

Litho**Vision** | 2009

Scanner-Dependent Optical Proximity Effects

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Motivations

- Leading-edge scanners explore unprecedented regimes of opto-mechanical complexity
 - Analysis of the scanner imaging must consider scanner signatures
- IC designs escalate the requirements for imaging models' accuracy
 - Model-based Optical Proximity Correction involves models embedding scanner signatures
- Nikon Scanner Signature Files, NSSFs, improve imaging models' accuracy
 - Used to setup scanner-based imaging models
- **Do optical models have to be customized to individual scanners?**
 - **What are the impact of scanner-specific signatures on imaging model accuracy?**

Scanner Signatures

Hyper-NA imaging models have to include scanner signatures

Laser

Illuminator

Projection Lens

Reticle and Wafer Stages

Spectral Bandwidth

Field Pattern

Polarization Pattern

Wave Front Aberrations

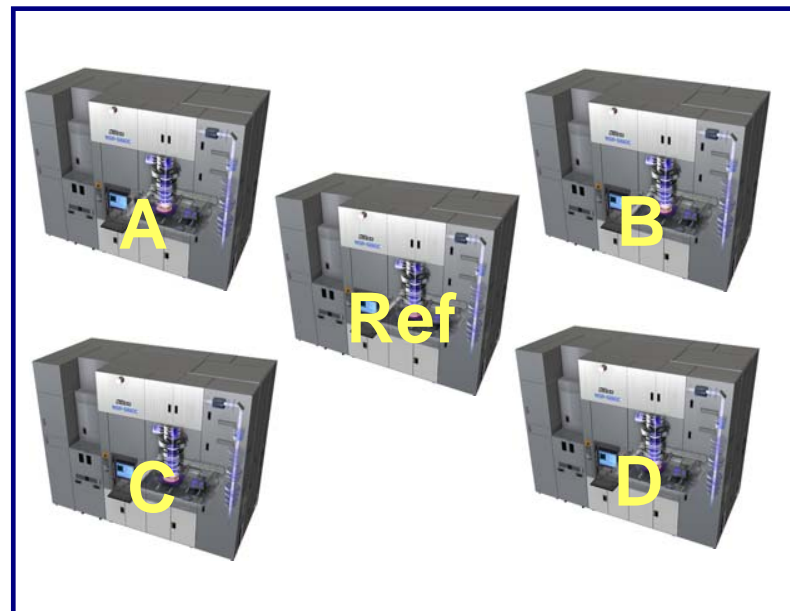
Chromatic Aberrations

Flare

Synchronization

Methodology

1. Five sets of scanner signatures prepared:
 - Ref representative of scanner type (NSSF 1.5)
 - A - D representative of four individual scanners (NSSF 2)



5. Comparison revealed imaging responses specific to each individual scanner

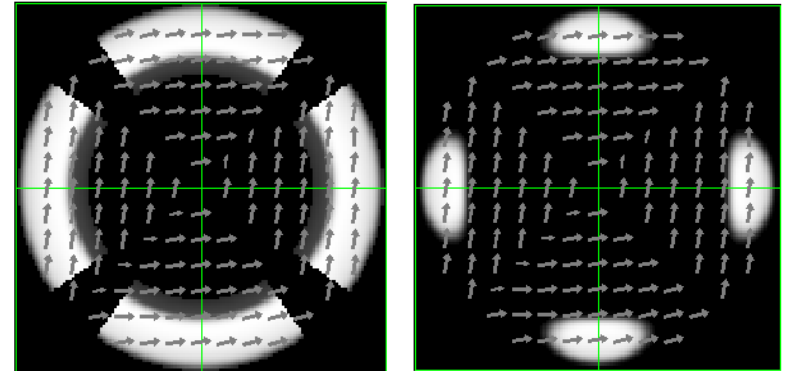
2. Five imaging models setup, each with one of the NSSFs

4. OPEs generated by models A - D compared to those of Ref model

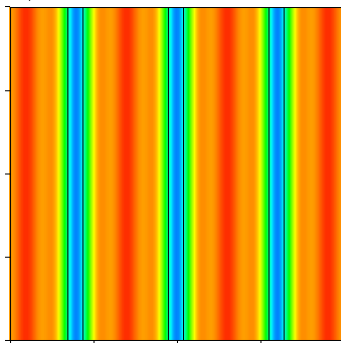
3. Each imaging model simulated three optical proximity effects

Simulation Setup

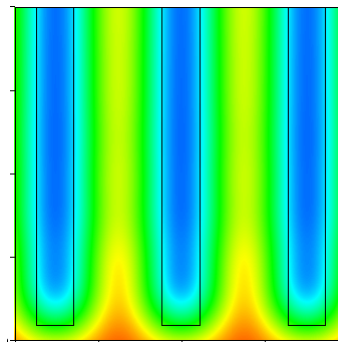
- NA = 1.3
- Two off-axis illuminators
- 6% transmitting, att PS mask
 - Mask line CD of 45 nm
- Imaging of:



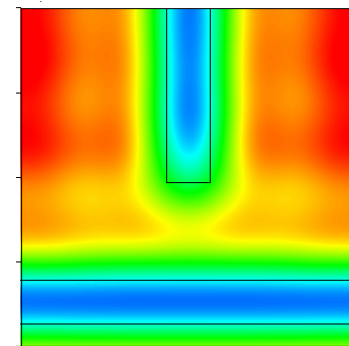
CD vs. pitch



Line end pullback

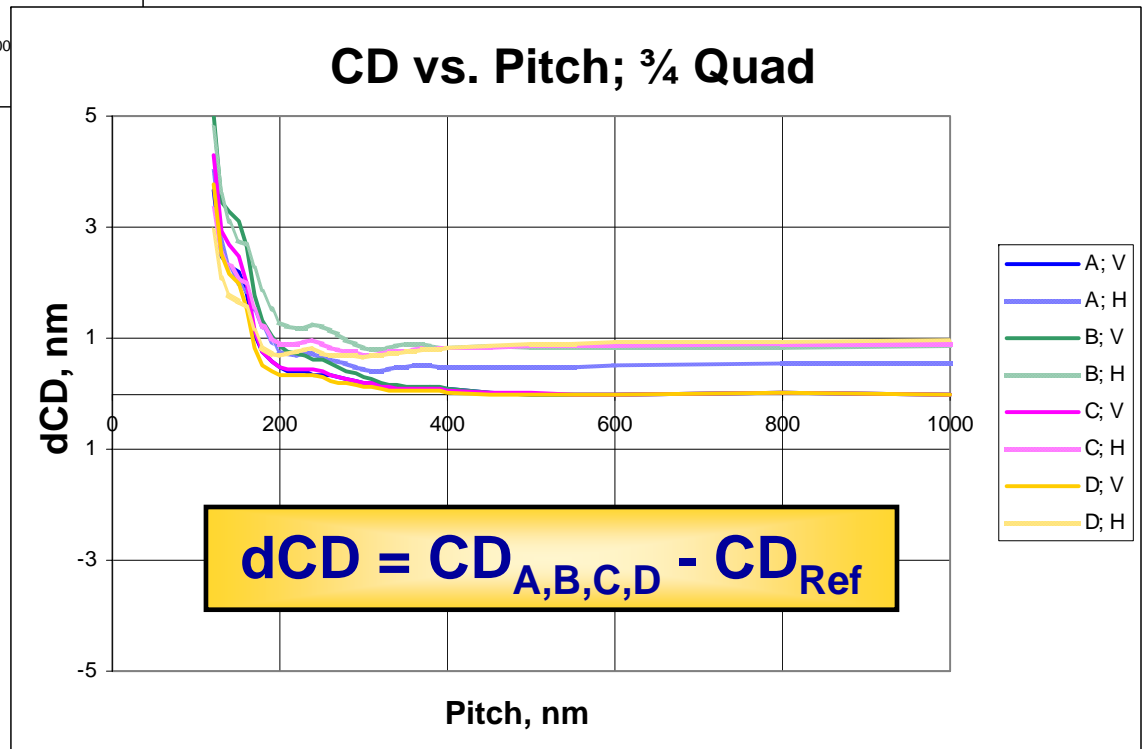
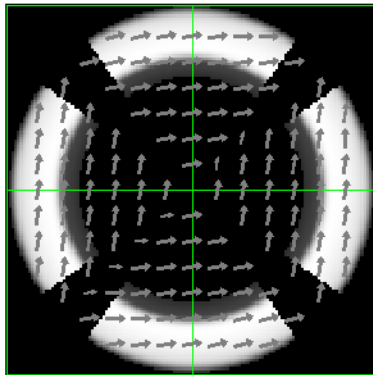
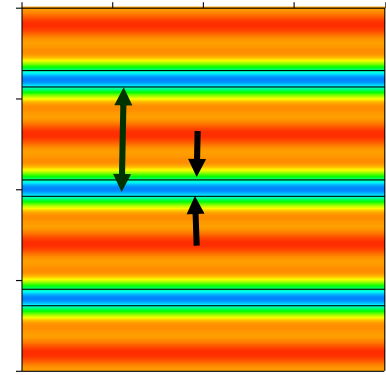
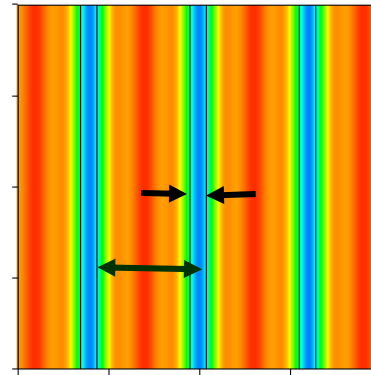
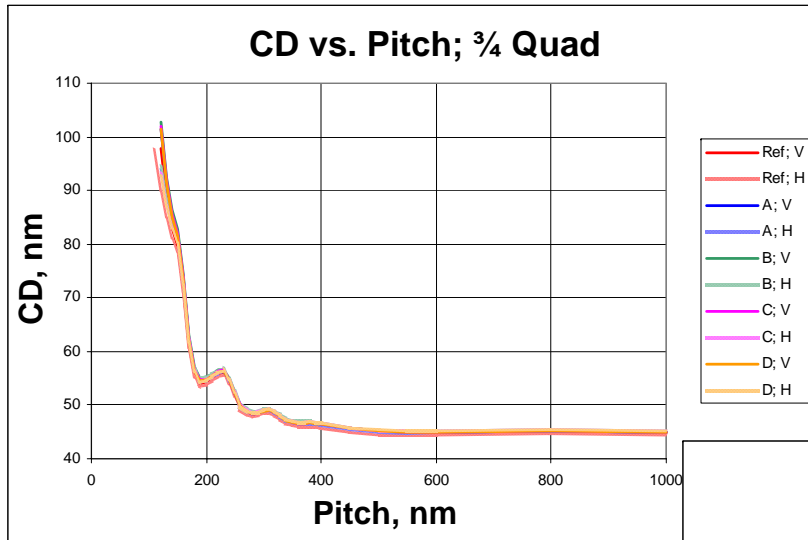


T-bar pullback

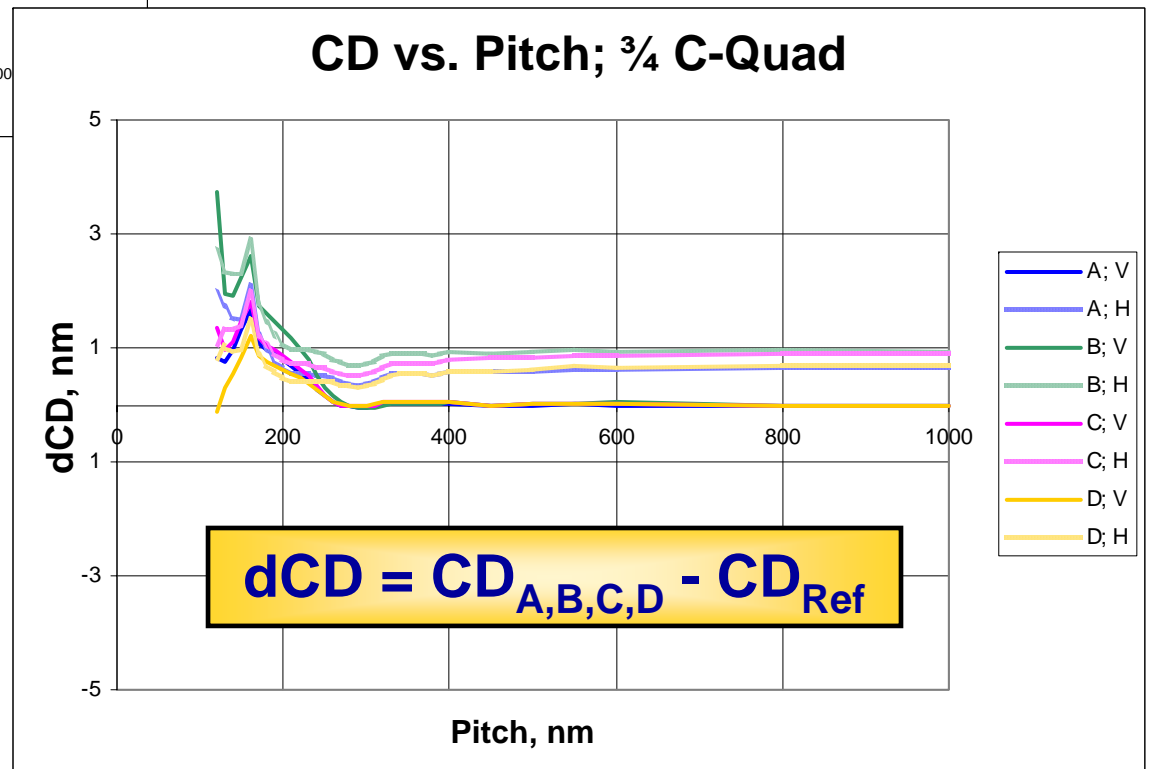
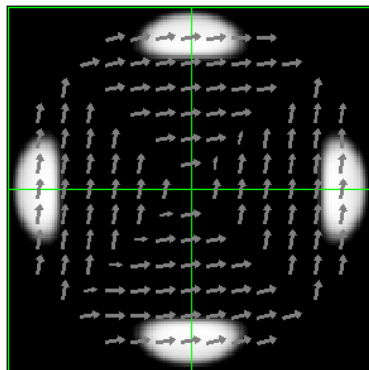
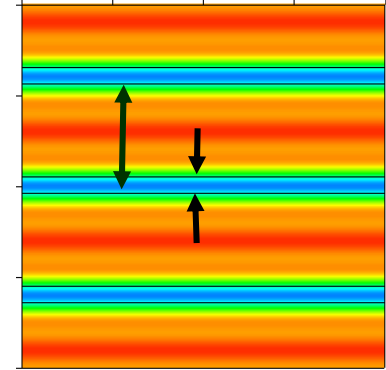
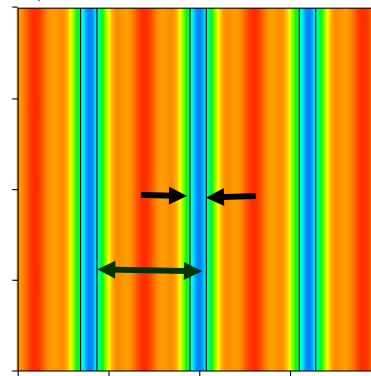
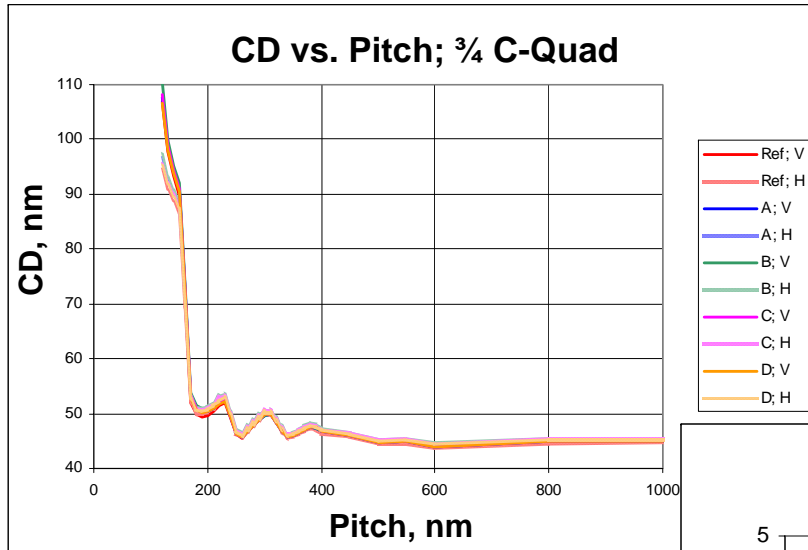


- All simulations anchored to deliver vertical line CD of 45 nm at pitch of 1 μm
- Analysis involved aerial images in the resist stack
 - BARC/Resist/TC

CD vs. Pitch; Quad Illumination

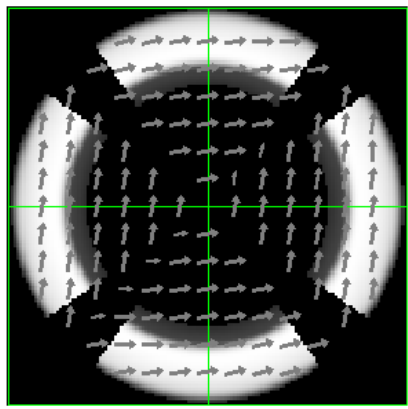
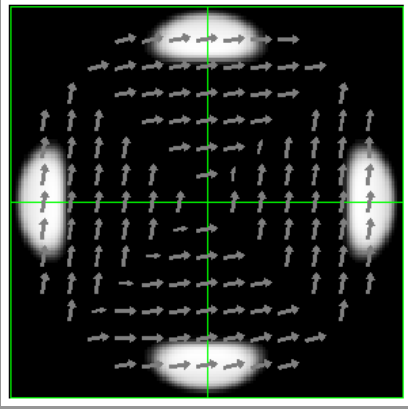


CD vs. Pitch; C-Quad Illumination



Scanner Specific CD vs. Pitch

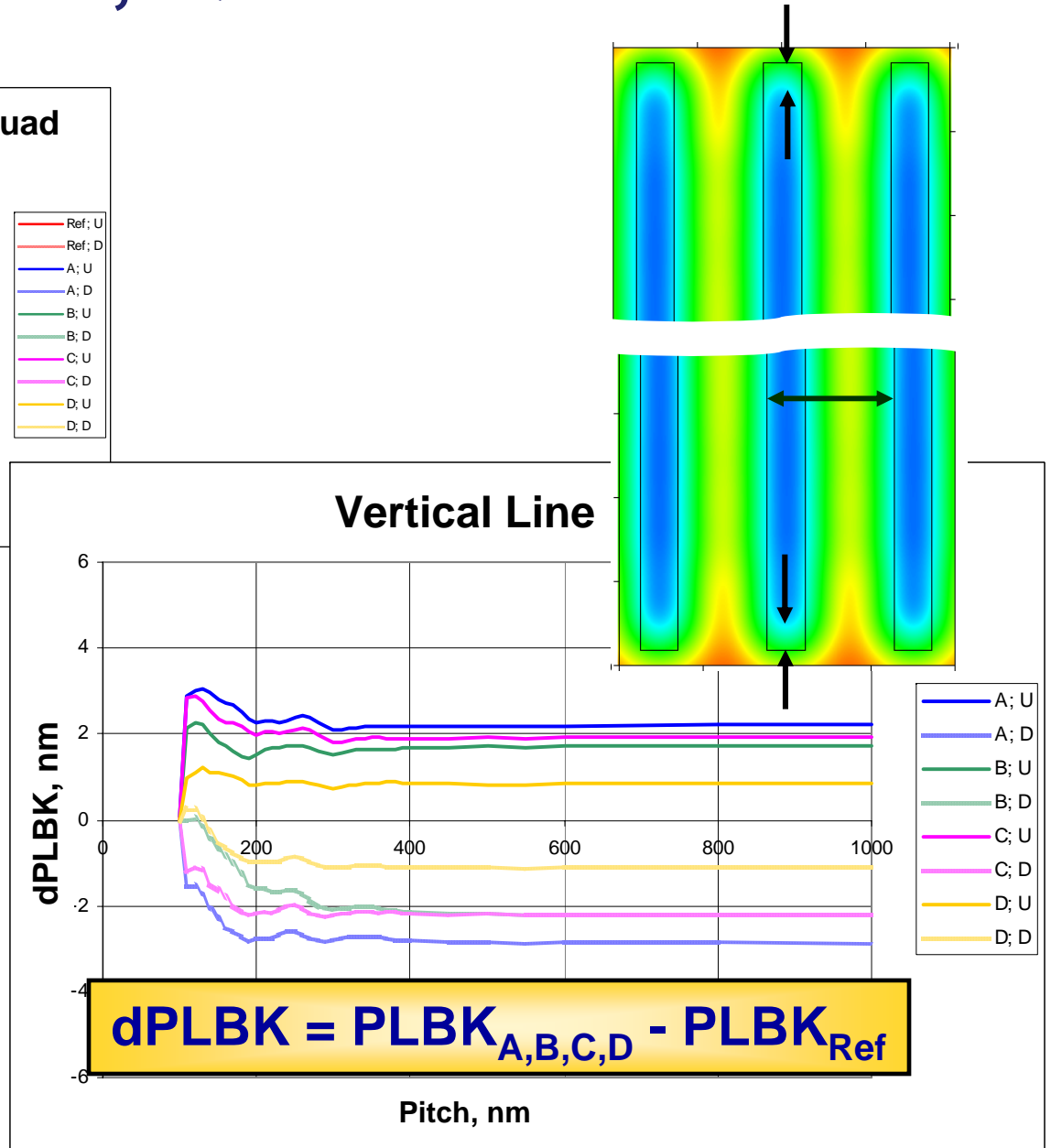
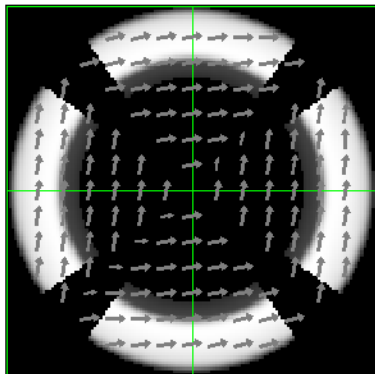
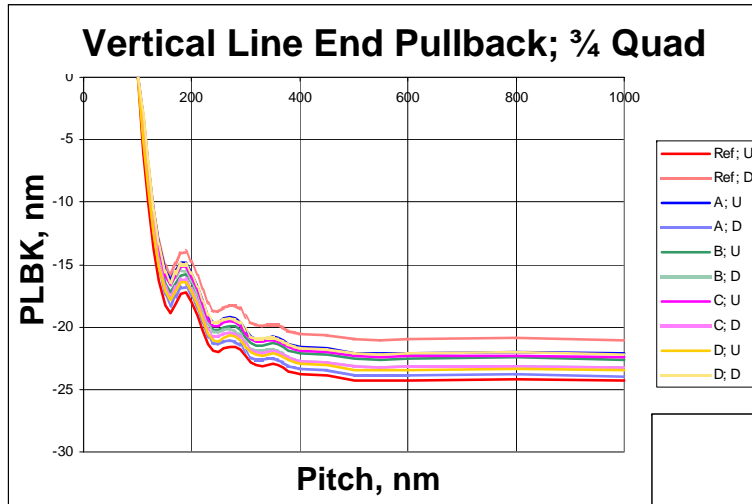
$dCD = CD_{A,B,C,D} - CD_{Ref}, \text{ nm}$

						
	Vertical	Horizontal	Ver/Hor	Vertical	Horizontal	Ver/Hor
Average*	0.6	1.1	0.9	0.4	0.8	0.6
Average at 1 μm **	0.5	1.1	0.4	0.4	0.9	0.4
Max*	5.1	4.8	5.1	3.7	2.9	3.7
Max at 1 μm **	0.0	1.0	1.0	0.0	1.0	1.0

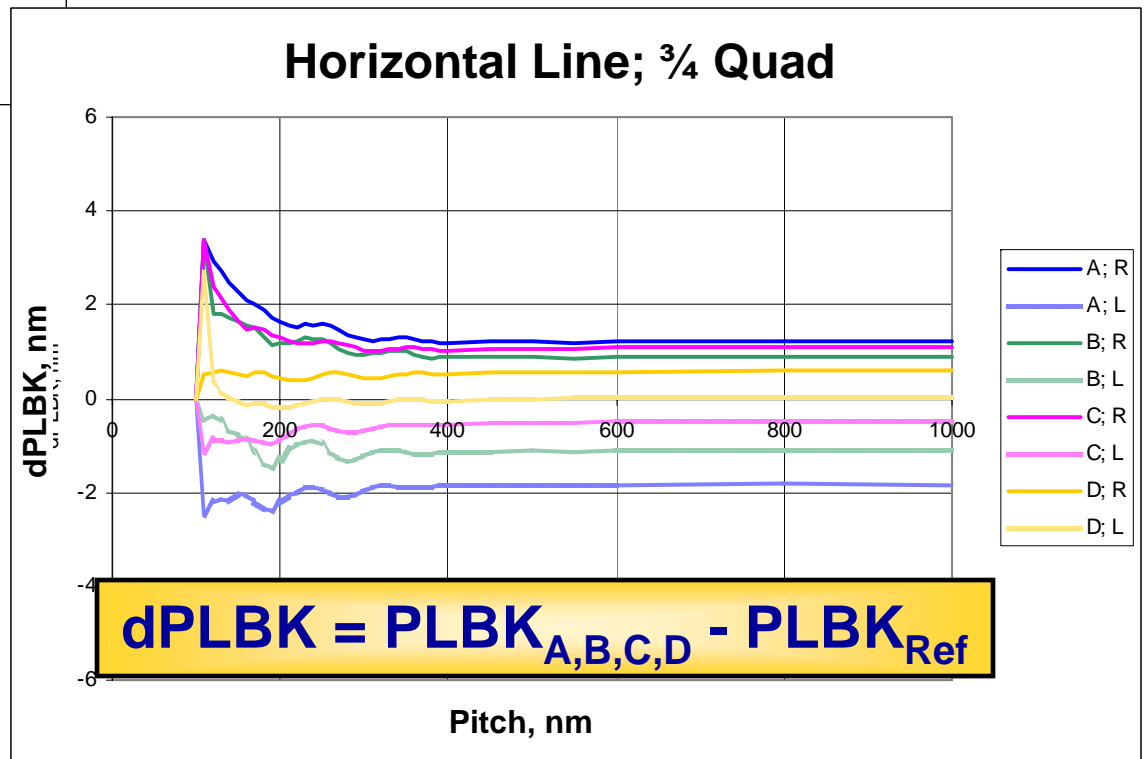
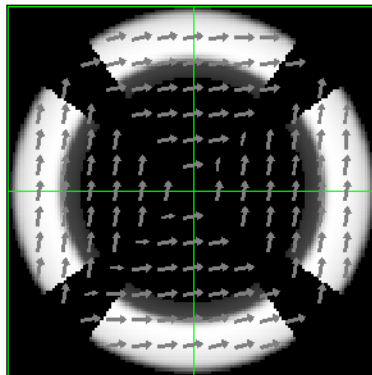
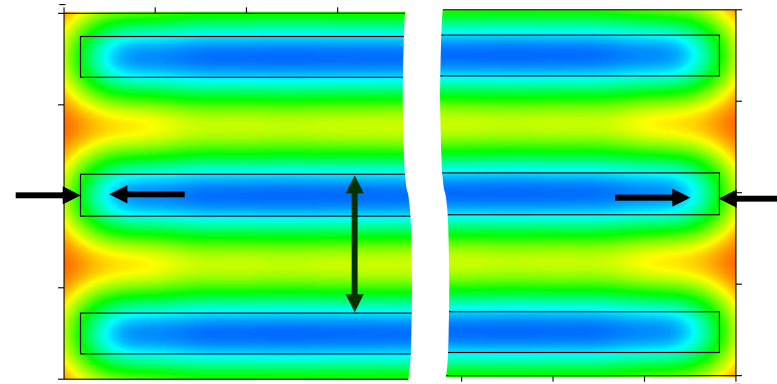
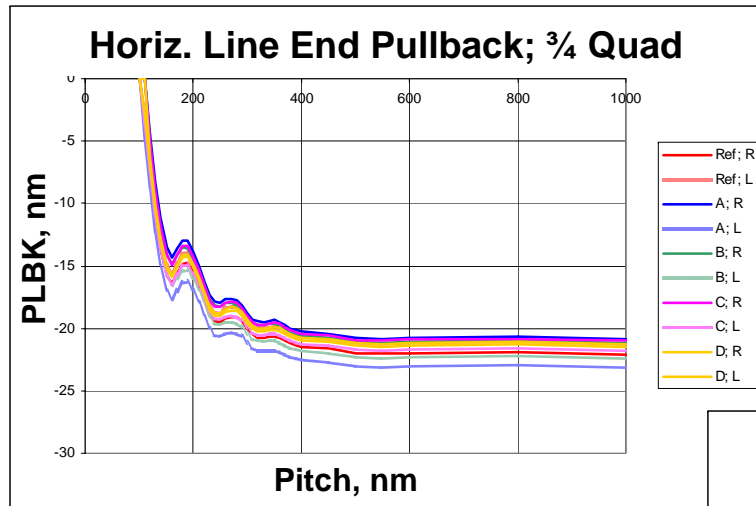
(*) – over the entire pitch range

(**) – at the pitch of 1 μm

Vertical Pullback; Quad Illumination

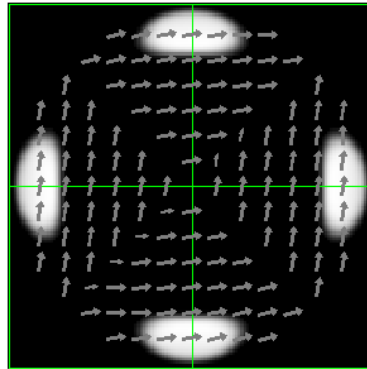


Horizontal Pullback; Quad Illumination

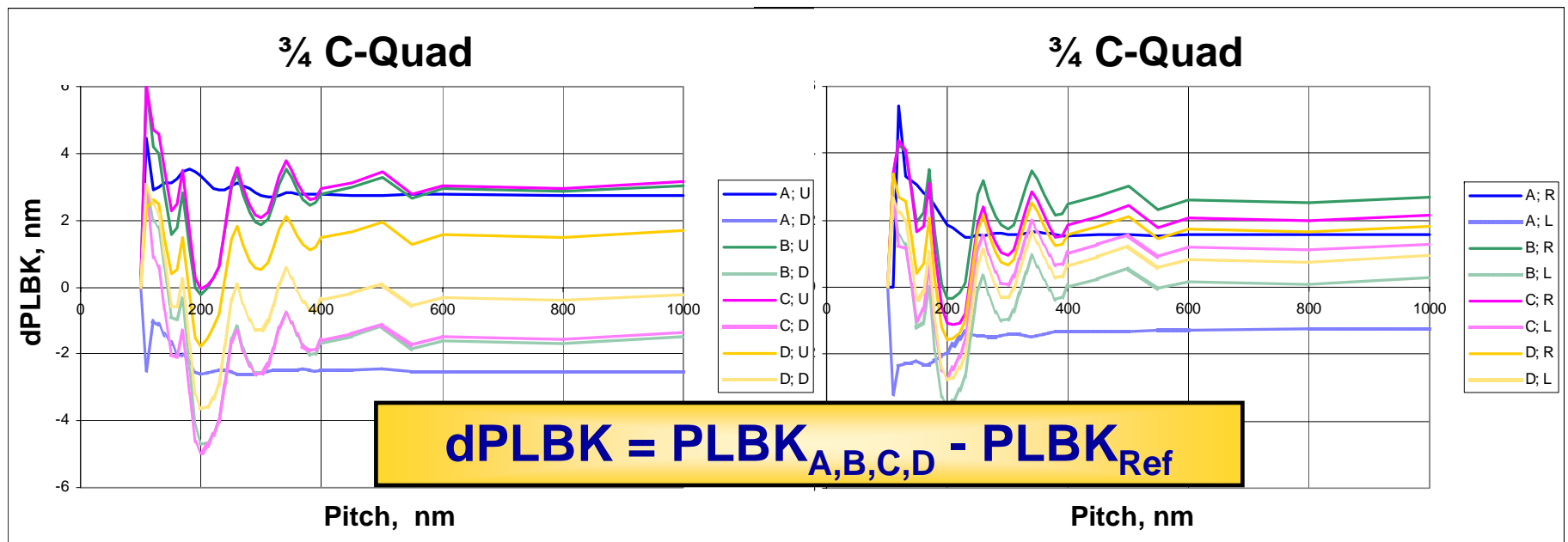


H/V Pullback; C-Quad Illumination

Vertical

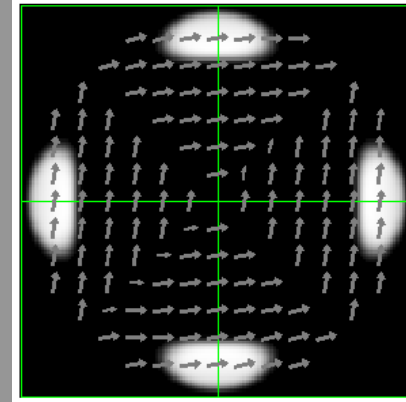
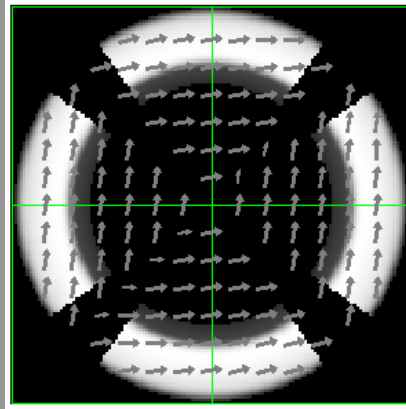


Horizontal



Scanner Specific Line End Pullback

$$dPLBK = PLBK_{A,B,C,D} - PLBK_{Ref}, \text{ nm}$$



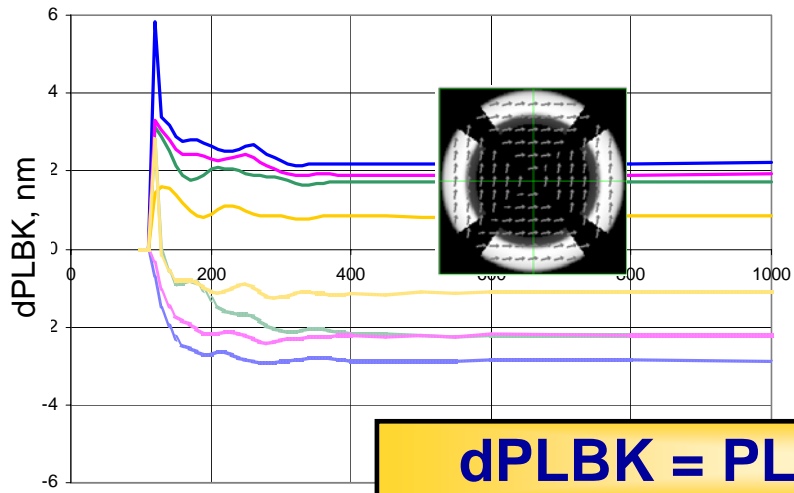
Vertical Lines	Up	Down	Up/Down	Up	Down	Up/Down
Average*	1.7	1.8	1.7	2.2	1.6	1.9
Average at 1 μm^{**}	1.7	2.1	1.9	2.6	1.5	2.0
Max*	3.1	2.9	3.1	6.1	5.0	6.1
Max at 1 μm^{**}	2.2	2.9	2.9	3.2	2.5	3.2
Horizontal Lines	Right	Left	Right/Left	Right	Left	Right/Left
Average*	1.1	0.9	1.0	1.7	0.4	1.0
Average at 1 μm^{**}	1.0	0.9	0.9	2.0	-0.2	0.9
Max*	3.4	2.5	3.4	5.4	3.6	5.4
Max at 1 μm^{**}	1.2	1.8	1.8	2.7	1.3	2.7

(*) – over the entire pitch range

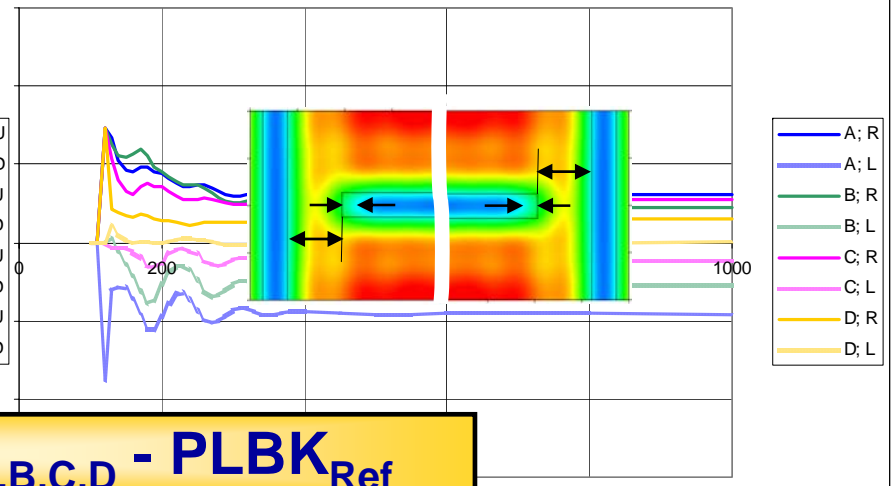
(**) – at the pitch of 1 μm

H/V T-Bar

Vertical T-Bar; 3/4 Quad

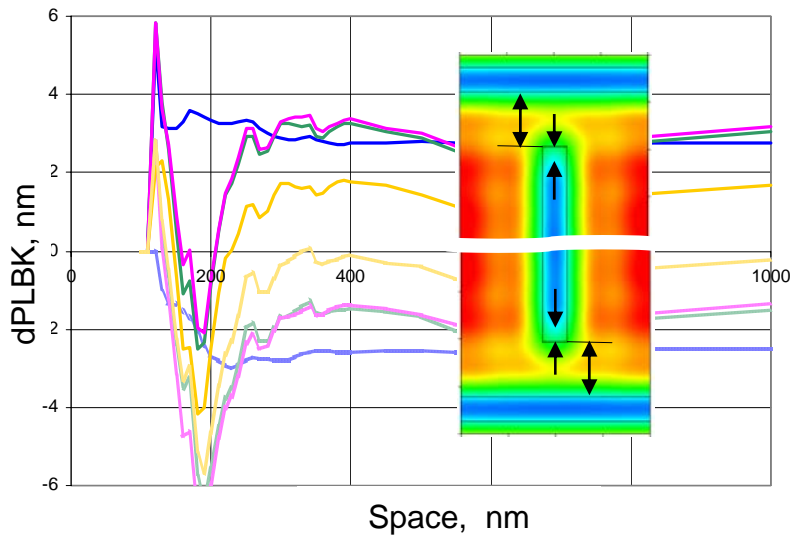


Horizontal T-Bar; 3/4 Quad

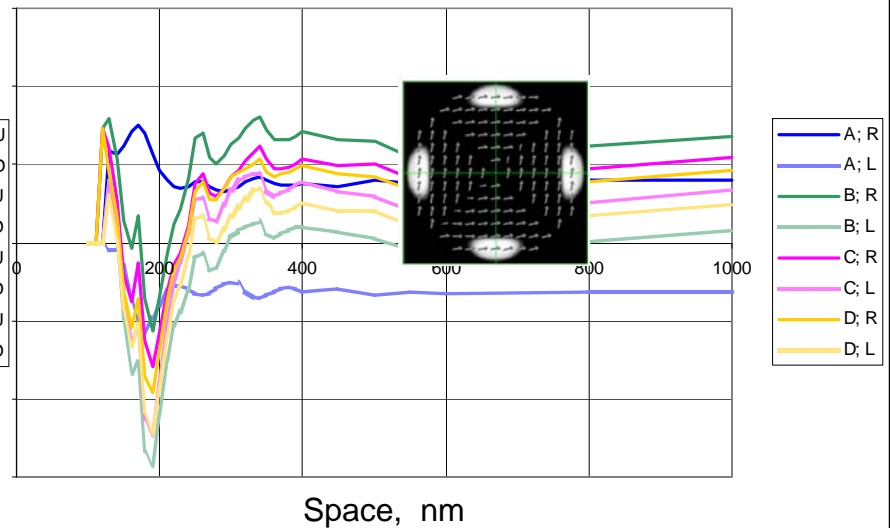


$$dPLBK = PLBK_{A,B,C,D} - PLBK_{Ref}$$

Vertical T-Bar; 3/4 C-Quad

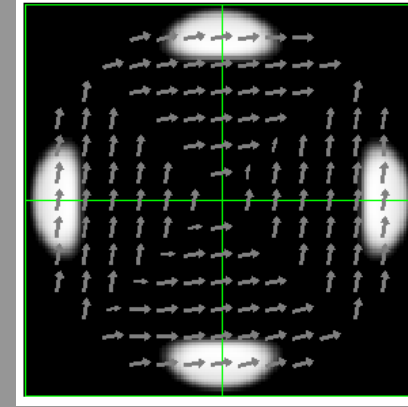
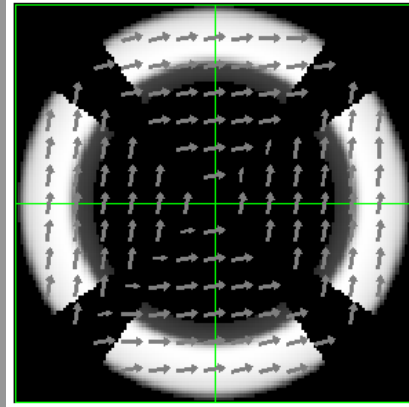


Horizontal T-Bar; 3/4 C-Quad



Scanner Specific T-Bar Pullback

$$dPLBK = PLBK_{A,B,C,D} - PLBK_{Ref}, \text{ nm}$$



Vertical Lines	Up	Down	Up/Down	Up	Down	Up/Down
Average*	1.8	1.7	1.8	1.9	1.9	1.9
Average at 1 μm **	1.7	2.1	1.9	2.6	1.5	2.0
Max*	5.8	2.9	5.8	5.8	7.2	7.2
Max at 1 μm **	2.2	2.9	2.9	3.2	2.5	3.2
Horizontal Lines	Right	Left	Right/Left	Right	Left	Right/Left
Average*	1.1	0.7	0.9	1.2	0.5	0.9
Average at 1 μm **	1.0	0.9	0.9	2.0	-0.2	0.9
Max*	2.9	3.5	3.5	3.2	5.7	5.7
Max at 1 μm **	1.2	1.8	1.8	2.7	1.3	2.7

(*) – over the space range

(**) – at the space of 1 μm

Conclusions

- At 45 nm HP and beyond, realistic scanner-based imaging models are required
- Through most of the performance range, predictions of average scanner-based and individual scanner-based models differ by 1 to 2 nm
- Near the scanner's resolution limit, accuracy of the imaging model is affected by the individual scanner signature
- For imaging of aggressive patterns with highly coherent illuminators, signatures of *individual scanners* should be considered in OPC tolerancing