Recent results of Multi-beam mask writer MBM-1000

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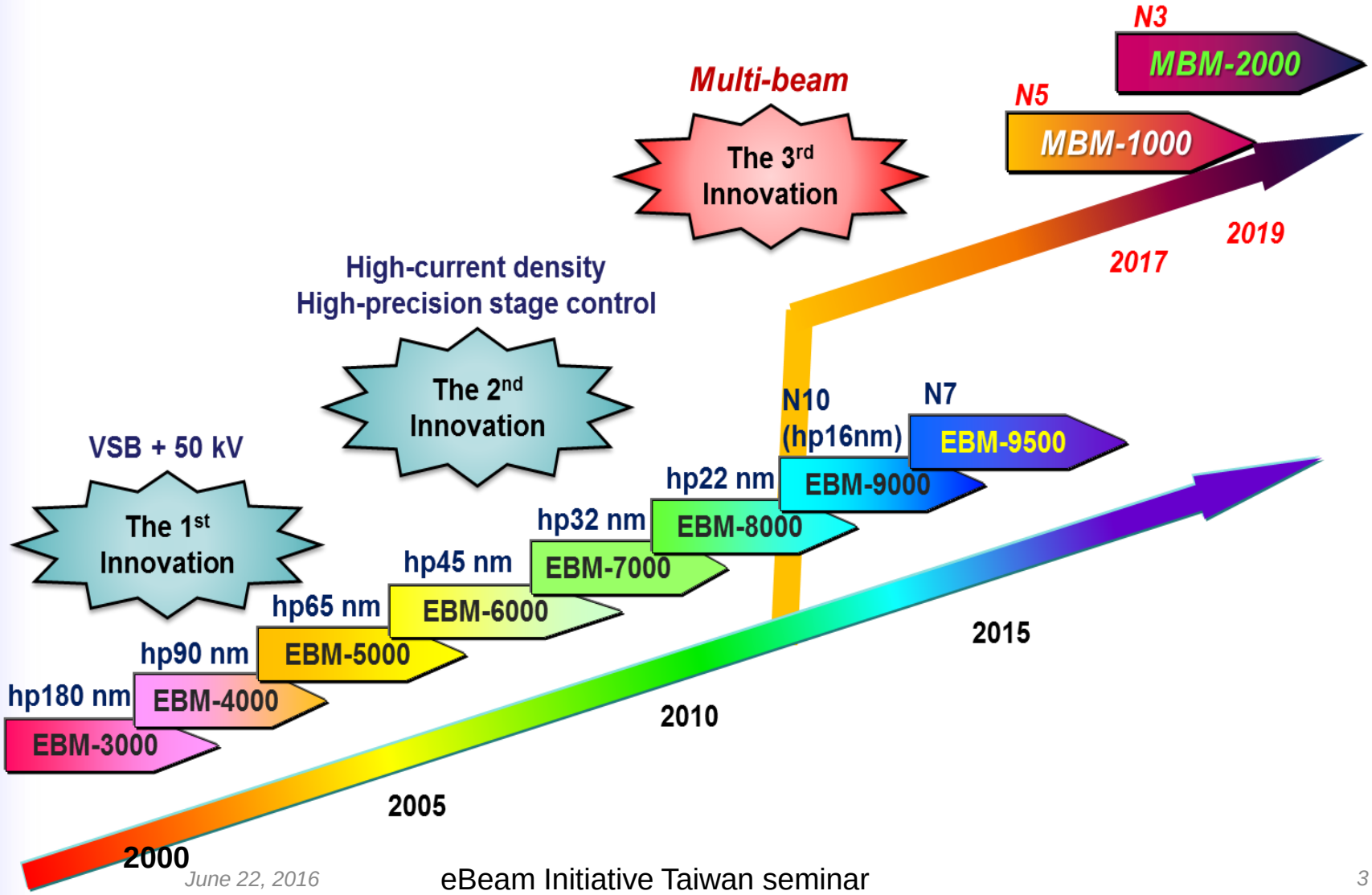
NFT's mask writer roadmap 2016

Device	Production	2016	2017	2018	2019	2020	Remarks
ITRS 2013	Logic	N10	N7	N7	N5	N5	Node name
	DRAM	22	20	18	17	15	Bit line hp (nm)
	Flash	14	13	12	12	12	Gate hp (nm)
Mask Writer	EBM-9000	2013					N14, 10
	EBM-9500	2015					N7
	MBM-1000		2017				N5
	MBM-2000				2019		N3

- NuFlare keeps on releasing leading-edge mask writers every two years to support semiconductor industry for more than 15 years.
- We will launch MBMW to comply with ITRS roadmap.
- ***MBM-1000*** is to be released in ***2017*** for N5.
- ***MBM-2000*** will be coming in ***2019*** for N3.

History of EB writer development

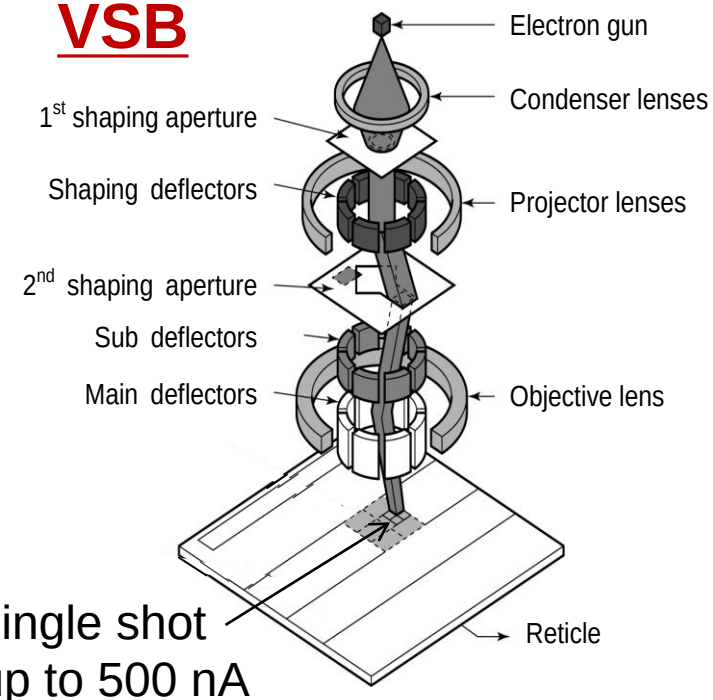
- The 3rd technical innovation for futuristic mask writing



MBM-1000

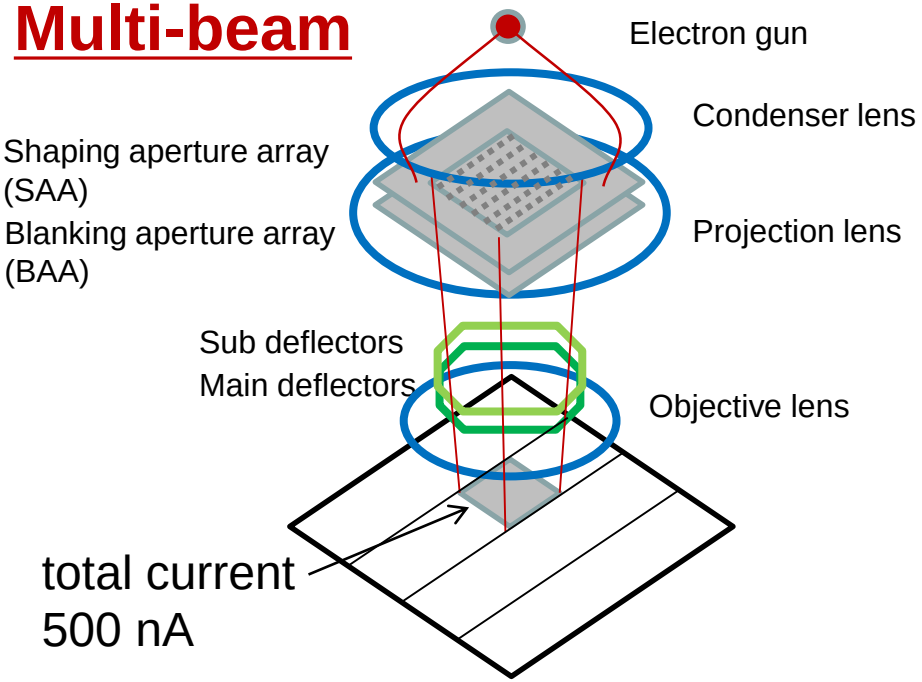
- NuFlare is evaluating MBM-1000 alpha tool.
- Assembly of beta tool is almost completed.
  - Beam on planned at the end of July.

VSB



single shot
up to 500 nA

Multi-beam



total current
500 nA

	VSB	MB
Key technologies	• Single Variable Shaped Beam • High current density • High speed deflection	• Massive number of beams • High-speed data path and BAA • Gray beam writing
Advantage	• Best cost performance for Med-Low pattern density/doses	• Constant write time for all pattern densities • Enables high doses
Limitation	• High doses and pattern densities impact write time	• Not cost effective for Med-Low pattern densities and doses • Narrow process window due to gray beam

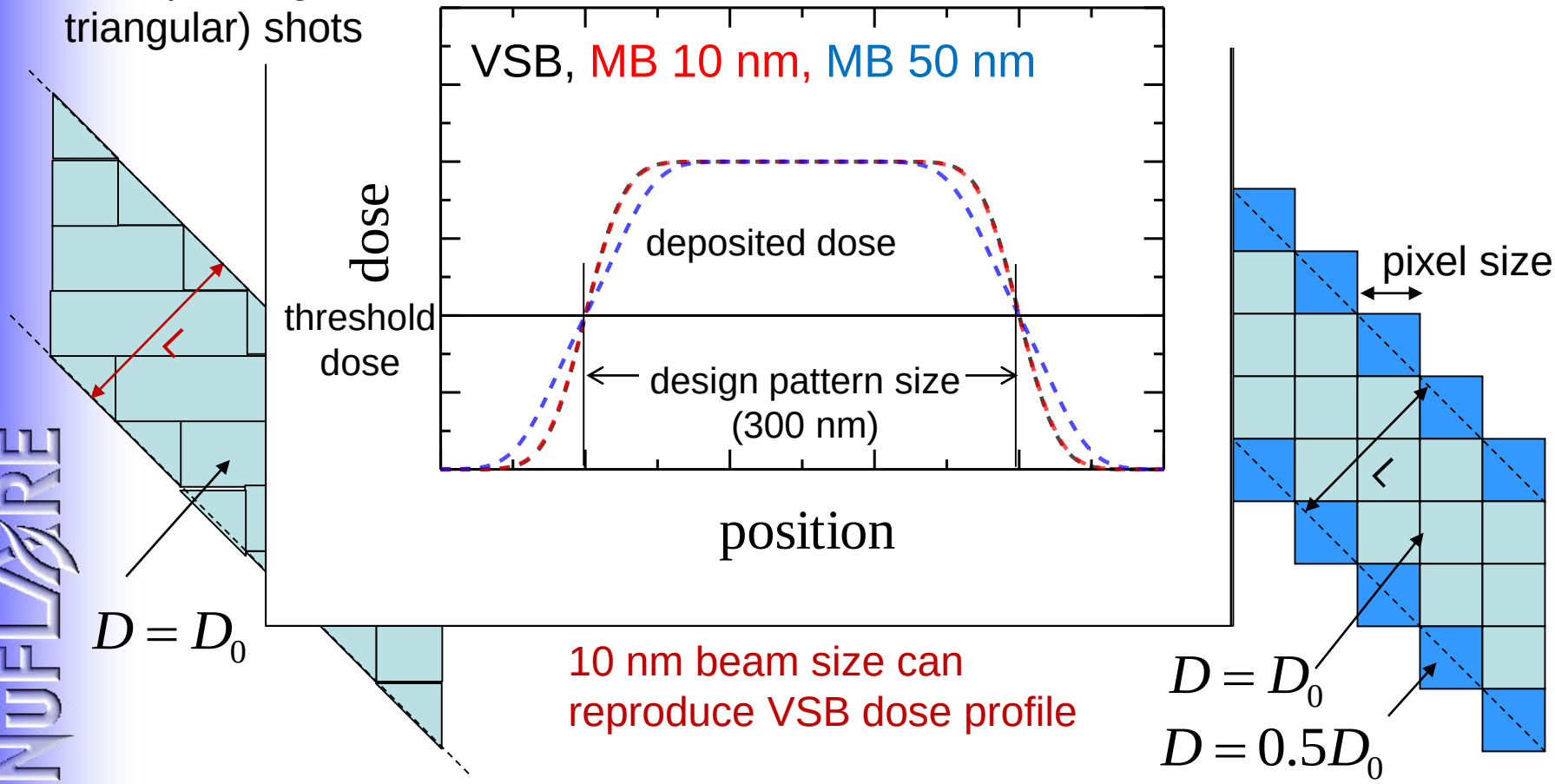
VSB vs. pixelated gray beam

VSB

No gray beam is used.
Dose profile is formed by VSB (rectangular and triangular) shots

Pixelated gray beam

Square beams with modulated dose are exposed



10 nm beam size can reproduce VSB dose profile

Strategy in design

- Resolution
  - 10 nm beam size for accurate edge position control by gray beam writing
  - Low-aberration optics
- Writing accuracy
  - 10-bit dose control
    - 0.1 nm CD/position resolution
    - PEC/FEC/LEC calculated based on physical models
  - Multi-pass writing
- Throughput
  - Massive number of beams with current density 2A/cm^2
    - Total beam current is 500 nA, which is equal to beam current at maximum shot size in EBM-9000.
  - High-speed BAA and data-path with real-time inline processing

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Tool configuration (EBM, MBM)

Item	EBM-9500	MBM-1000
Accel. voltage	50 kV	50 kV
Cathode	1200 A/cm^2	2 A/cm^2
Beam current	500 nA @ max shot size	500 nA in total
Beam blur	r	< r
Beam size	VSB (≤ 250 nm)	beamlet (10 nm x 10 nm)
Field size	90 µm	512 x 512 beamlets in 82 µm x 82 µm area
Stage	Frictional drive with variable speed	Air bearing stage with constant speed
Data format	VSB12i, OASIS.MASK	MBF (polygon support), VSB12i, OASIS.MASK
Corrections for writing accuracy	PEC/FEC/LEC, GMC, CEC, GMC-TV, TEC	PEC/FEC/LEC, GMC, CEC, GMC-TV, EUV-PEC

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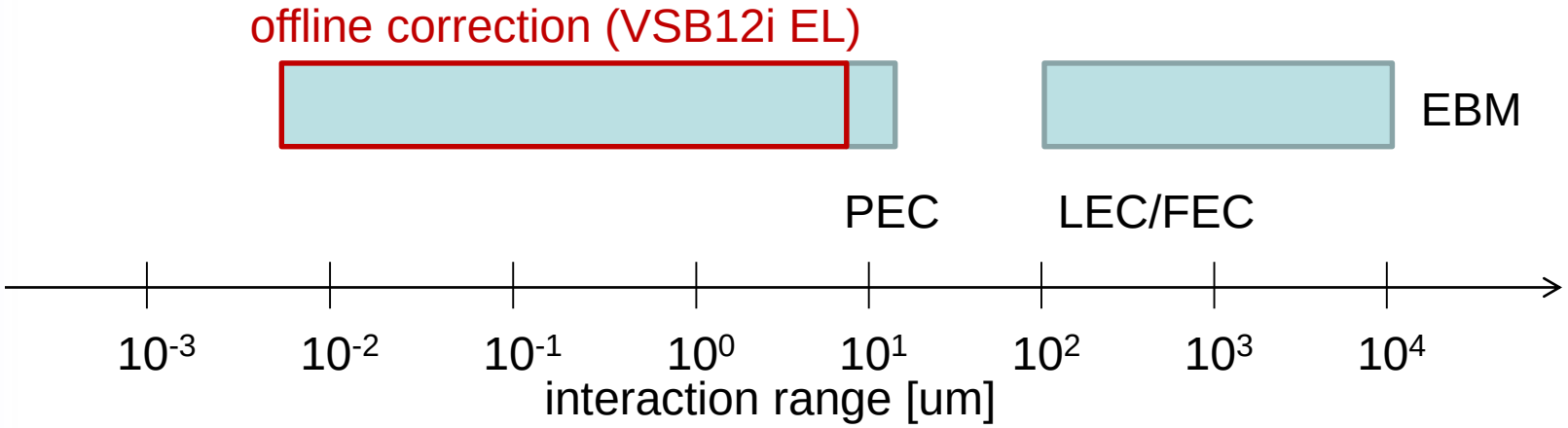
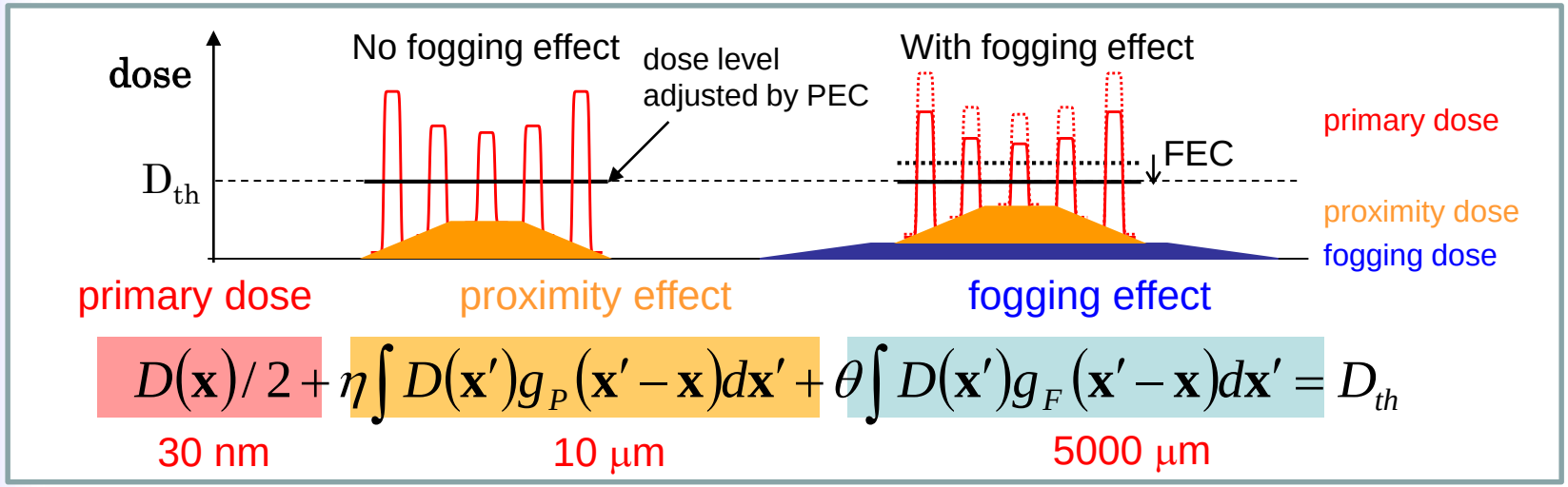
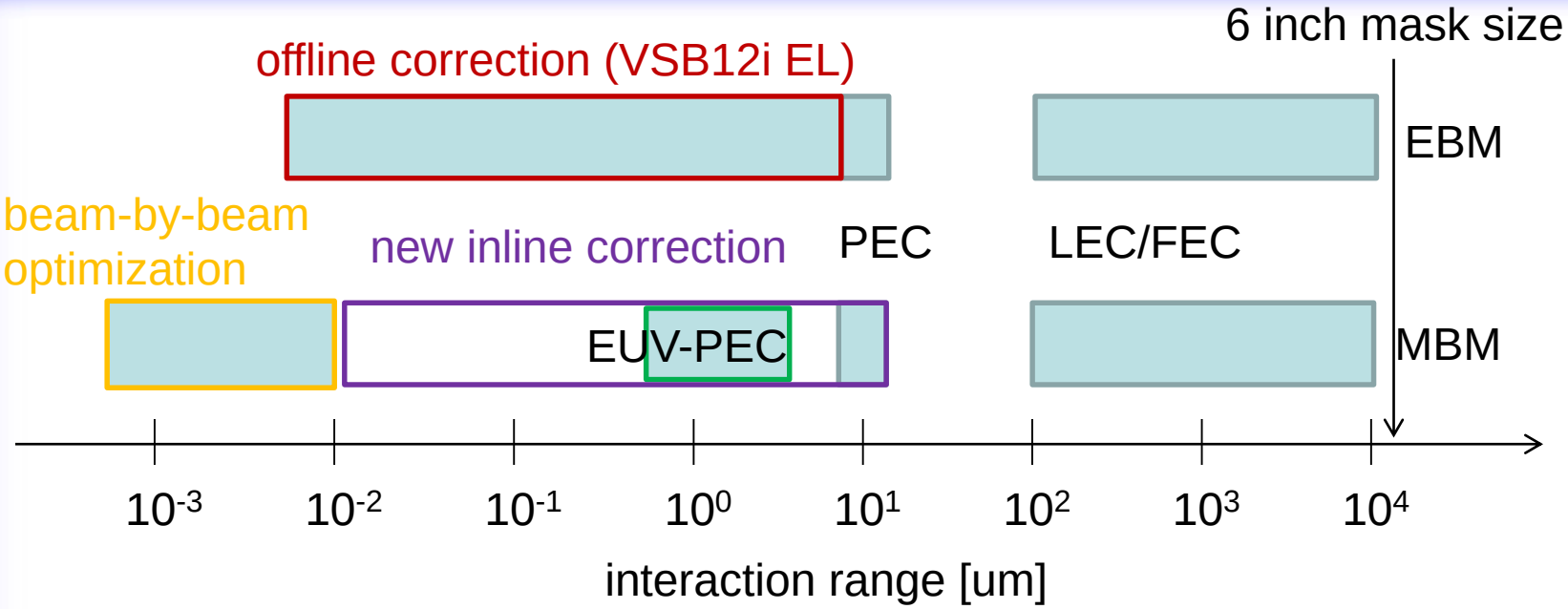
Correction function





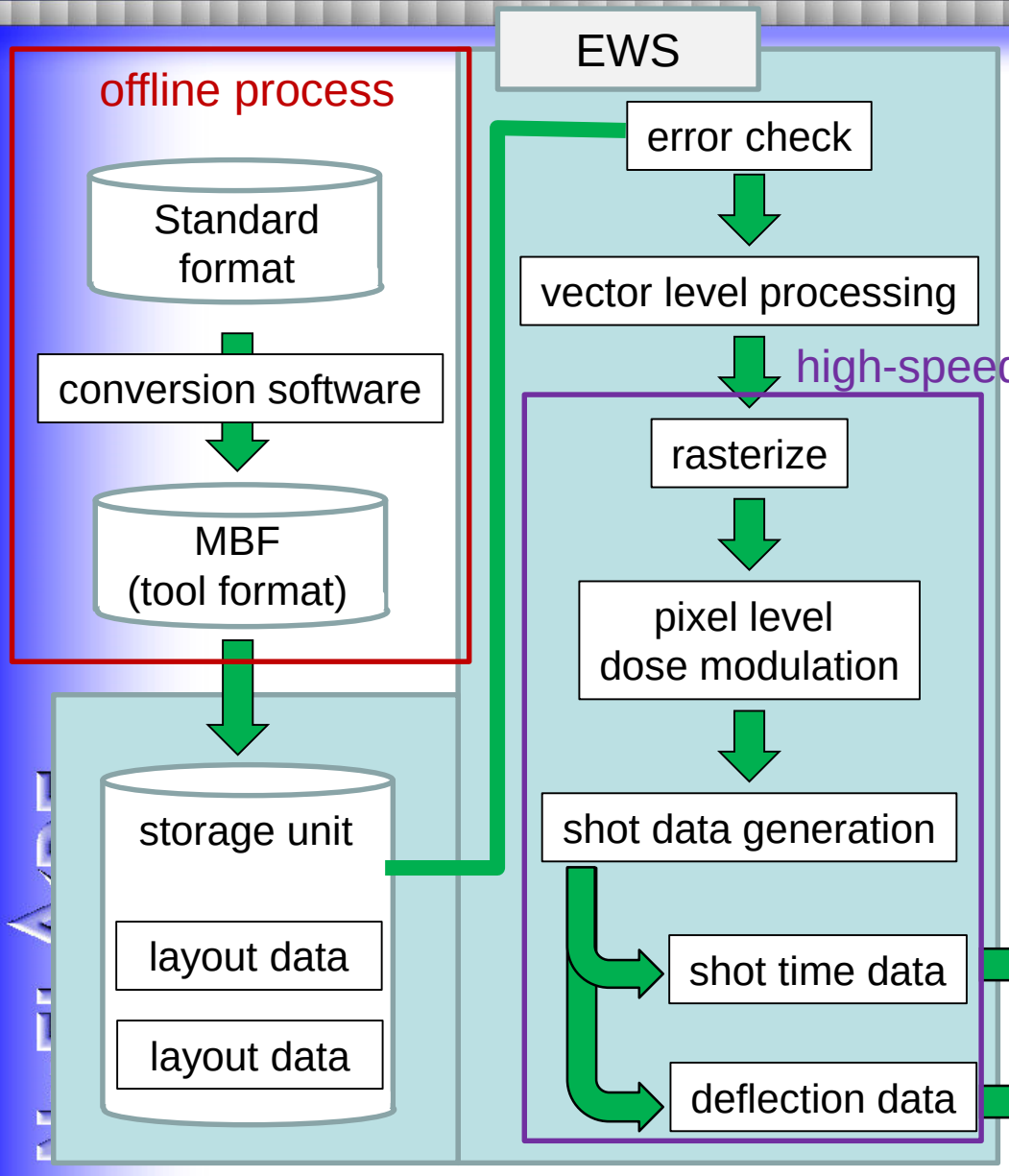
- Offline dose modulation can be used for short range correction with VSB12i EL function.

Correction function



- MBM is capable of all corrections done by inline and real-time.
- New inline correction function provides
  - PEC, EUV-PEC, fidelity optimization
  - Long-range correction (LEC/FEC) and beam-by-beam optimization.

Inline/realtime data path



Data integrity is checked during preceding mask writing and mask transfer.

PEC/FEC/LEC/GMC are applied.

Polygon pattern can be used

Systematic error compensation
Fidelity optimization

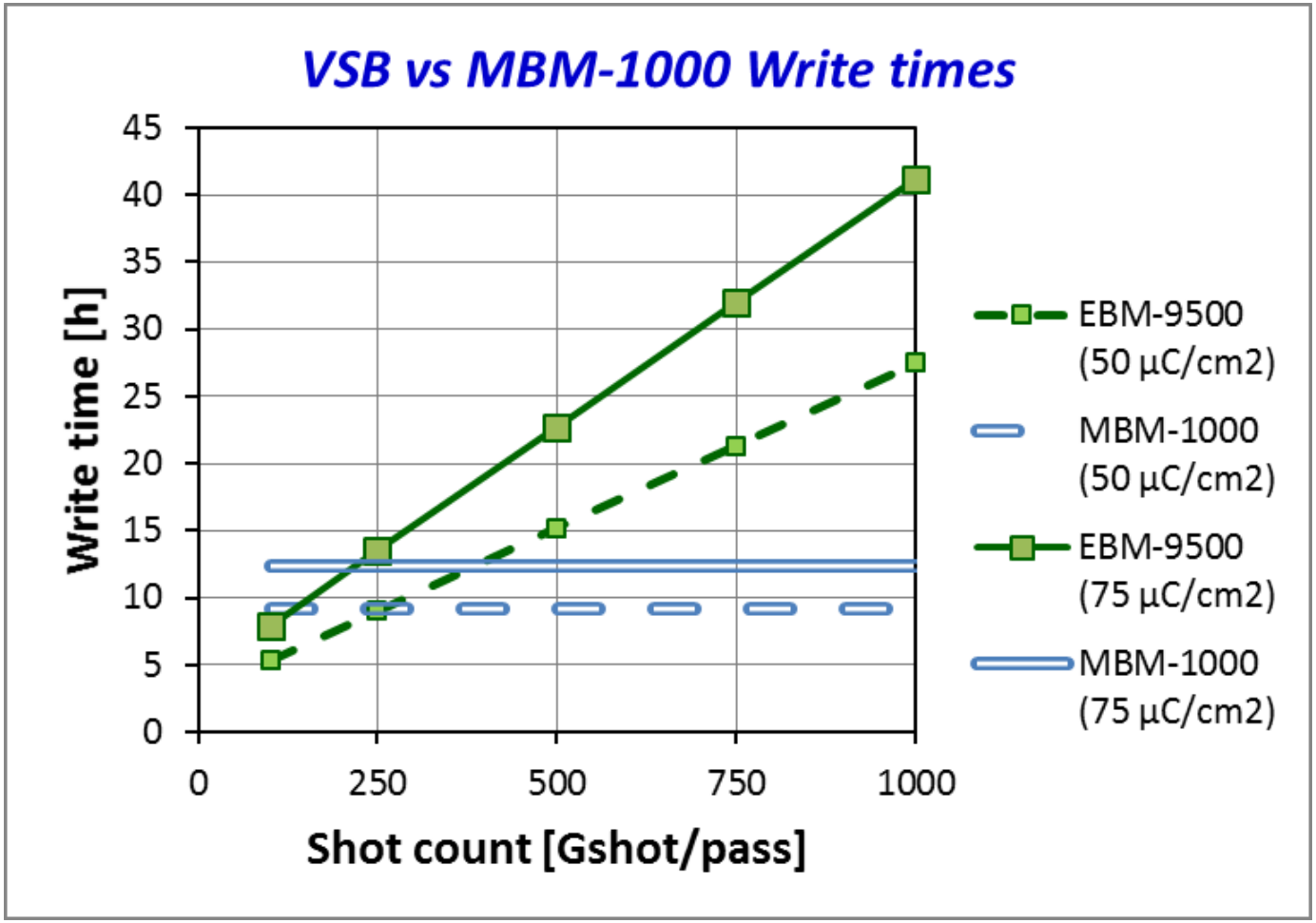
Create low level format data directly send to BAA

Standard specification

Specification		EBM-9000	EBM-9500	MBM-1000
Global Image Placement accuracy [nm 3σ]		3.0	2.1	1.5
CD Uniformity [nm]	Global [3σ]	3.0	2.5	1.5
	Local [3σ]	1.3	1.3	1.0
Beam blur		r	←	< r
Mask write time [hours] (130mmx100mm)		-	-	12 @ 75 μC/cm^2
Beam size [nm]		VSB (0.1 to 250)	VSB (0.1 to 250)	10
Current density [A/cm^2]		800	1200	2

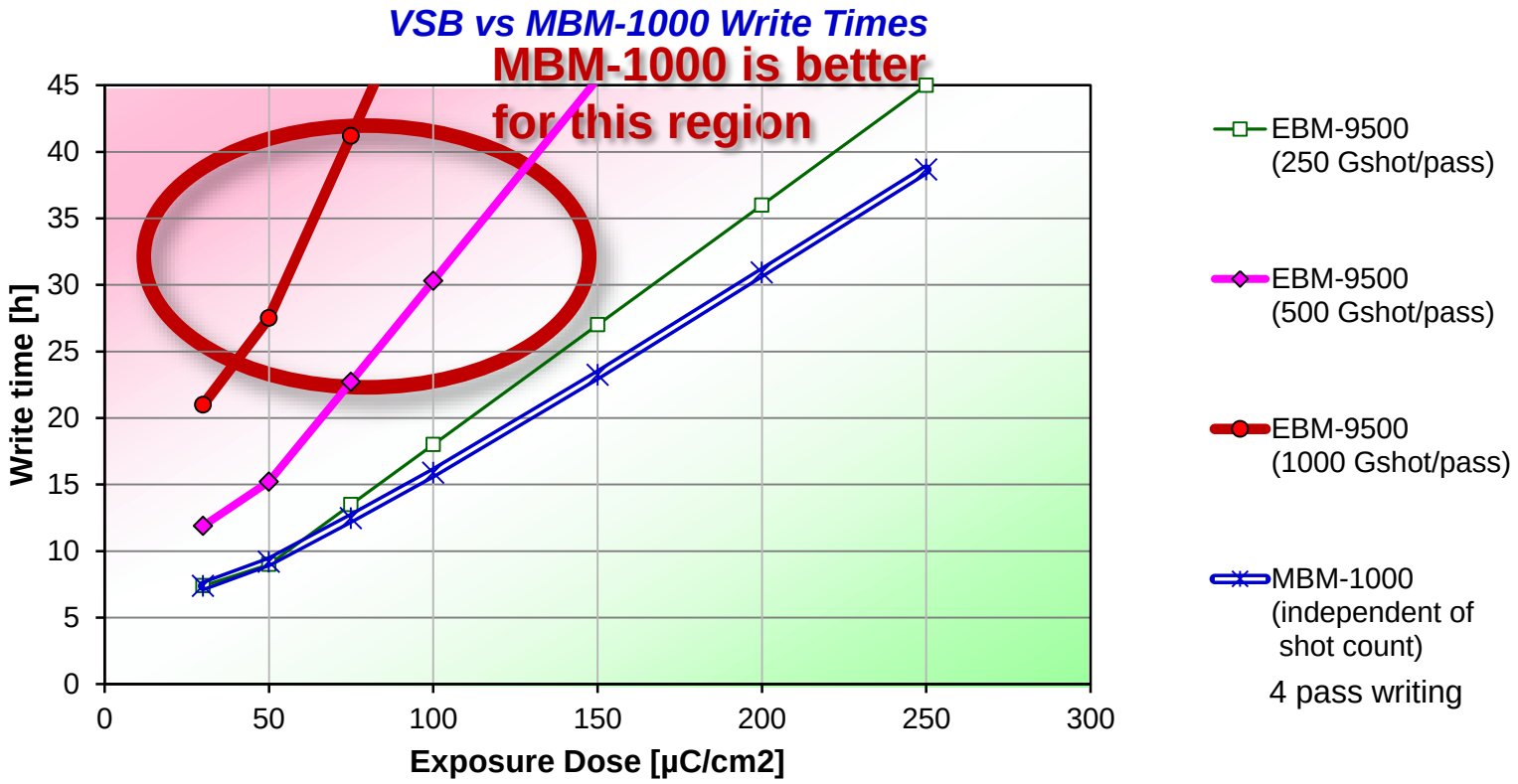
Throughput relative to Shot Count

- MB is advantageous with shot counts > ~200 Gshot/pass.



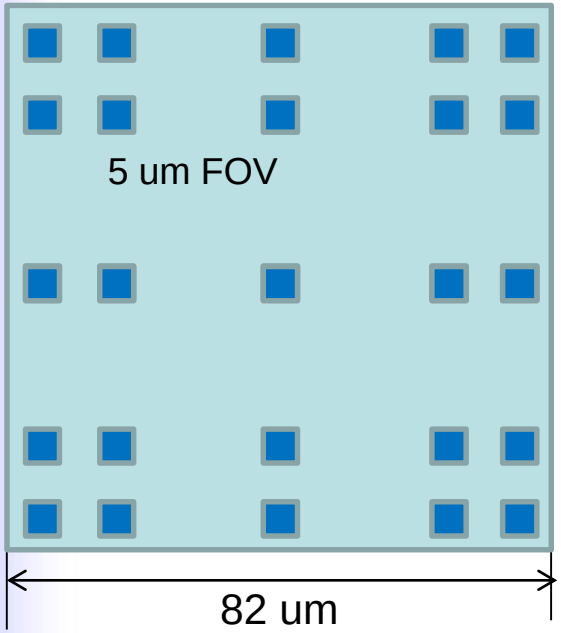
Throughput relative to Dose

- MB is advantageous for
  - Shot count > 200 G/pass and
  - Resist sensitivity > 75 uC/cm^2



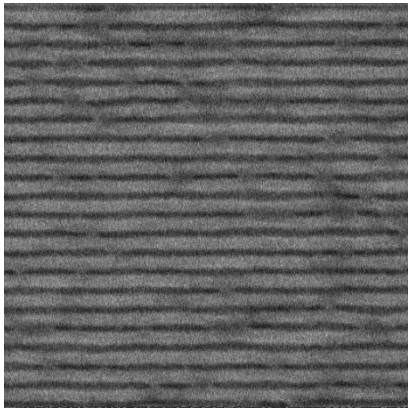
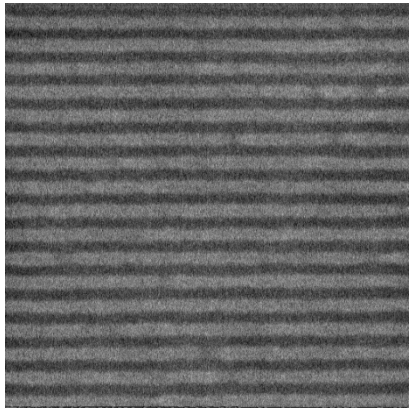
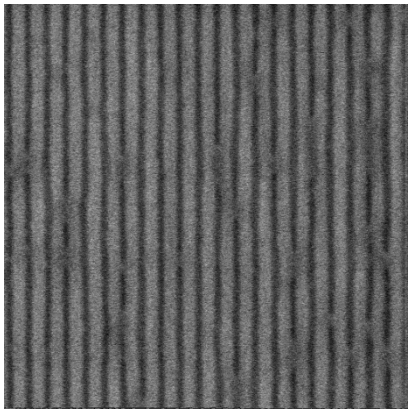
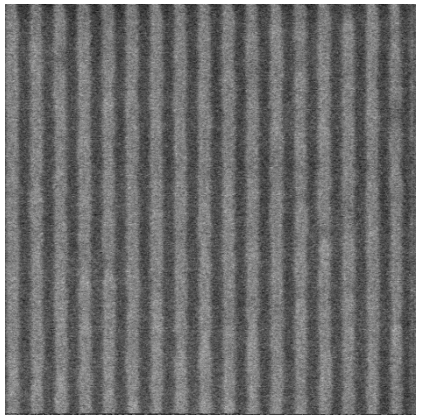
Patterning resolution test

- 20 nm hp resolved within 70 um sq. area.
  - Patterning quality was degraded at the area closed to perimeter of 82 um field



X/Y pos. [um]	-35	-25	0	+25	+35
+35					
+25					
0					
-25					
-35					

Patterning resolution test

	hp 16 nm	hp 20 nm
horizontal		
vertical		

Resist images using ZEP520A
50 nm thickness @ 160 uC/cm^2

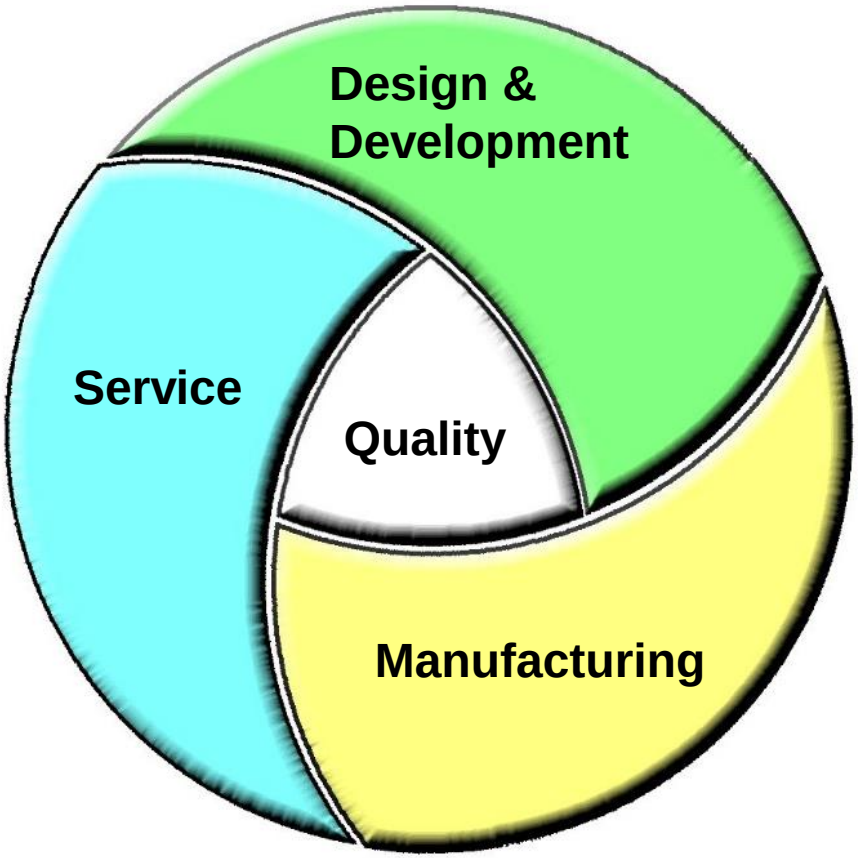
- MBM shows better than hp 20 nm resolution.

Schedule

- Local area writing by Alpha tool: Dec. 2015
  - Demonstrated better resolution than EBM-9500
- Test pattern full area writing : Mar. 2016
- Beta tool beam on : Jul. 2016
- *Customer pattern demo writes : Oct. 2016*
- Upgrade to high-speed data path : Q1 2017

First HVM delivery : Q4 2017

NuFlare, Integrating your needs…



THANK YOU !!!