Impact of 3-D Mask Effects on CD and Overlay over Image Field in Extreme Ultraviolet Lithography

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qimonda

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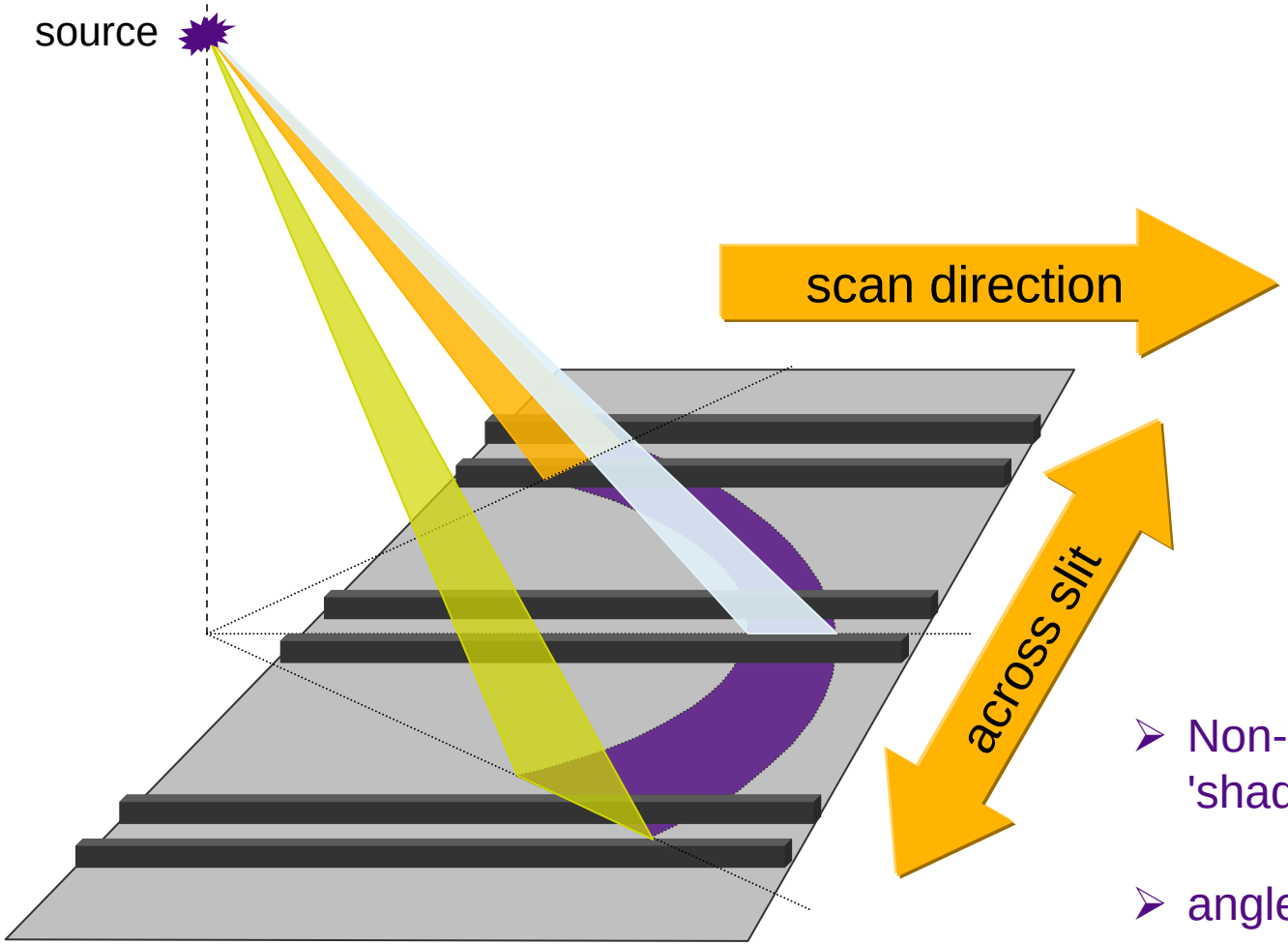
Outline

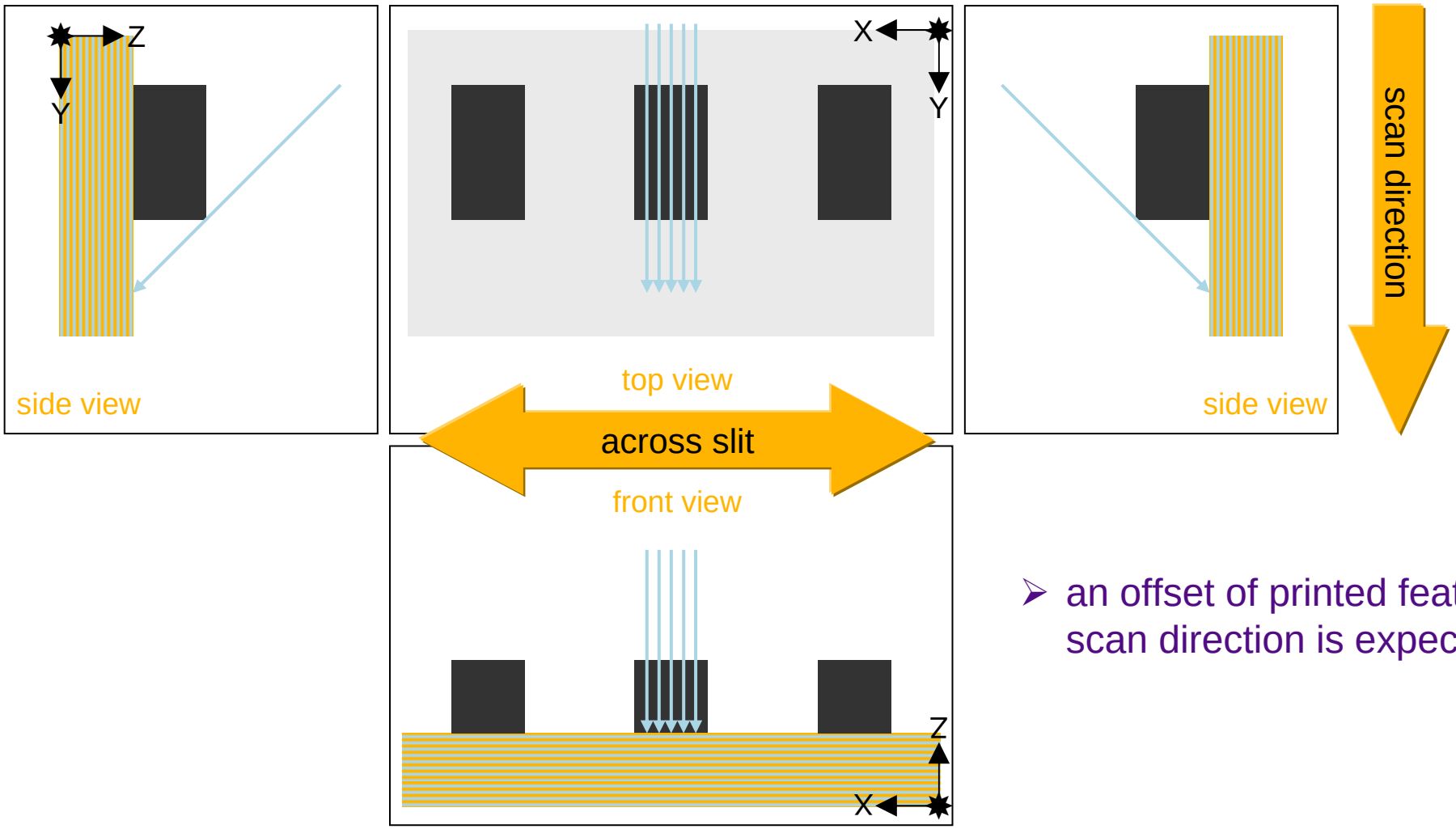
- shadowing – root causes and effects
- ITRS: requirements on CD-control and Overlay
- simulation results (angle variations across slit)
- one possible way to minimize shadowing effects
- summary

'shadowing' effect – root cause



- Non-telecentricity on reticle causes 'shadowing effect'
- angle of incidence (with respect to scan-direction) varies across the illumination slit

'shadowing' effect – root cause



- an offset of printed features in scan direction is expected

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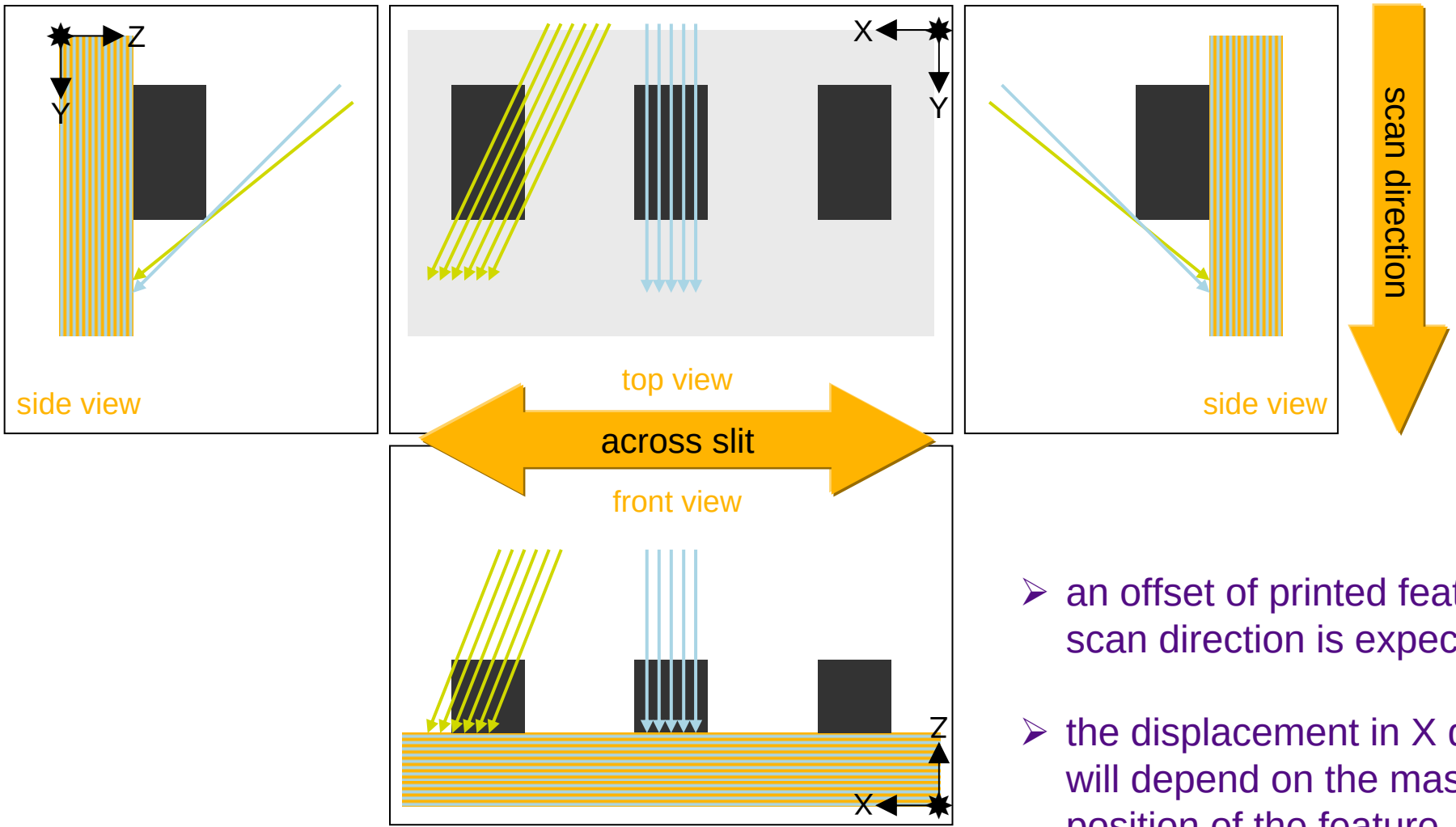
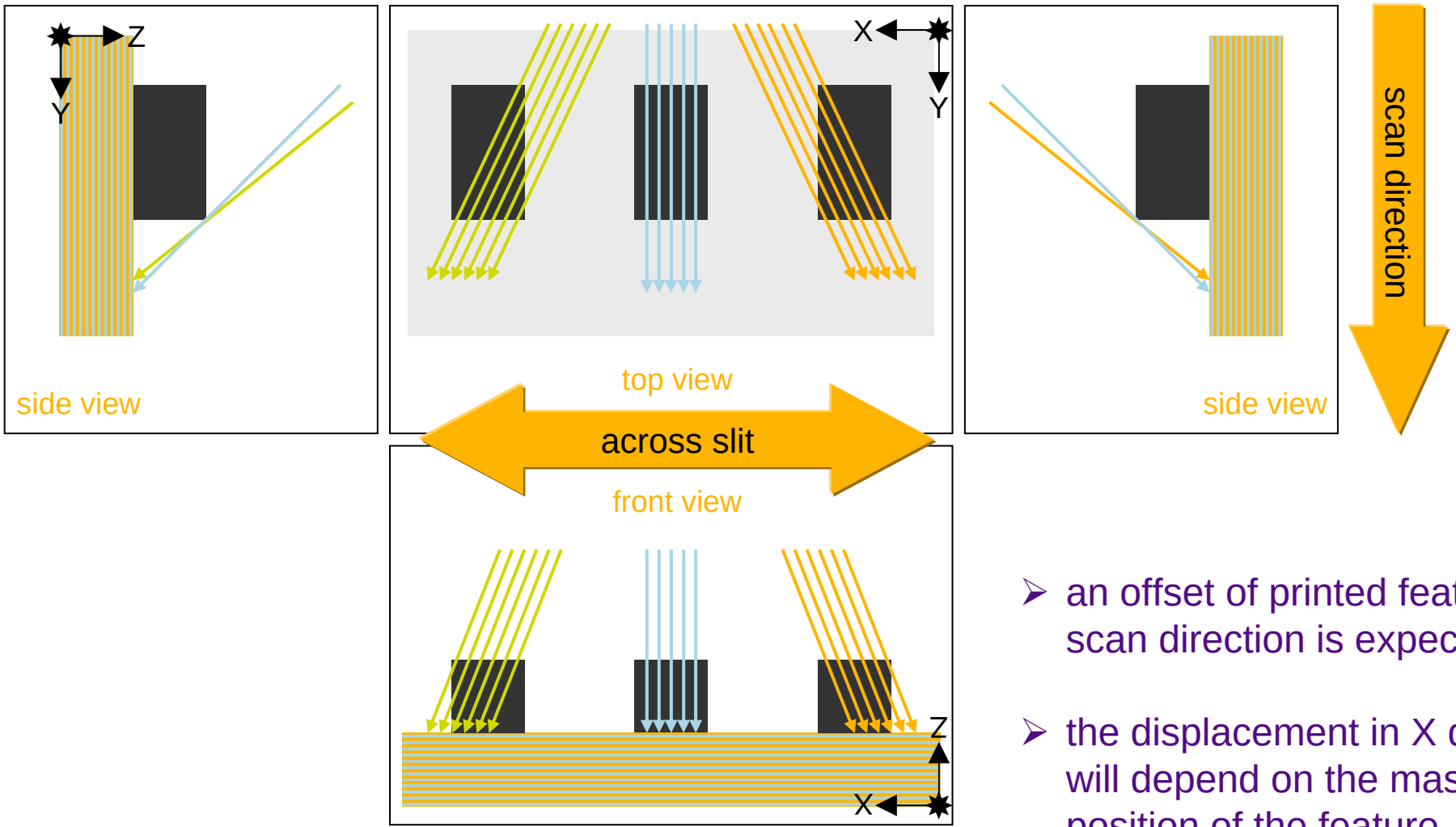


- an offset of printed features in scan direction is expected
- the displacement in X direction will depend on the mask-position of the feature

'shadowing' effect – root cause



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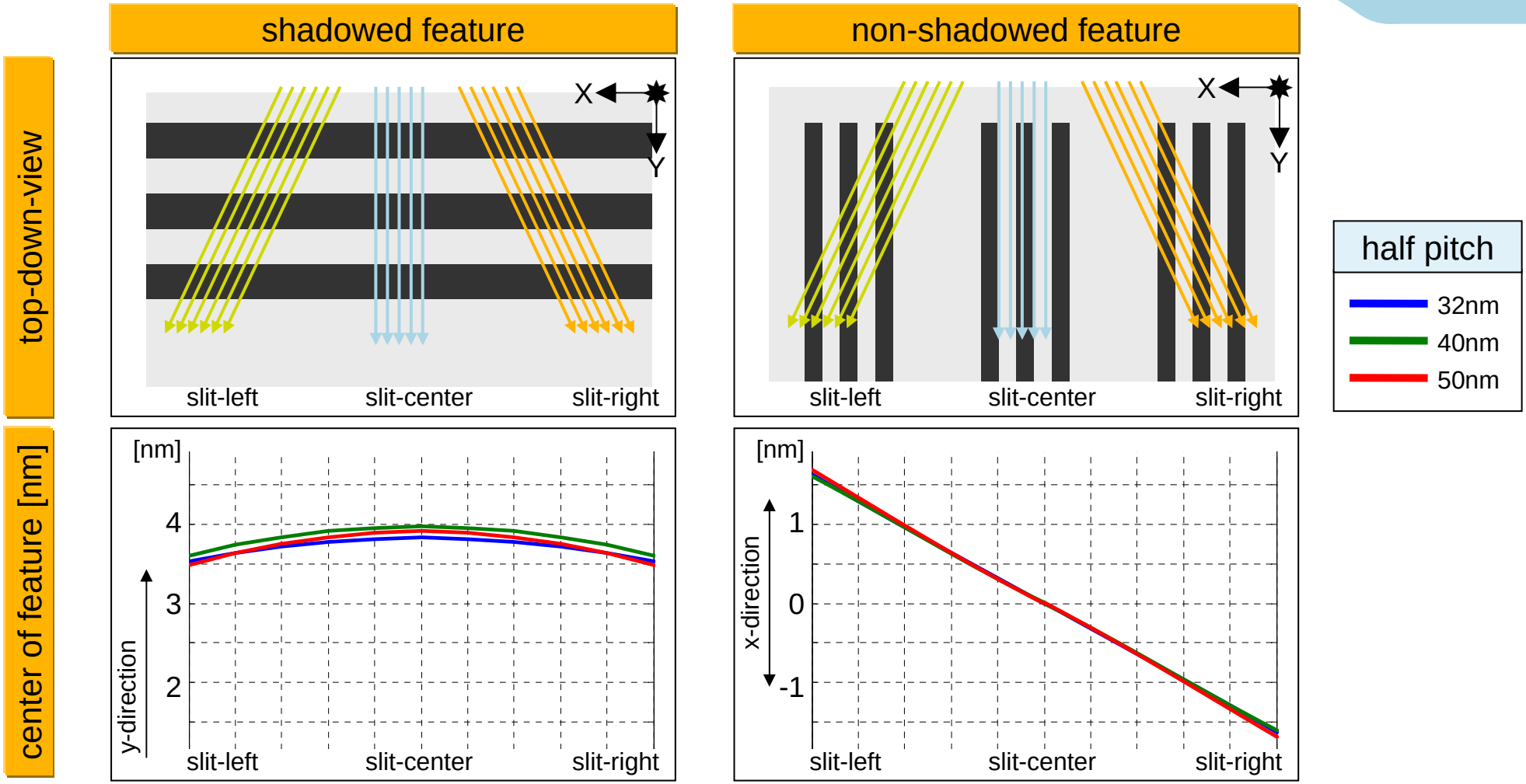
Feature displacement across slit at best dose and focus



ITRS Roadmap (2005)

Year of Production		2009	2010	2011	2012	2013
DRAM ½ pitch (contacted)	*(nm)*	50	45	40	36	32
Flash ½ pitch (un-contacted poly)	*(nm)*	45	40	36	32	28
Contact in resist	*(nm)*	56	50	44	39	35
Contact after etch	*(nm)*	51	45	40	36	32
Overlay (3 sigma)	*(nm)*	9	8	7.1	6.4	5.7
CD control (3 sigma)	*(nm)*	5.3	4.7	4.2	3.7	3.3

Overlay (nm) — Overlay is a vector component (in X and Y directions) quantity defined at every point on the wafer. It is the difference, O, between the vector position, P1, of a substrate geometry, and the vector position of the corresponding point, P2, in an overlaying pattern, which may consist of resist. O=P1-P2. The difference, O, is expressed in terms of vector components in the X and Y directions, and the value shown is three times the standard deviation of overlay values on the wafer.

CD control (nm) — Control of critical dimensions compared to mean line width target at all pattern pitch values, including errors from all lithographic sources (due to masks, imperfect optical proximity correction, exposure tools, and resist) at all spatial length scales (e.g., includes errors across exposure field, across wafer, between wafers and between wafer lots)

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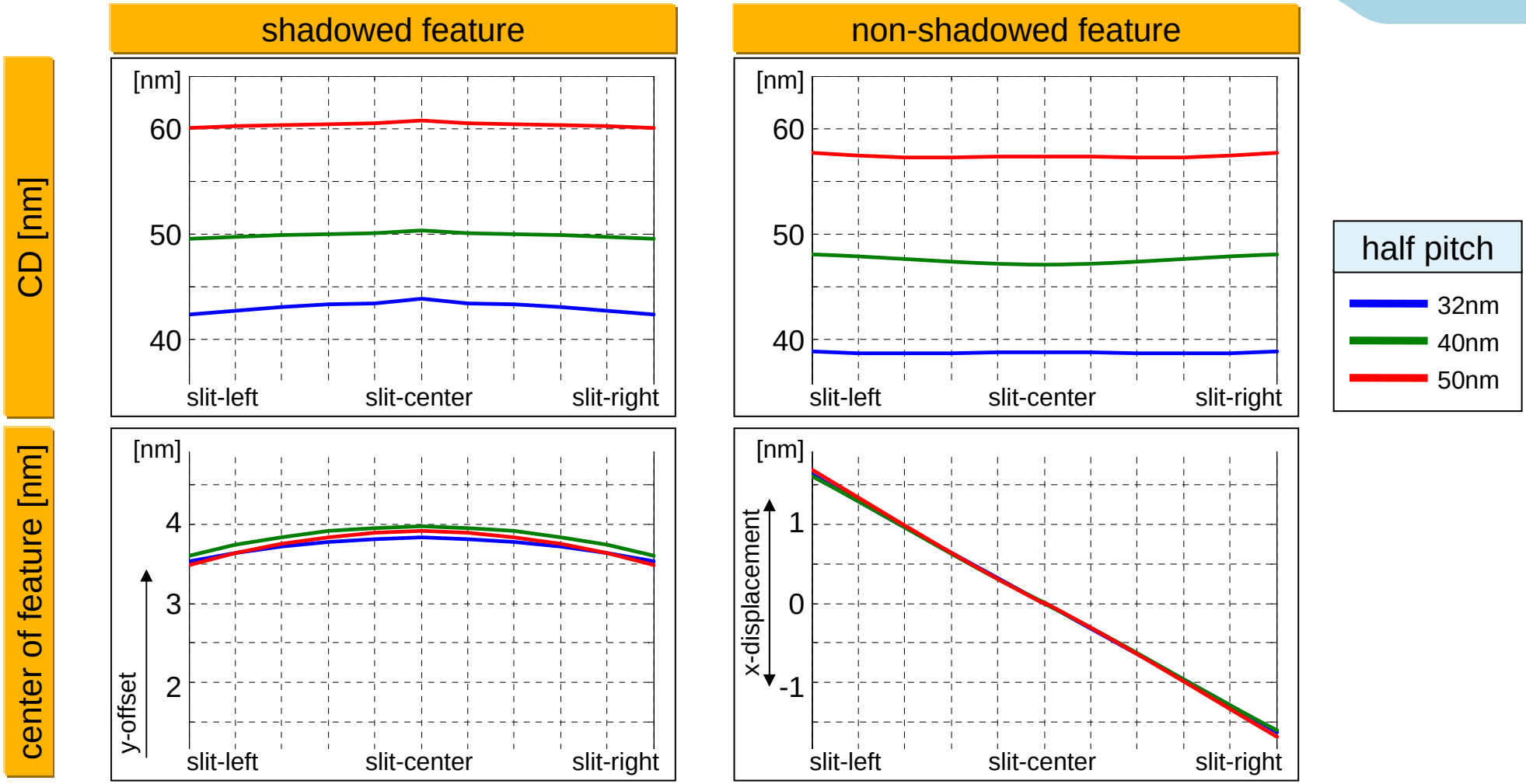
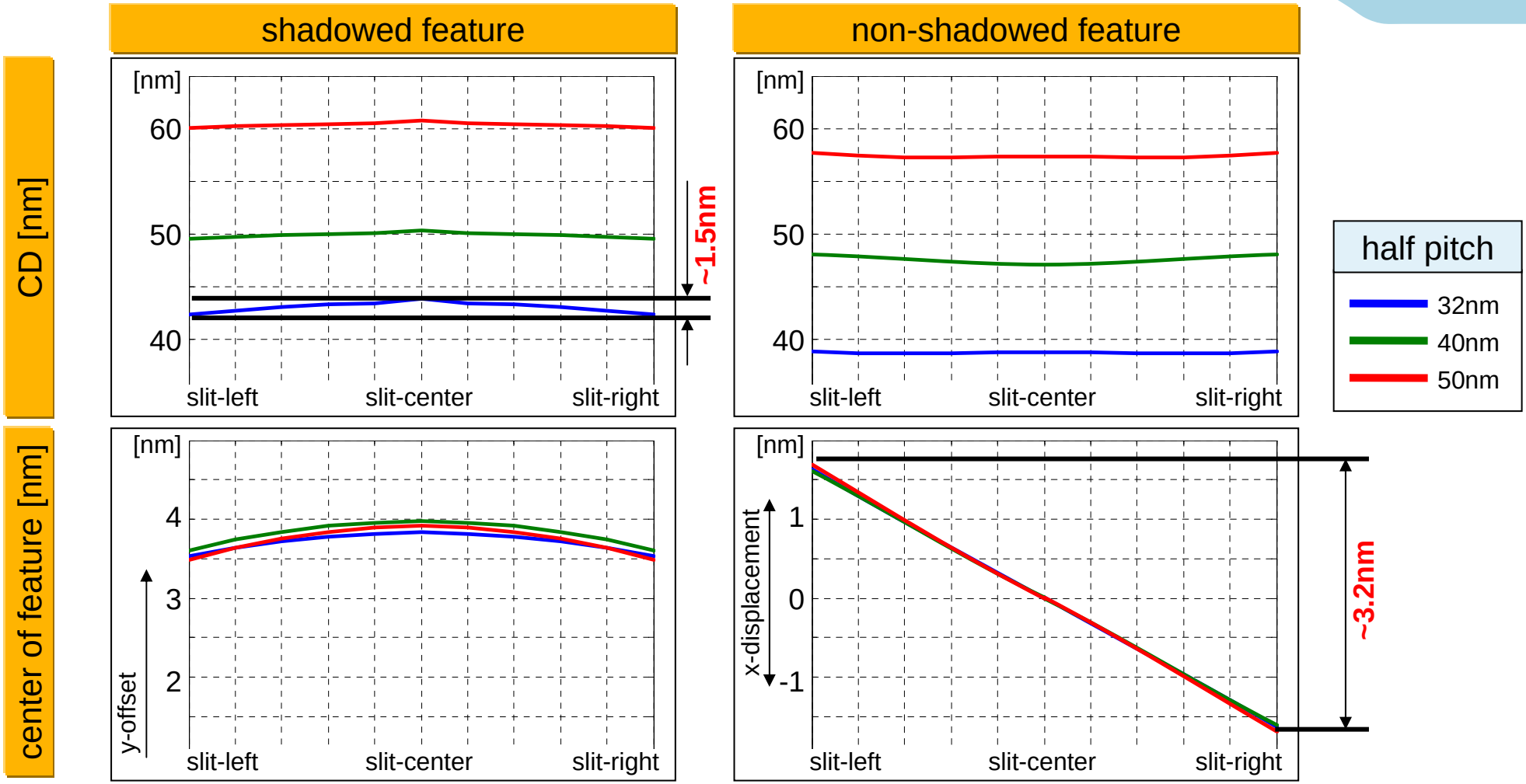
CD-variation and feature displacement across slit at best dose and focus



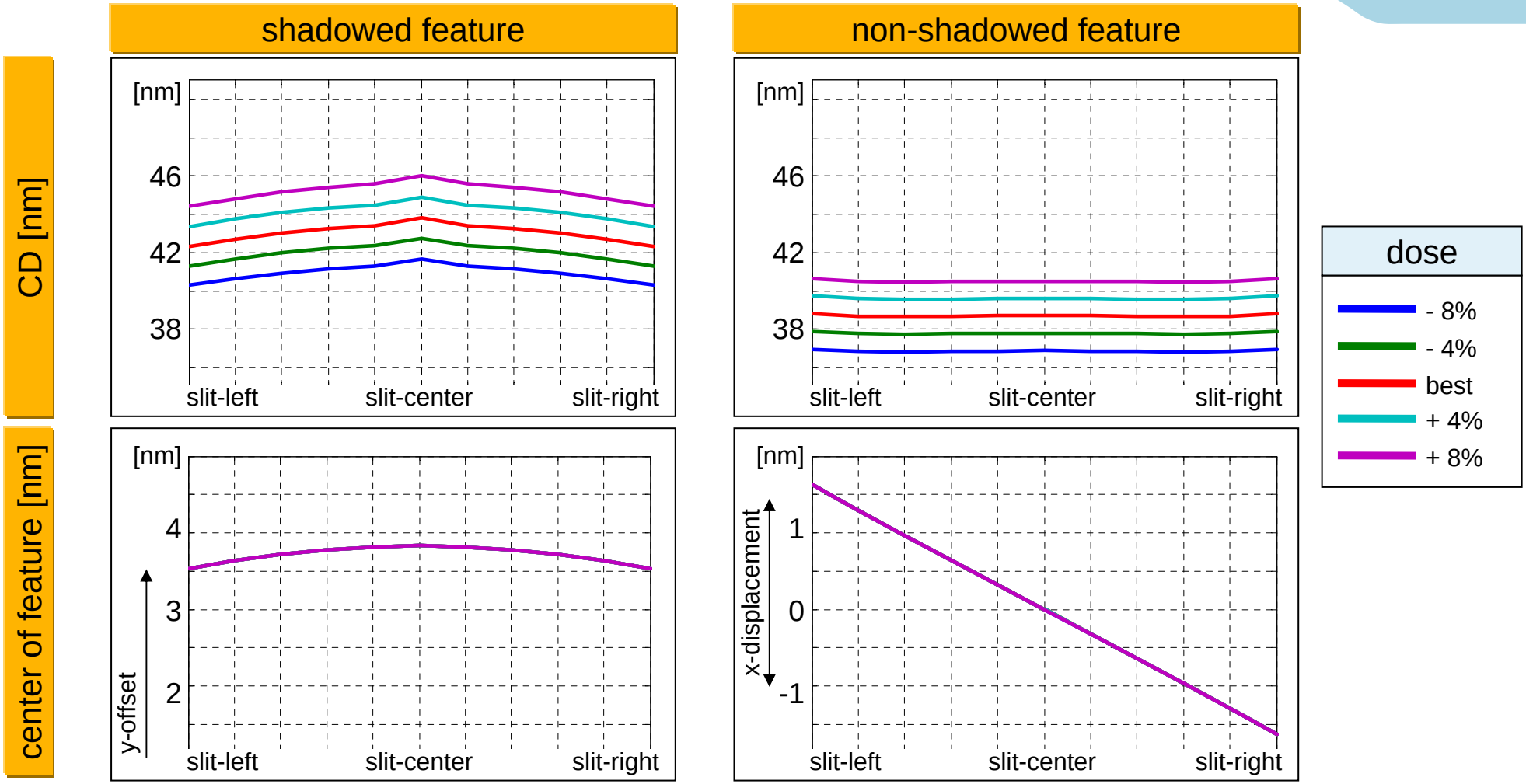
(absorber thickness = 70nm, dense L/S, data out of aerial image simulations, NA=0.25, σ=0.5, dose-to-size with +7nm offset for dark feature)

CD-variation and feature displacement across slit at best dose and focus



➔ 45% of the total CD control (32nm node) and 56% of total Overlay budget (32nm node) lost due to different illumination angles

CD-variation and feature displacement for 32nm node over dose



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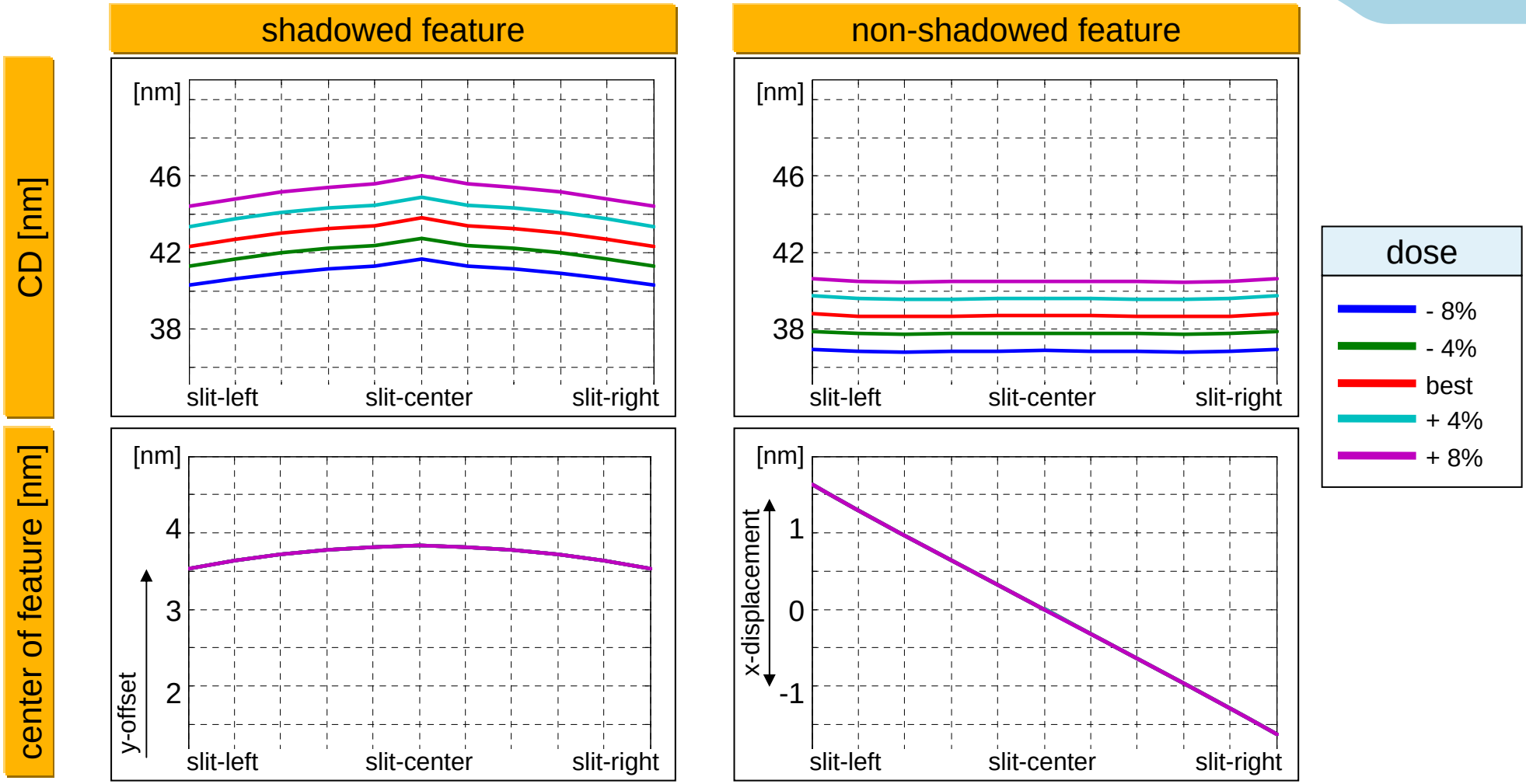
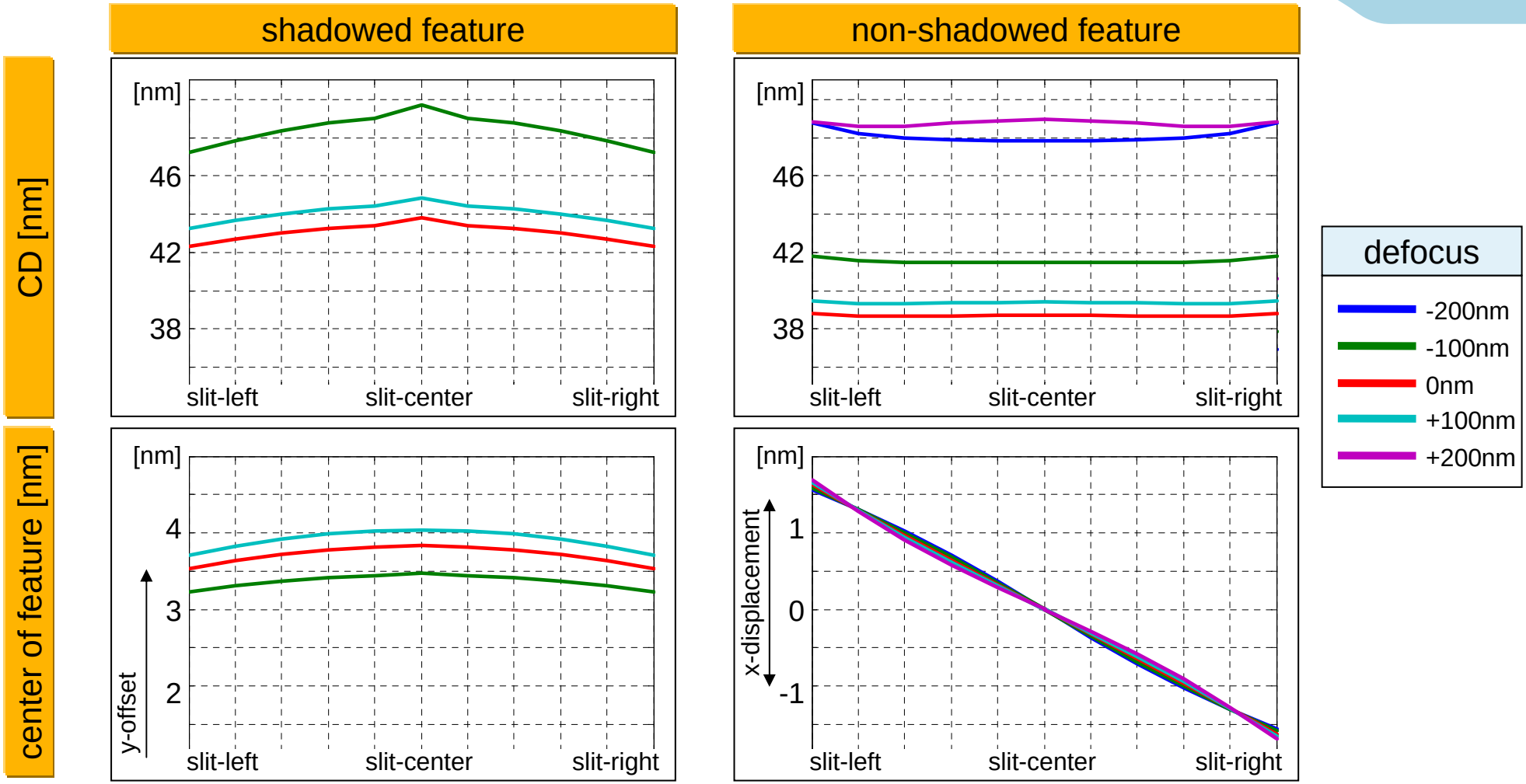
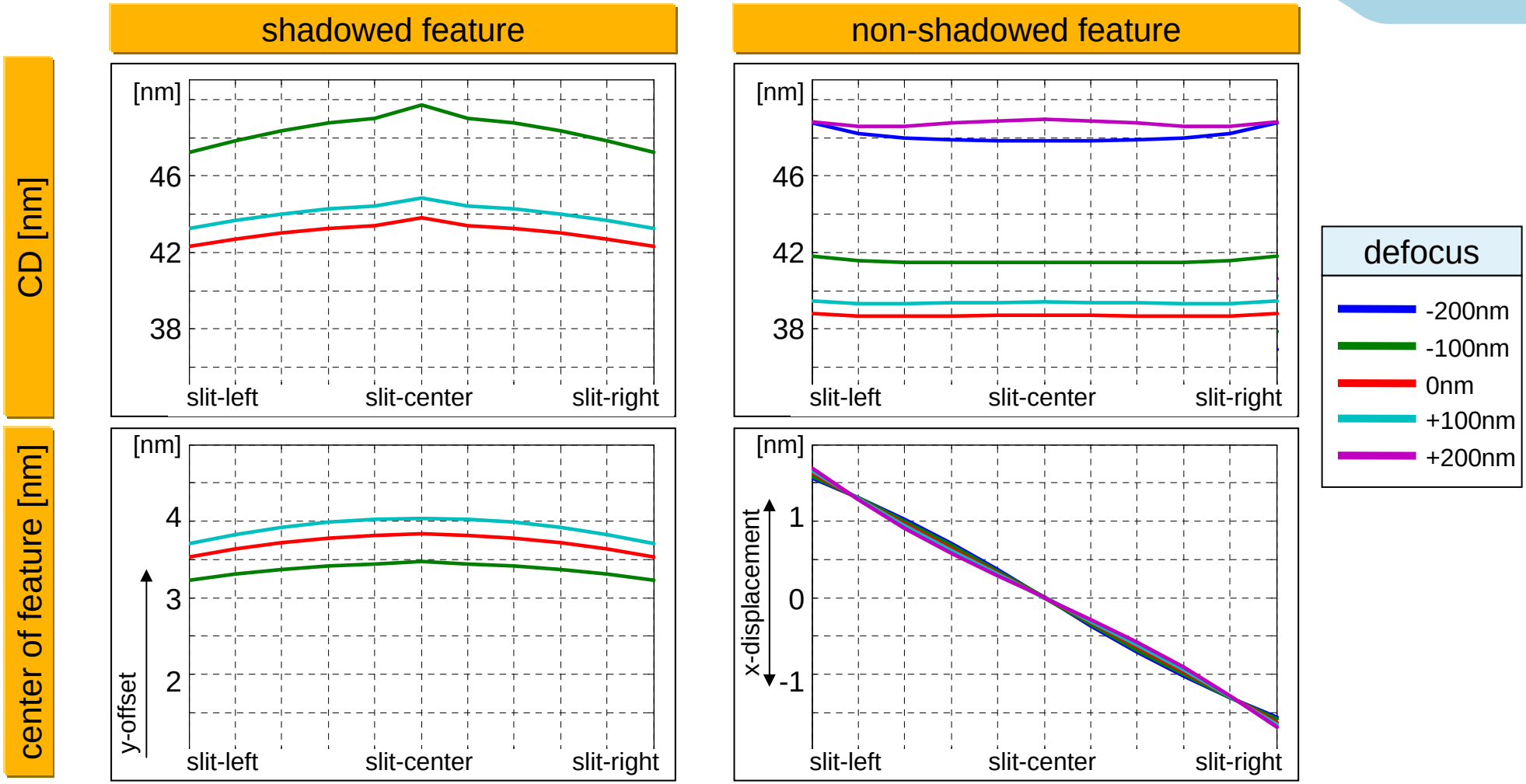


➔ Overlay error stable at dose variations, only negligible changes in CD signature

CD-variation and feature displacement for 32nm node over defocus



CD-variation and feature displacement for 32nm node over defocus



➔ X-Overlay-error is stable, while Y-Overlay-error sensitive to focus shifts, CD-control of shadowed features is very delicate due to a focus shift

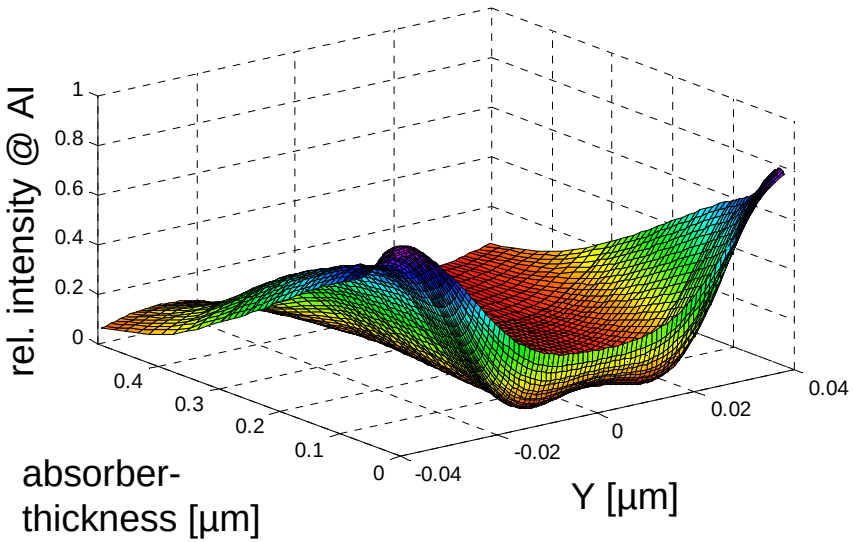
Conclusions

- 'shadowing' effects due to non-telecentric illumination will consume at least 50% of the Overlay- and CD-Control budget defined in ITRS roadmap for the 32nm node
- massive full-field OPC and/or tuning of tool settings may reduce the impact for a dose range - but only for one fixed focus
- changes in CD-signature across illumination slit due to defocus-variation will reduce the useable process-window

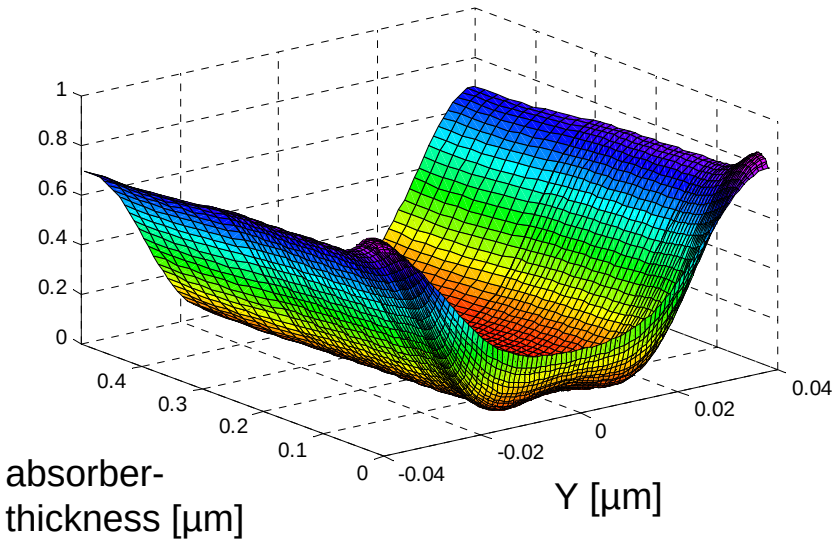
➔ Will an enhanced absorber stack solve the problem?

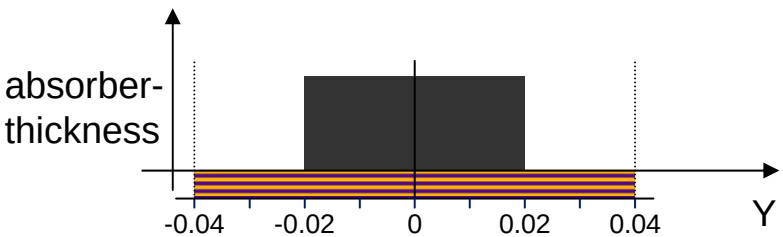
Aerial image intensity as a function of absorber thickness

shadowed feature



non-shadowed feature

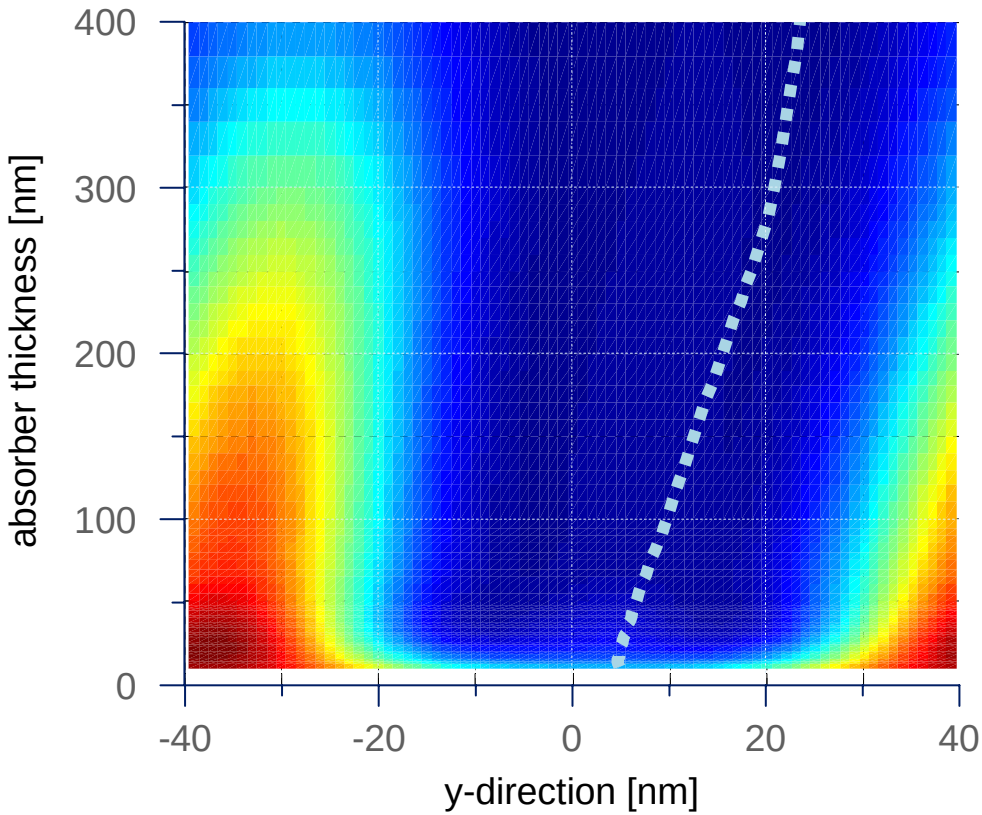




- shadowed features determine the upper limit of absorber thickness
- contrast requirements determine the lower limit of absorber thickness

Center of printed feature as function of absorber thickness

shadowed feature



center of printed feature (displacement)

- displacement as a function of absorber thickness shows a linear trend (in a 1st order approximation)
- a thinner absorber will reduce displacement errors

summary

- 'shadowing' effects of EUV absorber masks in a non-telecentric projection system will consume 50% and more of the ITRS Overlay-budget if no full-field OPC or tool tuning is applied
- CD-signature across illumination slit might be balanced by a massive full-field OPC
- since CD-signature of shadowed features is non-comparable with non-shadowed features an adjusted dose-distribution across slit will not help

- simulations show that an enhanced absorber stack will reduce 'shadowing' effects as well as improve aerial image contrast
- due to the high flare level of early EUV tools the advantage of the enhanced absorber stack needs experimental verification

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Thank you

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