Multi-Beam activity from the 1980s

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Multi-Beam Concepts for Nanometer Devices

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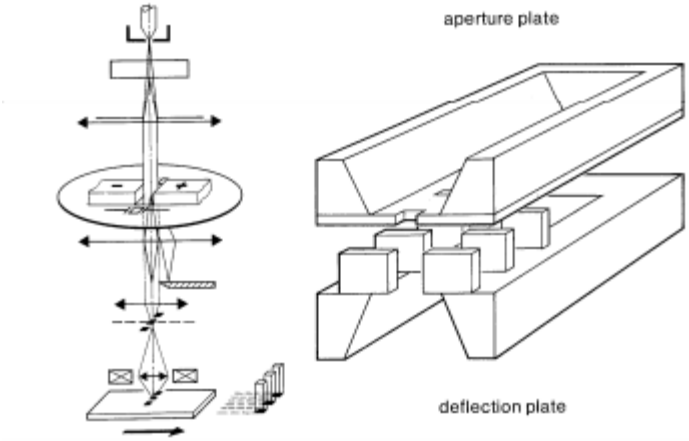


Fig. 8. Control plate, consisting of a probe forming aperture plate and a deflection plate for individual beam blanking.

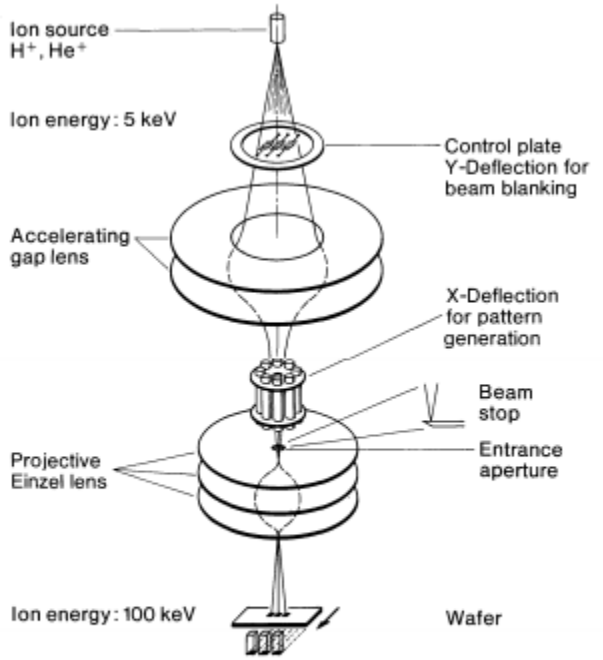


Fig. 14. Ion beam stepper with modifications (control plate, ribbon beam illumination, beam stop) for multi beam applications (by permission of IMS, Vienna, Austria).

Jiun Sonja (1718-1805)
Buji Kore Kinin
"Only those who live simply, live nobly"
Genzō Hattori Collection

Multi-Beam Mask Writer

Hans Loeschner

IMS Nanofabrication AG
Vienna, Austria

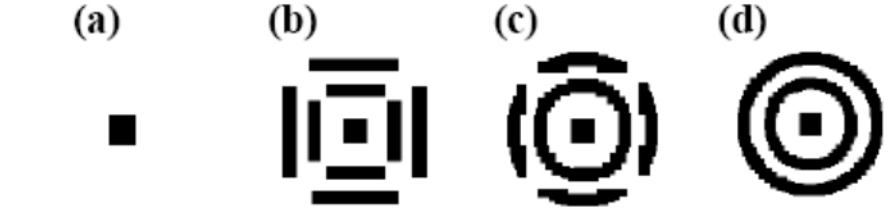
Apr 18, 2013

Kobori Sōchū (1786-1867)
Mei Rekireki Ro Dōdō
"Everything lies openly before us, plainly and undisguised"
Genzō Hattori Collection

SMO (Source Mask Optimization) with OPC and ILT

28nm

Source: Samsung

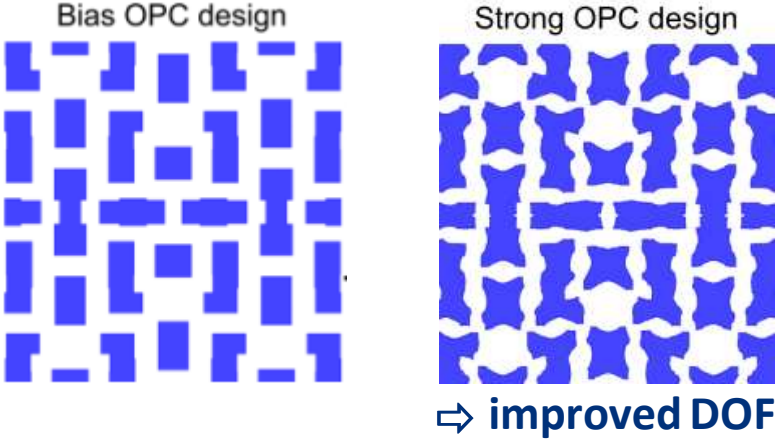


Source: Jin Choi et al., Samsung, Photomask Japan 2009

14nm

Source: DNP

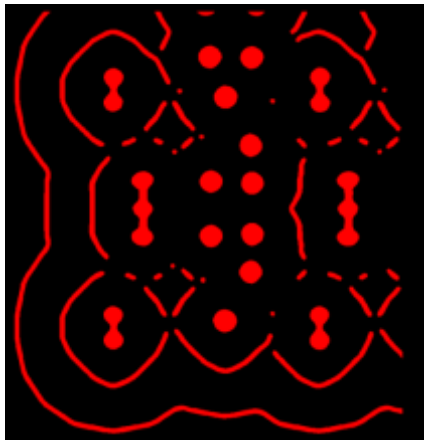
Optical Proximity Correction



⇨ improved DOF

Source: Naoya Hayashi, DNP, LithoVision 2012

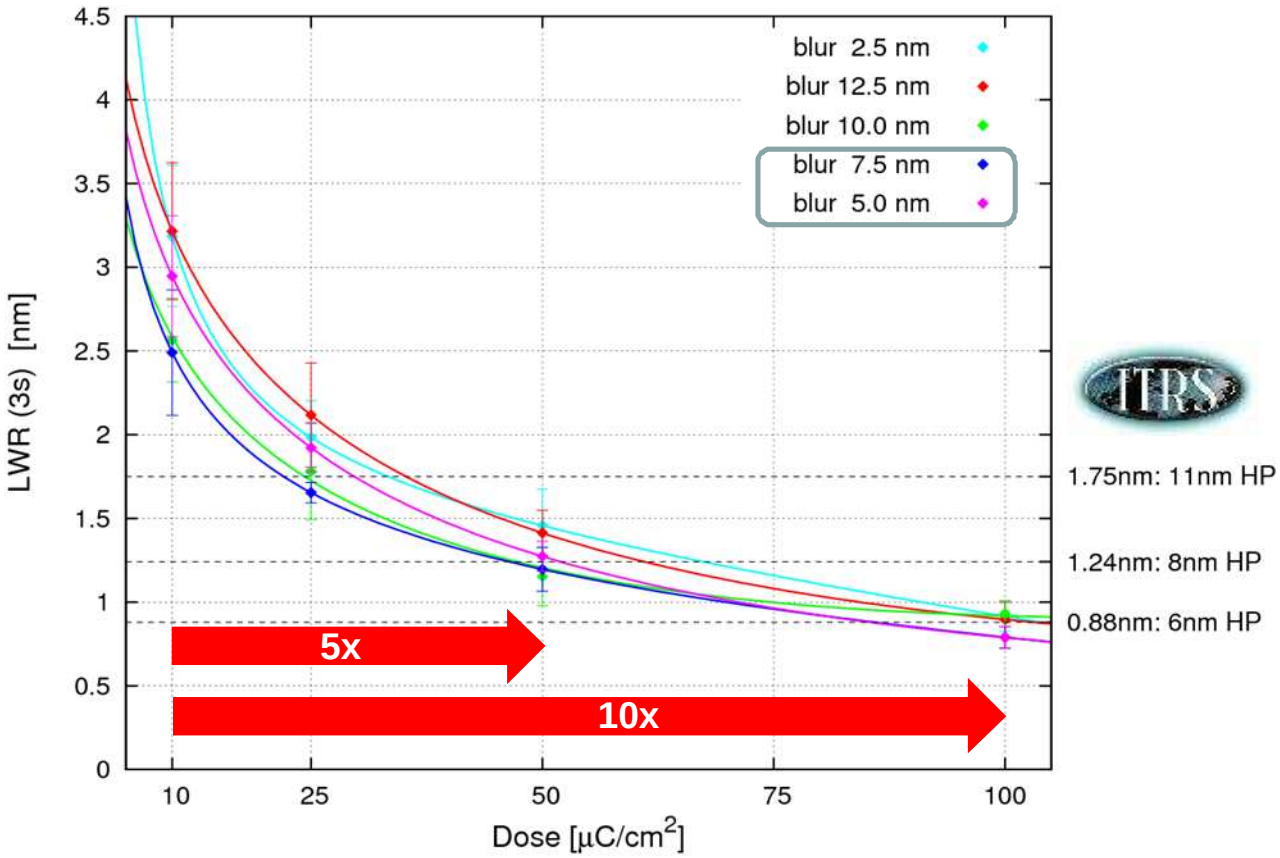
Inverse Lithography Technology



Source: Naoya Hayashi, DNP

Exposure Dose

LWR Monte Carlo simulation results for CD = 30nm



For the 11nm HP mask technology node and below the

resist exposure dose must be increased by a factor of 5 to 10

VSB vs MB

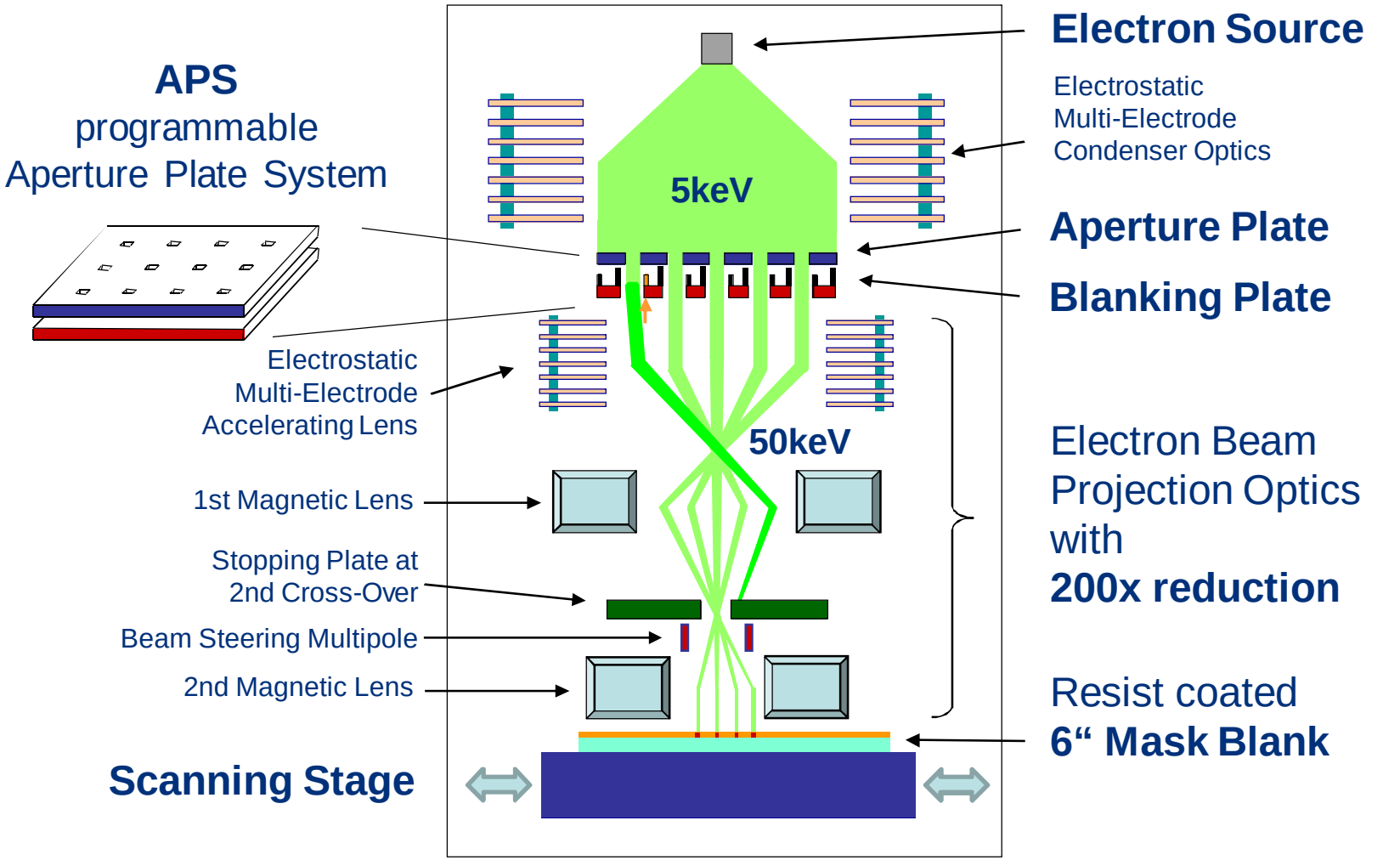
50keV electron
Variable Shaped Beam
(VSB)
Mask Writer

# beams:	1
Shape size:	variable
Current density:	800 A/cm^2
Current:	80nA / 100nm square
	3.2nA / 20nm square
	0.8nA / 10nm square

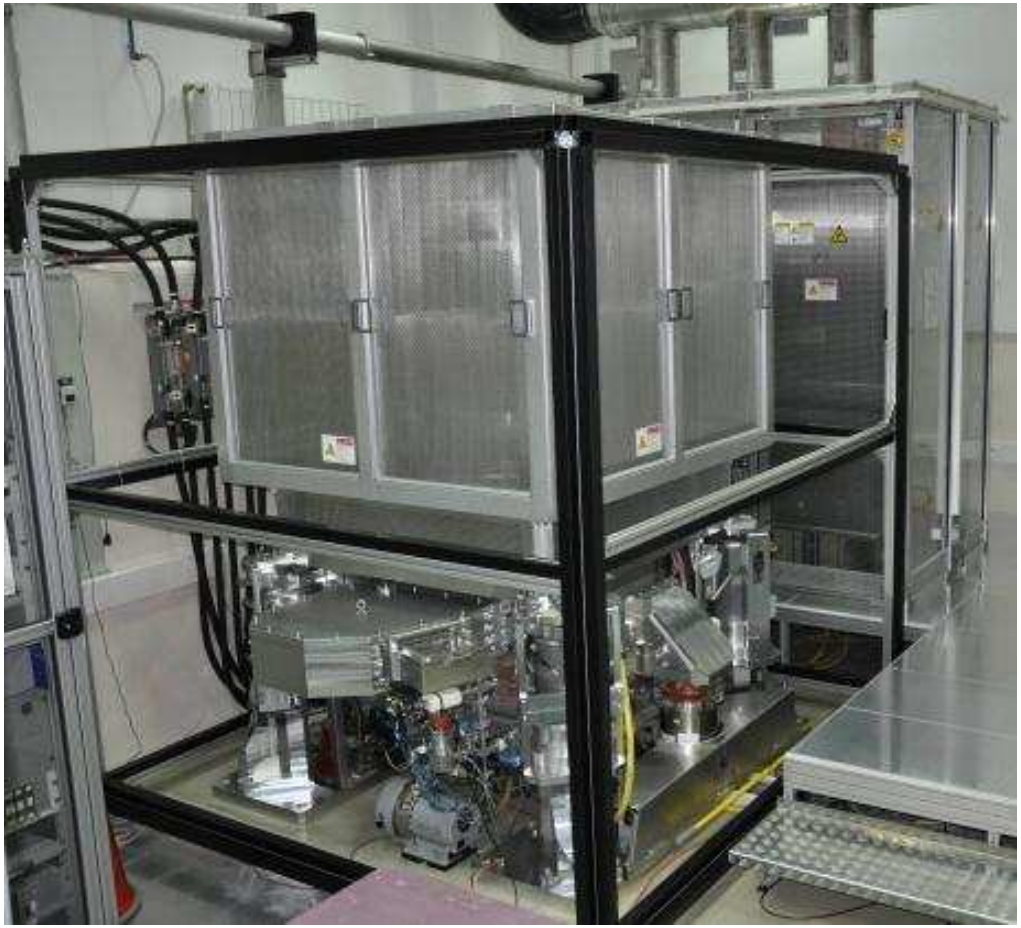
50keV electron
Multi-Beam
(MB)
Mask Writer

# beams:	262,144 (512 x 512)
Beam size:	fixed, 20nm,10nm, ...
Current density:	1 A/cm^2 / 20nm beam
	4 A/cm^2 / 10nm beam
Current:	
(all beams "on")	1 µA / 20nm beam
	1 µA / 10nm beam

MB Mask Writer Tool Principles



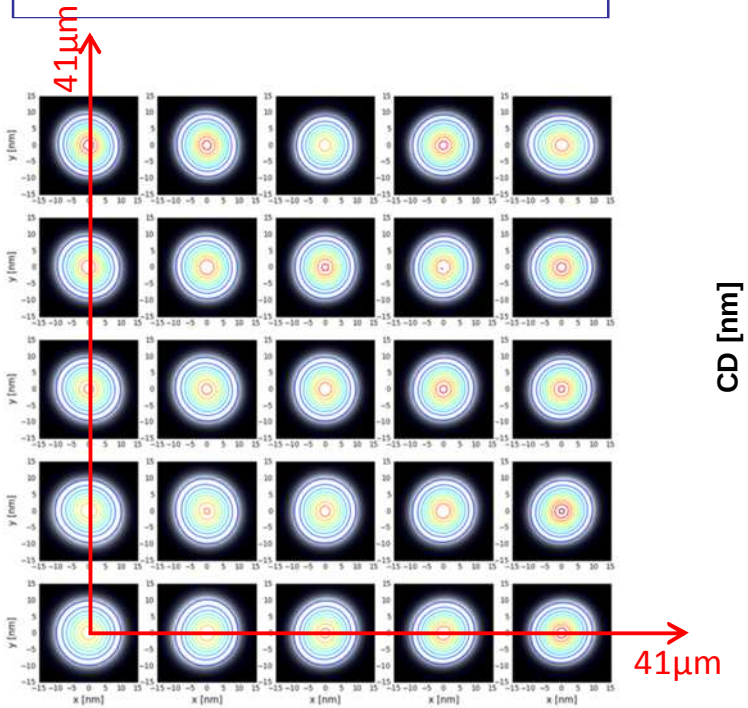
eMET POC – Proof-of-Concept electron Mask Exposure Tool



- # of programmable beams: 262,144
- Data Path: 12.8 Gbits/s
- Beam energy: 50 keV
- Beam size: 20 nm
- Column Blur: 5nm 1sigma
- Address grid: 0.1nm
- Writing: Scanning stage
- Current: 0.1µA - 1µA
- TPT: up to 10cm²/h

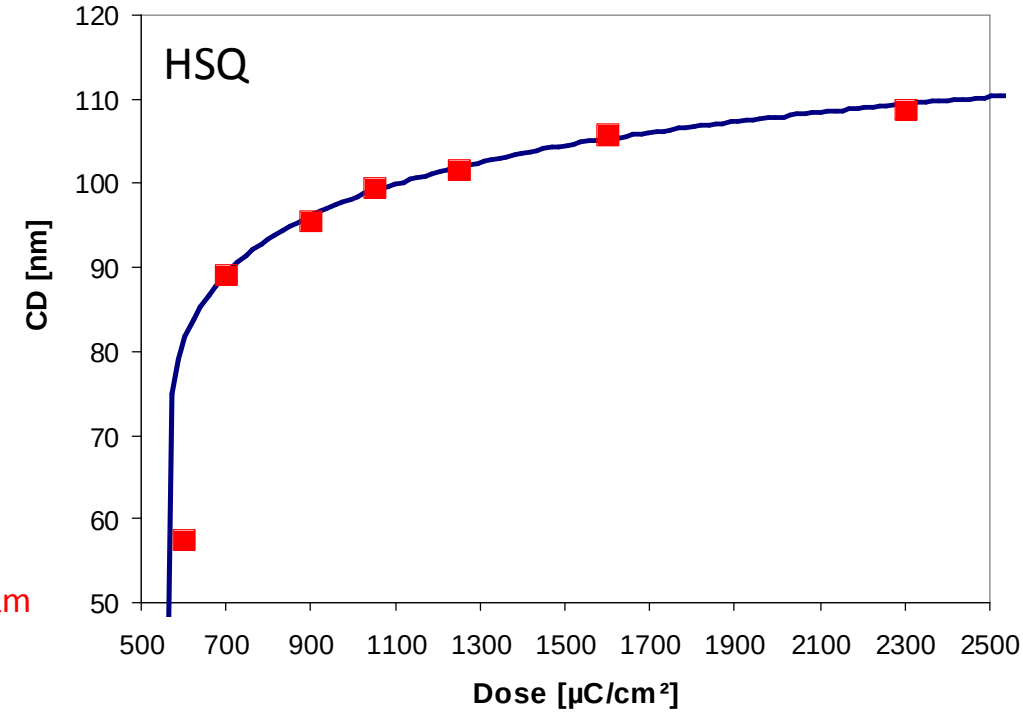
MB Column Blur: 5nm 1sigma

Simulation



one image quadrant

Experiment



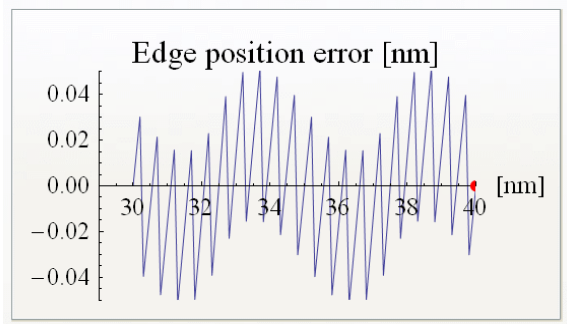
Simulated 1sigma blur:
5.3 nm
@ 82µm x 82µm beam array field

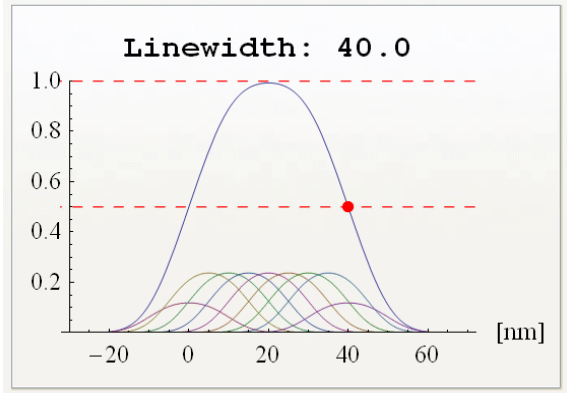
Measured 1sigma blur (incl. resist):
6.65 nm (Center); at Corners:
– 0.45nm, 0.02nm, 0.045nm, 0.70nm

0.1nm Address Grid by MESA (Multiple Exposure Shot Addressing)

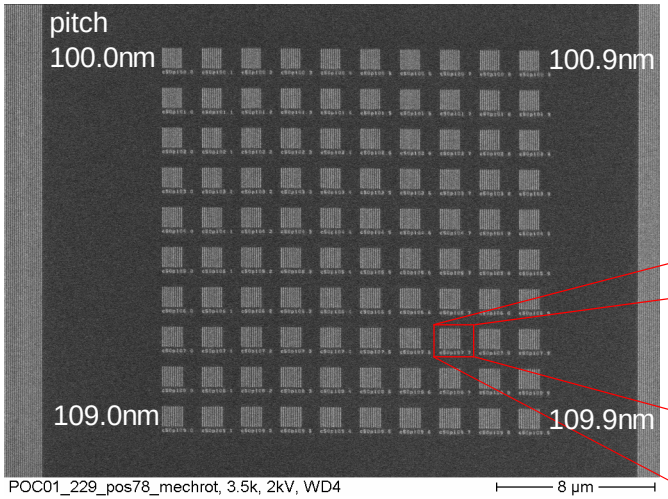
- Overlapping Shots: Pixel = ¼ Beam Size
- Every 20nm shot exposed with 4bit = 16 dose levels (0, 1, 2,….15)

Beam Size:	20 nm
Pixel Size:	5 nm
⇨	
16 x 15 + 1:	241 dose levels / area
4 x 15 + 1:	61 dose levels / edge



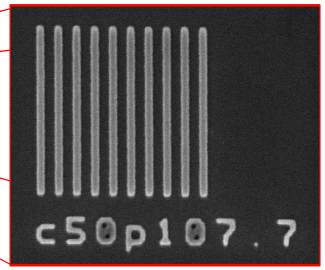


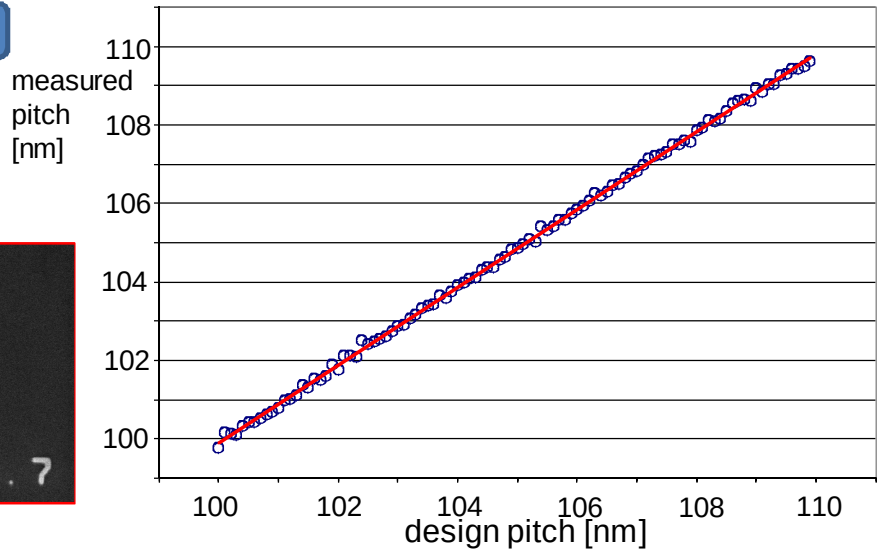
Multi-Beam Writing @ 0.1nm Address Grid

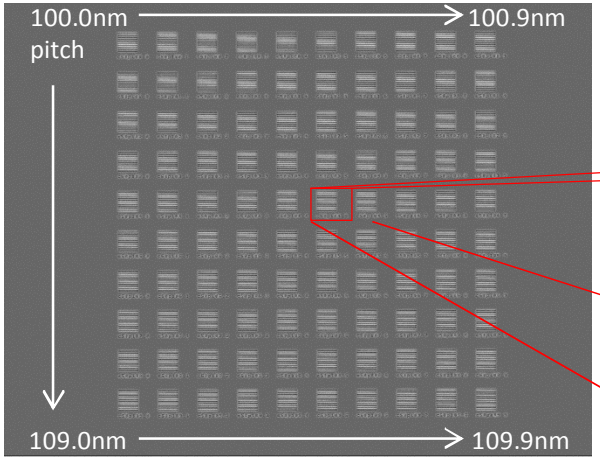


BACUS 2012

HSQ

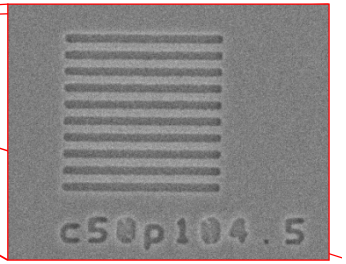


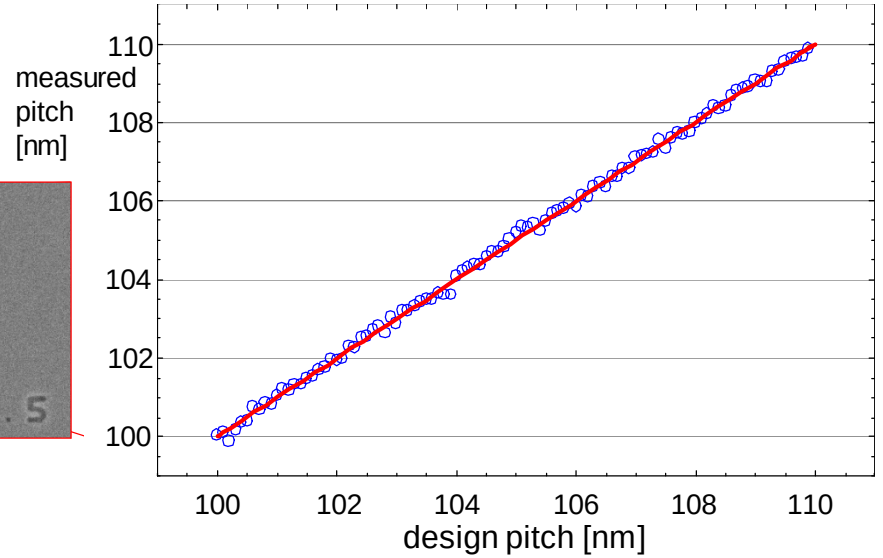




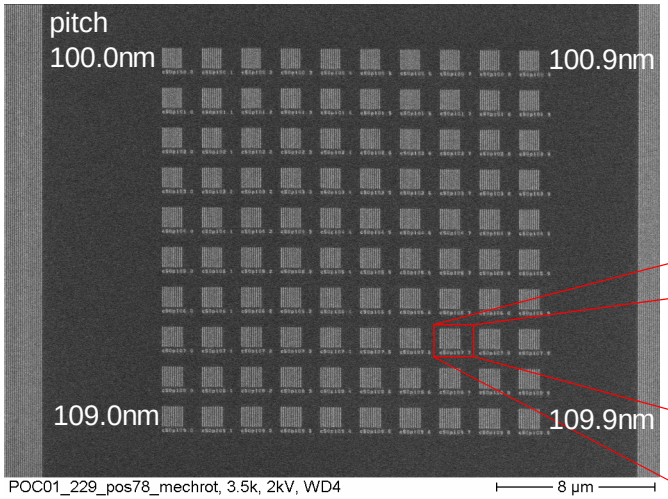
SPIE 2013

PCAR



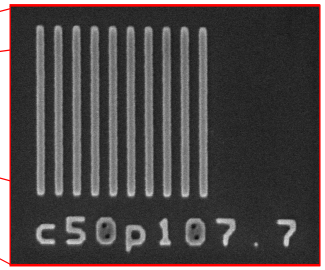


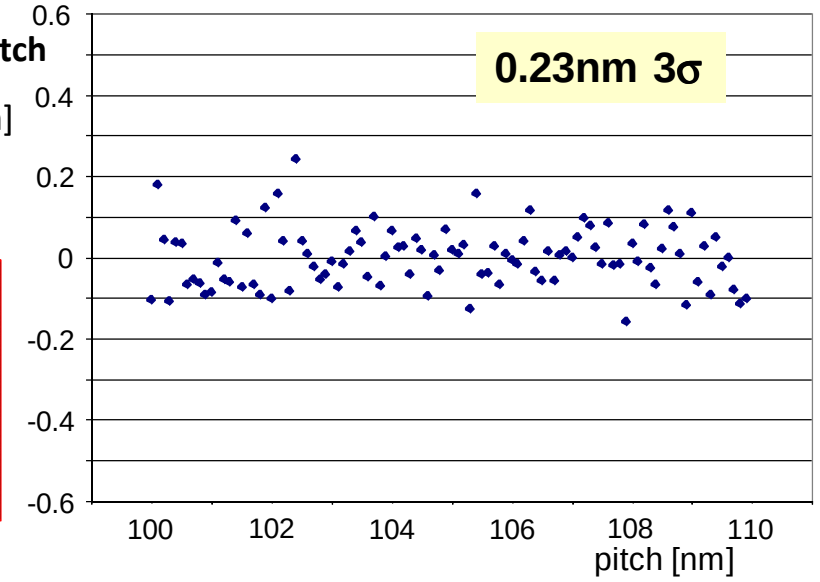
Multi-Beam Writing @ 0.1nm Address Grid

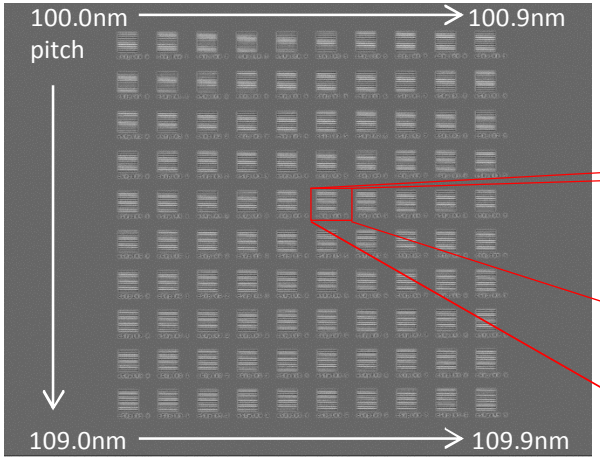


BACUS 2012

HSQ

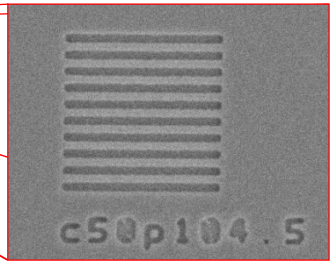


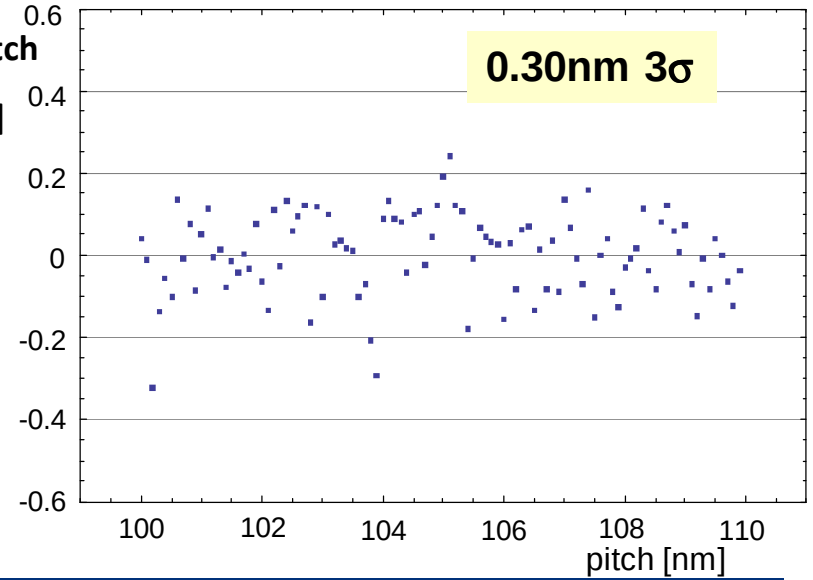




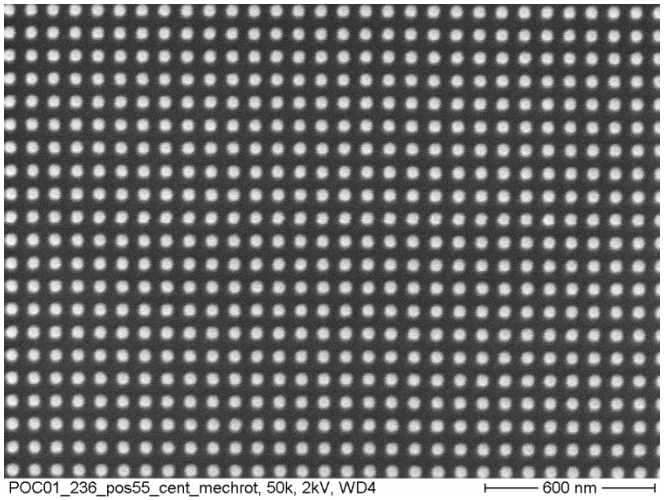
SPIE 2013

PCAR





40nm Dots with at slightly modified grid



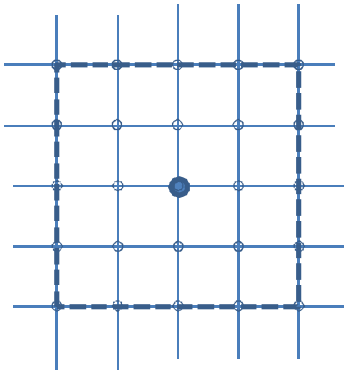
40nm dots with 80nm pitch

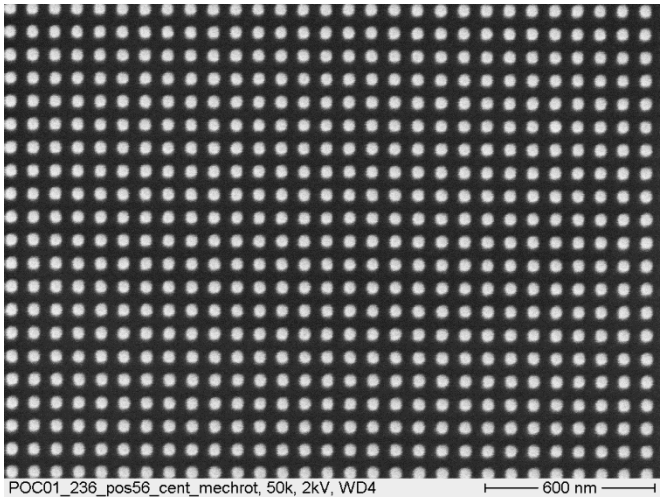
LCDU = 1.63nm 3sigma

64 shots per dot!

Every dot on equivalent grid position

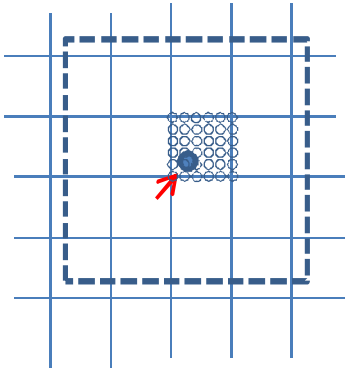
5nm physical grid



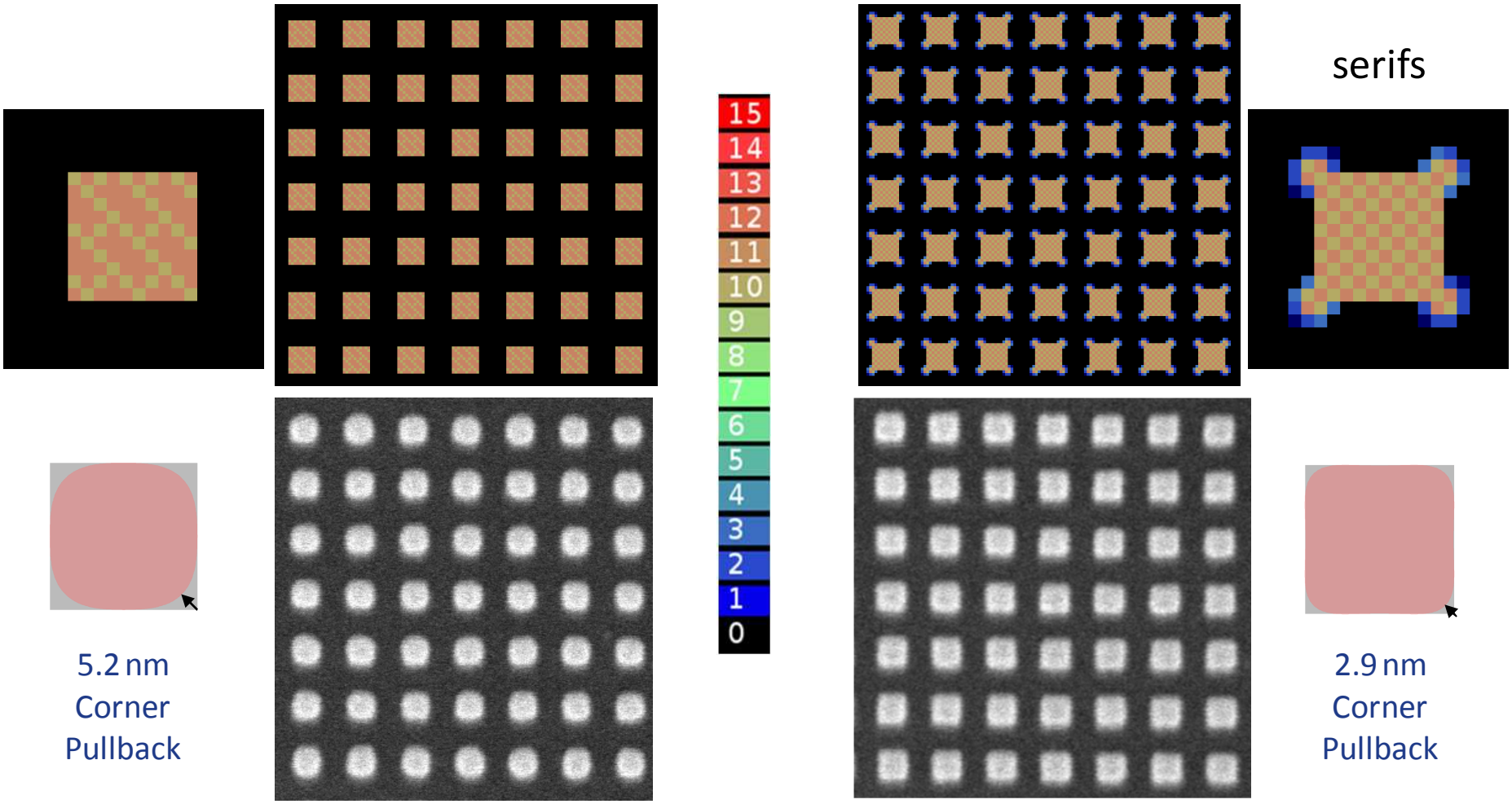


40nm dots with 81nm pitch

LCDU = 1.61nm 3sigma

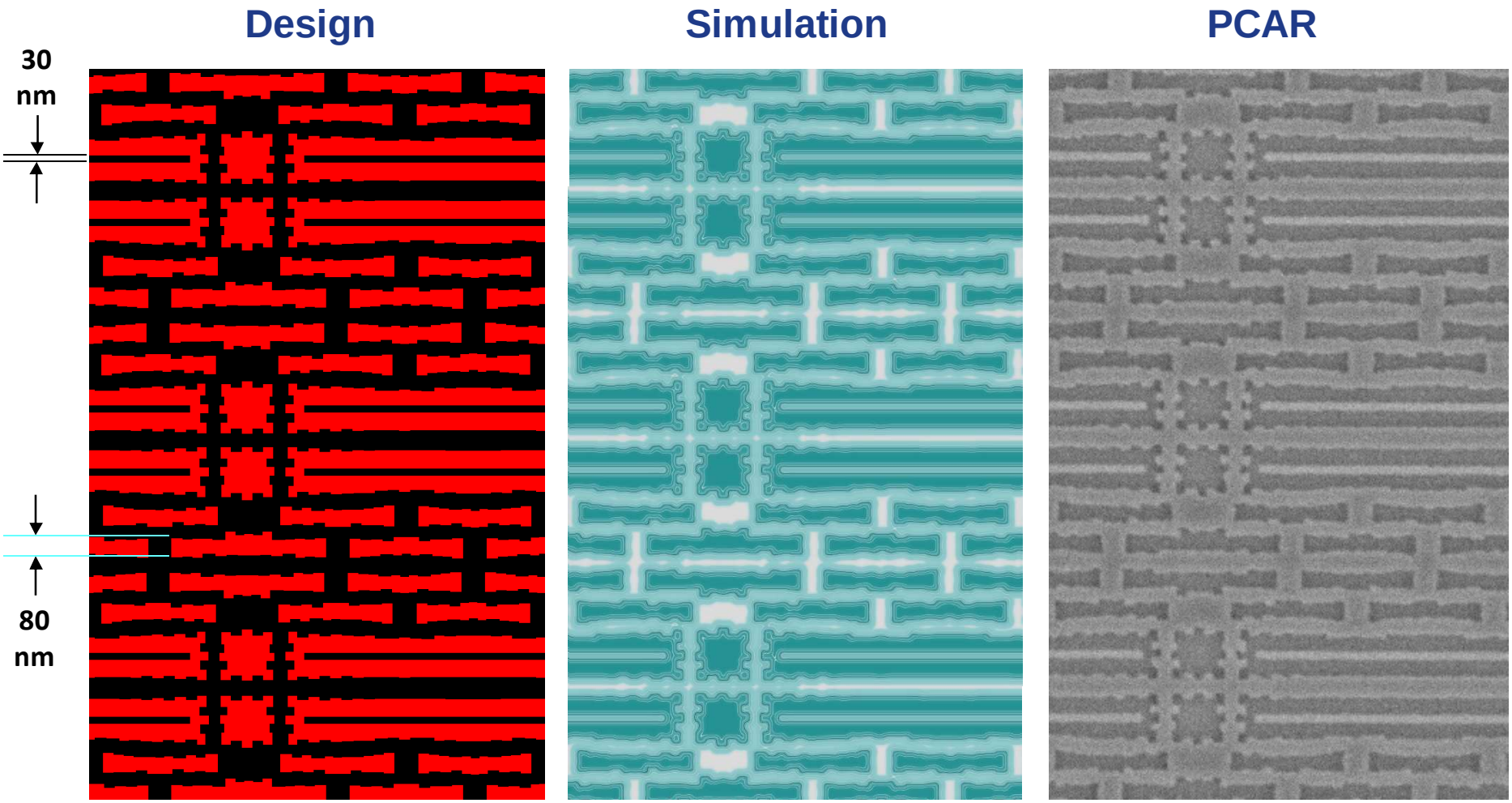


Corner Radius Improvement

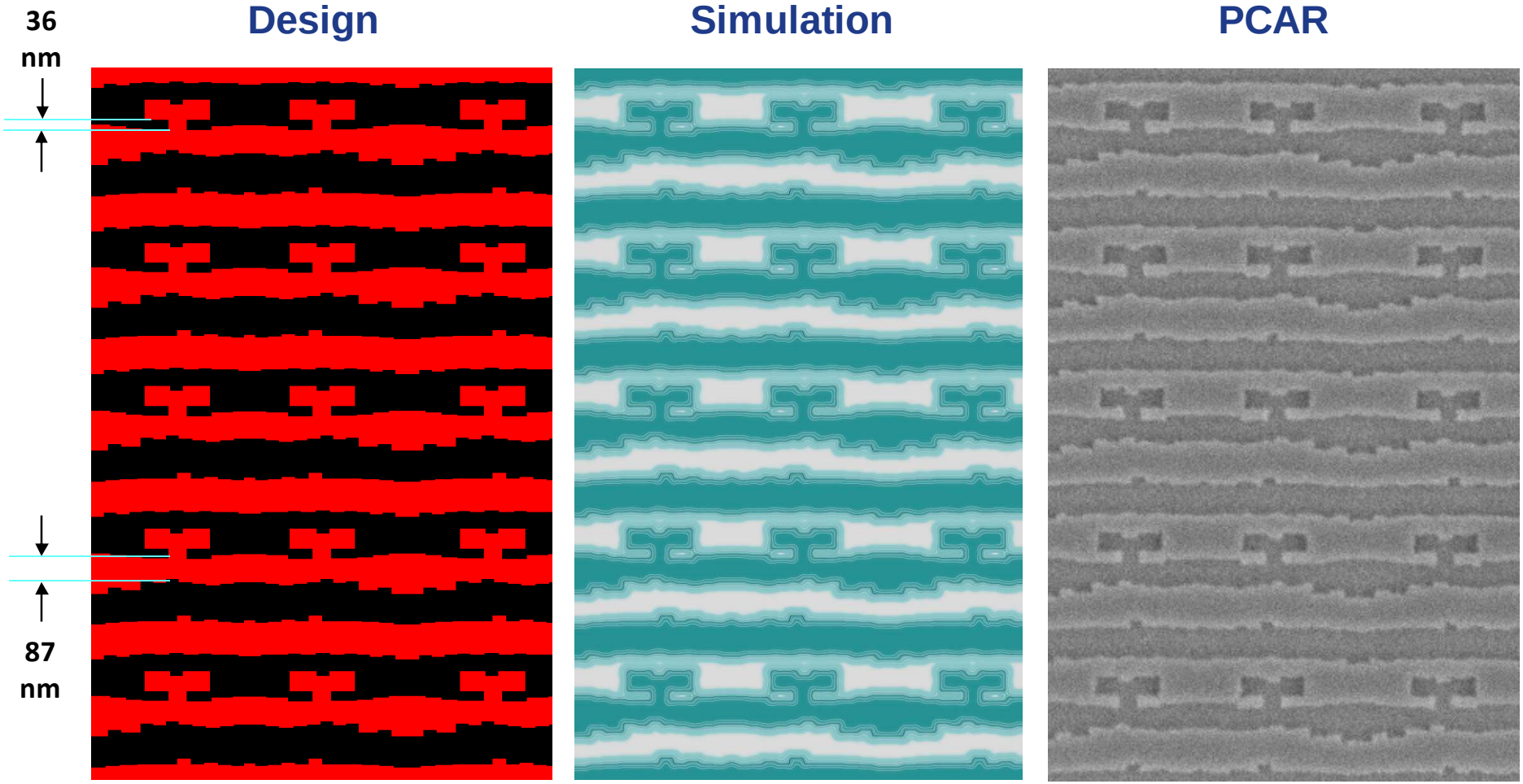


Additional Shots are NOT degrading TPT

Exposure of aggressive OPC Pattern



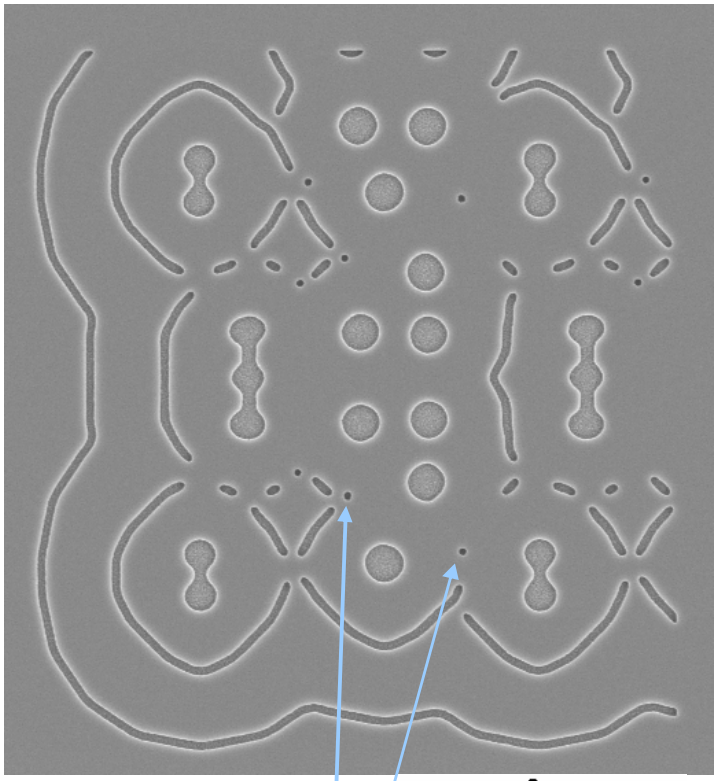
Exposure of aggressive OPC Pattern



Exposure of ILT test pattern

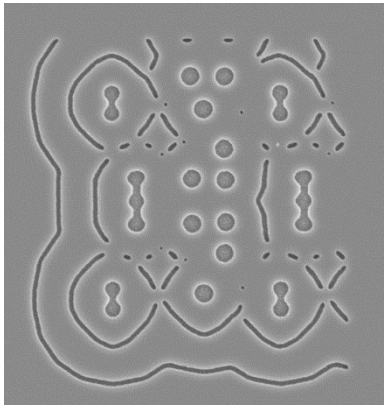
ILT design: DNP

PCAR



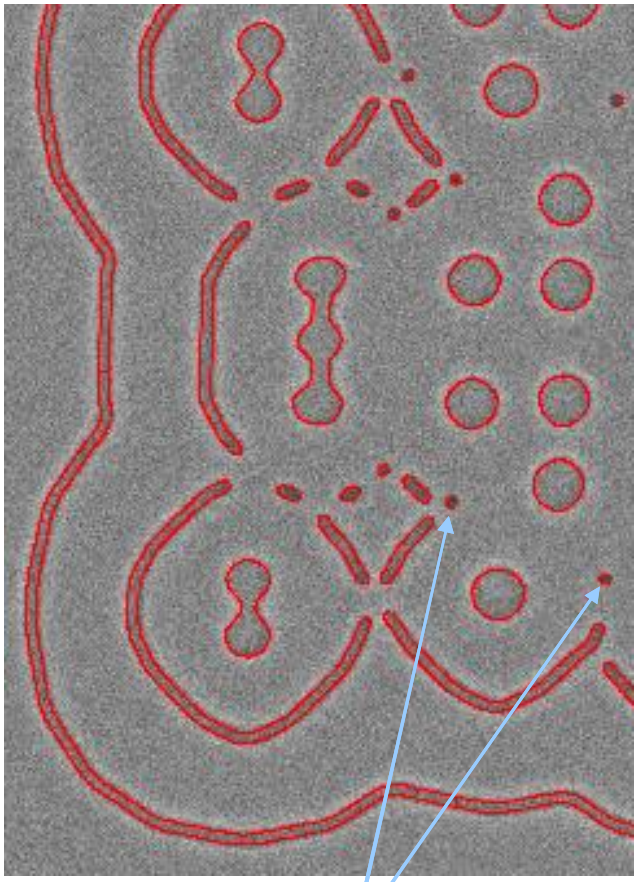
60nm features

PCAR



2-times shrinked

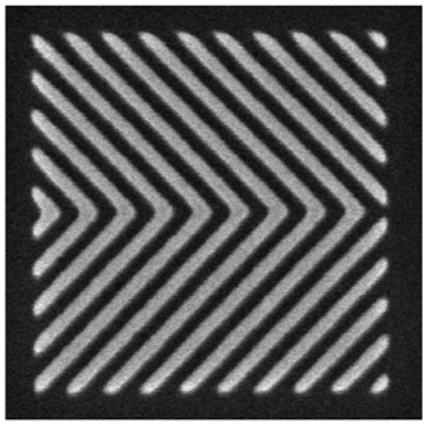
Design



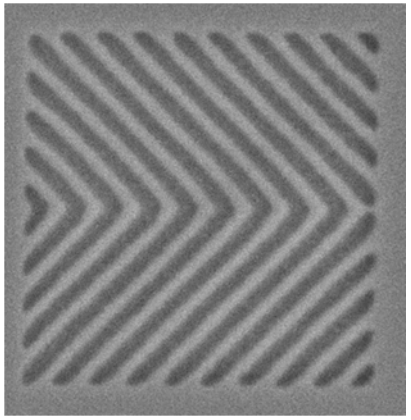
30nm features

Realized MB Column: Extendibility to sub-10nm nodes

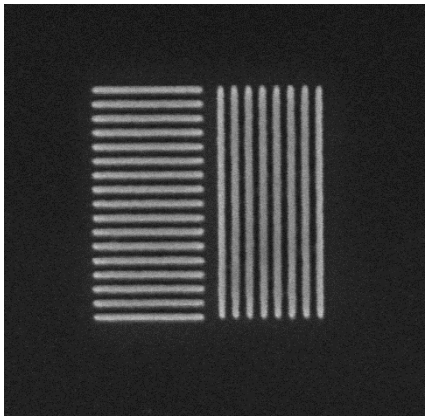
30nm HP in HSQ negative resist



30nm HP in PCAR positive resist



24nm HP in HSQ negative resist

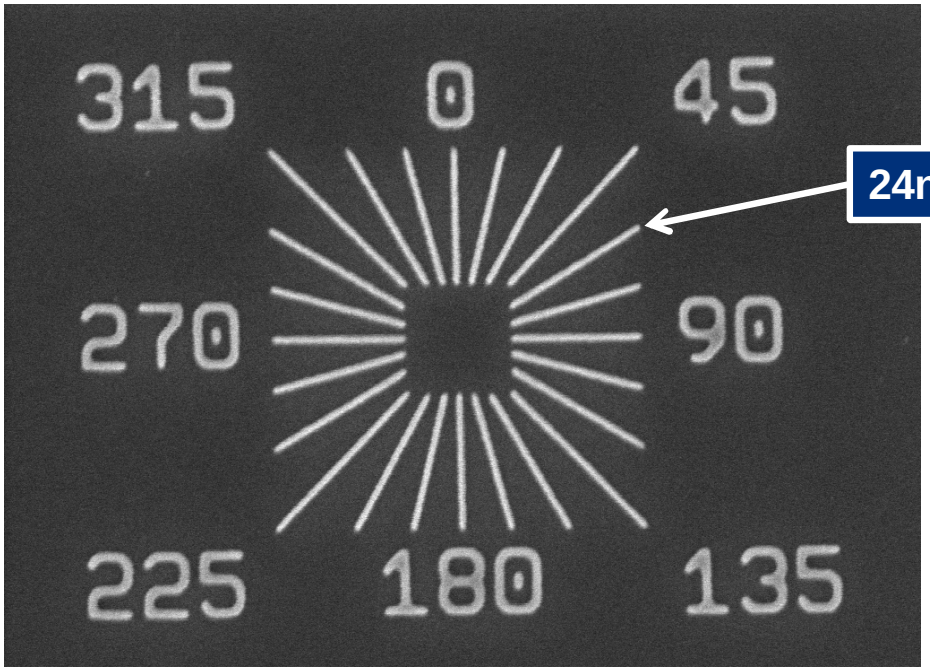


50keV electron multi-beam exposure with **20nm beam size**

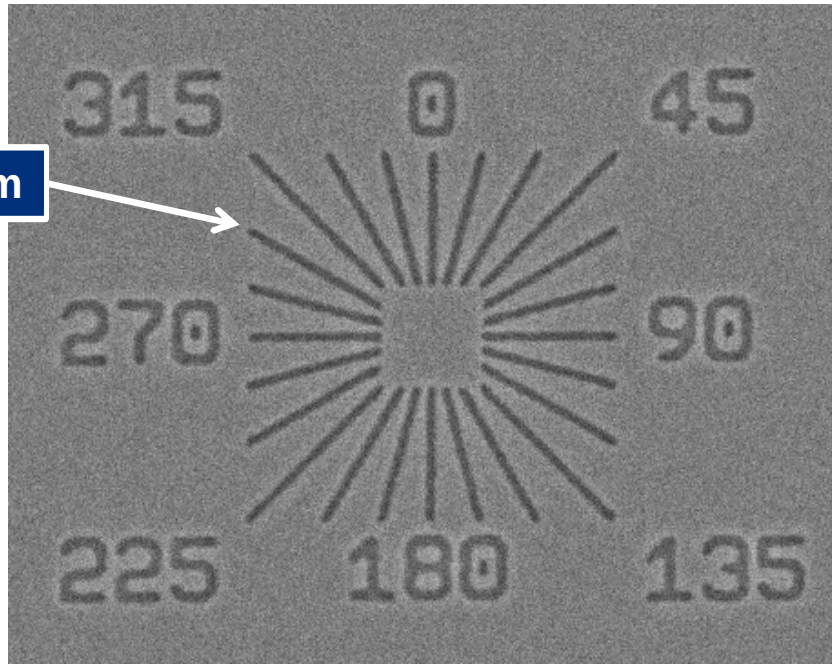
Realized MB Column: Extendibility to sub-10nm nodes

24nm any angle iso lines

HSQ negative resist



PCAR positive resist



50keV electron multi-beam exposure with **20nm beam size**

Multi-Beam Mask Writer Roadmap

	POC	ALPHA	BETA	1st gen. HVM
	2012	**2014**	**2015**	**2016**
Technology Node	Test: 11nm HP (7nm Logic)	11nm HP (7nm Logic)	11nm HP (7nm Logic)	11nm HP (7nm Logic)
Beam Array Field	82µm x 82µm	82µm x 82µm	82µm x 82µm	82µm x 82µm
# Beams	262,144	262,144	262,144	262,144
max Current (all beams "on")	0.1 - 1 µA	1 µA	1 µA	1 µA
Throughput (≥ 100µC/cm²)	<10 cm²/h	**15h / mask**	**10h / mask**	**10h / mask**

Thank You for Your Attention !

Kawai Gyukudō (1873-1957)
Shōrai Zensei
"The Rustling of the Pine Tree,
the Voice of the Cicada"
Genzō Hattori Collection