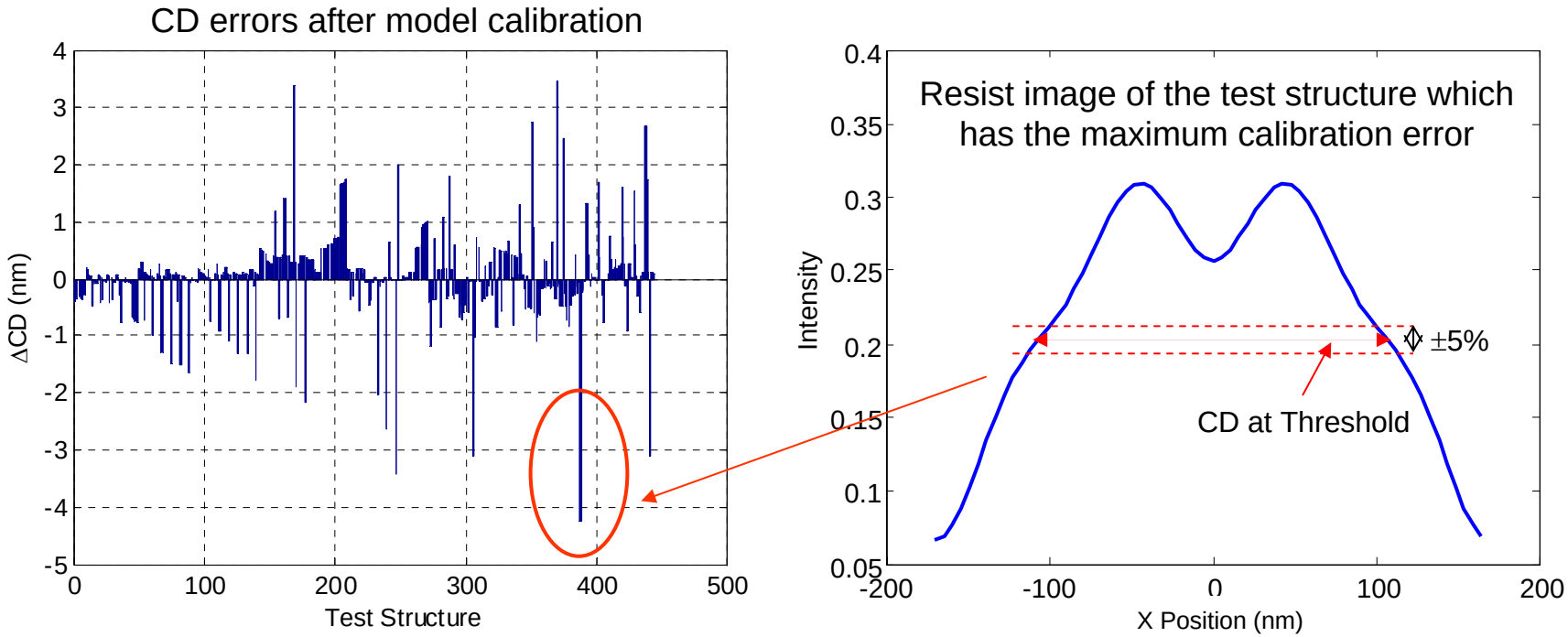
OPC Setup and Verification

- Setup of Three Imaging Models
  - Model A: NSSF Model
    - Generated using the information in NSSF 1.5
    - Generate images of a set of calibration patterns using this model.
  - Model B: Calibrated Model
    - Generic OPC model. No NSSF information was input to this model.
    - Adjust threshold, resist, defocus and lens pupil parameters of Model B so that Model B matches the calibration data generated using model A as closely as possible.
  - Model C: Basic Model
    - No stepper signature information; ideal pupil, ideal top hat illumination; no model calibration.
- Optical Proximity Correction
  - Conduct OPC of NAND-flash pattern
  - Generate Masks A, B, and C, using imaging Models A, B, and C
- OPC Verification
  - Simulate images of Mask A, B, and C using the imaging NSSF Model (Model A).
  - Extract Edge-placement-errors (EPE), relative to the target layout
  - Quantify and analyze resist pattern errors of Mask A, B and C images

Calibrated Model B

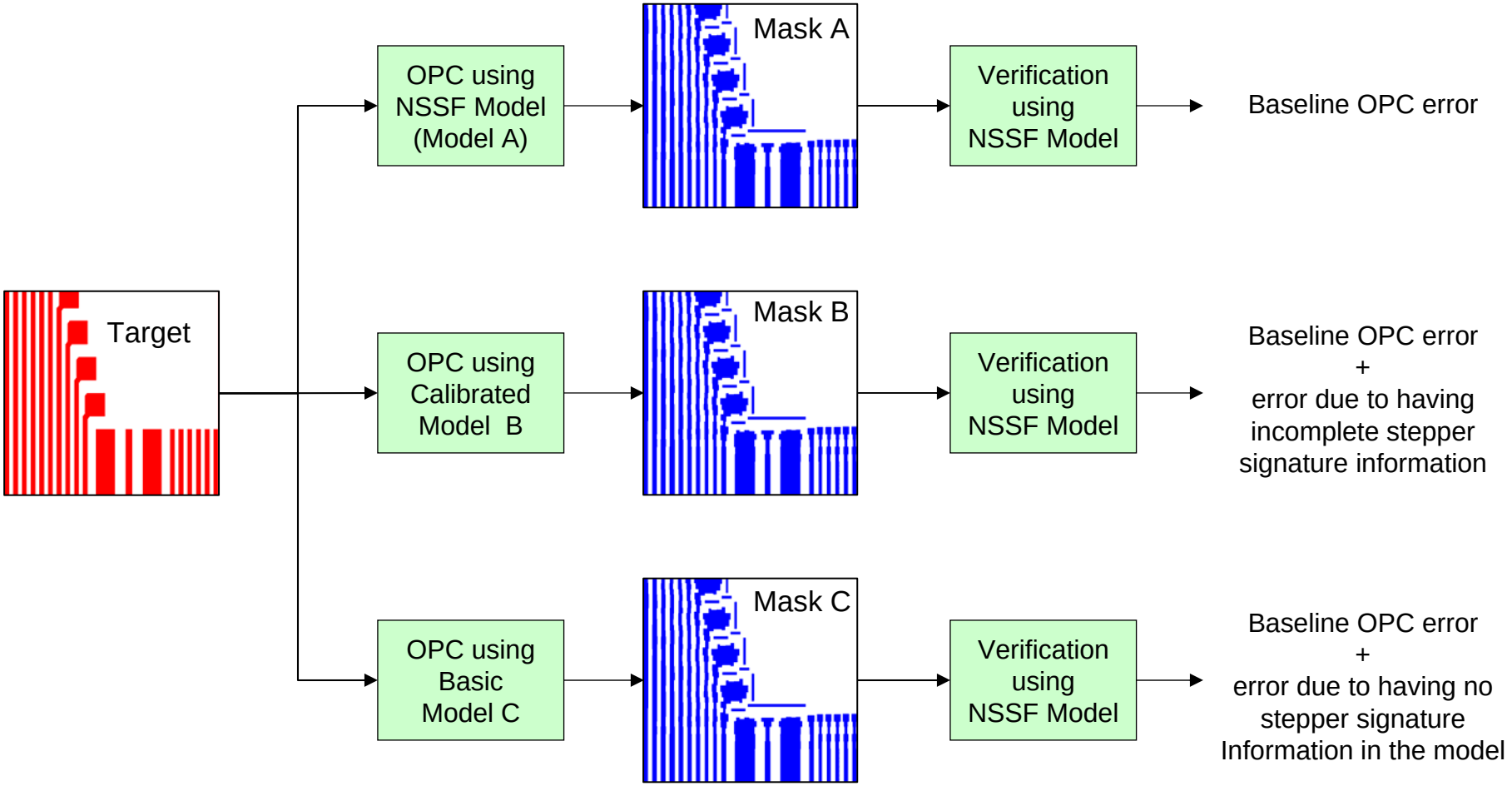
- Presently, OPC models are calibrated to match SEM measurements taken on printed test patterns.
  - Printed test patterns are affected by the stepper signature
- As printed patterns are affected by the stepper signature, model calibration partially and indirectly captures the stepper signature.
- Calibration of imaging models to SEM measurements can be simulated by calibrating Model B to agree as closely as possible with imaging predications of Model A, imbedding NSSF.
- To quantify the benefit of NSSF to OPC accuracy, we need to compare post-OPC imaging errors of Mask A, OPCed by Model A, to post-OPC imaging errors of Mask B, OPCed by the calibrated Model B.

Calibration of Model B

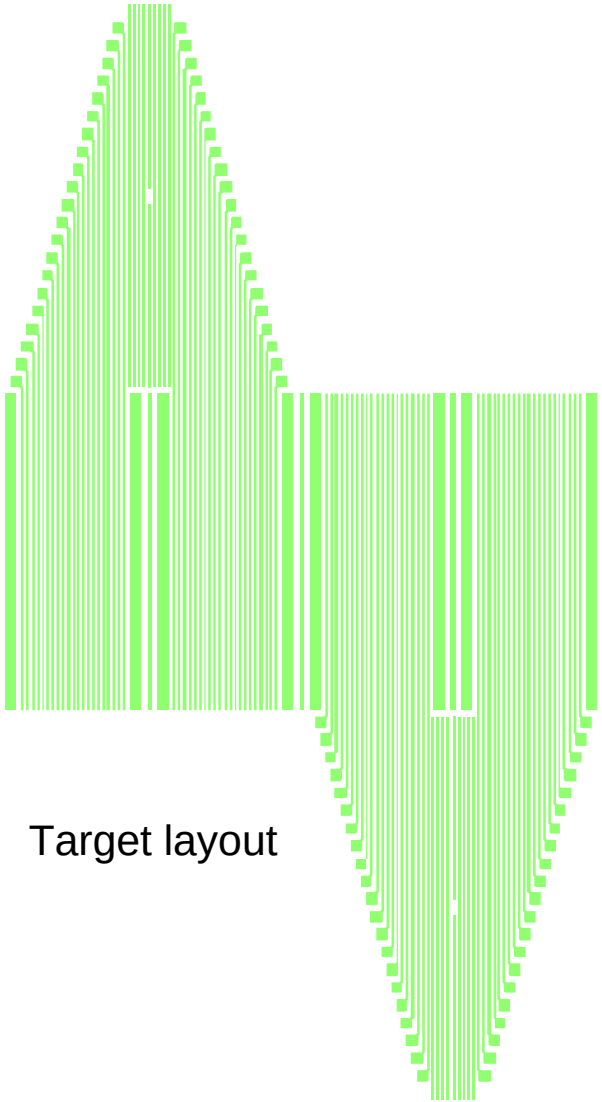


- ΔCD (CD error) = CD (Model B) – CD (Model A)
- Parameters of Model B are adjusted to minimize the sum of squares of ΔCD
  - Parameters relating to threshold, resist, defocus and lens pupil are adjusted
  - CD error after calibration is 0.7 nm RMS, 4.3 nm maximum.
  - Test patterns with resist line or space width < 30 nm are not used.
  - Test patterns having local minimum or maximum intensity within ±5% of dose-to-clear are not used.

Flow of the Numerical Experiment

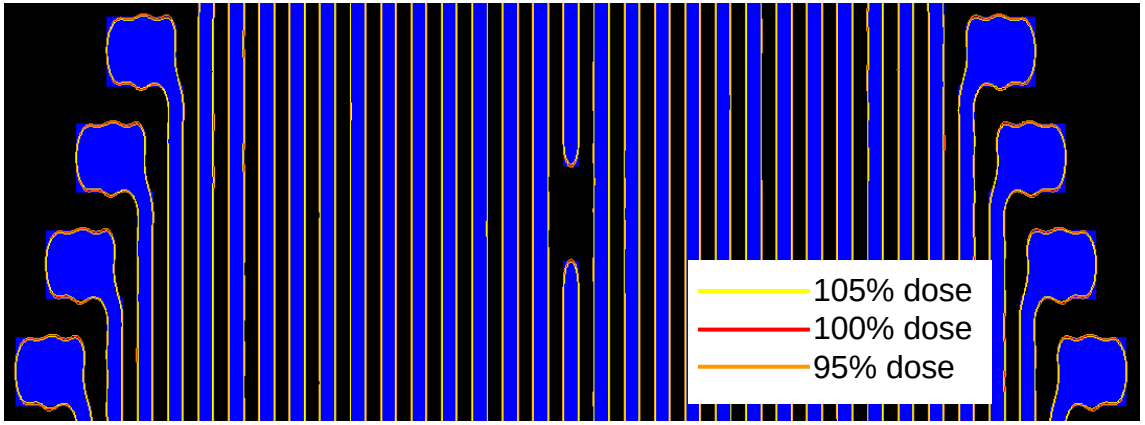


42 nm NAND Flash Layout

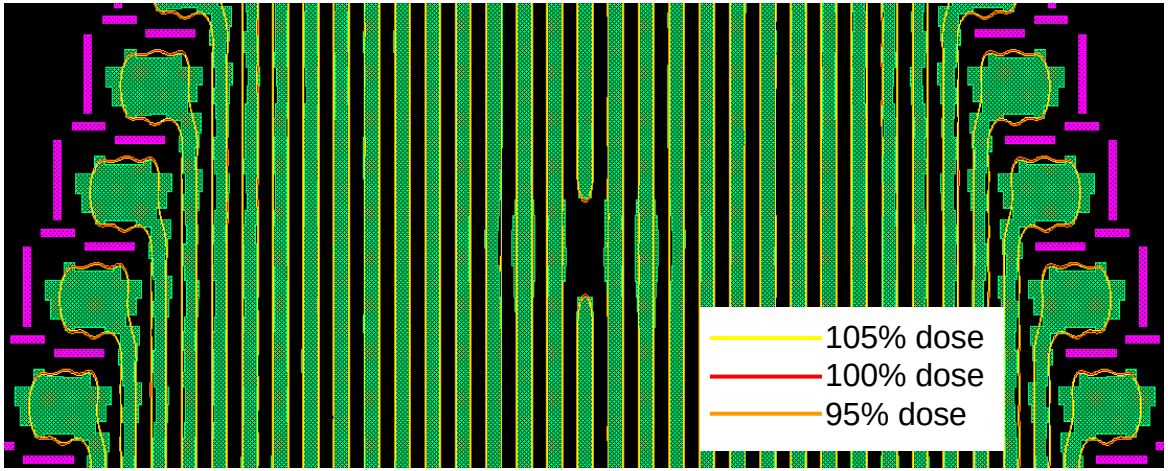


Target layout

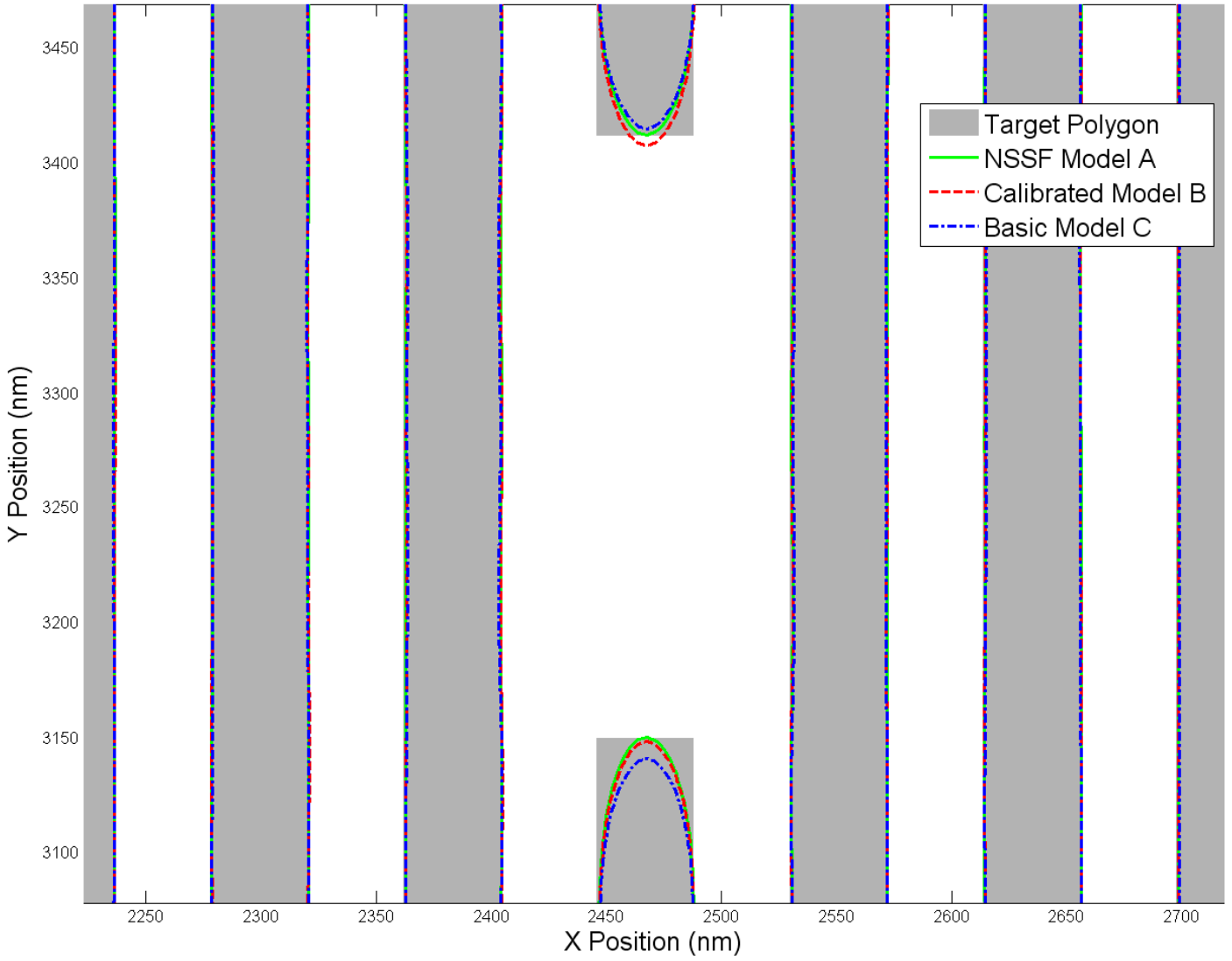
Target layout and simulated resist contours for Mask A



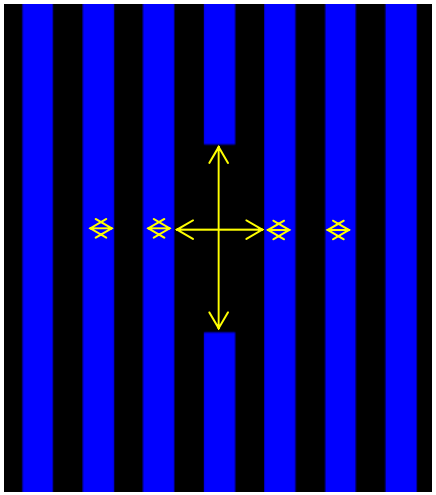
Mask A polygons and simulated resist contours using Model A

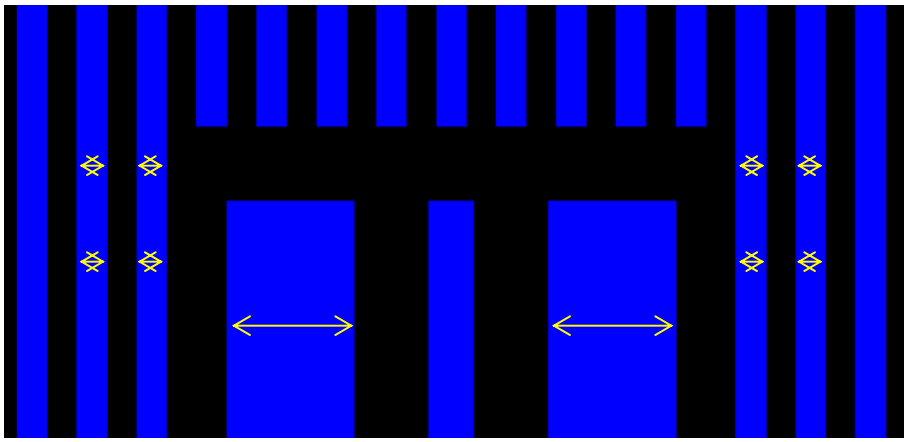


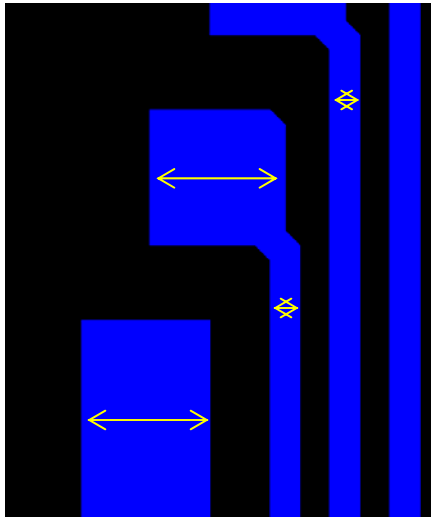
OPC Verification Contours

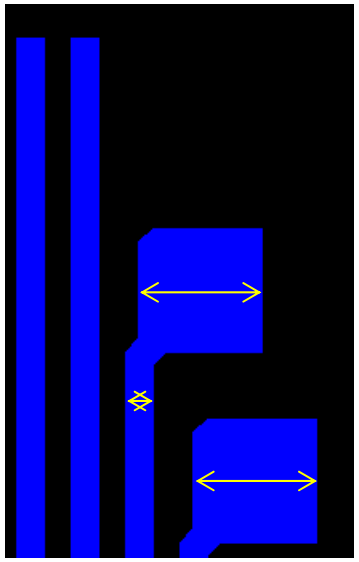


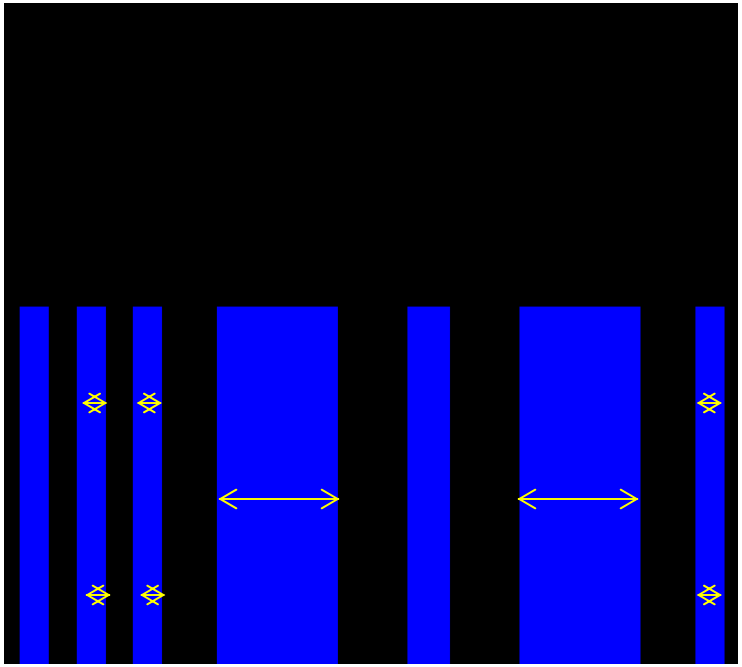
Critical Dimensions Selected for Monitoring OPC Accuracy











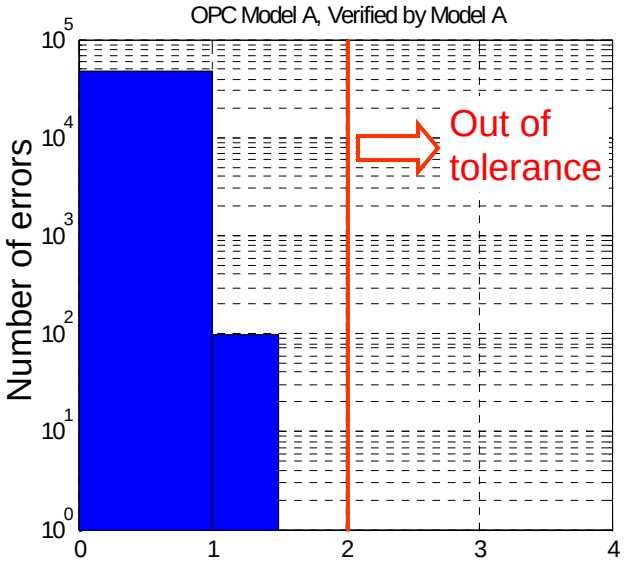
OPC Verification of Critical Dimensions

Mask:		A	B	C
Model used in OPC:		NSSF Model	Calibrated Model	Basic Model
Error source:		OPC Baseline	Incomplete Signature Characterization	No Signature Info
Edge Placement Error (EPE)	Min	-3.07	-4.65	-4.20
	Mean	-0.48	-0.53	-1.36
	Max	1.28	1.62	9.13
	RMSE	1.16	1.36	1.83
CD Error	Min	-1.88	-3.03	-6.68
	Mean	-0.97	-1.06	-2.71
	Max	0.36	1.29	11.91
	RMSE	0.69	1.17	2.80

RMSE: Root Mean Square Error

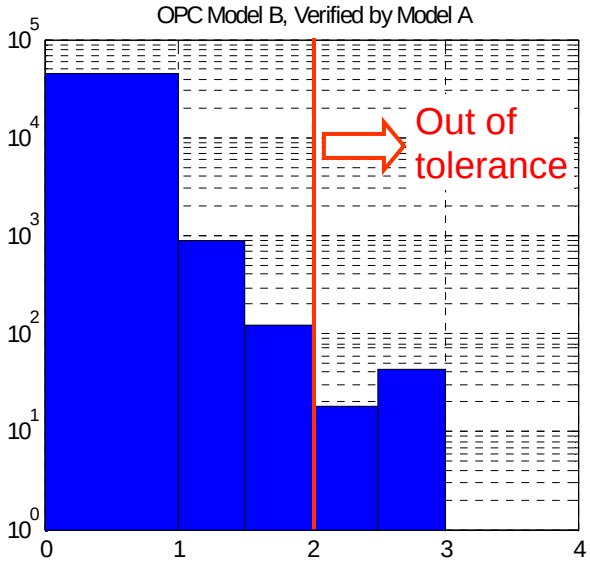
Edge-Placement Error Distribution on Long, Straight Edges

Mask A: OPC using NSSF Model



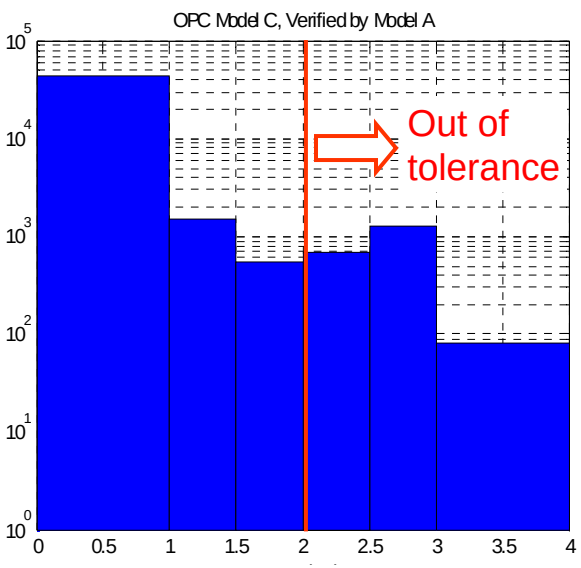
OPC Baseline Error

Mask B: OPC using Calibrated Model



Additional error due to incomplete characterization of the stepper signature by model calibration

Mask C: OPC using Basic Model



Additional error due to no stepper signature information

Conclusion

- The OPC model calibration shown here in model B only partially captures the stepper signature.
  - We see significant error reduction compared to no-signature modeling
  - There are still too many edge-placement errors.
- NSSF 1.5 reduces OPC error further.
  - NSSF 1.5 includes necessary vectorial aberration and polarization information.
  - CD errors are reduced.
  - 10× reduction in edge-placement errors greater than 1 nm.
- NSSF 1.5 enables the most accurate OPC.