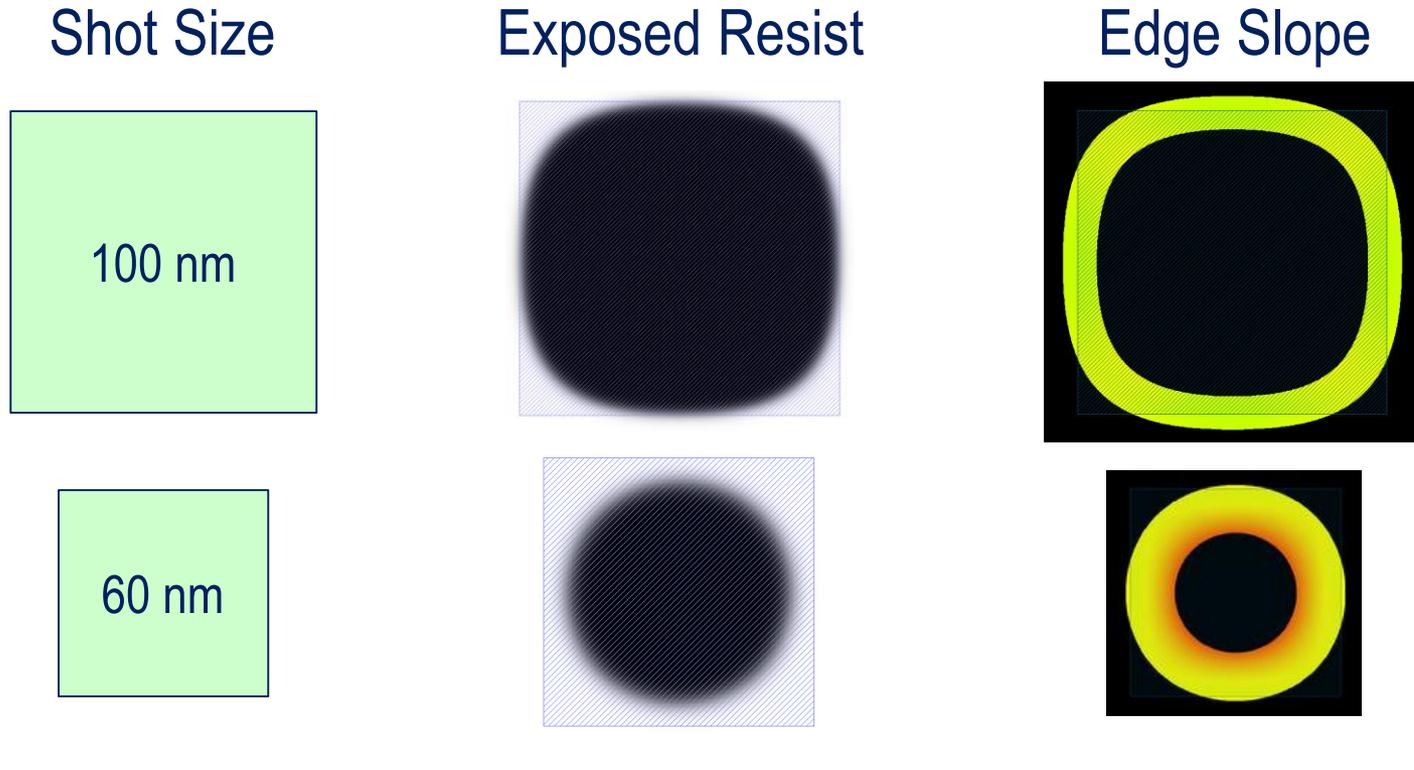

The Latest Progress in Model-Based Mask Data Preparation

Linyong (Leo) Pang

Bo Su

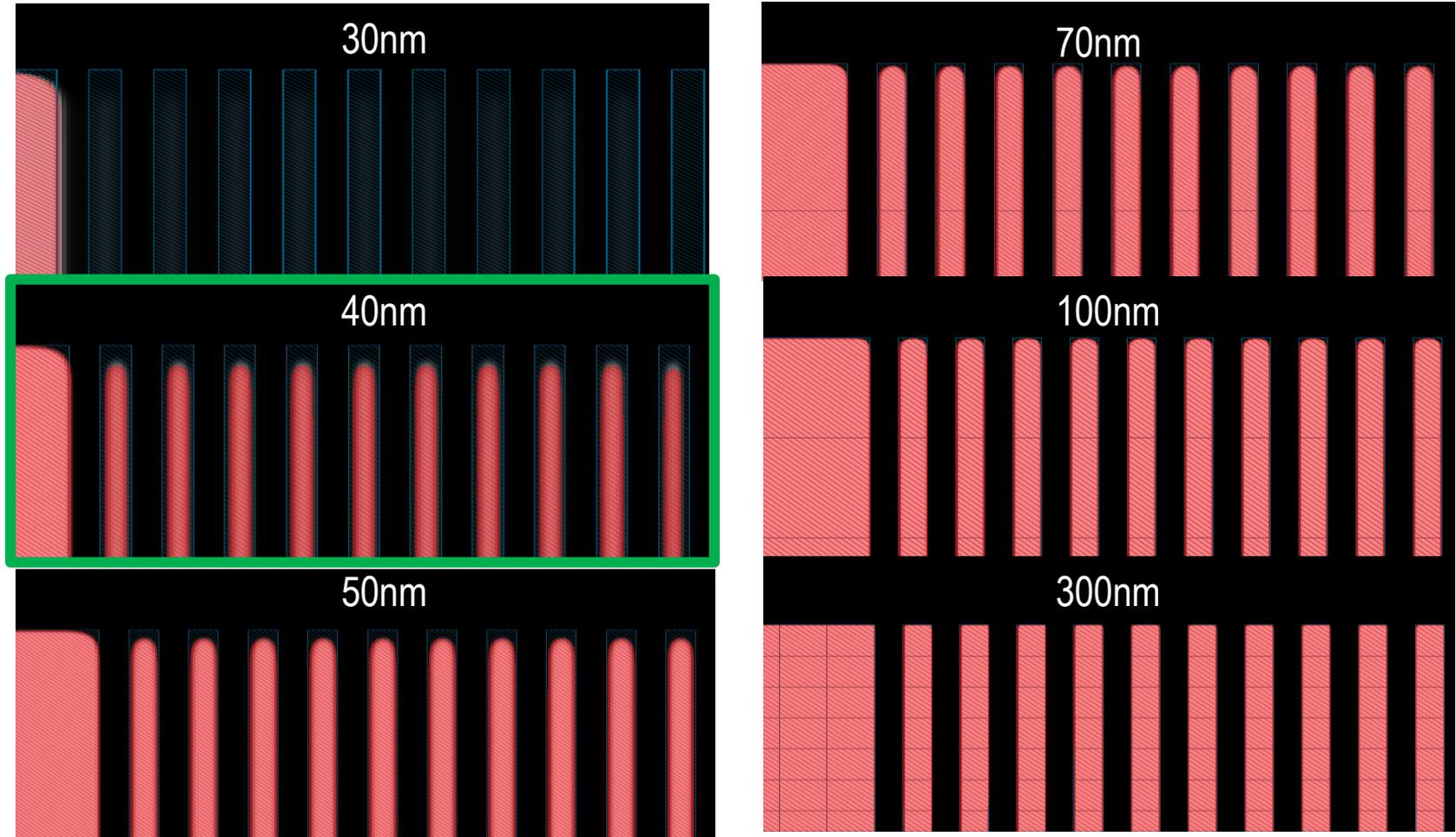
D2S, Inc.

eBeam Needs Proximity Correction

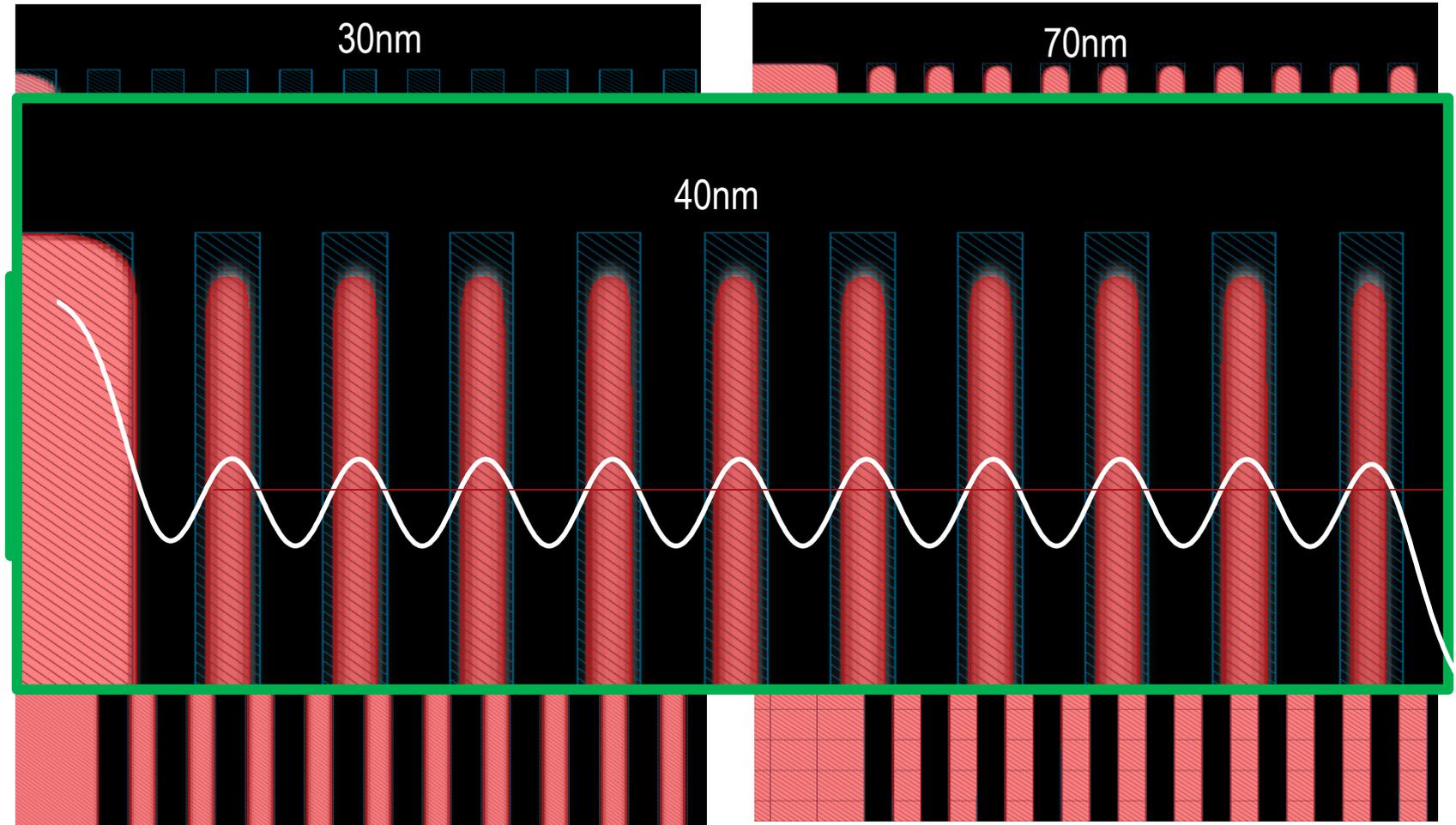


- At 20nm node, eBeam writing is no longer “faithful”
- Needs proximity correction, like OPC at 90/65nm
- Dose margin is the problem

< 50nm, Context is Critical



< 50nm, Context is Critical

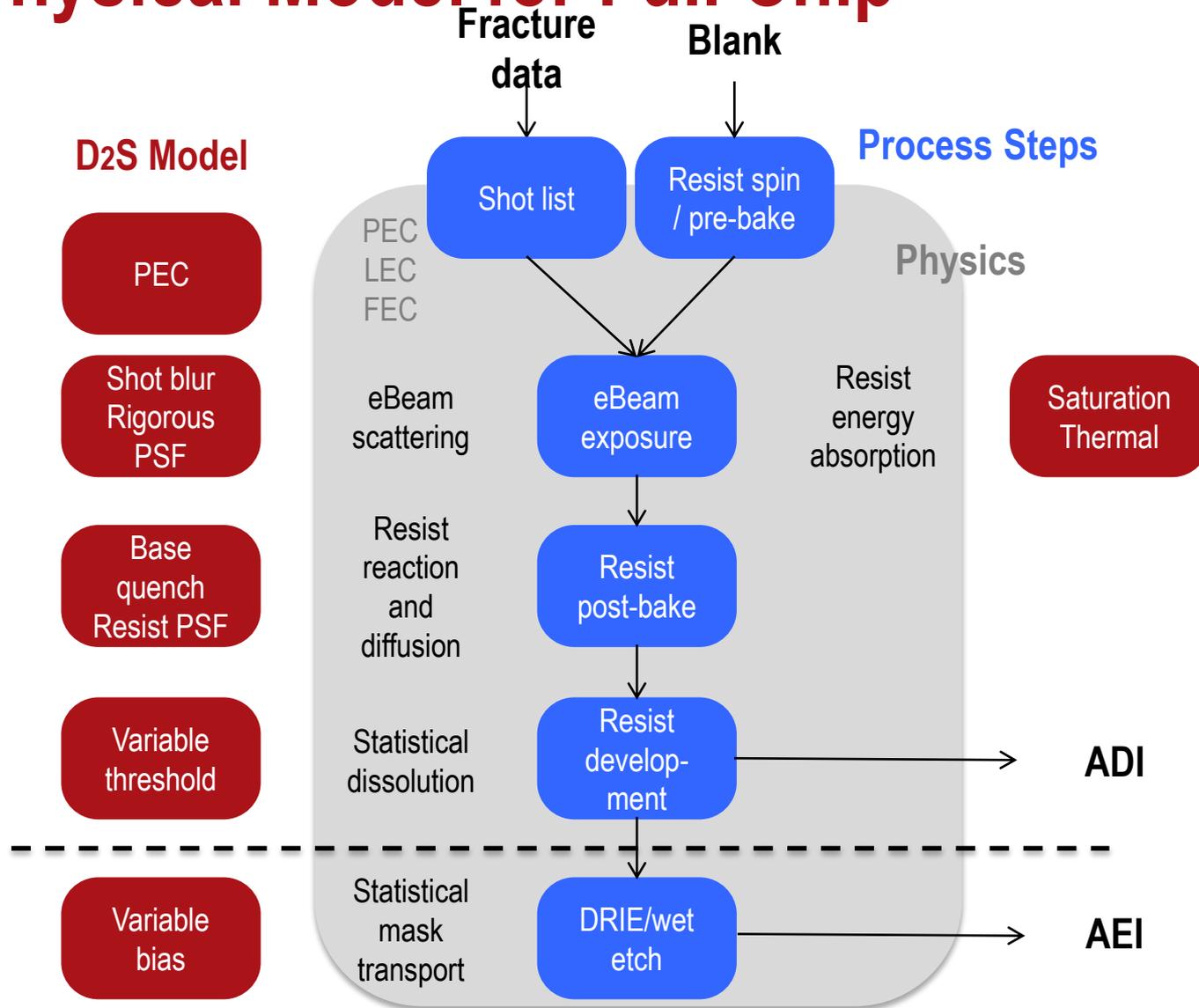


Pictures enlarged to show contour

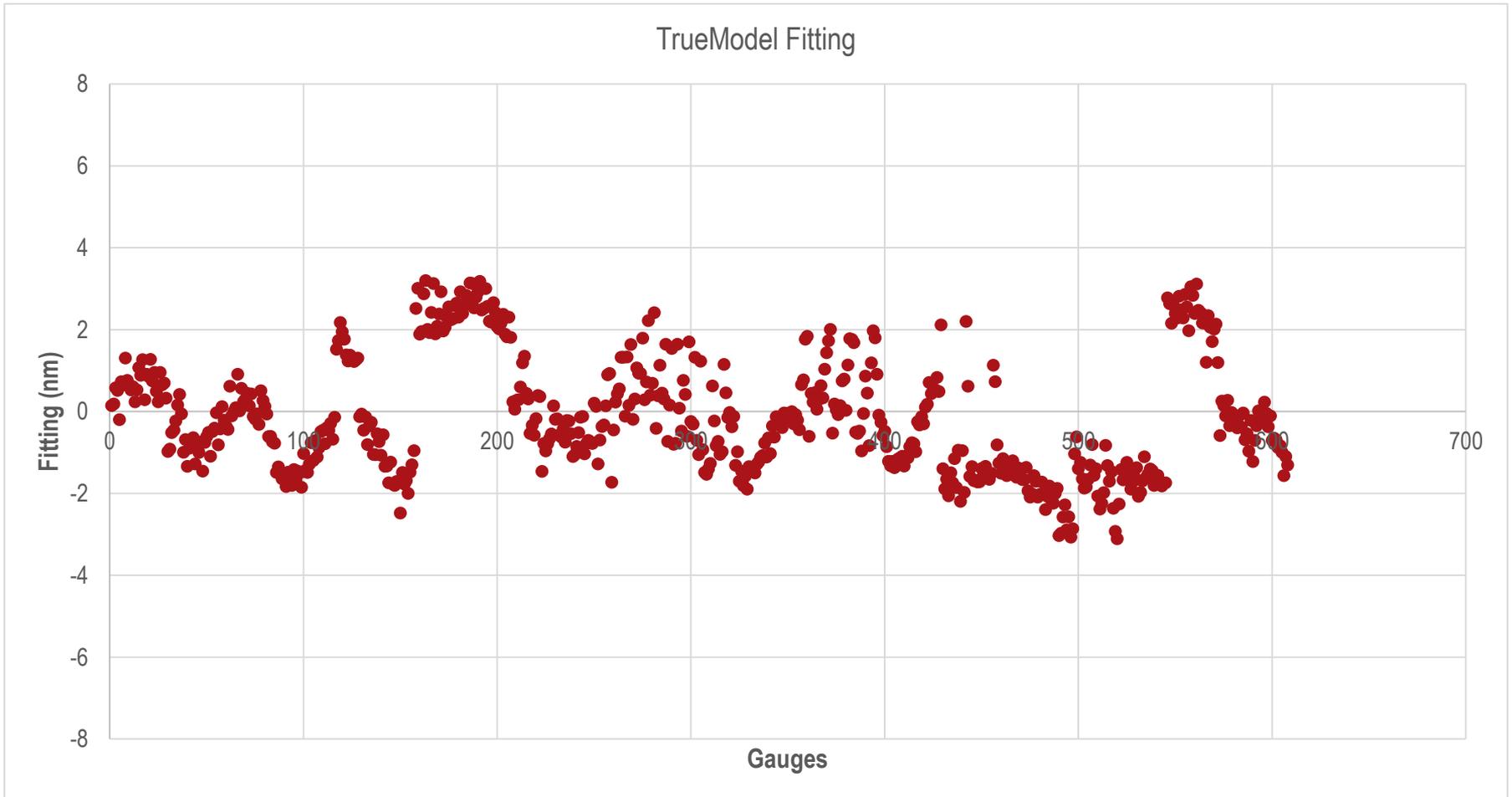
Model-Based MDP is the Answer

- Above 50nm, context-independent, rules-based processing works well enough
- Below 50nm, context is critical
- If we can't push below 40nm, we leave the benefits of Moore's Law on the table
- Simulation-based mask processing is the answer

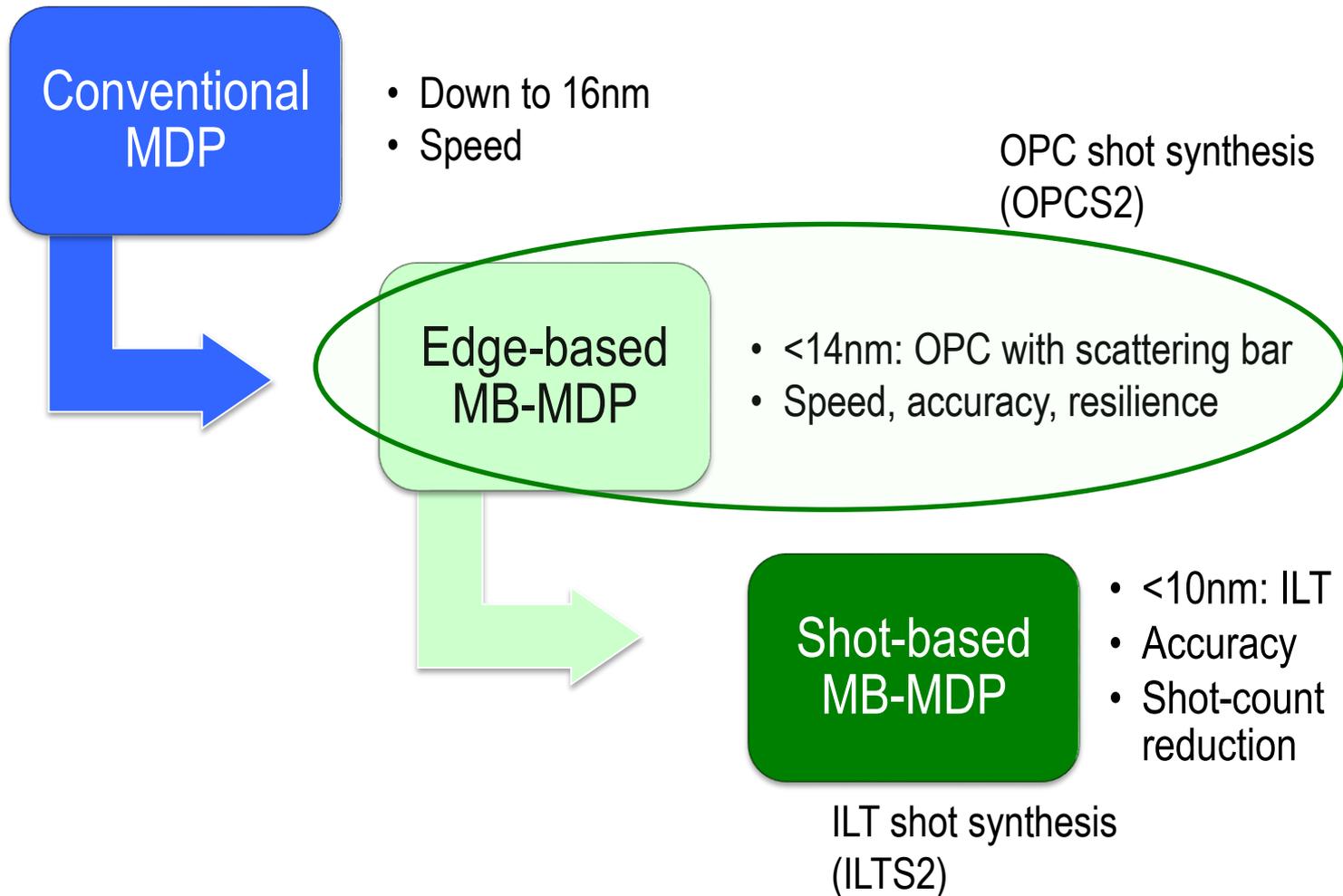
Mask Model is the Key: TrueModel[®] is a Fast Physical Model for Full Chip



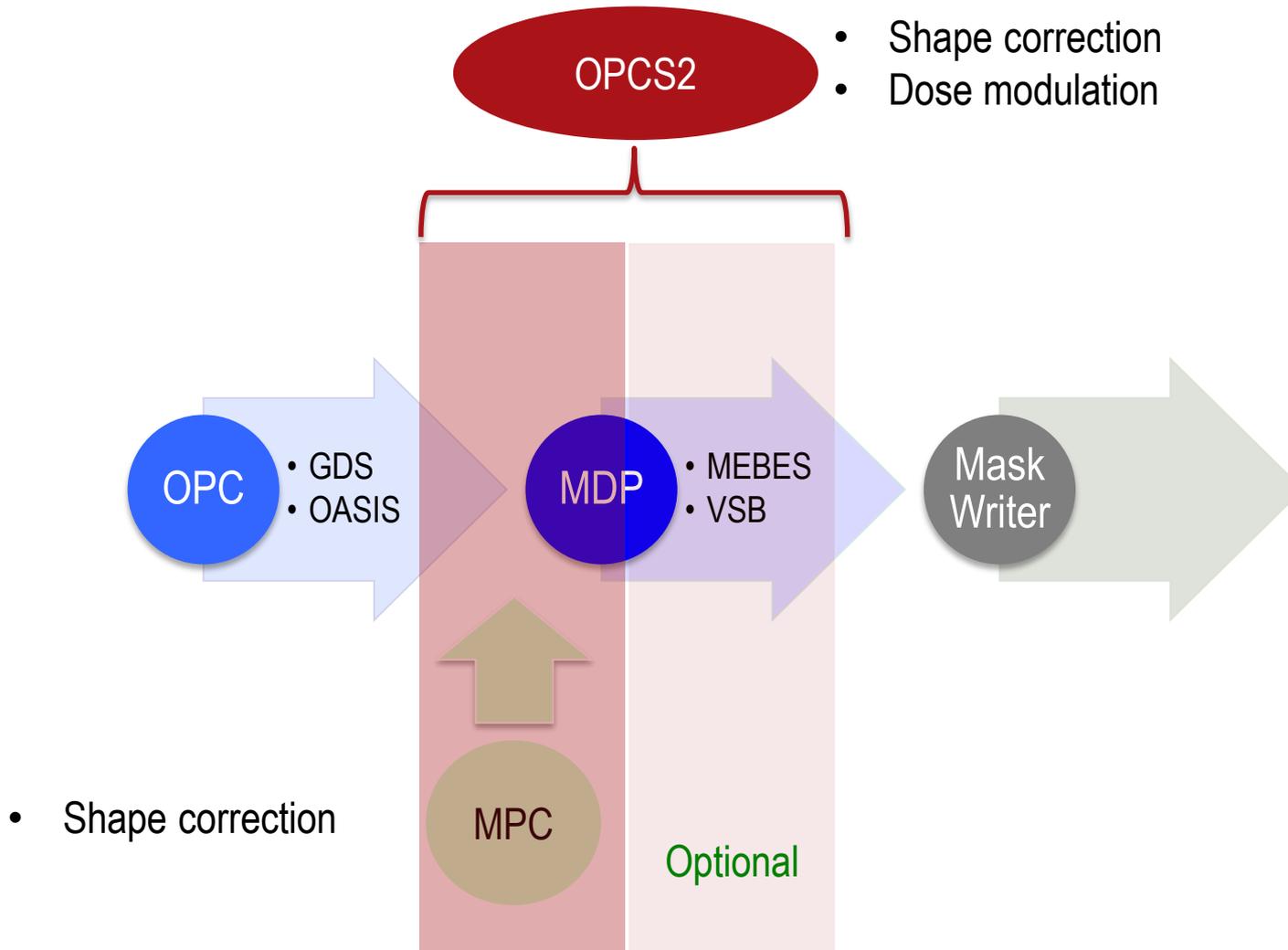
D2S TrueModel is Reaching 1.5nm RMS, Qualified at World Leading Semi Companies



MB-MDP Has Right Approaches for both OPC and ILT Masks



OPCS2 = MPC+ Dose Modulation + Conventional MDP

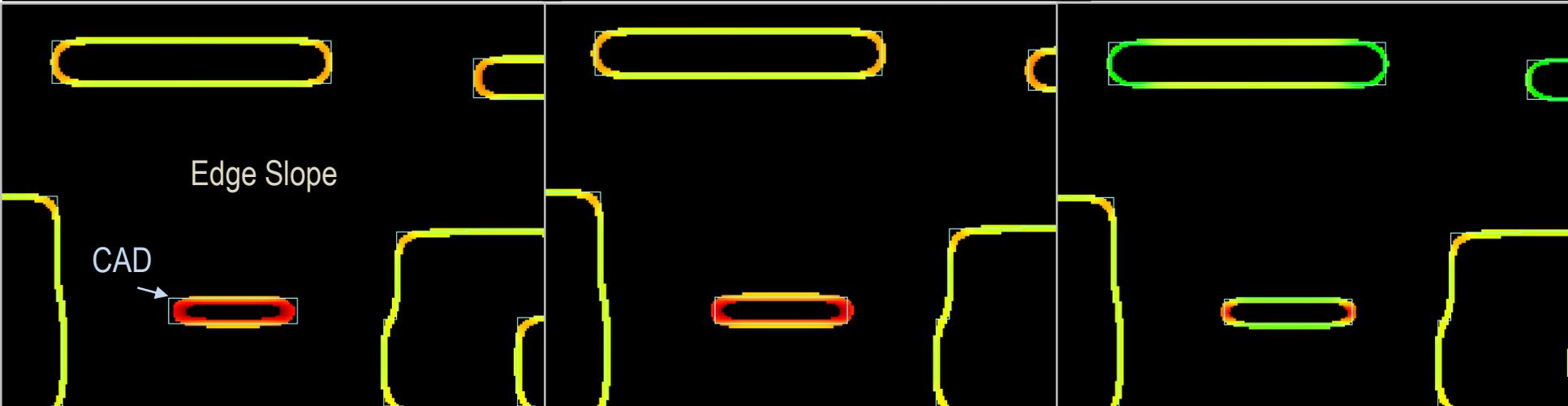
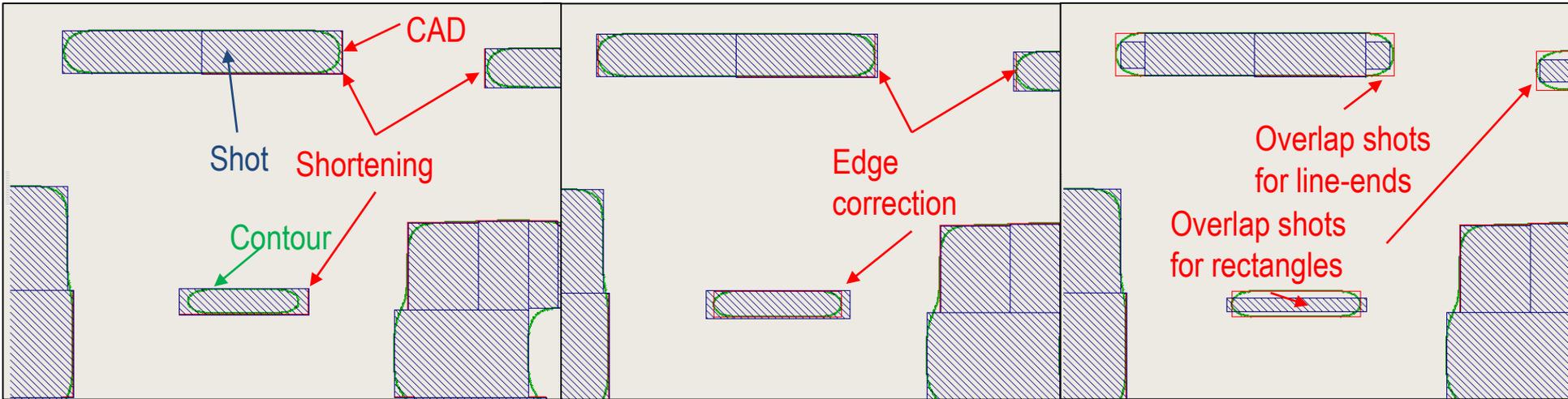


OPCS2 Efficiently Improves SRAF Printing and Linearity for Normal OPC

Conventional

MPC

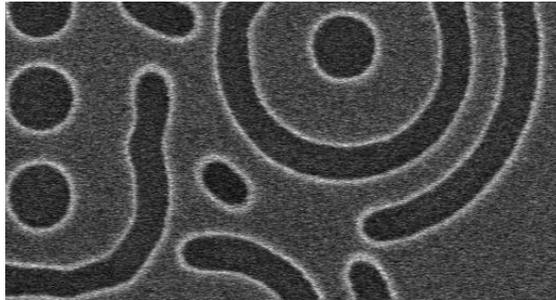
OPCS2



But ILT is Coming

EAGLES

2005



6

Papers

2

Foundries

1

Memory

1

Mask shop

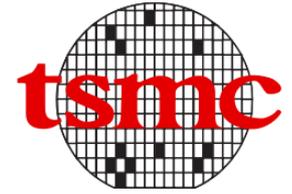
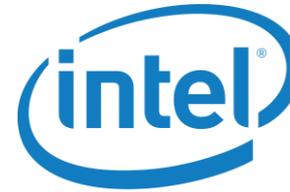
Luminescent
TECHNOLOGIES™

Enter the complex mask...

ILT Adopted as the Way Forward



>200
Papers



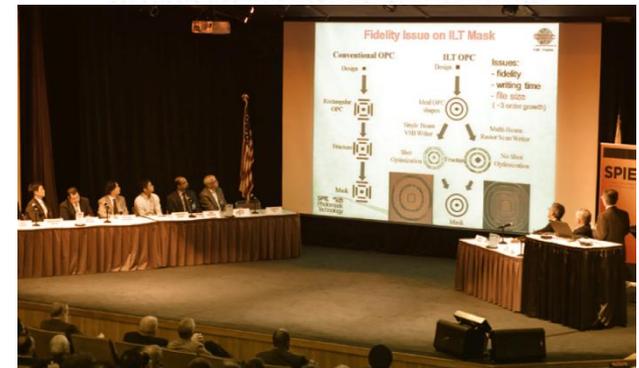
台灣積體電路製造股份有限公司
Taiwan Semiconductor Manufacturing Company, Ltd.

Officially
announced

Today



台灣積體電路製造股份有限公司
Taiwan Semiconductor Manufacturing Company, Ltd.



ILT expertise proliferated

2014 panel

Complex Masks Pose Challenges, in Particular, Mask Writing



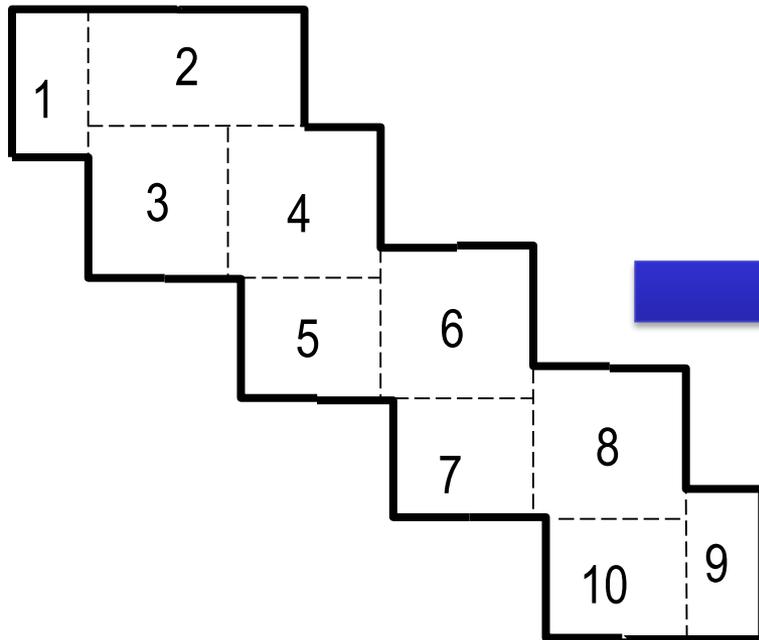
Long VSB write-times



Low accuracy
due to proximity effect

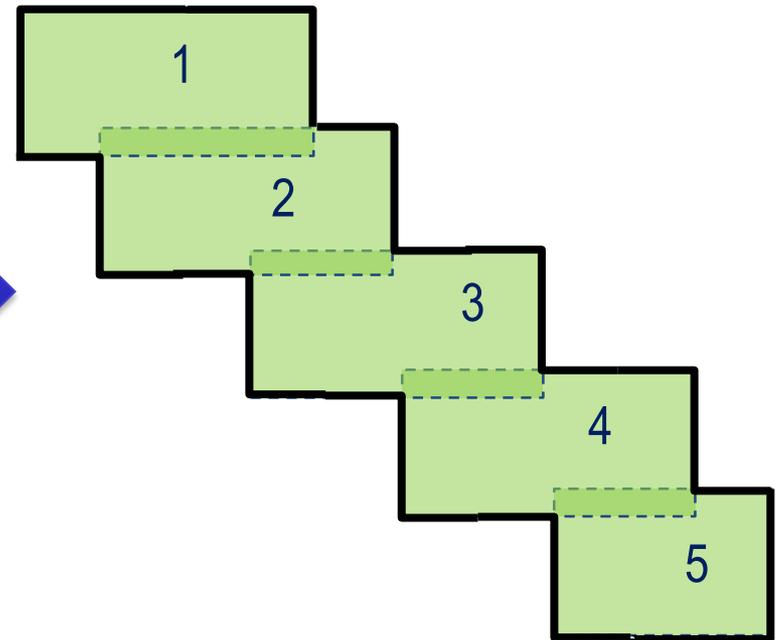
Overlapping Shots = Reduced Shot Count

10 conventional shots



5 overlapping shots

Plus, extra energy in overlapping areas



Overlapping shots cast more energy in less mask-writing time:

= Better process margin

= Better CDU

= No mask-write time vs. mask-quality compromise

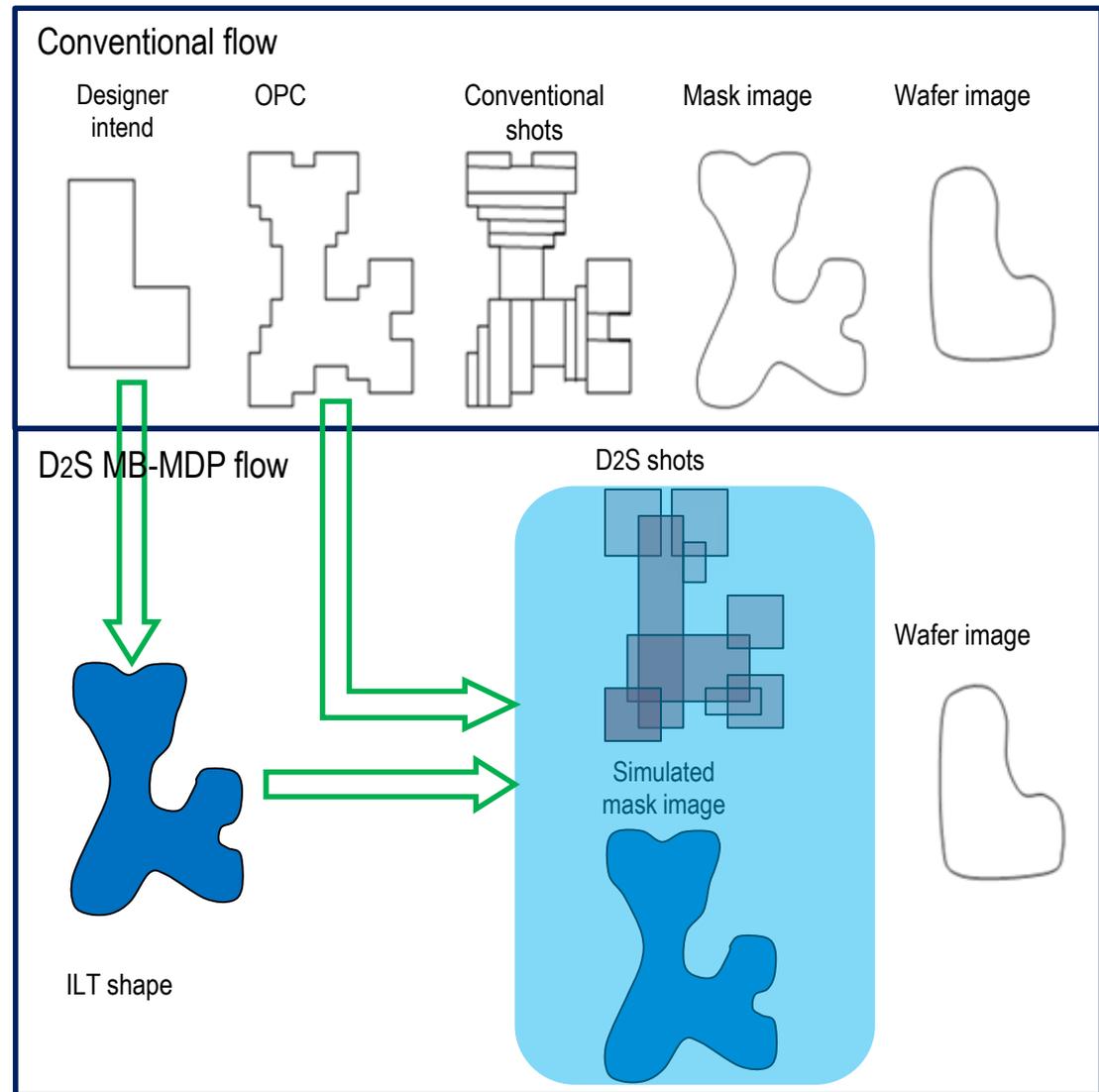
MB-MDP, Overlapped Shots Required with VSB for Complex Masks

- Conventional solution:

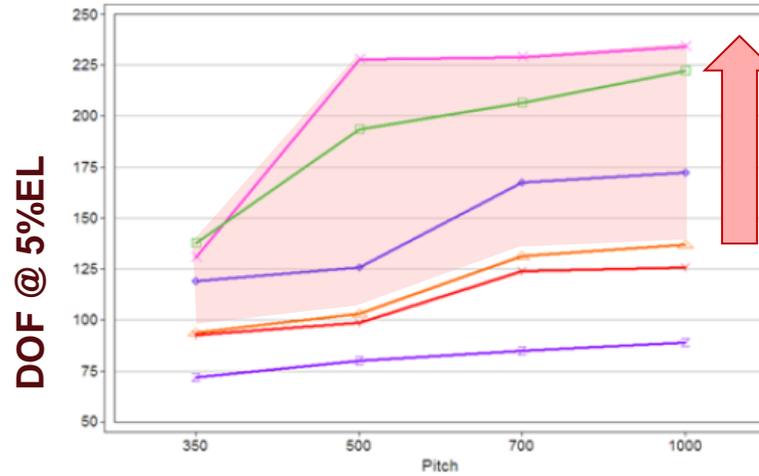
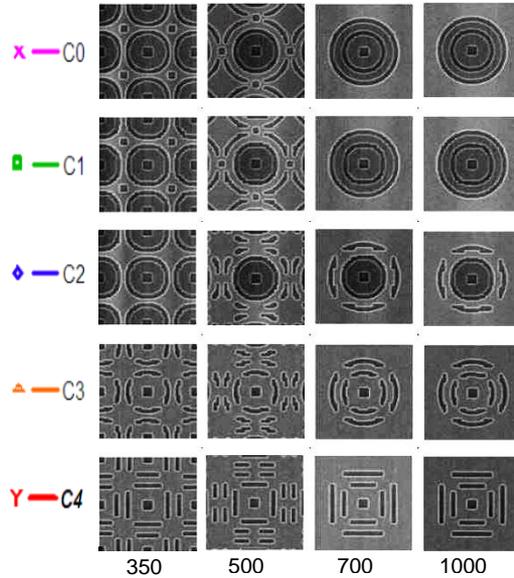
- Geometry-based
- Shots cover CAD layout without overlapping
- More shot count and worse mask fidelity

- D2S solution:

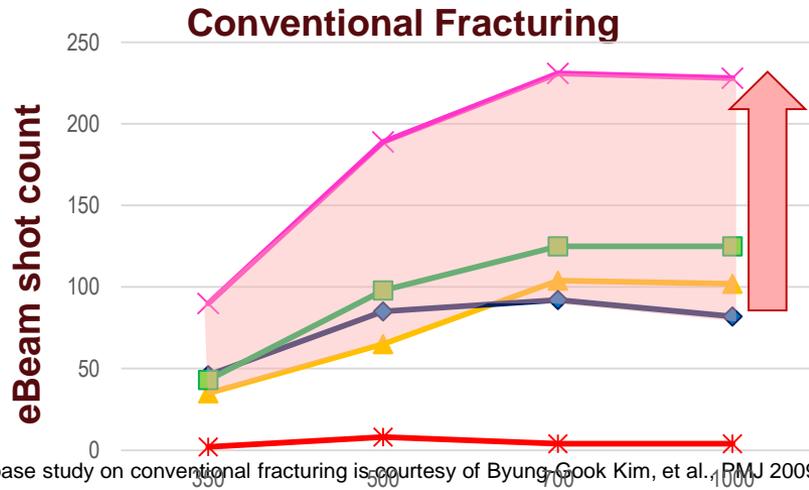
- Model-based, better CDU control
- Utilizes overlapping shots to maximize shot contribution to the final mask shapes
- Less shot count and better mask fidelity



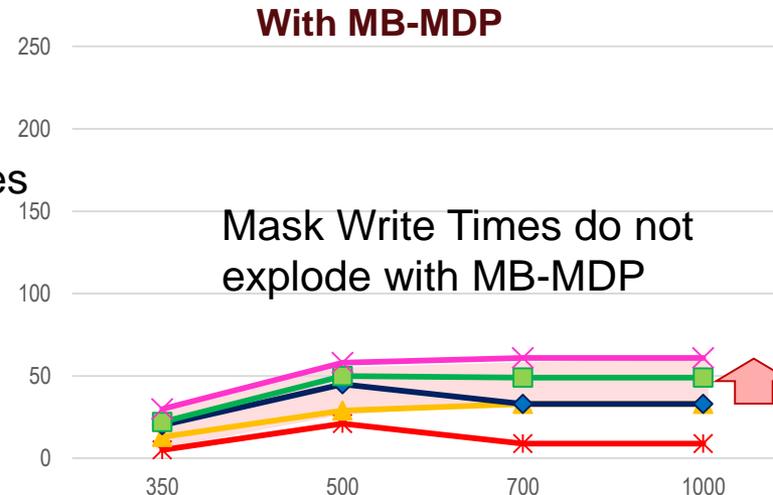
Complex Shapes are only Feasible with MB-MDP and Overlapped Shots



Much better DOF possible with unconstrained shapes



But Mask Write Times Exploded



Mask Write Times do not explode with MB-MDP

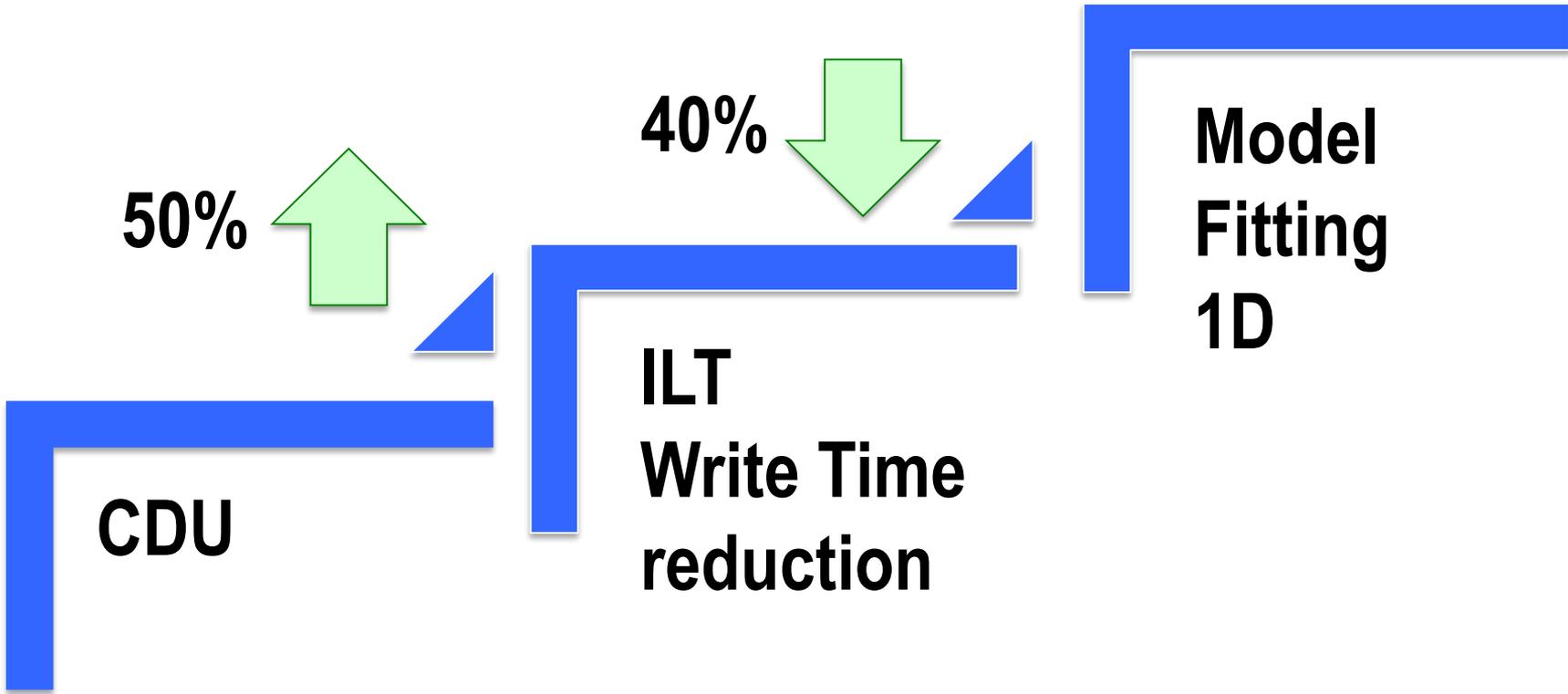
The base study on conventional fracturing is courtesy of Byung-Gook Kim, et al., PMJ 2009

Benefits of MB-MDP Proven at Key Customer Sites

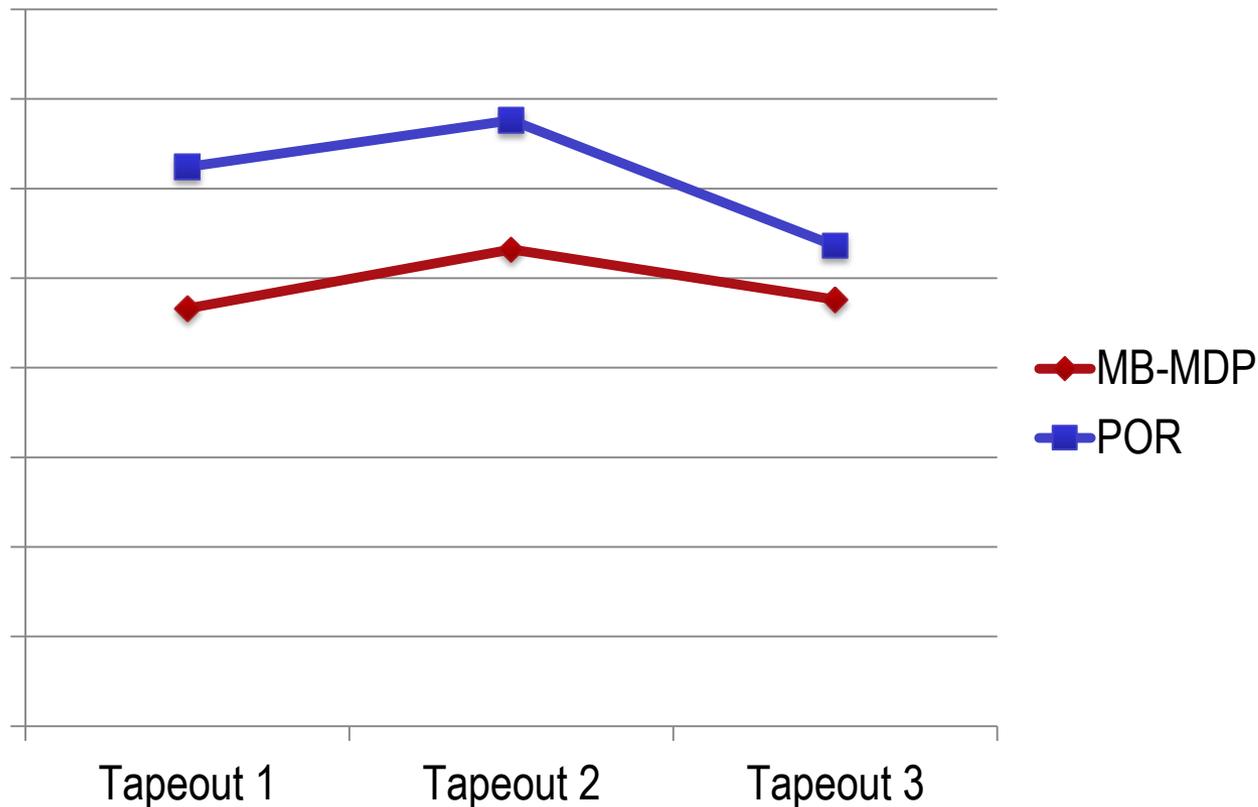
“Enabler for the next generation mask process”

Head of customer OPC team

1.5nm



~50% CDU Improvement on 7nm OPC Mask using MB-MDP OPCS2



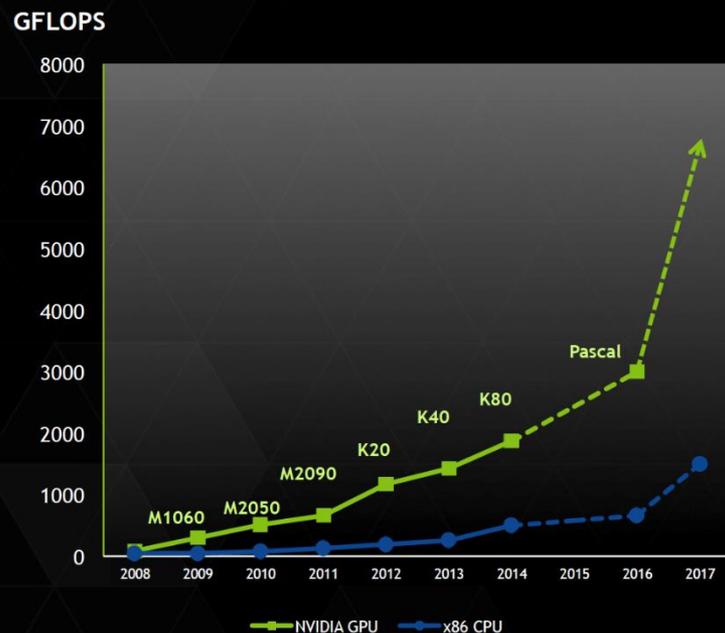
Is MB-MDP Run Time Ready for Production Use?

- Over 100X more computation than MB-OPC
- Mask scale 4X of wafer scale
 - Imagine calculation on every 1nm on wafer scale
- Requires optimization on fracturing
 - Break the OPC pattern into shots
- Has to consider overlapped shots
- eBeam proximity effect has short (nm), mid, and long range (mm)

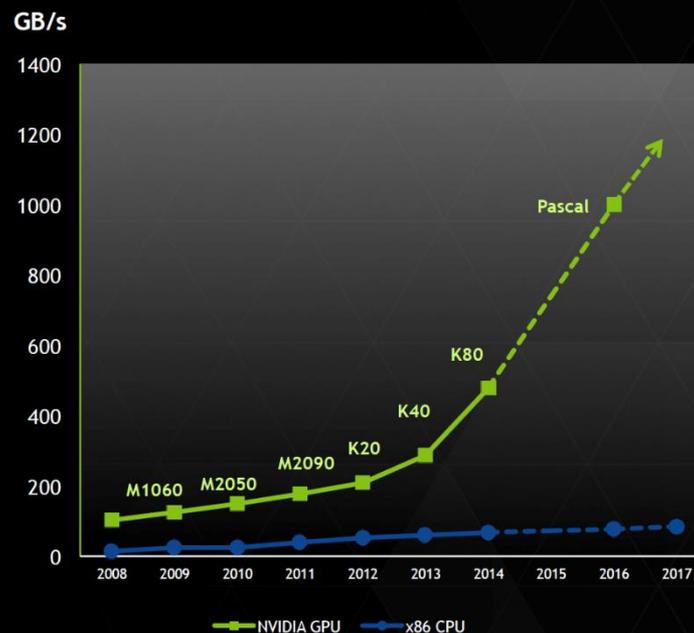
Scientific Computing Is Moving to GPU

PERFORMANCE GAP CONTINUES TO GROW

Peak Double Precision FLOPS



Peak Memory Bandwidth



Jen-Hsun Huang, CEO of NVIDIA, GPU Technology Conference, 2015

D₂S 400TFLOPS CDP Using GPUs Is In Production Use at Mask Shops

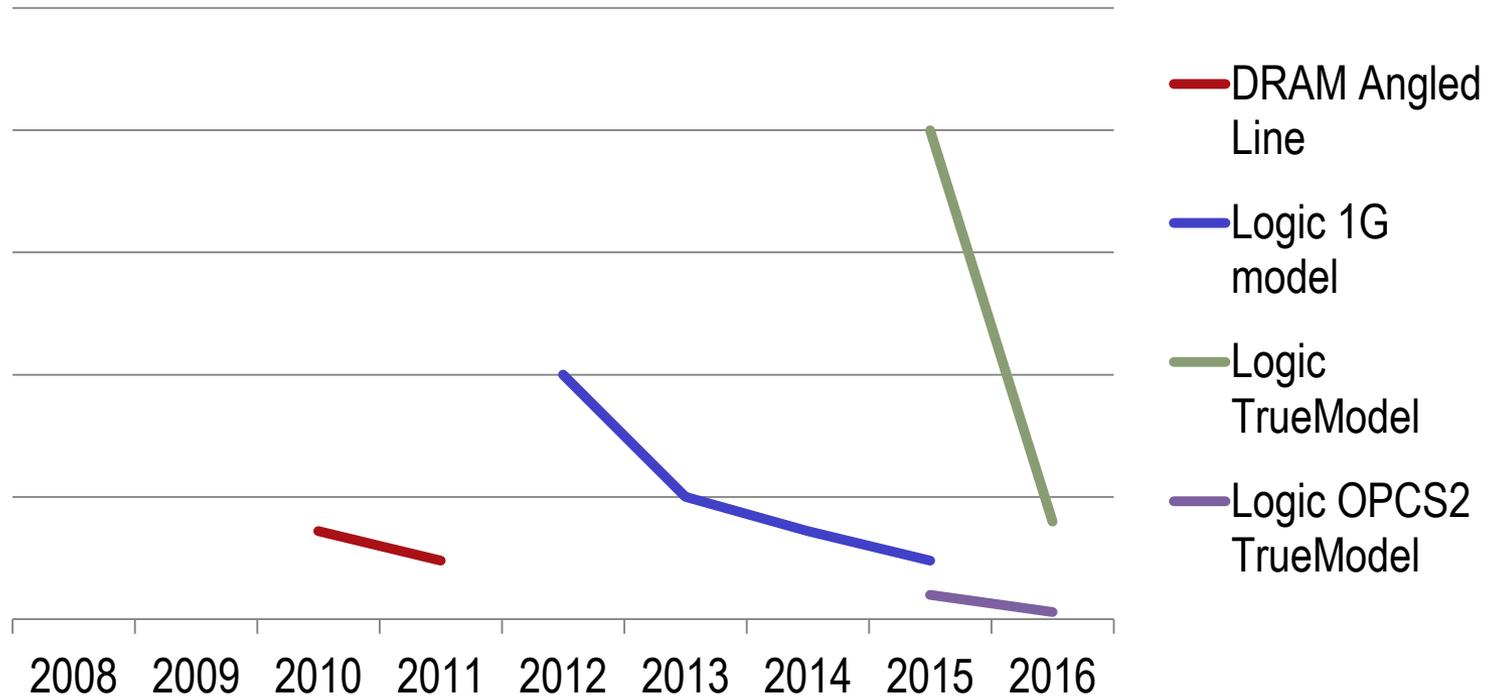


- 400 TFLOPS
- Simulates the entire mask plane
- All standard parts, with built-in redundancy
- 10th CDP being Installed this month

With 8 Years Development, We Are There!

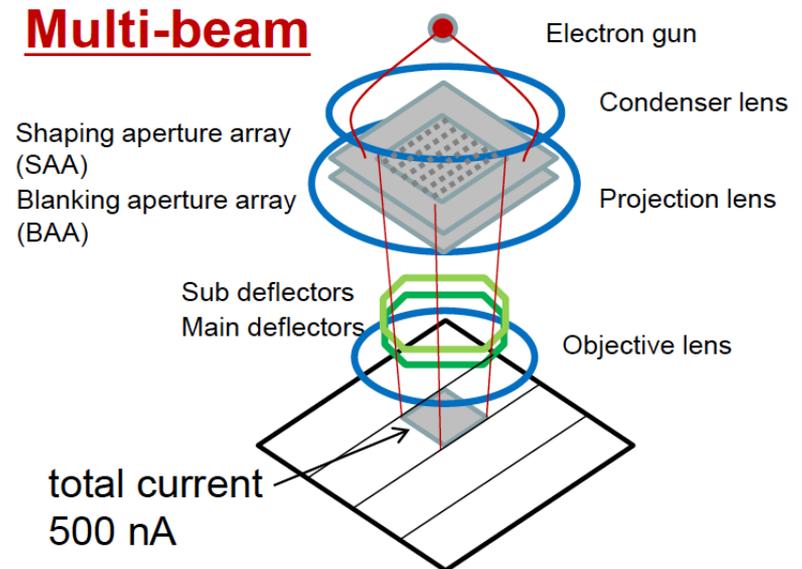


MB-MDP Run Time Improvement



Multi-Beam Mask Writer Will Need Simulation-Based Processing Even More

- Multi-beam mask writer is the ultimate answer for ILT
 - Write-time independent of mask complexity
 - Use slower resist
 - Smaller features
- It requires MB-MDP
 - Large data set to process
 - Needs dose modulation



H. Matsumoto, 2016 Introduction and recent results of Multi-beam mask writer MBM-1000, SPIE 2016 eBeam Initiative Luncheon Event

MB-MDP is Being Deployed in Production



- ILT is being deployed in production at the leading edge. Mask makers are faced with ILT masks
- Overlapped shots and MB-MDP enable VSB mask writer to write complex ILT masks
- GPU-accelerated MB-MDP can meet the speed requirement of mass production
- MB-MDP is being deployed in production for both OPC and ILT masks
- Multi-beam mask writer will require MB-MDP, too

