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Silicon to Software™

eBeam Initiative

The Resurgence of ILT

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Synopsys, eBeam Initiative Member

Outline

- ILT Overview
- ILT Use Cases
- ILT Future Extensions

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ILT Overview

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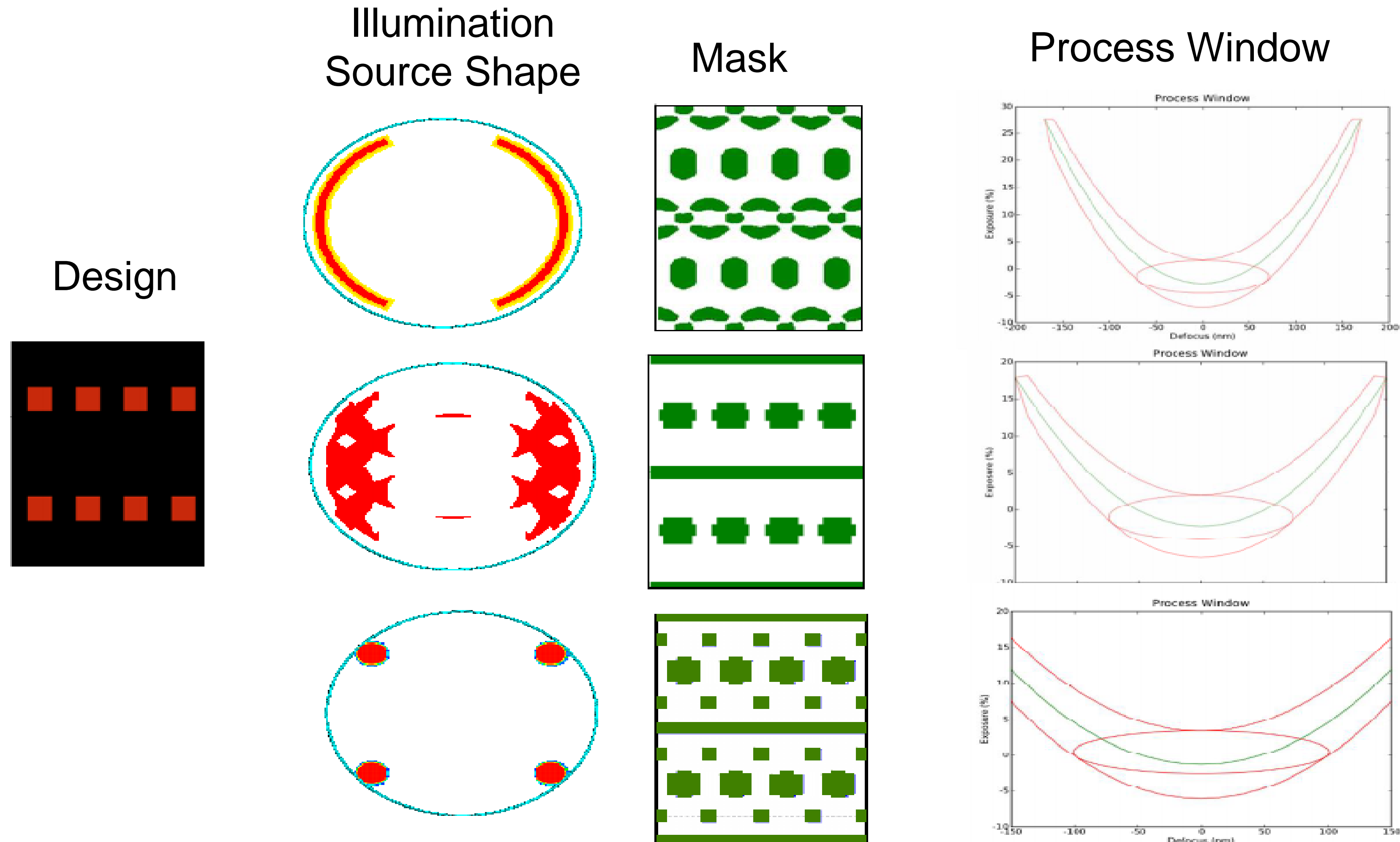
Why do we need ILT?
Sensitivity to Illumination Source Shape



Validation of inverse lithography technology (ILT) and its adaptive SRAF at advanced technology nodes - art. no. 69240T
Article (PDF Available) in [Proceedings of SPIE - The International Society for Optical Engineering](#)
6924 · March 2008

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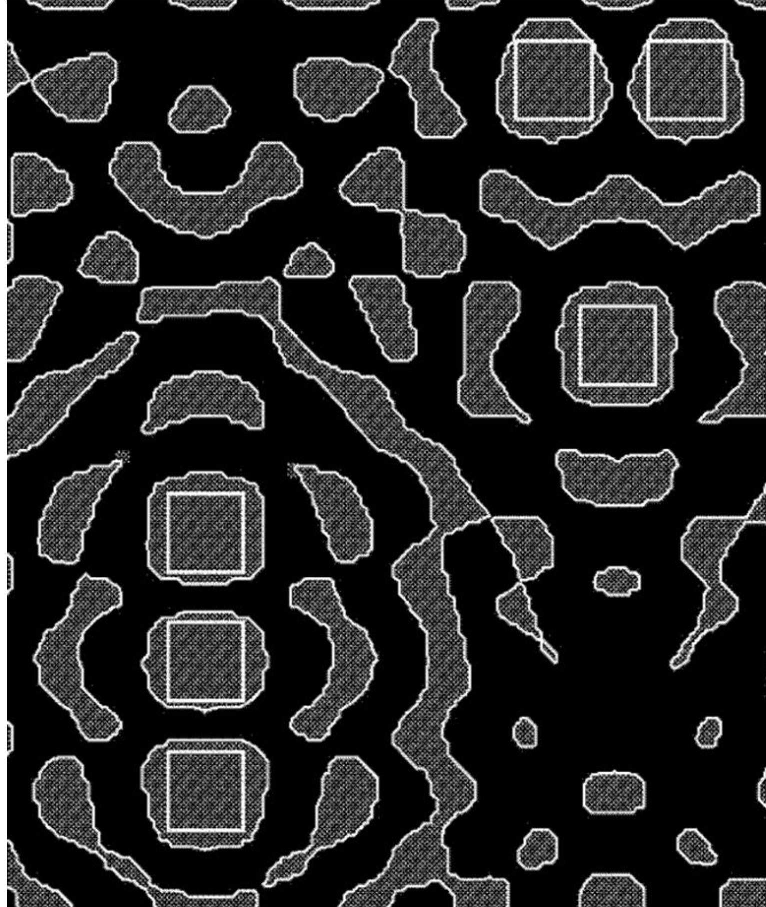
Why do we need ILT?
Sensitivity to Local Design Variation

- Interaction range from design edge to AF is measured in hundreds of nm

- Uniquely capturing this in a simple rule table of AF distances from design edges is difficult/impossible



Inverse lithography for 45-nm-node contact holes at 1.35 numerical aperture
Monica Laurel Kempsell ; Eric Hendrickx ; Alexander Tritchkov ; Kyohei Sakajiri ; Kenichi Yasui ; Susuki Yoshitake ; Yuri Granik ; Geert Vandenberghe ; Bruce W. Smith
[+] Author Affiliations
J. Micro/Nanolith. MEMS MOEMS. 8(4), 043001 (November 18, 2009). doi:10.1117/1.3263702

- Also, sensitivity to other complicated short range effects:
  - CPL
  - EUV complications, e.g. mask 3d, anamorphic, etc.

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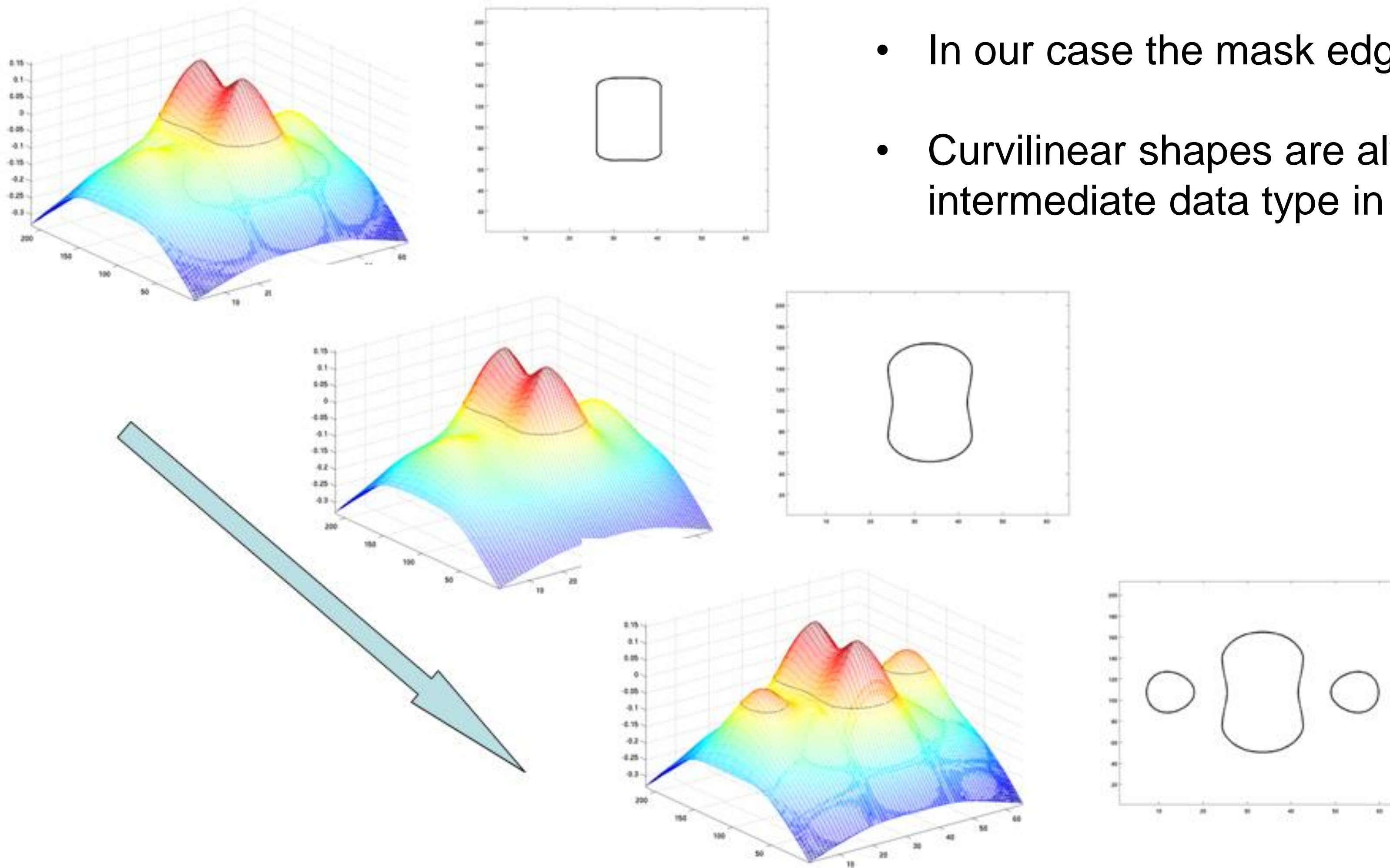
ILT Levelset Optimization

Optimization Driven Mask Creation

- Levelsets are a way to track a moving interface
- In our case the mask edge is the moving interface
- Curvilinear shapes are always created as an intermediate data type in the ILT flow



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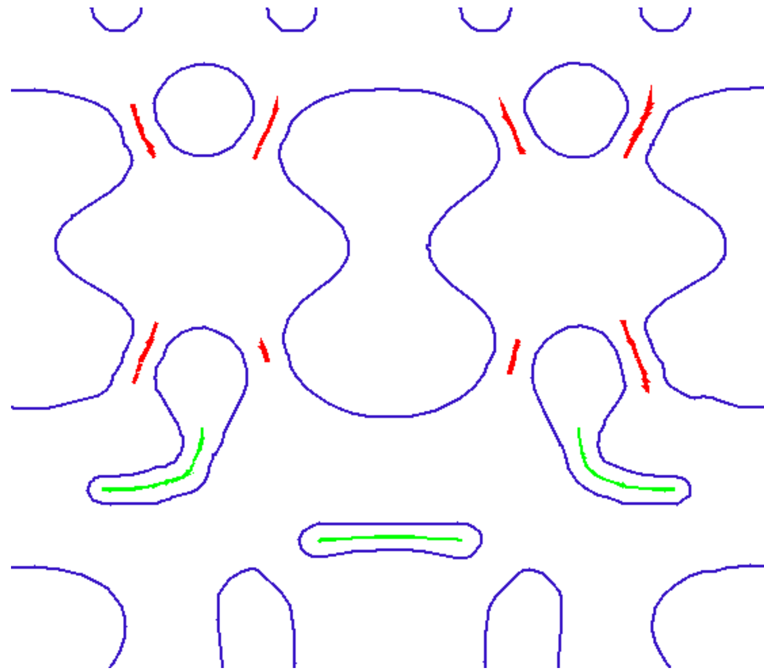
ILT Manufacturability

Various Levels of Mask Complexity Control Are Available

All Angle MRC



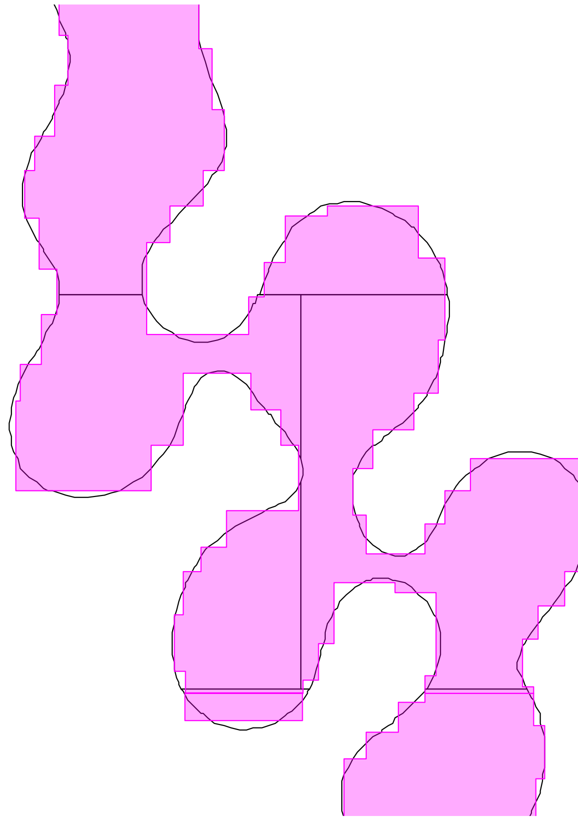
Skeletons used in MRC processing of raw mask.

Blue: raw mask edge.

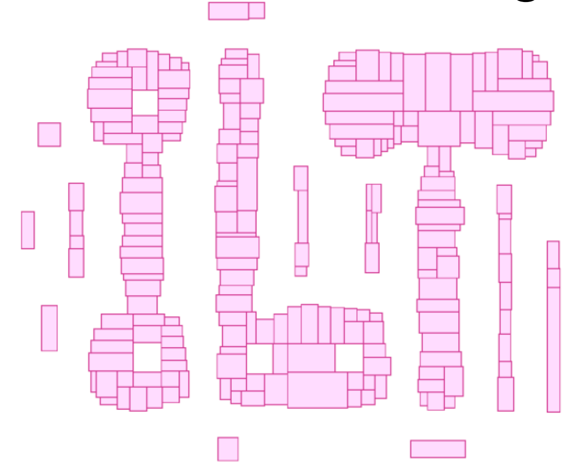
Green: interior skeleton (width).

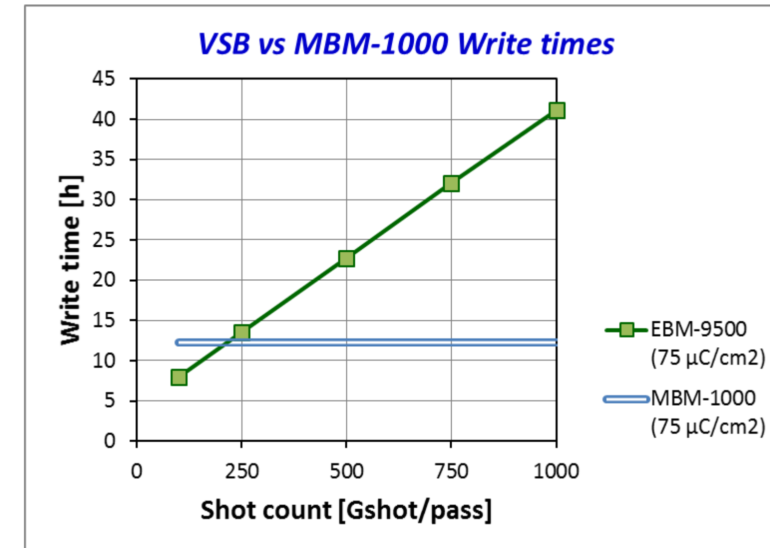
Red: exterior skeleton (spacing).

Manhattanization



Fracture/Writing





Source: NuFlare Technology
PMJ 2016

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ILT Use Cases

Development, Memory, Logic

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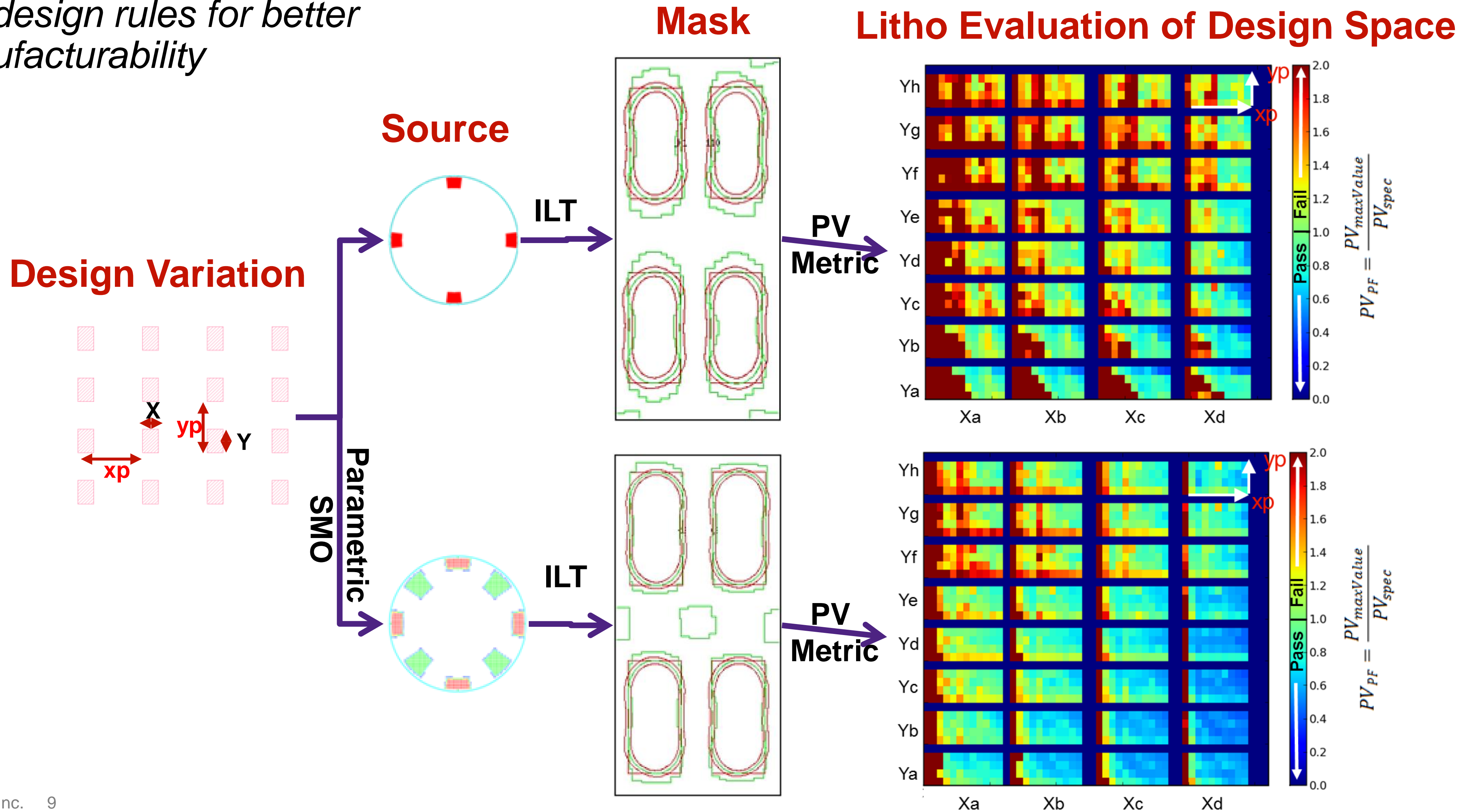
Process/Design Development: SMO & Design Exploration

Establishing optimal source shape and design rules for better manufacturability



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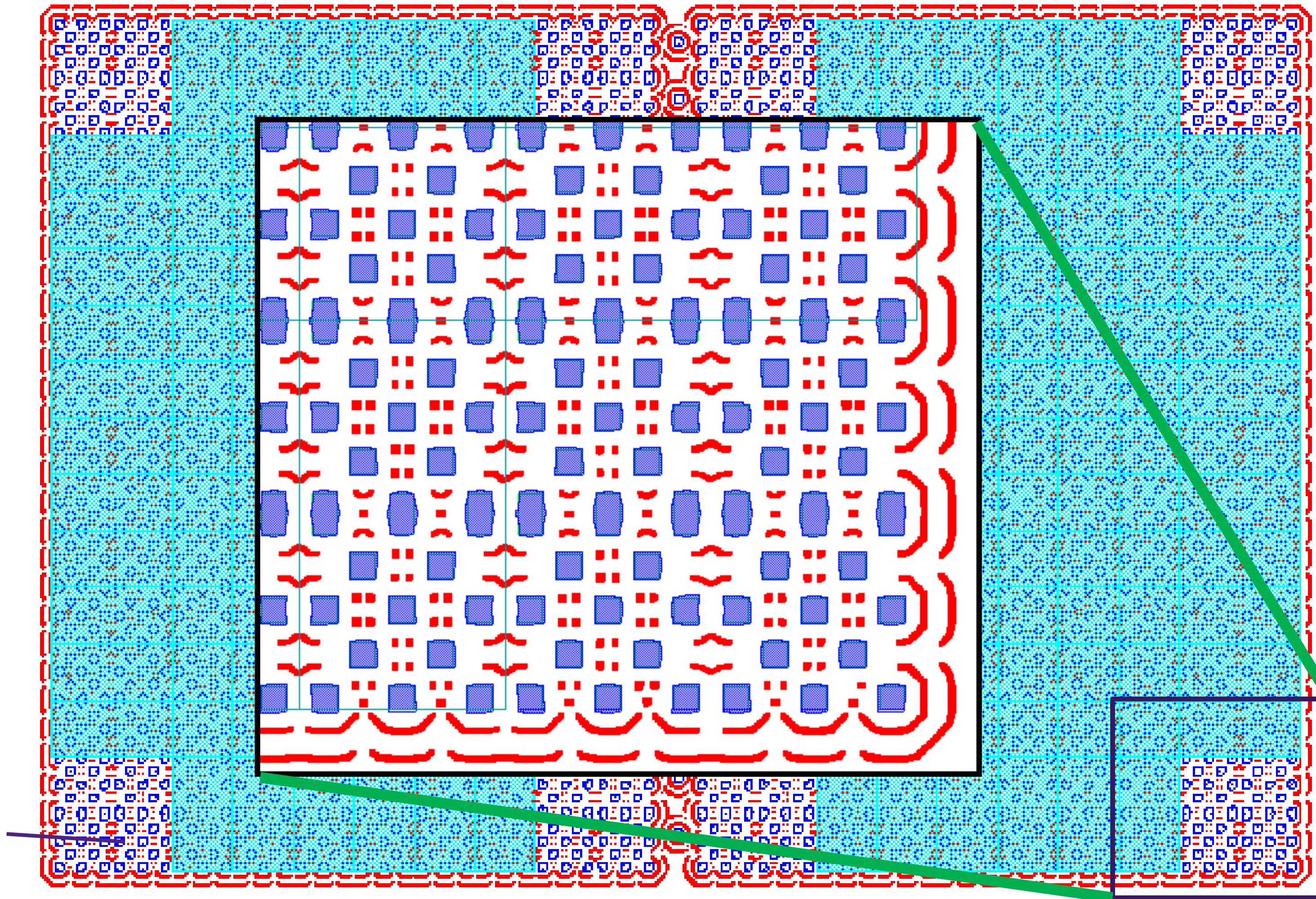
Memory: Cell Level ILT

Aggressive ILT for Highly Repetitive Critical Areas

Cell Level



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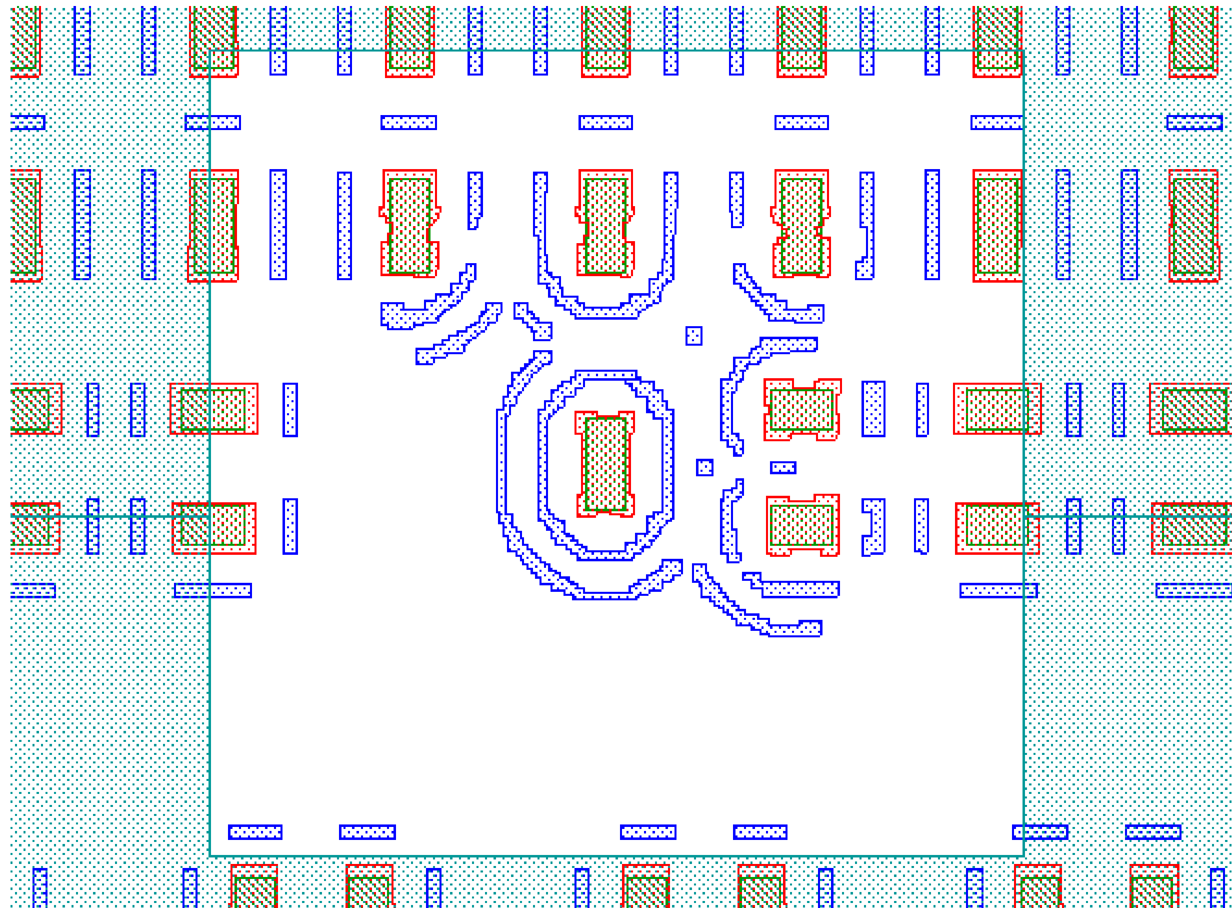
Memory and Logic: Hot Spot Fixing

Minimal TAT Overhead with Maximal Litho Improvement

Hot Spot Fixing



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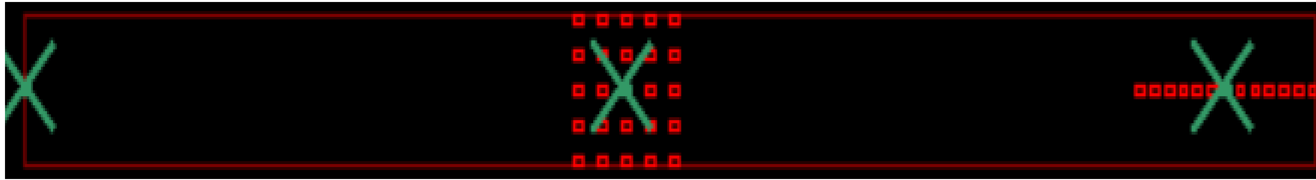
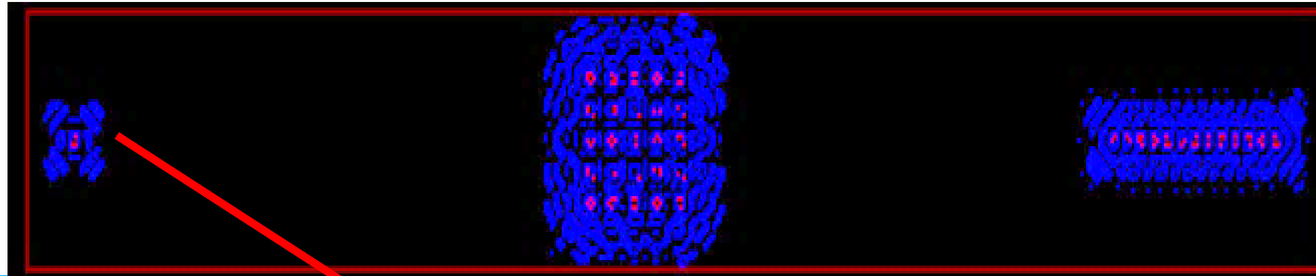
ILT Generated Rule Table For 2d Areas

ILT Guided AF Rules To Apply to Large Areas Quickly and Accurately

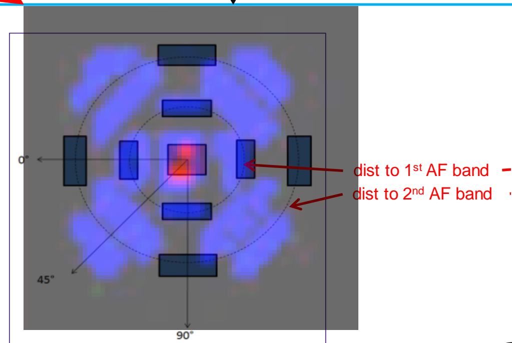
1. Mark features to be measured



2. Get ILT AFs



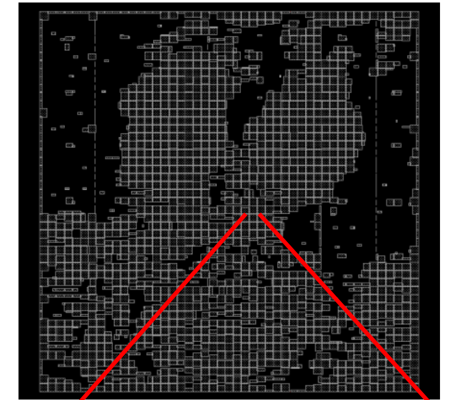
3. Create RBAF rules

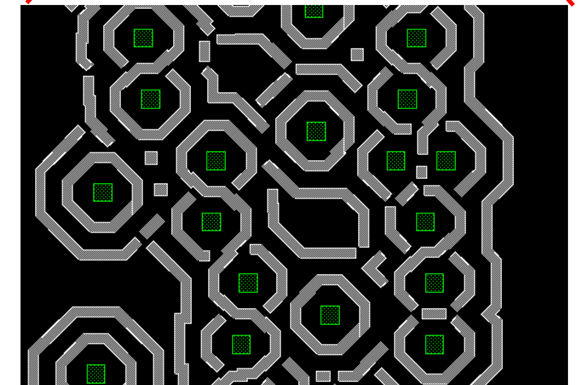


Rule1:
Aparam1: 100
Aparam2: 95.0
.
.
.
AparamN: 64.0

RBAF2D rule files

4. Place Afs On Random Layout Using Rules





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ILT Future Extensions

DSA, EUV

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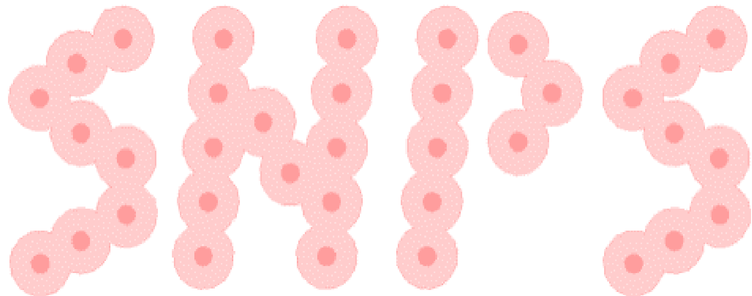
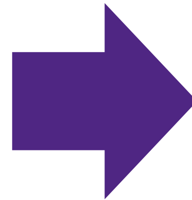
DSA Template Example

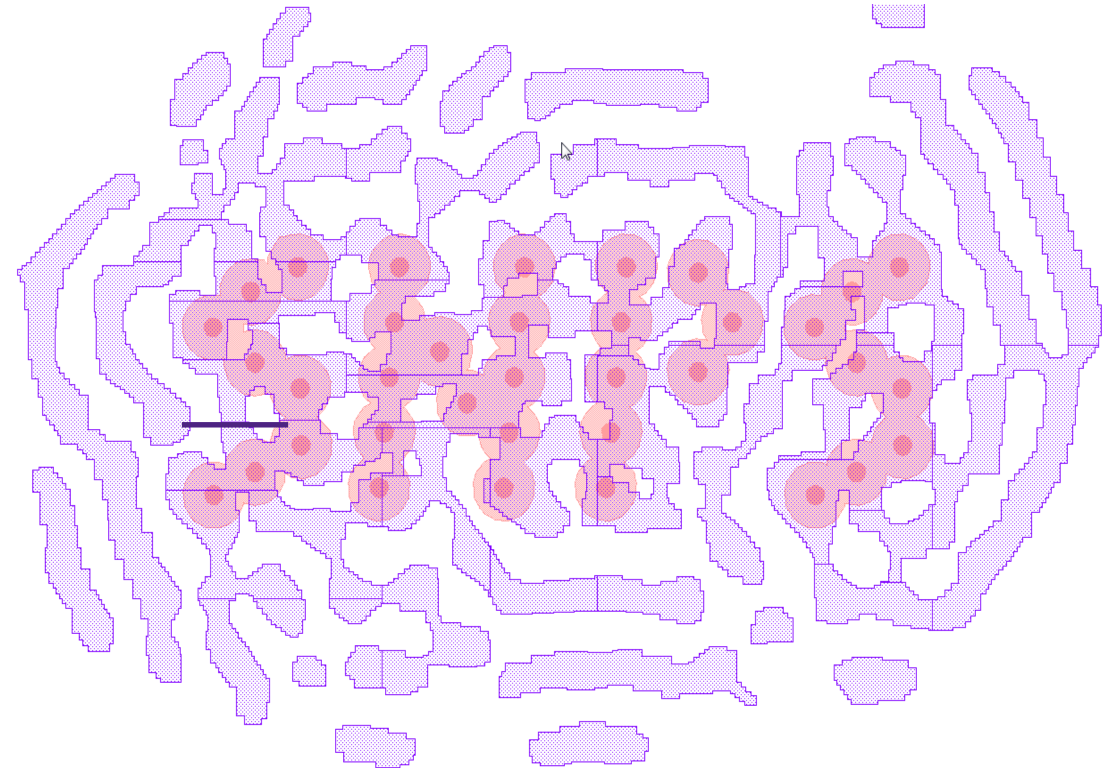
ILT Naturally Finds Merged Main and AF Solution to Resolve Overly Dense Regions

DSA-like
Freeform Target





ILT Mask



Note: difficult to distinguish MF from AF

Applying ILT for Design Exploration and Optimization,
Thuc Dam, Guangming Xiao & Kevin Lucas
LithoVision 2016

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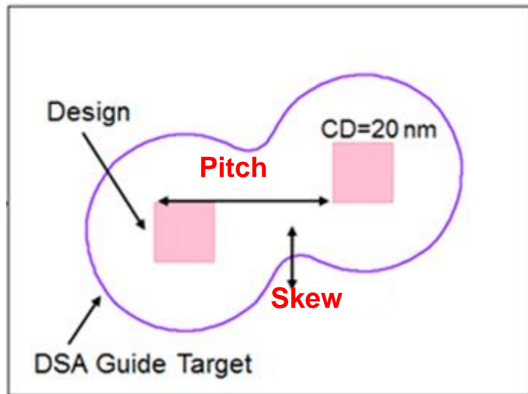
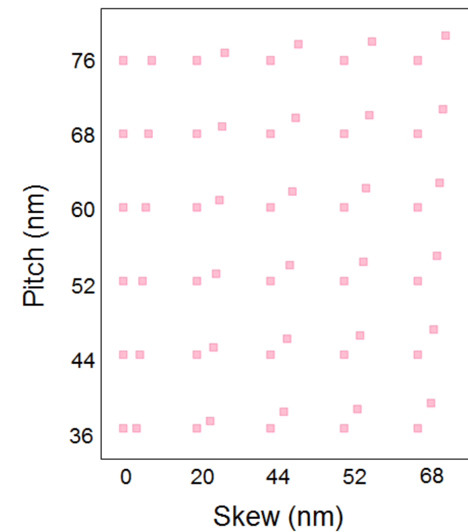
DSA Design Rule Exploration

ILT Aids Development of DSA Template Design

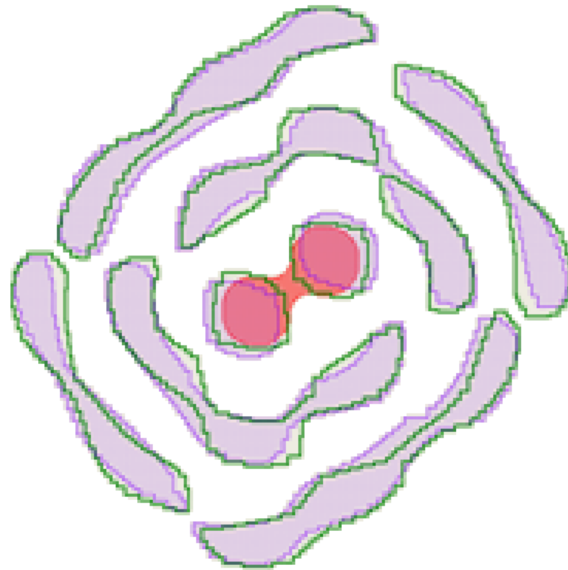
Design Variation





ILT

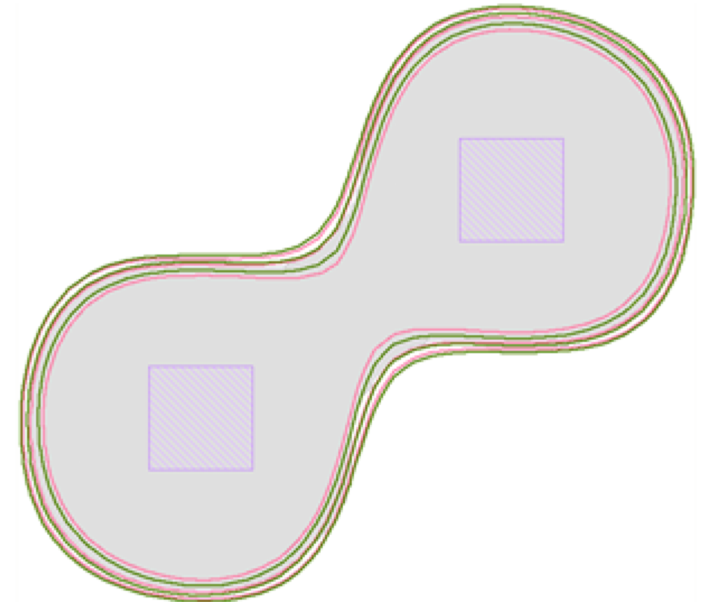
Mask Variation



Purple – Mask w/Cost Function1
Green – Mask w/Cost Function2

Litho
Simulation

Lithographic Variation



Red – PV of Mask w/Cost Function1
Green – PV of Mask w/Cost Function2

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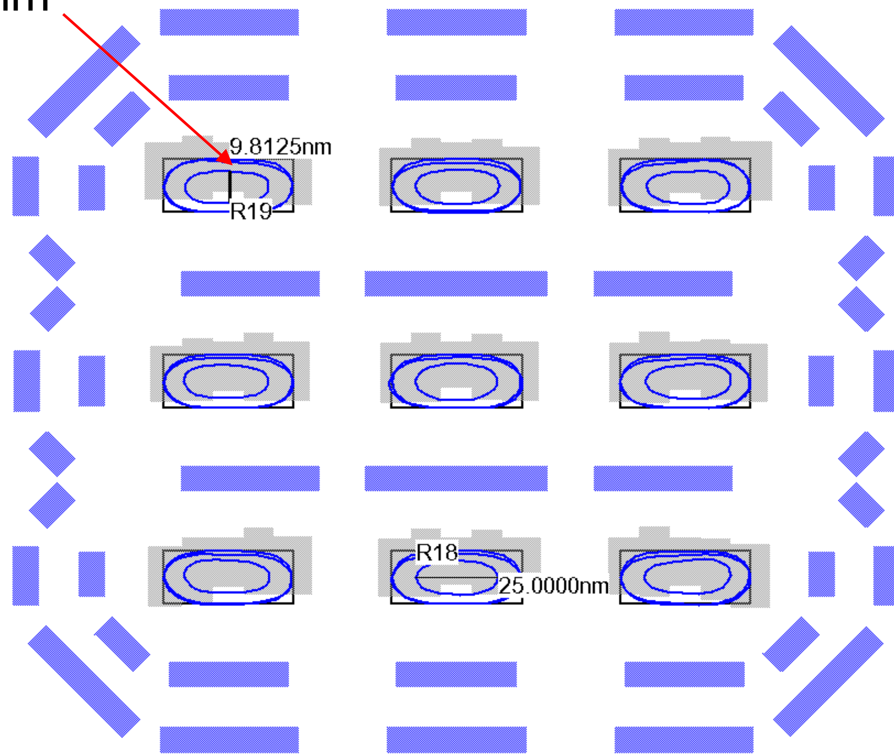
EUV 3x3 Slot Contact Array – OPC vs ILT

Asymmetric AFs Generated By ILT for PW Improvement

- 70nm X pitch by 60nm Y pitch
- Right edge of reticle
- Contours shown nominal, +/-50 nm defocus

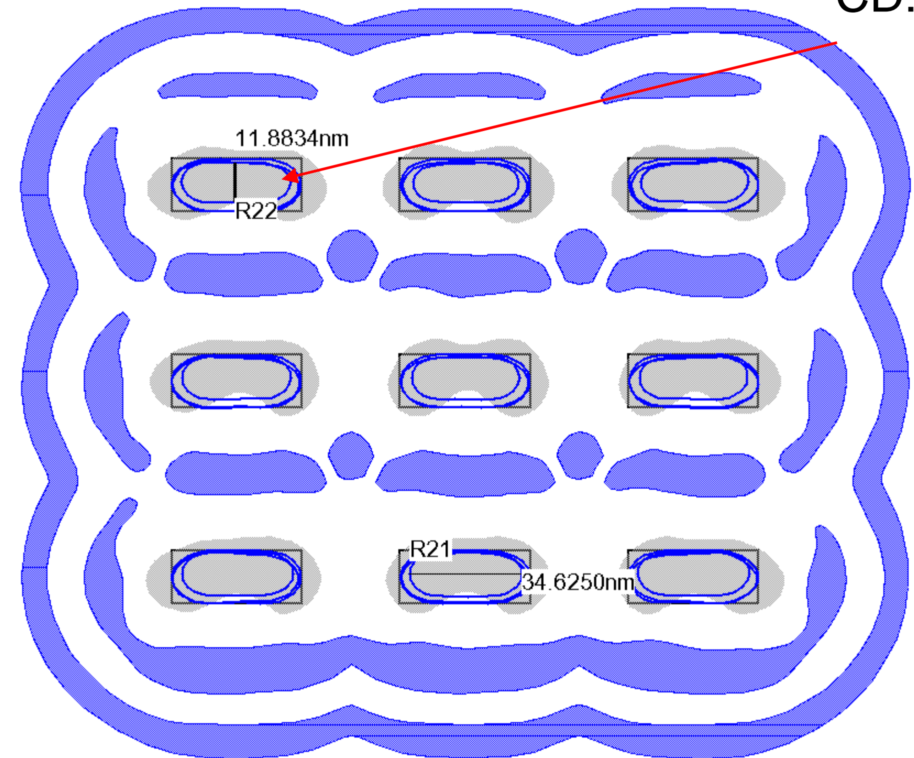
RBAF and OPC

CD: 9.8125nm



ILT

CD: 11.8834nm



See more at: New methodologies for lower-K1 EUV OPC and RET optimization, paper 10143-45, March 2

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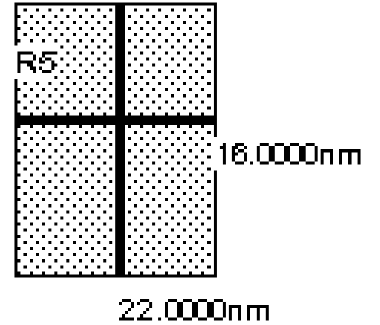
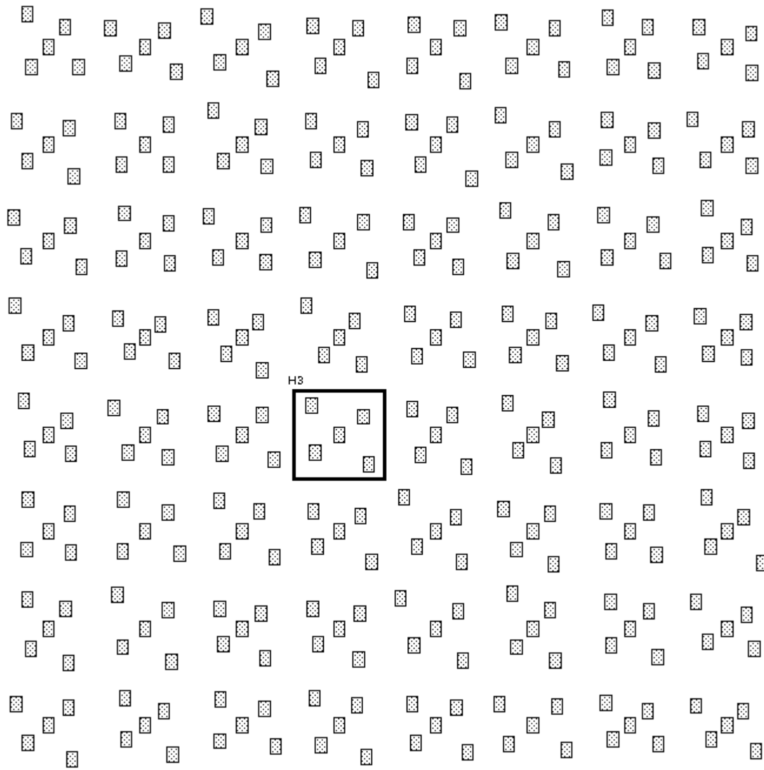
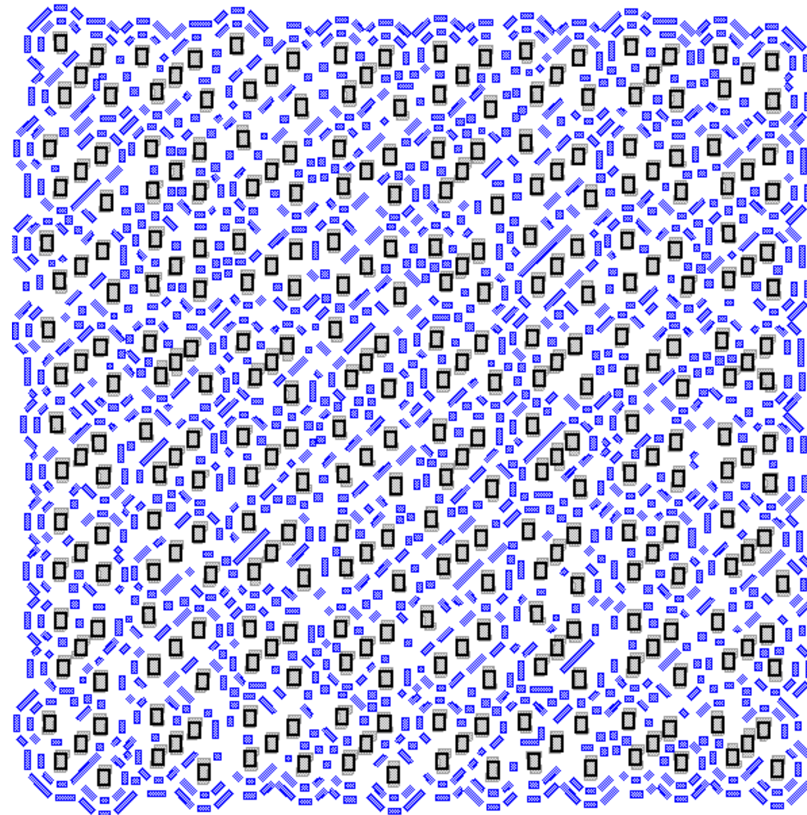
EUV Via random pattern – PV Band improvement

- Random via pattern – random “X” configurations of 5 contacts
- Drawn CD: 16nm x 22nm

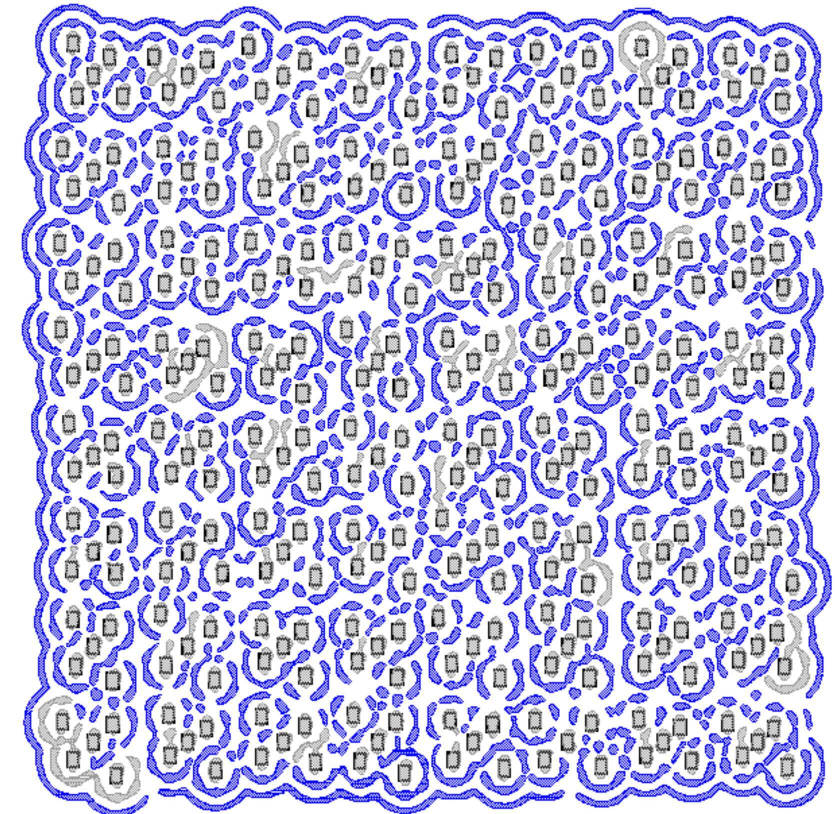




Design



OPC



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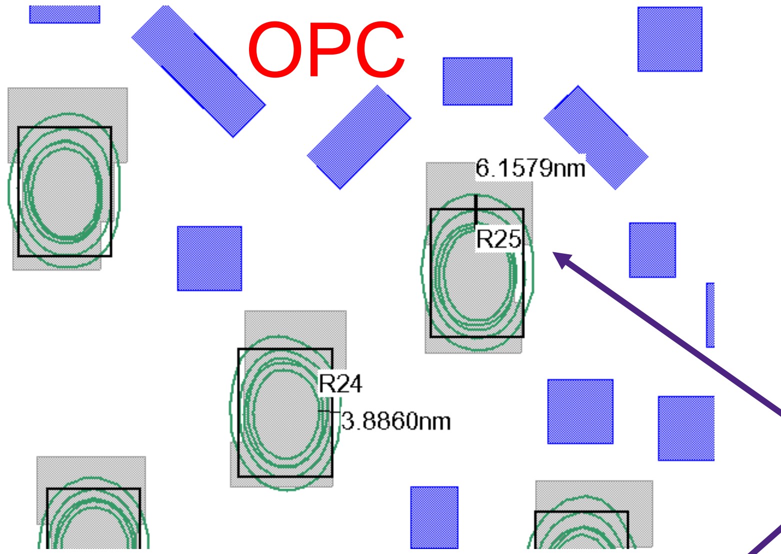
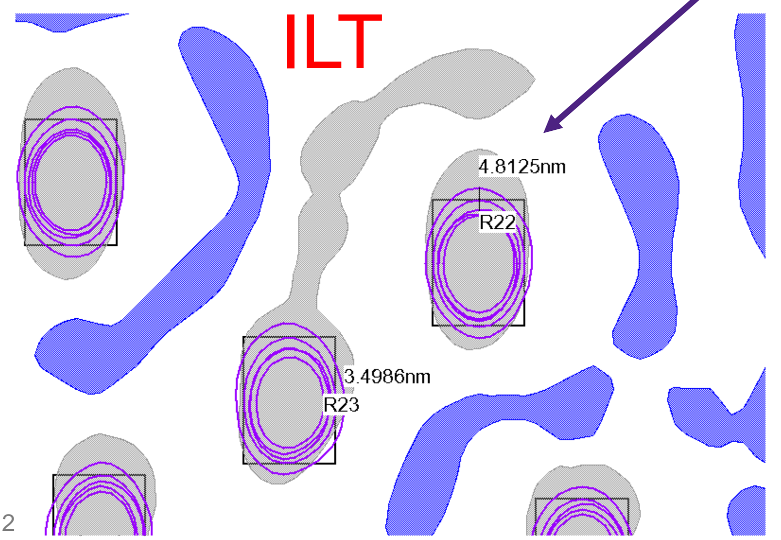
EUV Via Random Pattern – PV Band Improvement

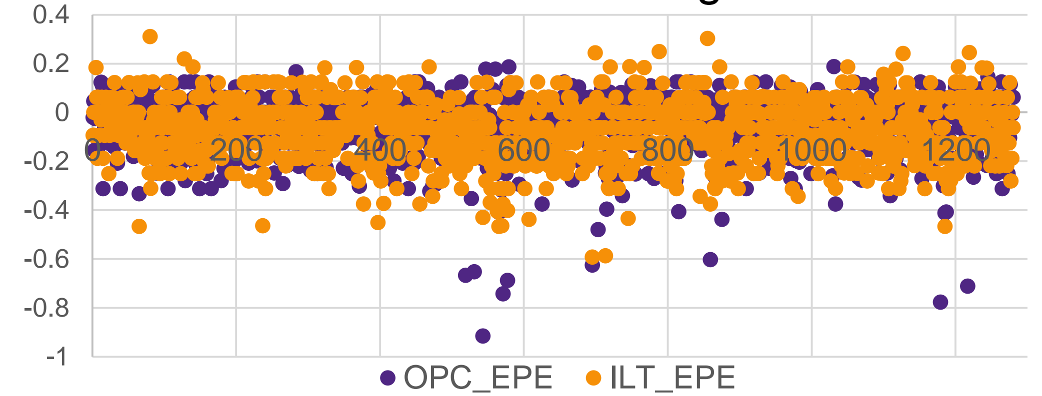
ILT Improves PV Band by > 20%

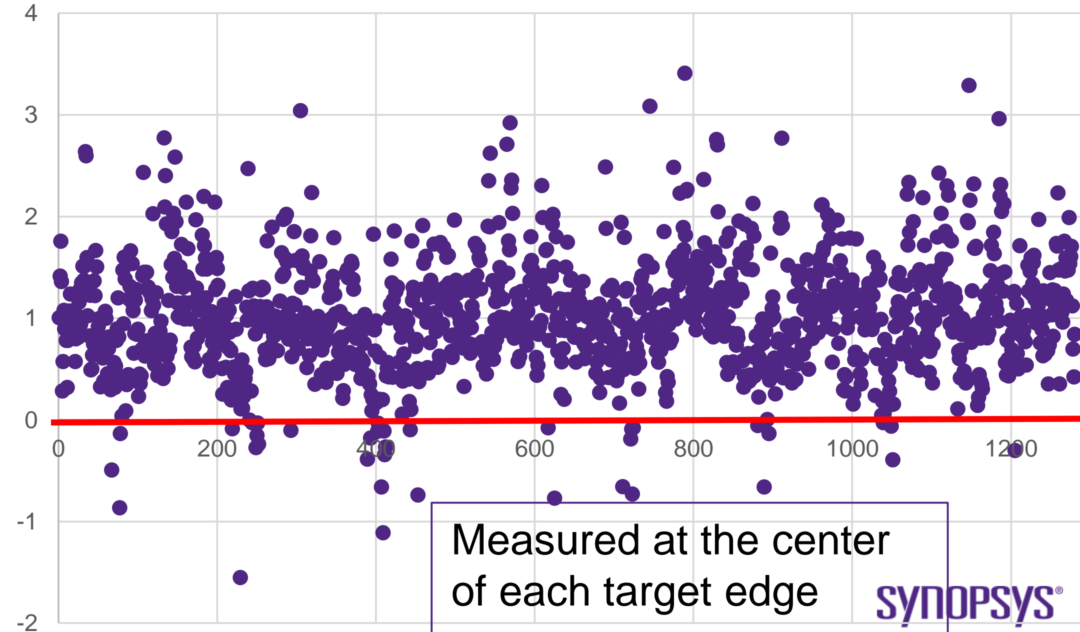




PV band measuring spread of

- +/-15% dose
- +/- 50 nm focus





ILT Improvement

Measured at the center of each target edge

© 2

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Summary

- ILT is being used in memory and logic areas
- Shrinking MRC, design CD, and complex physical interactions make ILT more attractive
- Curvilinear ILT output is available and produces the best results
- DSA, EUV have issues that ILT can help to solve, in both development and production

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Thank You