

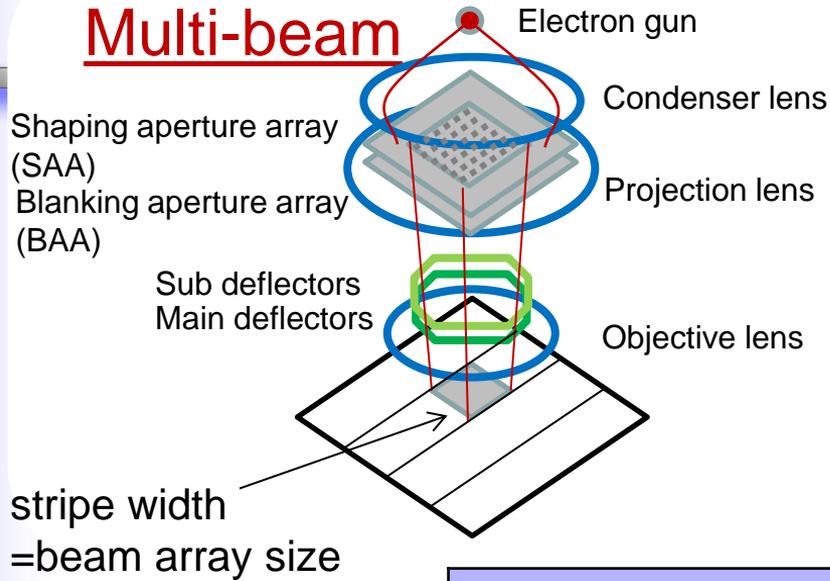


Multi-beam mask writer MBM-1000 for advanced mask making

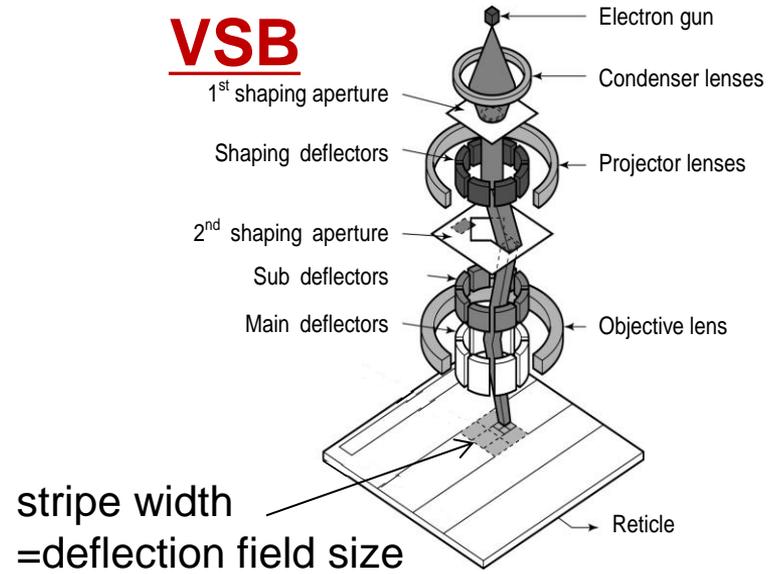
H. Matsumoto
NuFlare Technology, Inc.



Multi-beam



VSB



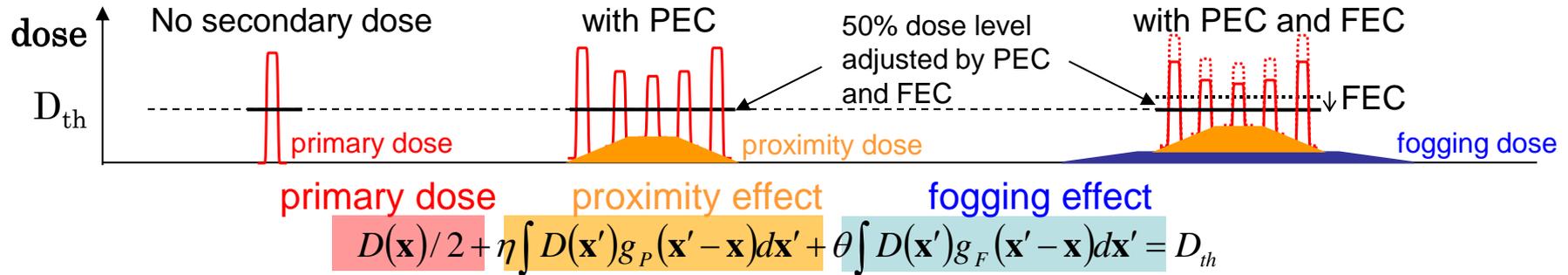
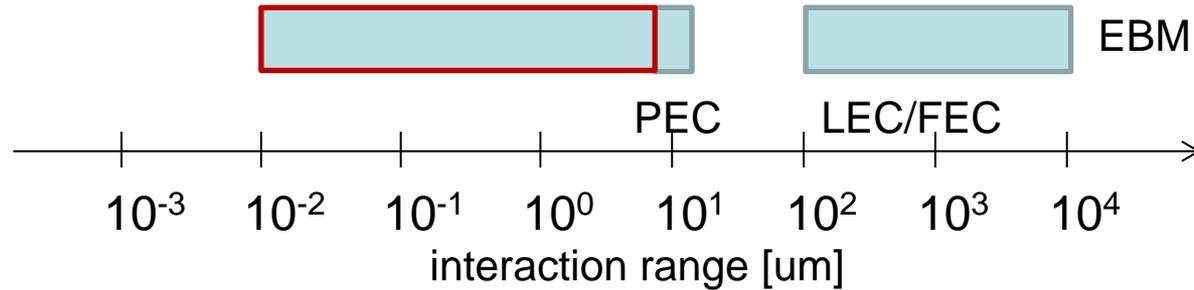
	MBM-1000	EBM-9500
current density (A/cm ²)	2	1200
max. total current (nA)	500	700
CD (nm[3σ])	1.0	1.3
registration (nm[3σ])	1.8	2.5
Shot count (G/pass)	0.9 [#] (pattern independent)	100-500 (pattern dependent)

[#] number of exposure by 512×512 beams for 150mm□ area



Correction functions (EBM series)

offline correction (VSB12i EL)



NFT uses consistent theory for PEC/FEC/LEC.

Offline correction can be handled by VSB12i EL function.

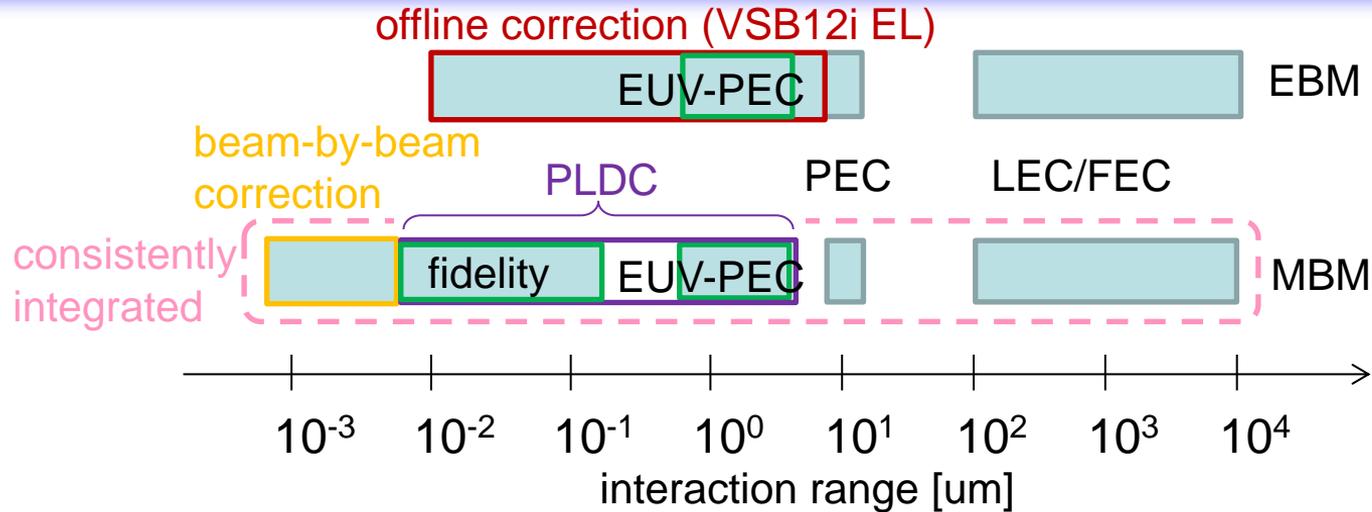
✦ MBM-1000 has pixel level dose correction (PLDC)

- Middle-range effect correction for EUV-PEC
- Short-range effect correction for linearity correction, fidelity improvement and better dose margin

➡ Corrections run inline.
No need for pre-writing calculation.



Correction functions (EBM/MBM)



- MBM does middle-range and short-range correction inline and real-time by using PLDC.
- Corrections by PLDC is consistent with PEC/LEC/FEC



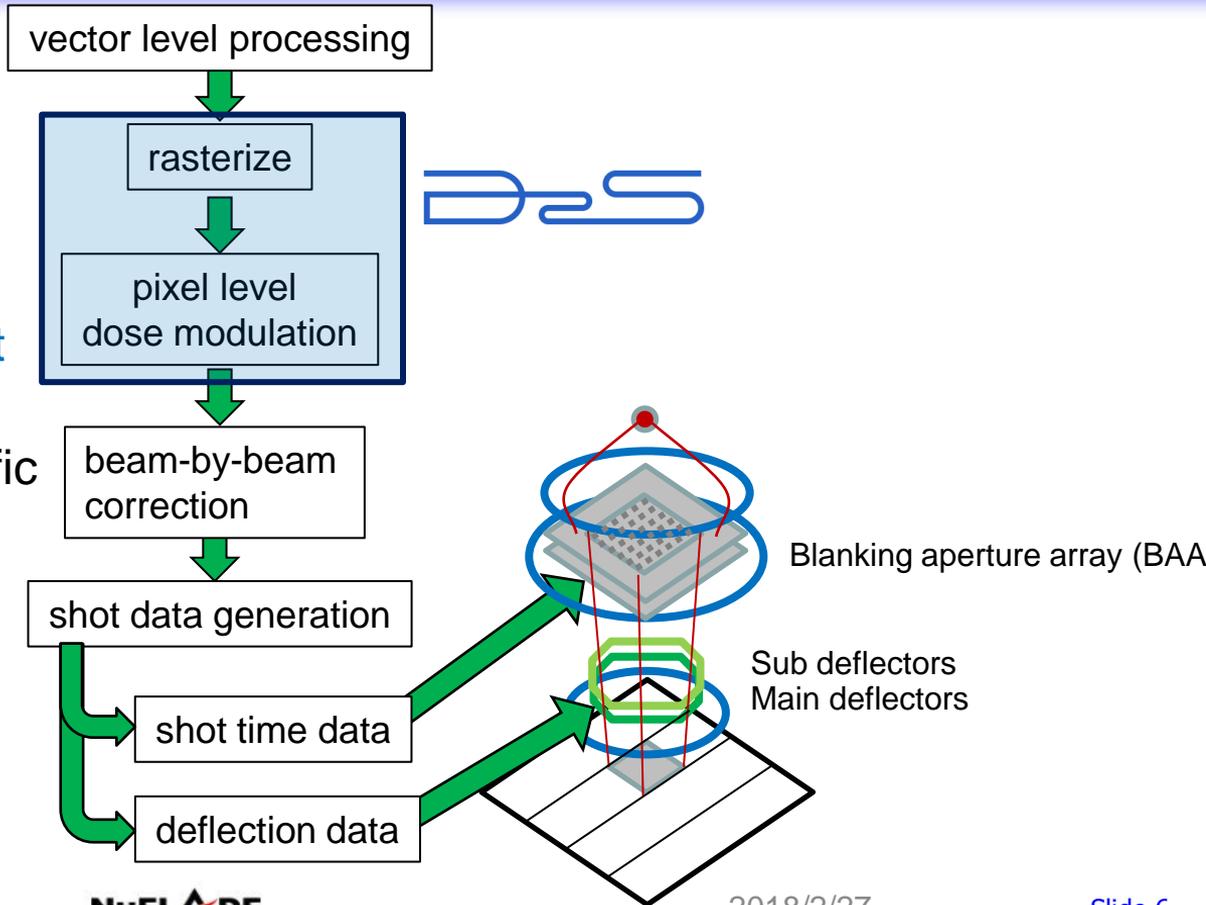
Data path in MBM-1000

PEC/FEC/LEC/GMC are applied.

PLDC integrated with rasterizer

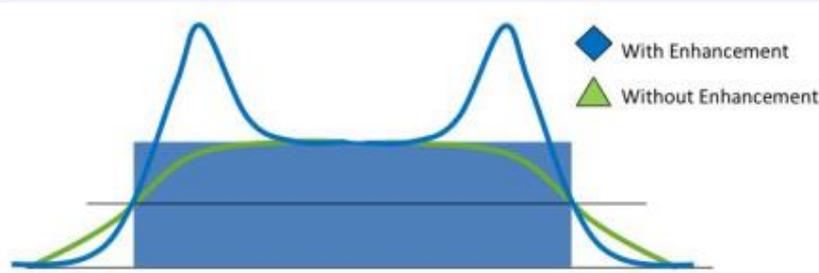
linearity correction
dose margin enhancement
EUV-PEC

tool-specific correction

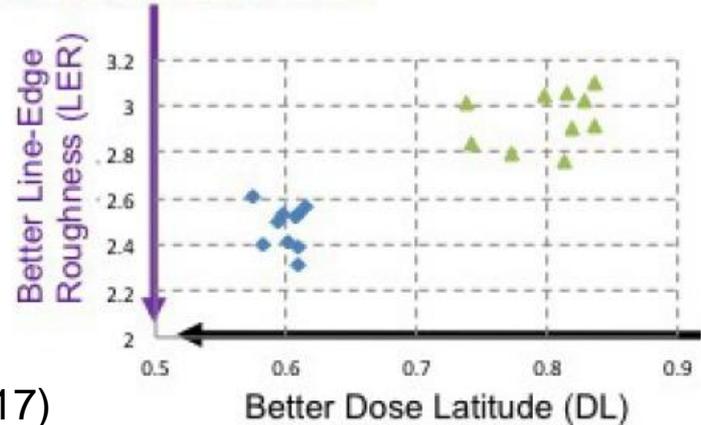




Resolution enhancement by PLDC



Zable et al.
Proc. of SPIE Vol. 10454 104540D-1 (2017)

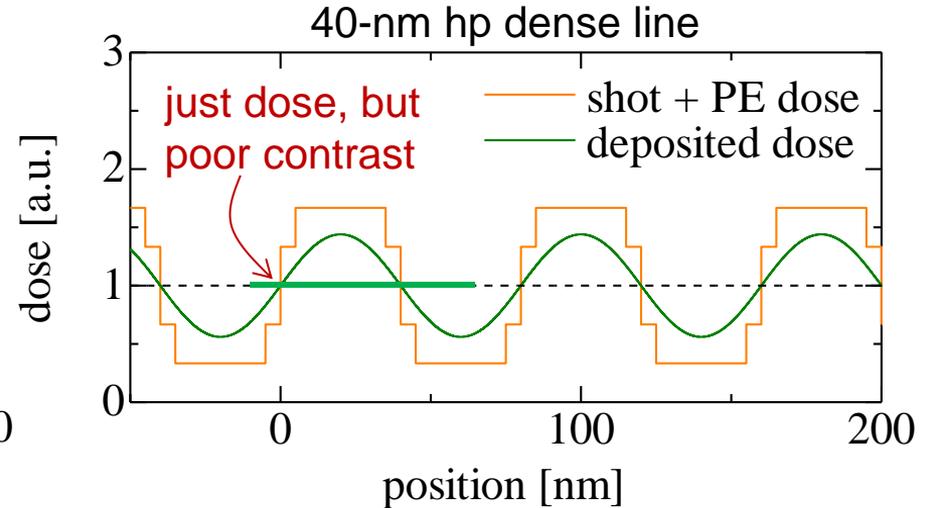
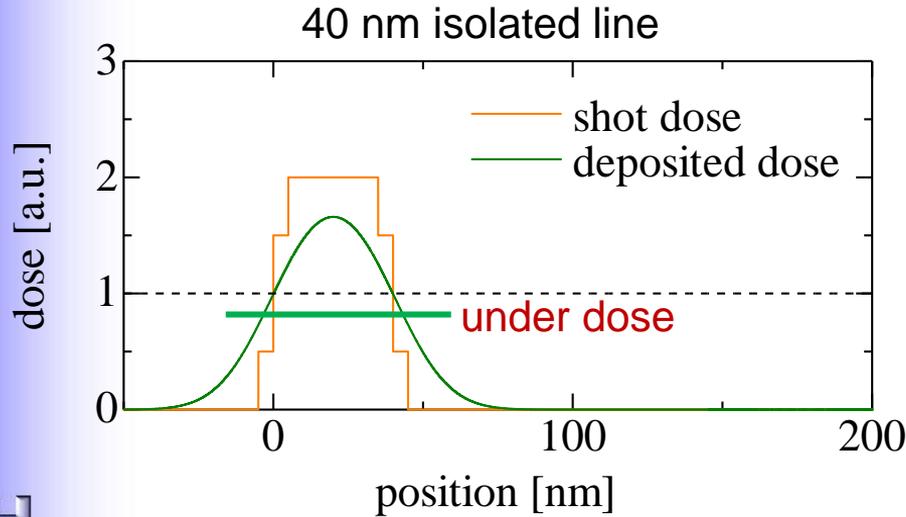


- PLDC improves dose profile by pixel-based dose correction.
 - Dose contrast at pattern edge is enhanced to widen process margin.
 - Dose profile can be adjusted to correct patterning linearity.



Linearity

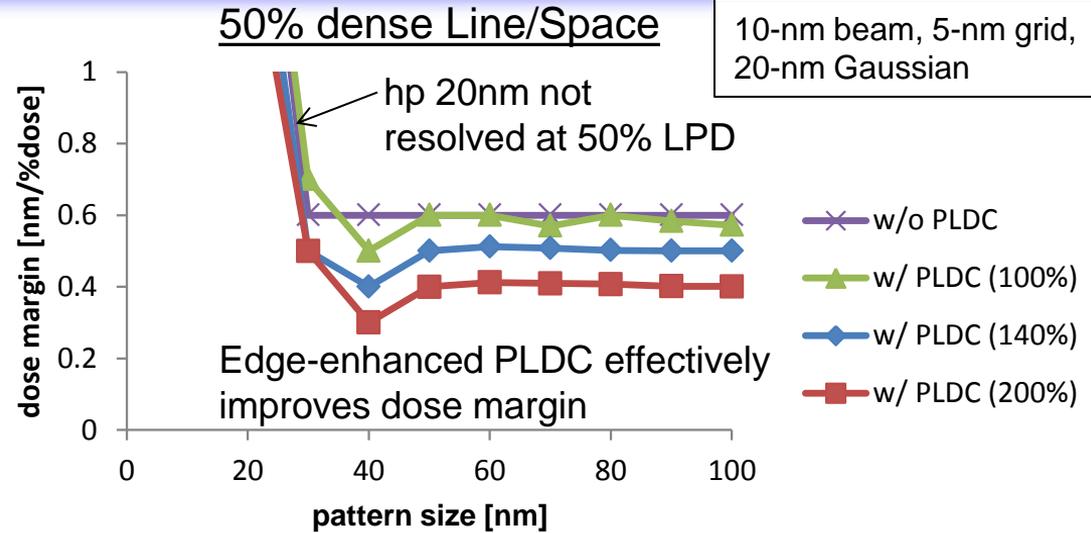
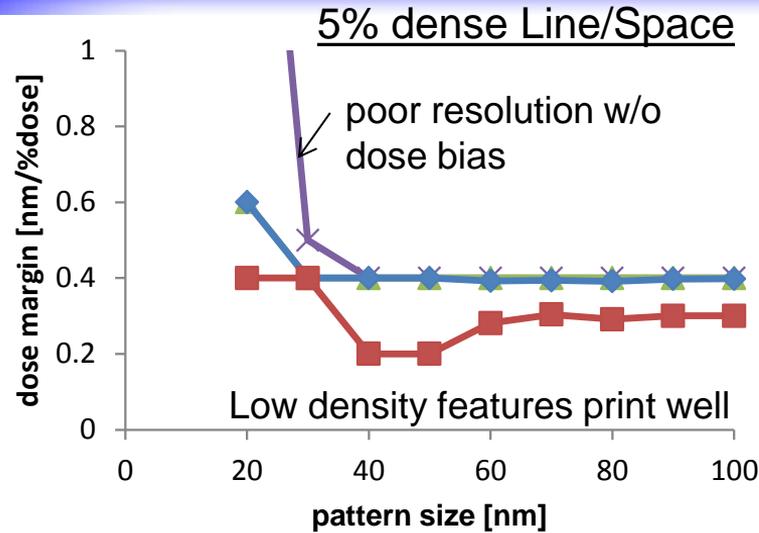
10-nm beam, 5-nm grid,
20-nm Gaussian



☛ Dose blurring limits patterning resolution at fine pitch.



PLDC enhances dose margin

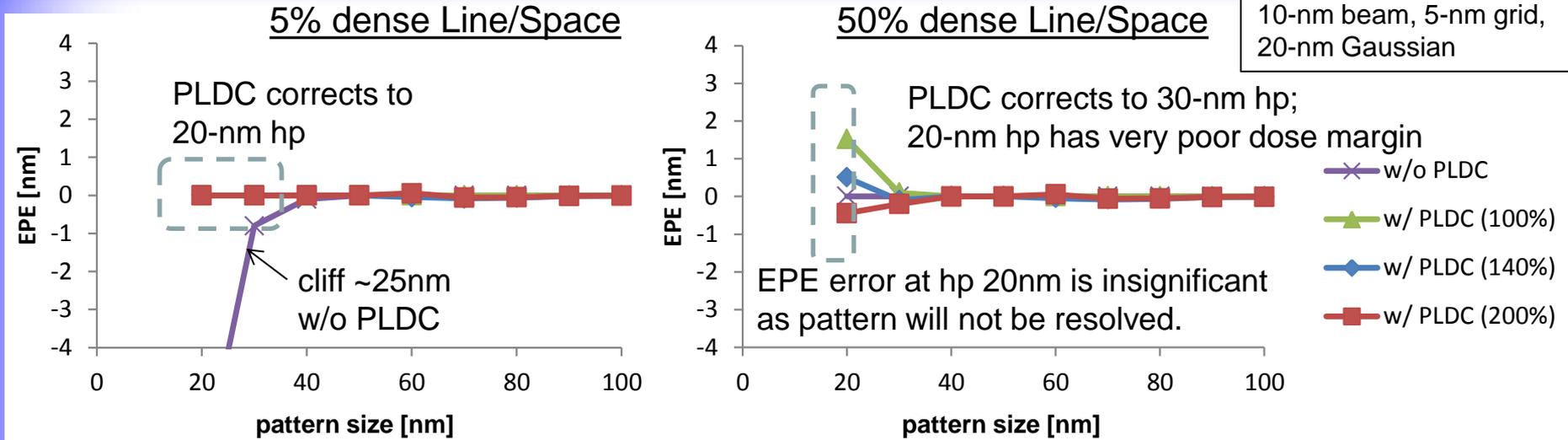


PLDC improves patterning resolution.

- Larger dose modulation leads to more improvement, but requires longer write time.
- PLDC is effective with 140% modulation which can be good option to balance improvement and TPT.



PLDC corrects for linearity

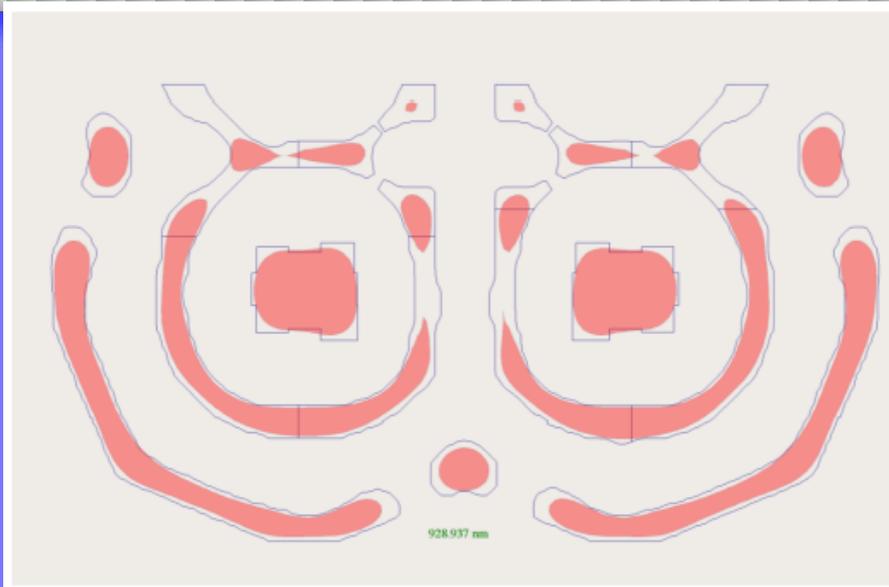


EPE linearity is corrected.

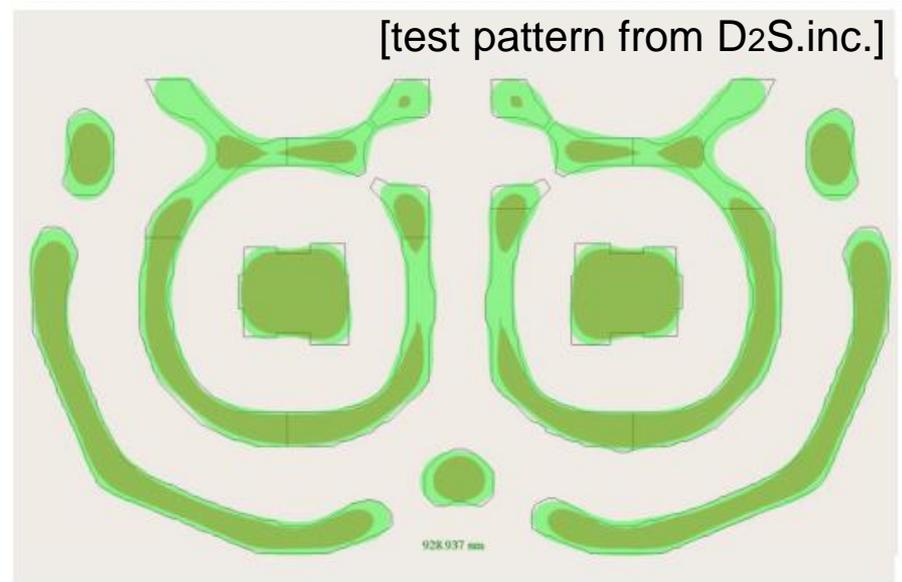
- PLDC corrects for linearity, with increasing dose margin.
- Correction accuracy is ok even with 100% dose modulation.



PLDC for curvilinear pattern



Simulation without PLDC



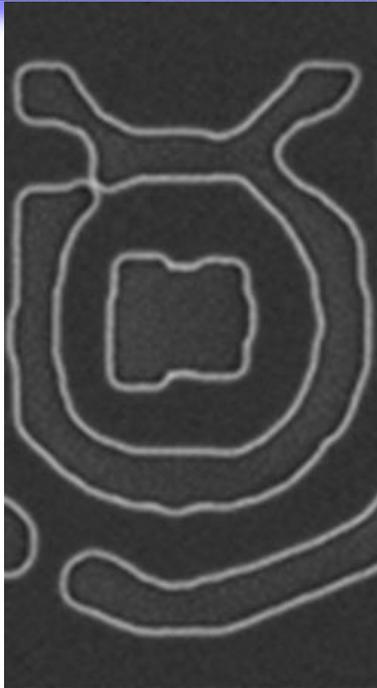
Simulation with PLDC for edge enhancement

H. Zable et al., " GPU-accelerated inline linearity correction: pixel-level dose correction (PLDC) for the MBM-1000" , Proc. SPIE 10454, 104540D-1, (2017).

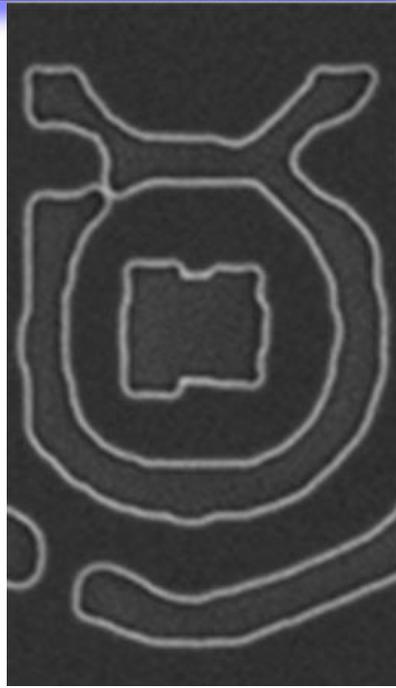
 **PLDC enables ILT patterning without turnaround time penalty**



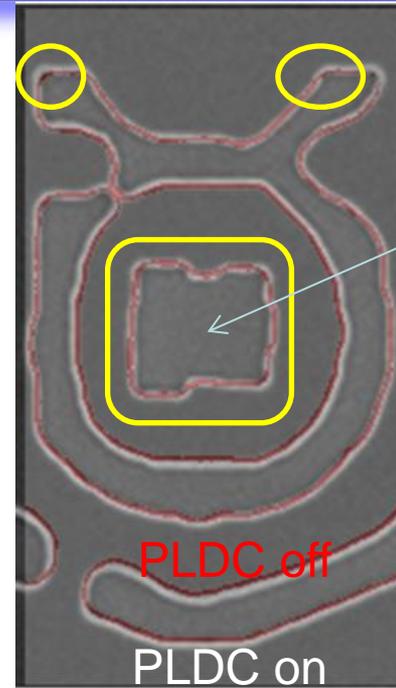
PLDC for curvilinear pattern



PLDC off



PLDC on



PLDC off

PLDC on

comparison

4X size of 80 nm contact

low sensitivity resist ($\sim 140 \text{ uC/cm}^2$)

 Pattern fidelity is improved by PLDC



Conclusion

- ✦ PLDC corrects linearity with increasing dose margin.
 - Effective with 140% dose modulation
 - Corrects to 20-nm hp (5% density) and 30-nm hp (50% density) with 20 nm total blur.
- ✦ PLDC provides EUV-PEC, which is middle-range PEC for EUV substrate.
- ✦ PLDC is integrated consistently with correction function of PEC/FEC/LEC



Thank you for your kind attention