APPLICATIONS

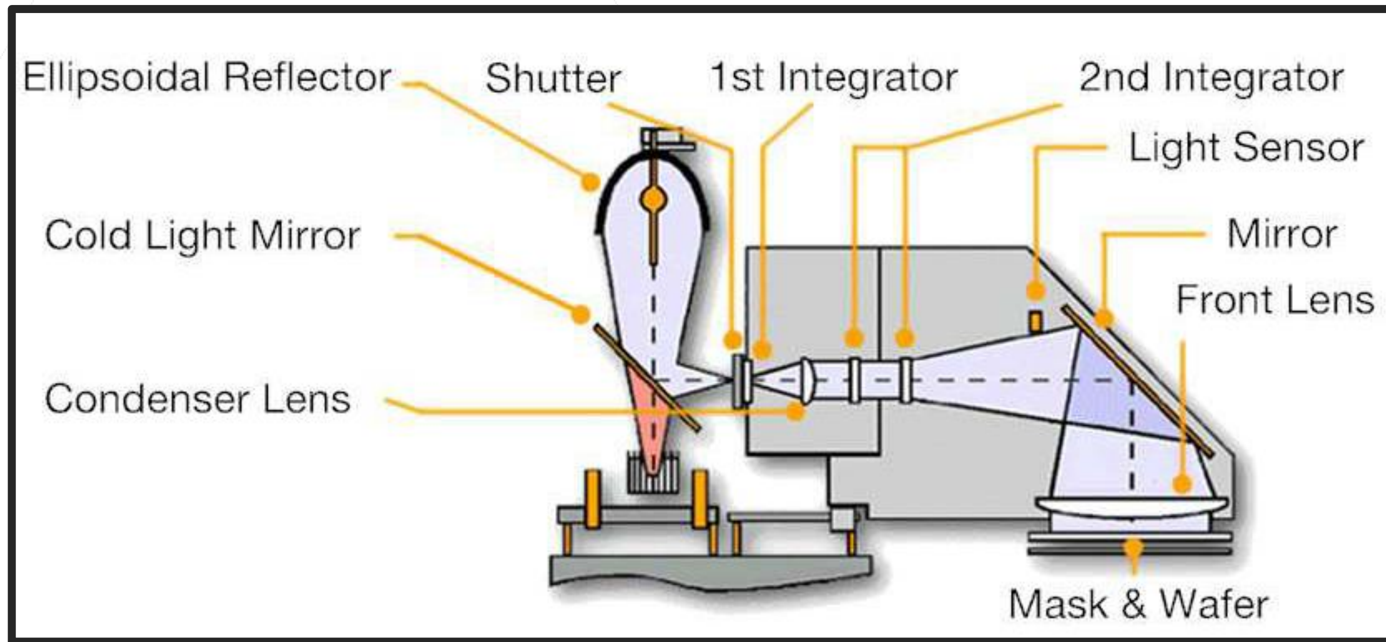
SÜSS-MicroOptics Source Mask Optimisation

Motivation

- SUSS Micro Optics (MO) is an illumination system introduced by **SÜSS MicroTec** for mask aligner lithography.
- MO optics allow shaping the angular spectrum of the illumination source enabling **Source Mask Optimisation** (SMO) to enhance stepper resolution.
- The illumination conditions (collimation angle and off-axis illumination) impacts the lithography result, the simulation of those conditions improve **resolution** and **process window**.
- **LAB** can simulate full exposure processes from light sources including its illumination shape to the 3D resist profile after development
- This application note focuses on:
  - Introduction of the SÜSS MO
  - Possibility for process analysis
  - Usage of LAB for effective source shaping and Optical Proximity Correction (OPC) design

Mask Aligner Lithography

- Schematic view of standard illumination system for mask aligner lithography:



- Contact or proximity printing without optical elements between mask and wafer.

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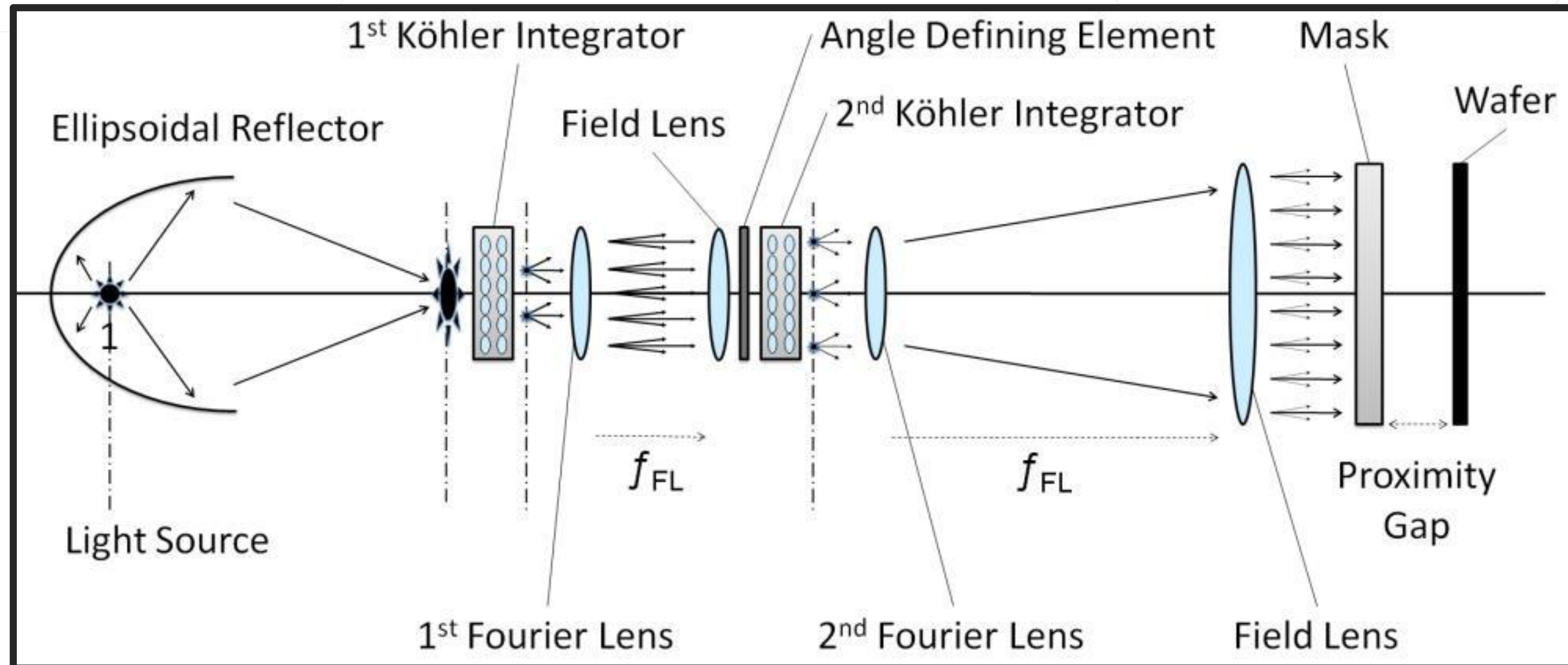
SÜSS MO Optics

- The scheme of the illumination system of SÜSS MO [1] is:

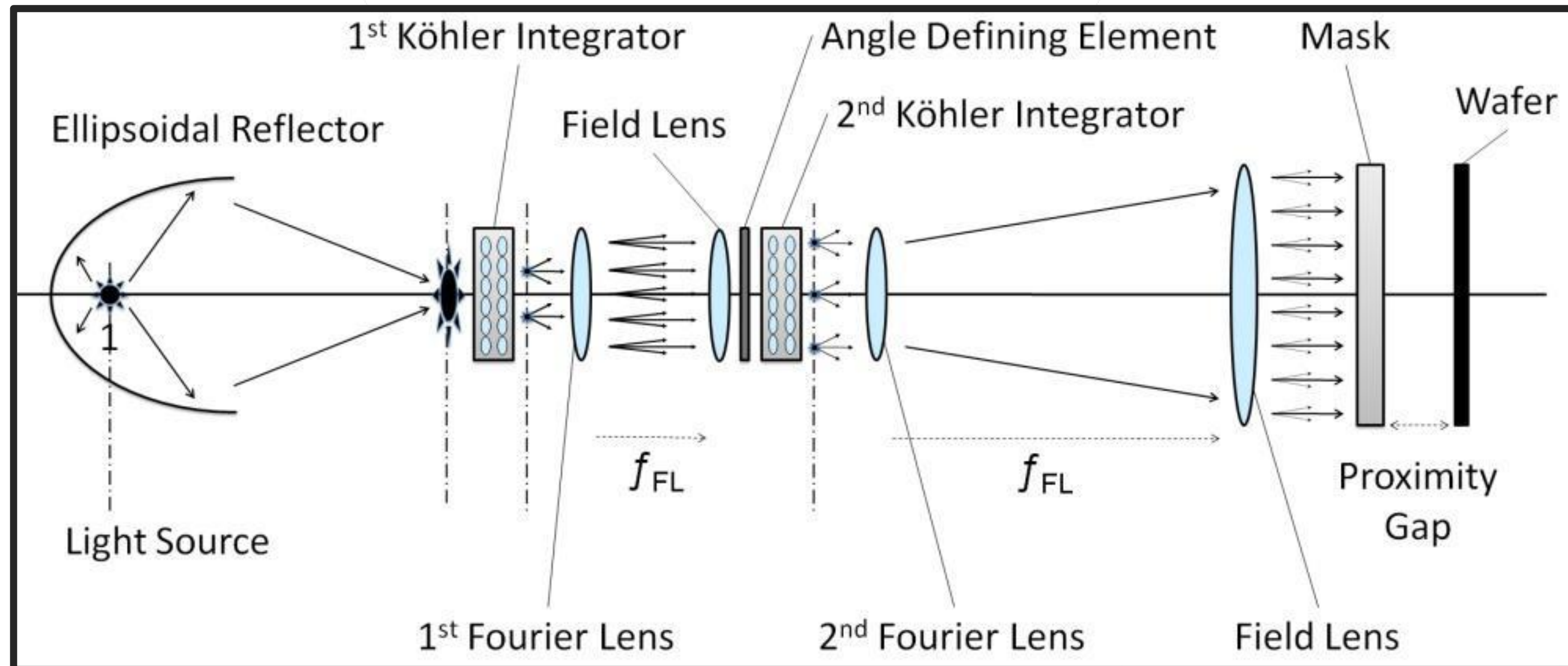


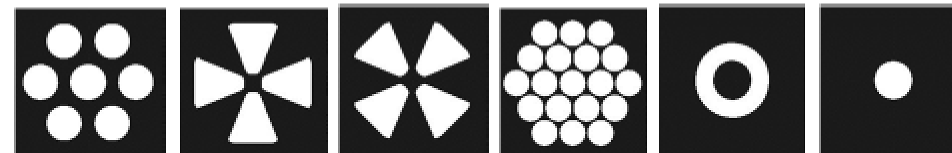
- MO exposure stabilise the illumination due to lamp misalignment using two high-quality arrays of microlenses immersed in fused silica (Köhler integrators)

[1] SÜSS report: Advanced mask aligner lithography (AMALITH)

Source Shaping

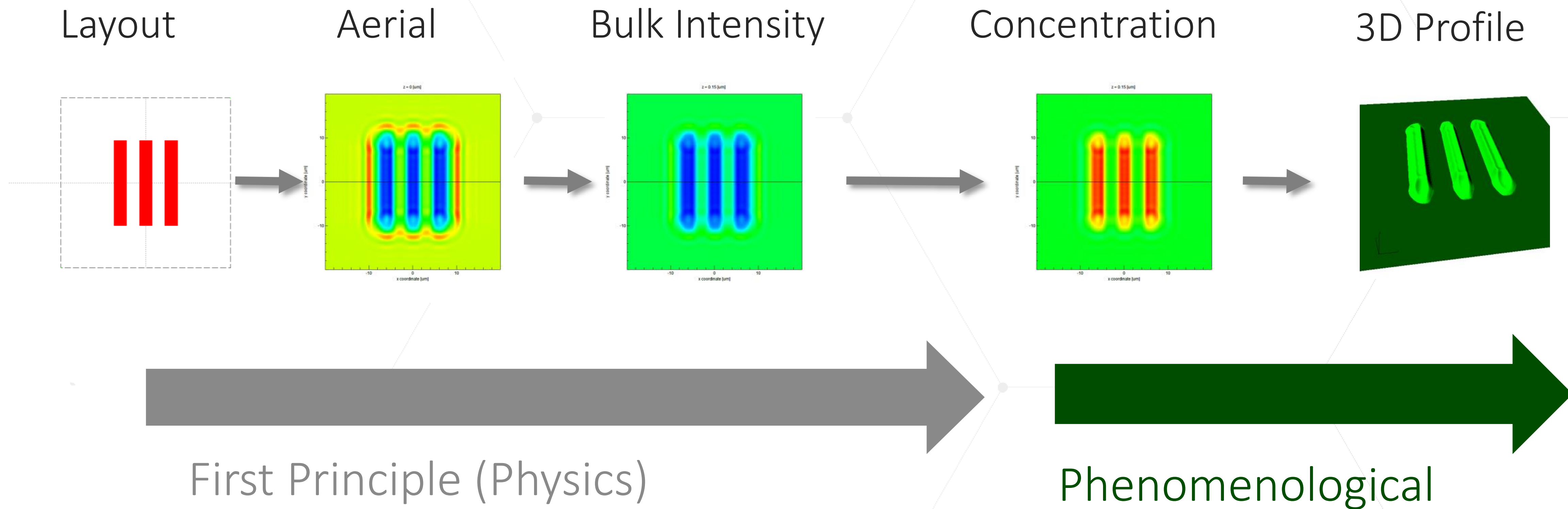
- Advantages of MO exposure:
  - Improved light uniformity, telecentric illumination
  - Shaping of the angular spectrum of the illumination via angle definition element (IFP)





[1] SÜSS report: Advanced mask aligner lithography (AMALITH)

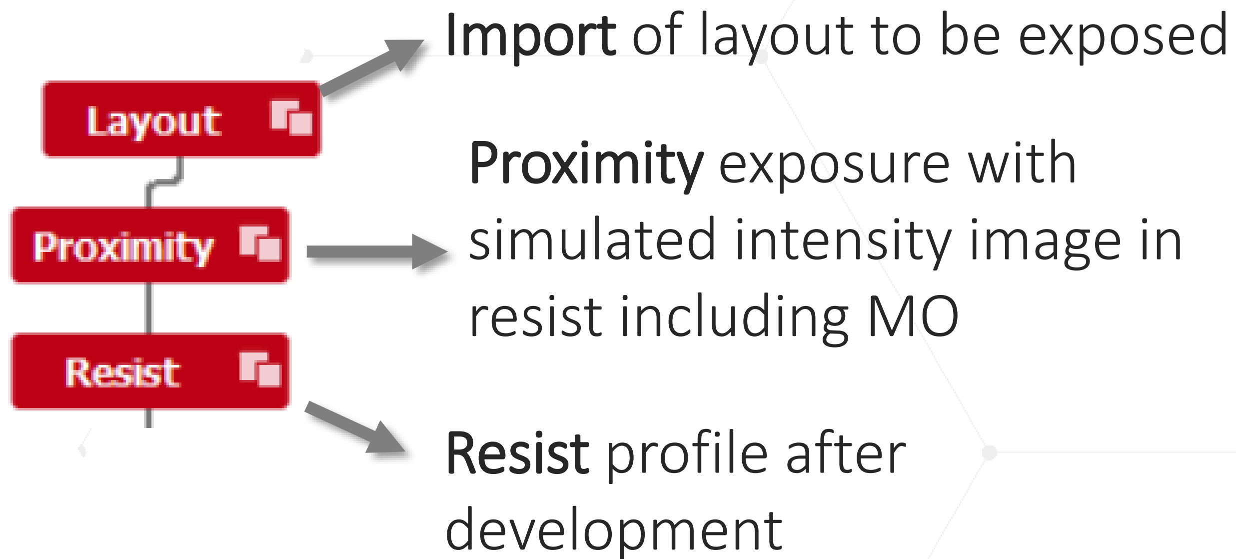
- **LAB** allows full simulation of proximity lithography in mask aligners, including **Bulk intensity** and **3D resist profile**.
- Pre-exposure simulation using LAB is cost-and-time effective.



LAB

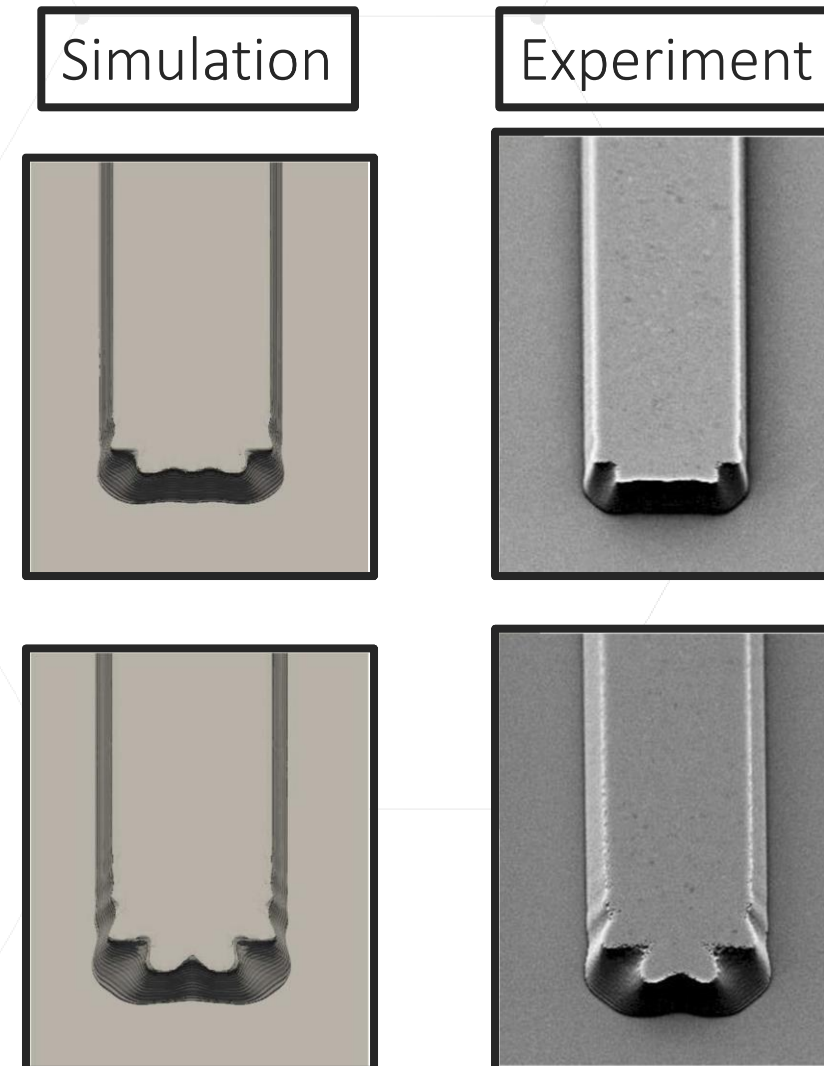
LAB Modelling

- LAB simulation flow:



- Comparison of the simulated resist profile and the experimental result shows the capability of simulation to predict the exposure on resist.

3D resist simulation vs experiment for two different IFPs [2]

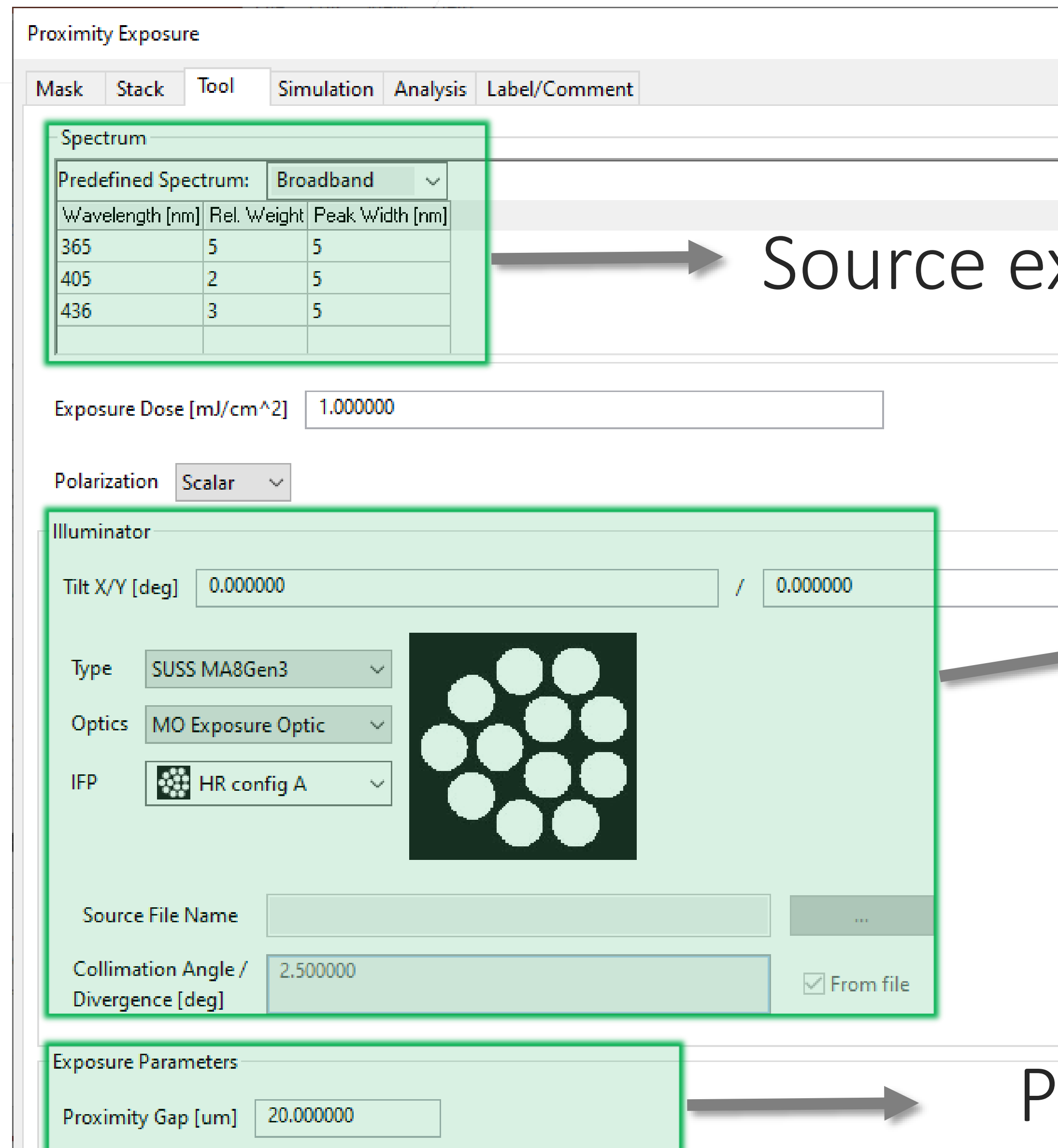


[2] GenISys BEAMeeting @ 38th International conference on Micro and Nano Engineering, Toulouse 2012

Exposure Setup

- Exposure module provides simulation of intensity distribution in resist.

Layout
Proximity
Resist



Source exposure spectrum

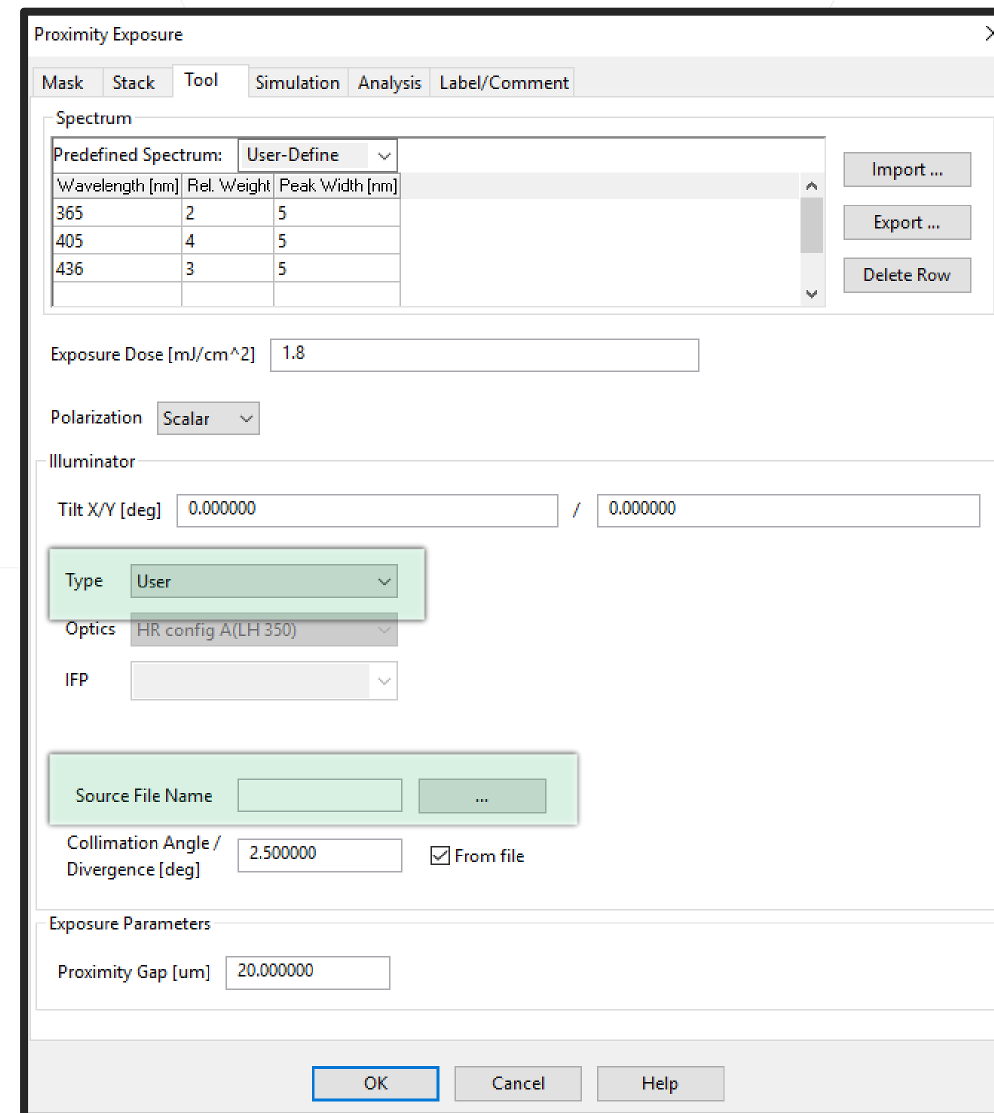
Source shaping:

- Selection of SÜSS mask aligner system
  - Available angular shaping of source via an IFP selection

Proximity gap

User-defined Source

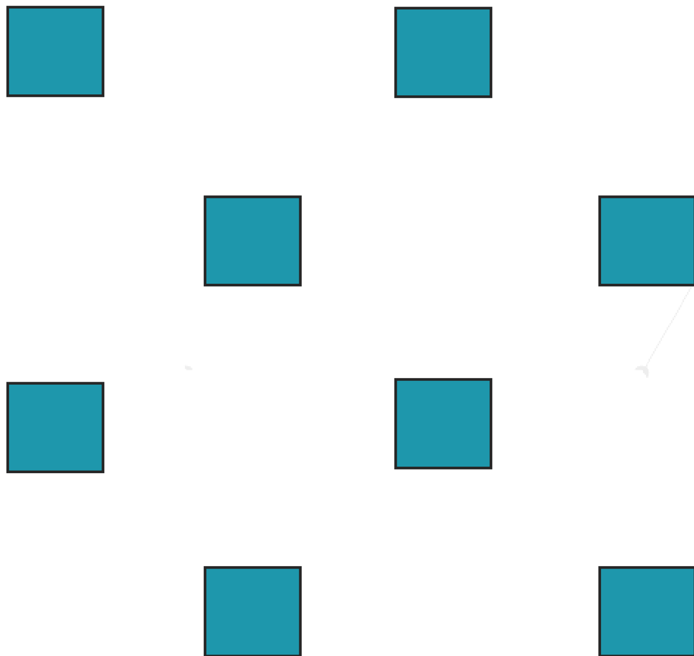
- The user can also define any specified source as a “User” defined source in “Type” selection, which provides flexibility in source shaping.
- Source shape file can be in SRC, MO and PNG format.



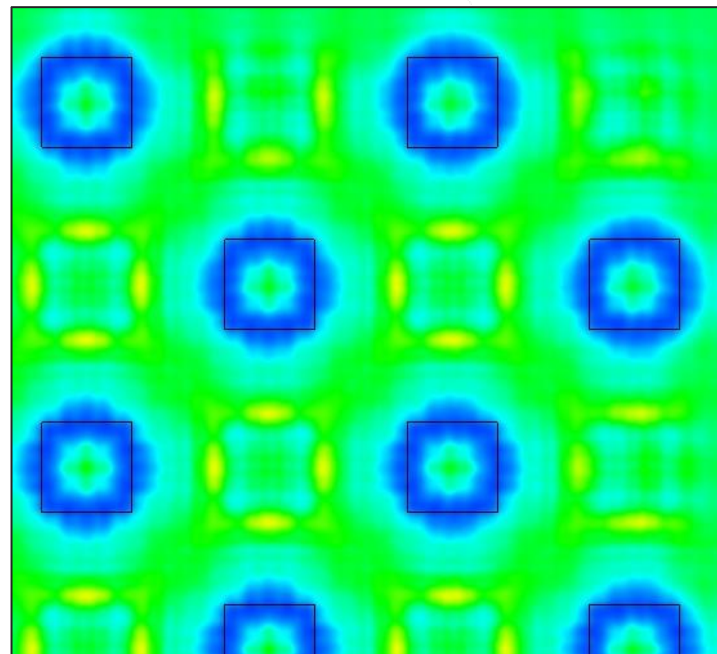
Intensity Image Analysis

- In most cases, the intensity in the resist is enough to analyse the exposure quality even if the resist development model is not calibrated.
- Example: Mask layout: 3 µm squares
  proximity gap: 20 µm
  2 µm resist AZ6624 on silicon

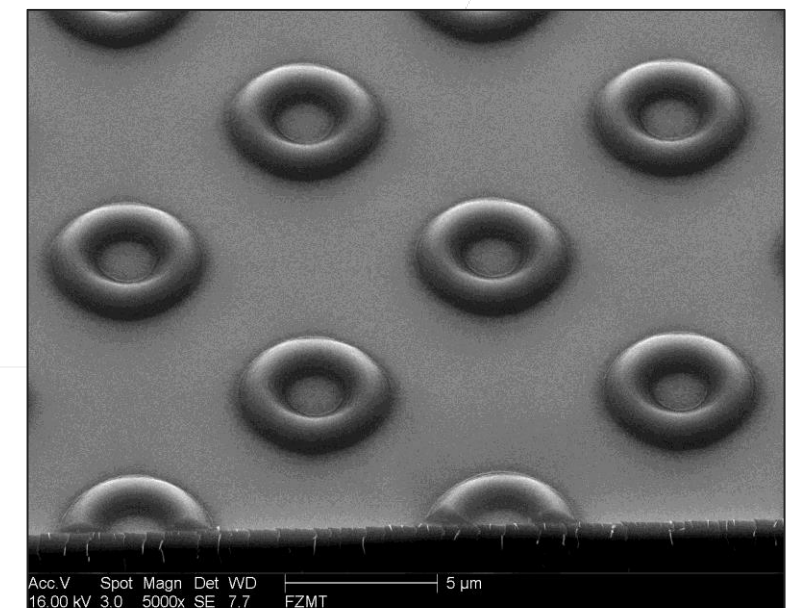
Exposure Pattern



Intensity at resist centre

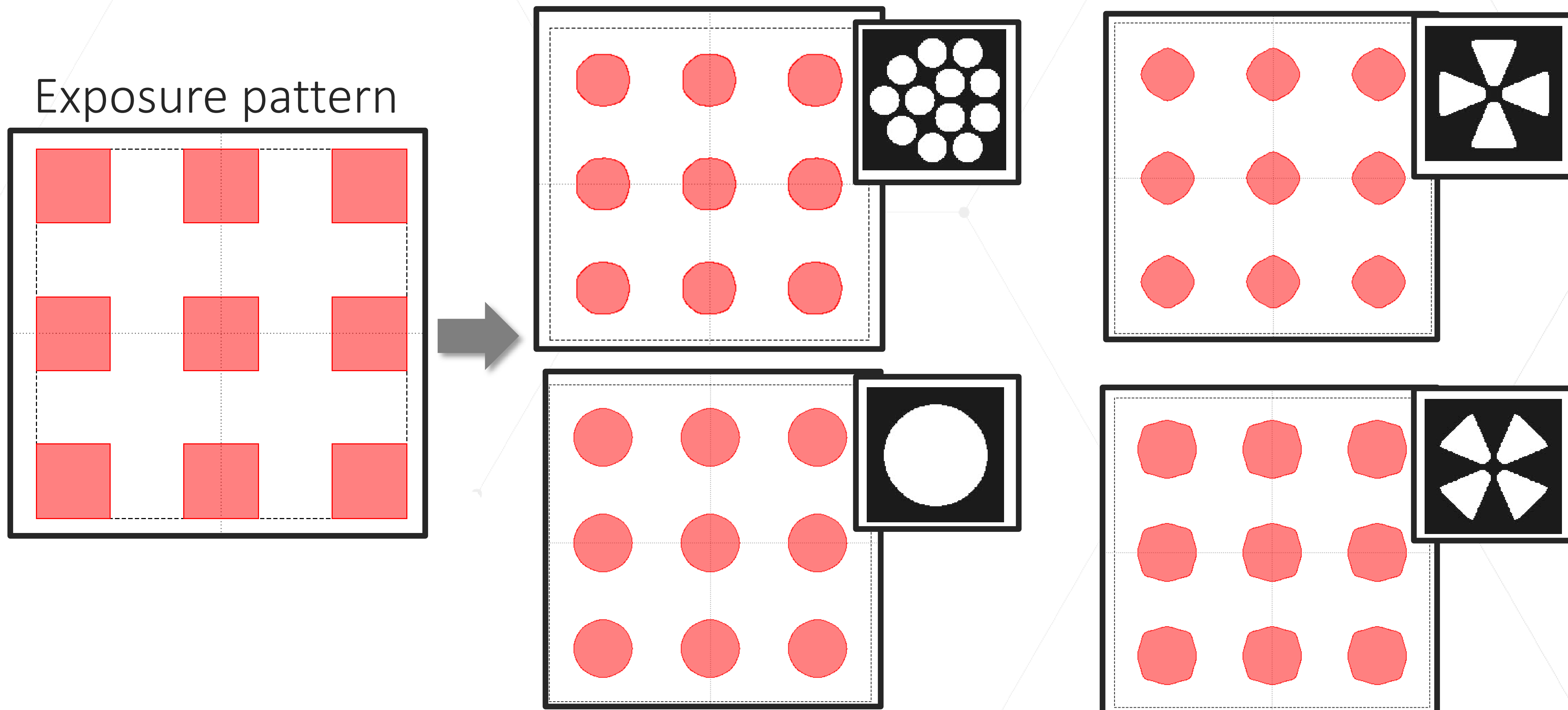


Experiment



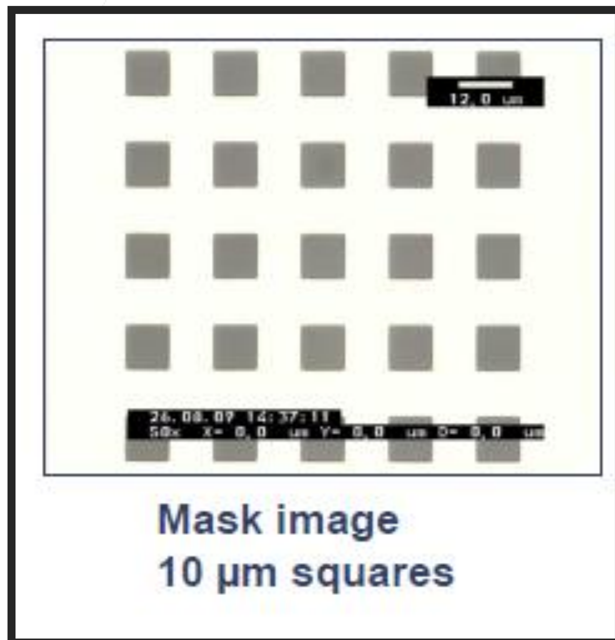
Source Shaping Example - Simulation

- Exposure of 10 µm square array at a proximity gap of 100 µm
- The simulation shows the resist profile (threshold intensity) when different IFPs (angular distribution of illumination) are chosen for exposure.

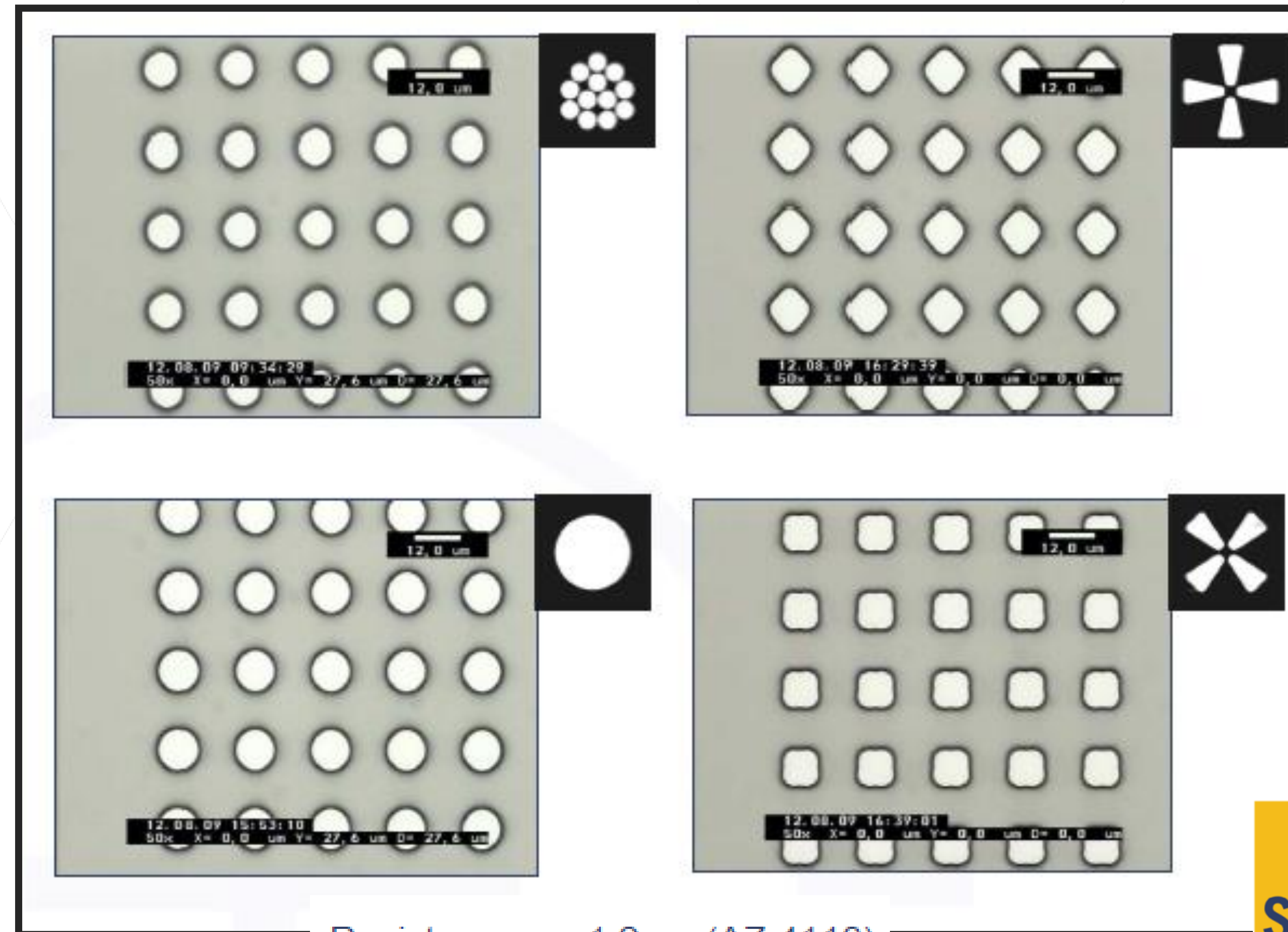


Source Shaping Example - Experiment

- Corresponding exposure results with SEM images, which match the simulation.



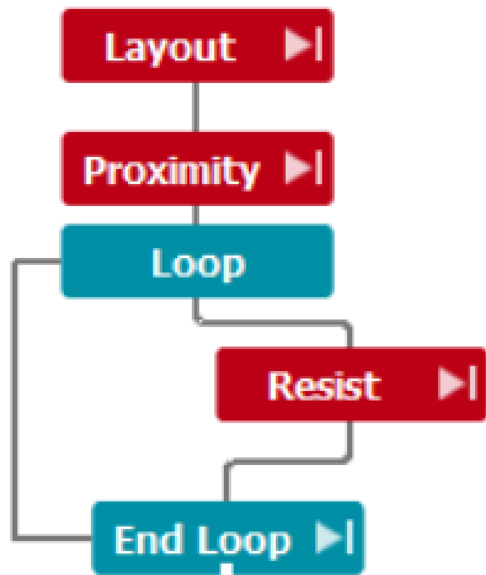
Mask image
10 µm squares



Resist: 1.2µm (AZ 4110)
Exposure gap: 100µm

Simulation Flexibility

- **Loop** module provides flexibility to visualise the influence of different parameters, e.g., proximity gap, dose, and mask correction.



Intensity [mJ/cm^2]

Source collimation angle

Proximity gap

Process Window Analysis

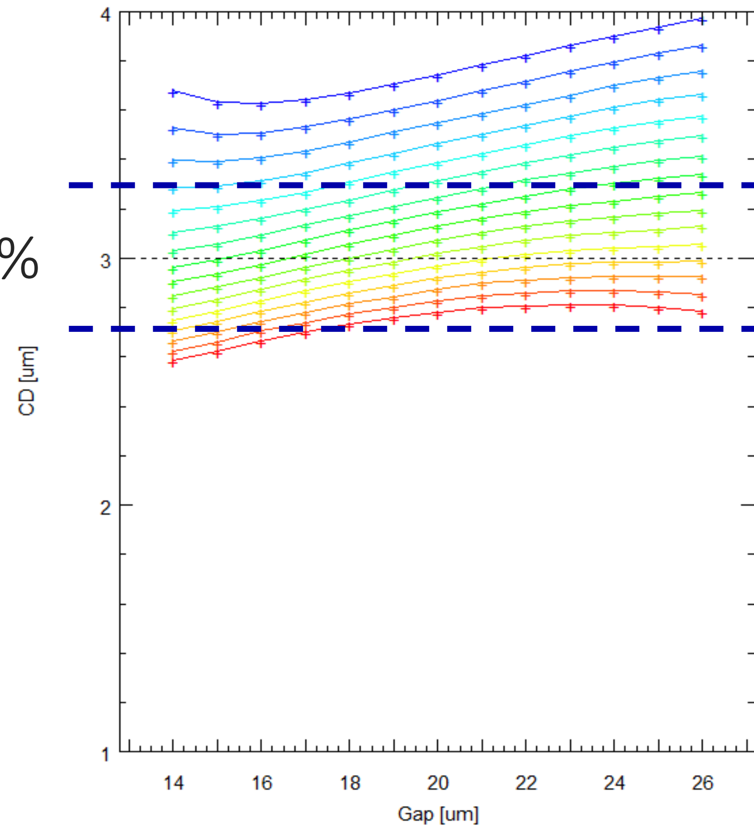
- LAB allows to analyse the process window of the exposed layout
- A simple example: patterning of 3 µm iso- and 1:1 line/space

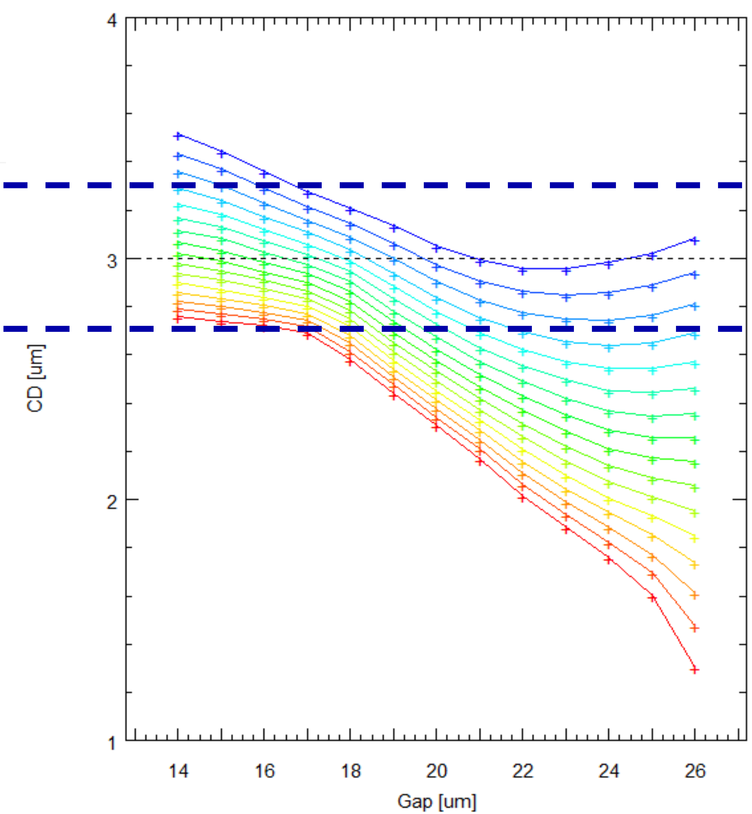
CD calculation for varying proximity gap and exposure dose

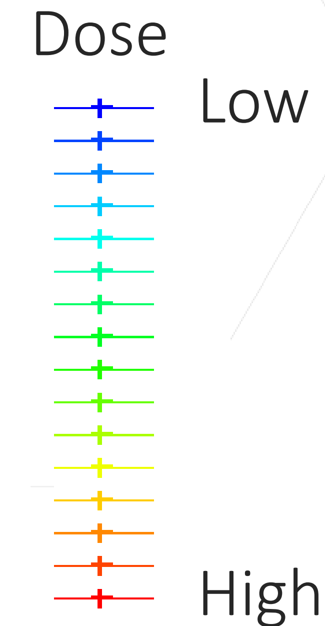
3 µm iso-line on mask

3 µm 1:1 line/space on mask

3 µm ± 10%



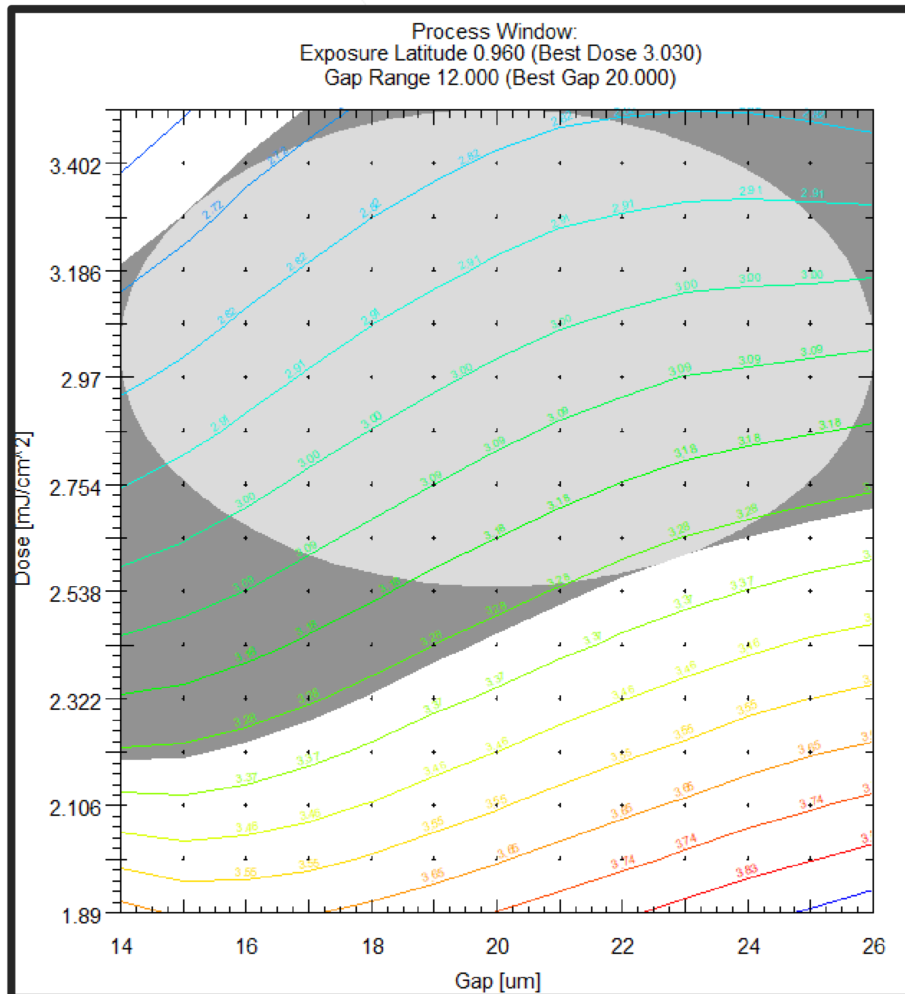




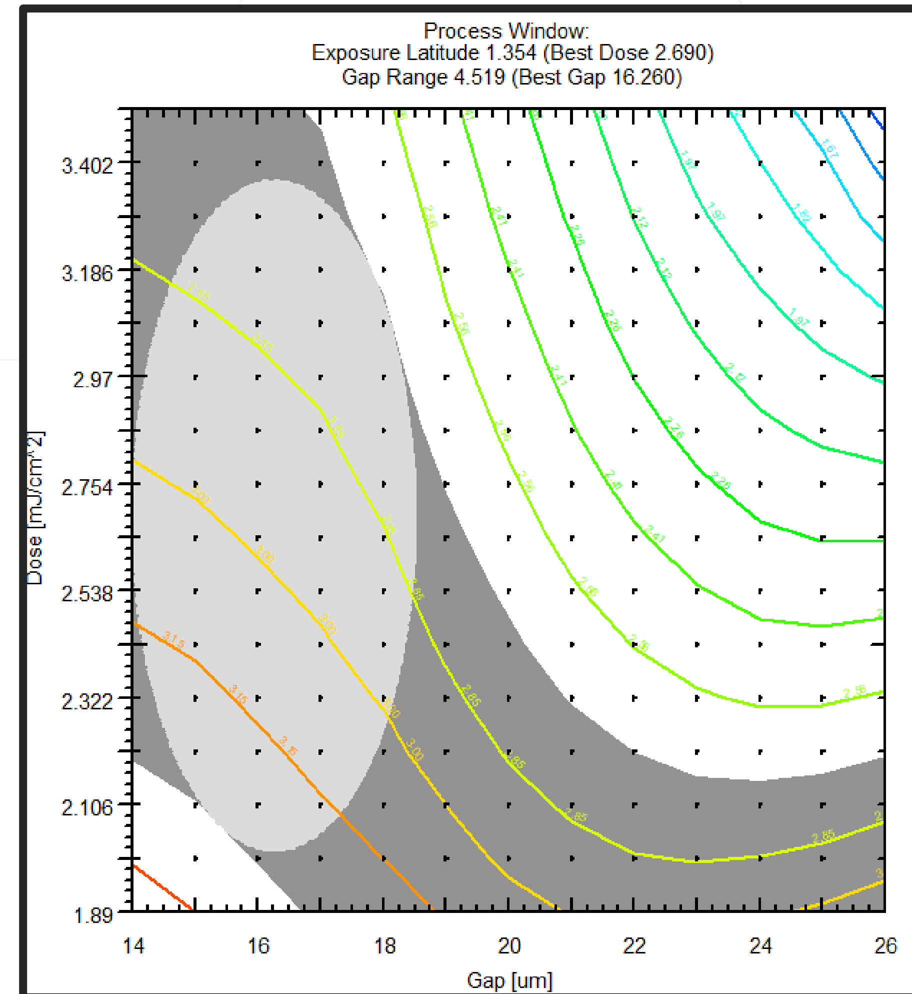
Process Window Analysis

Process window calculation for iso line and line/space separately.

3 µm iso-line on mask

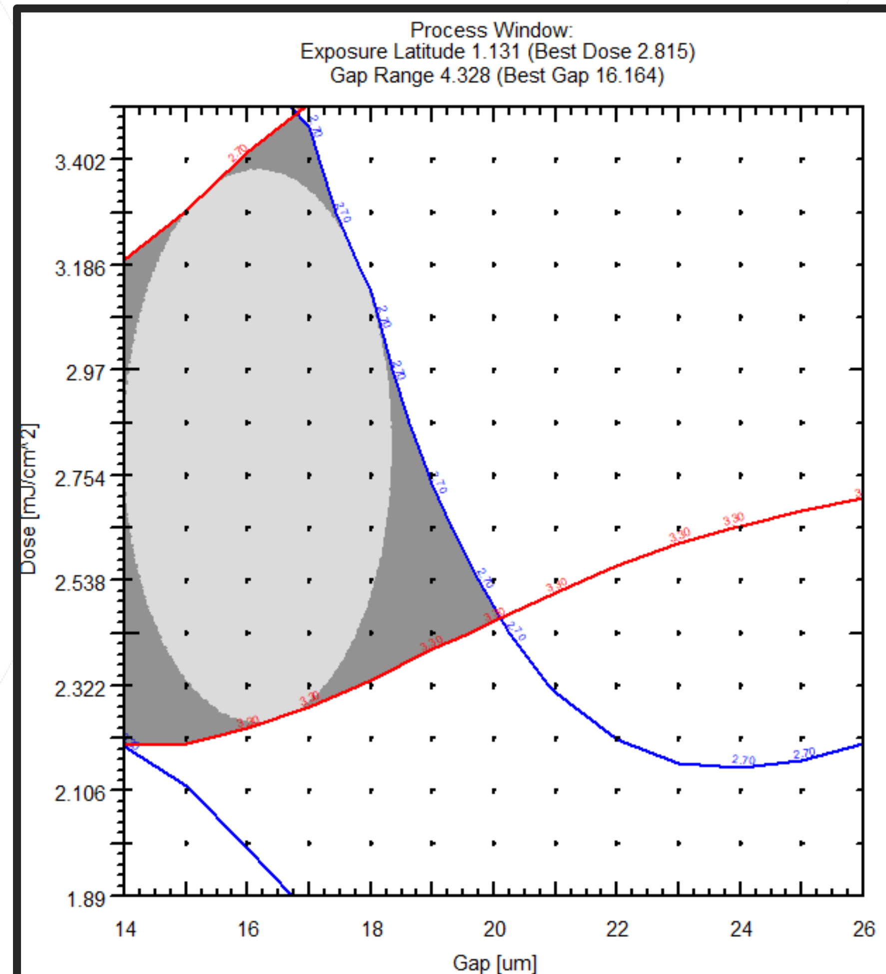


3 µm 1:1 line/space on mask



Process Window Analysis

- Overlap of the process window shows:
  - Impossible to print both iso-line and line/space at gap larger than 20 µm



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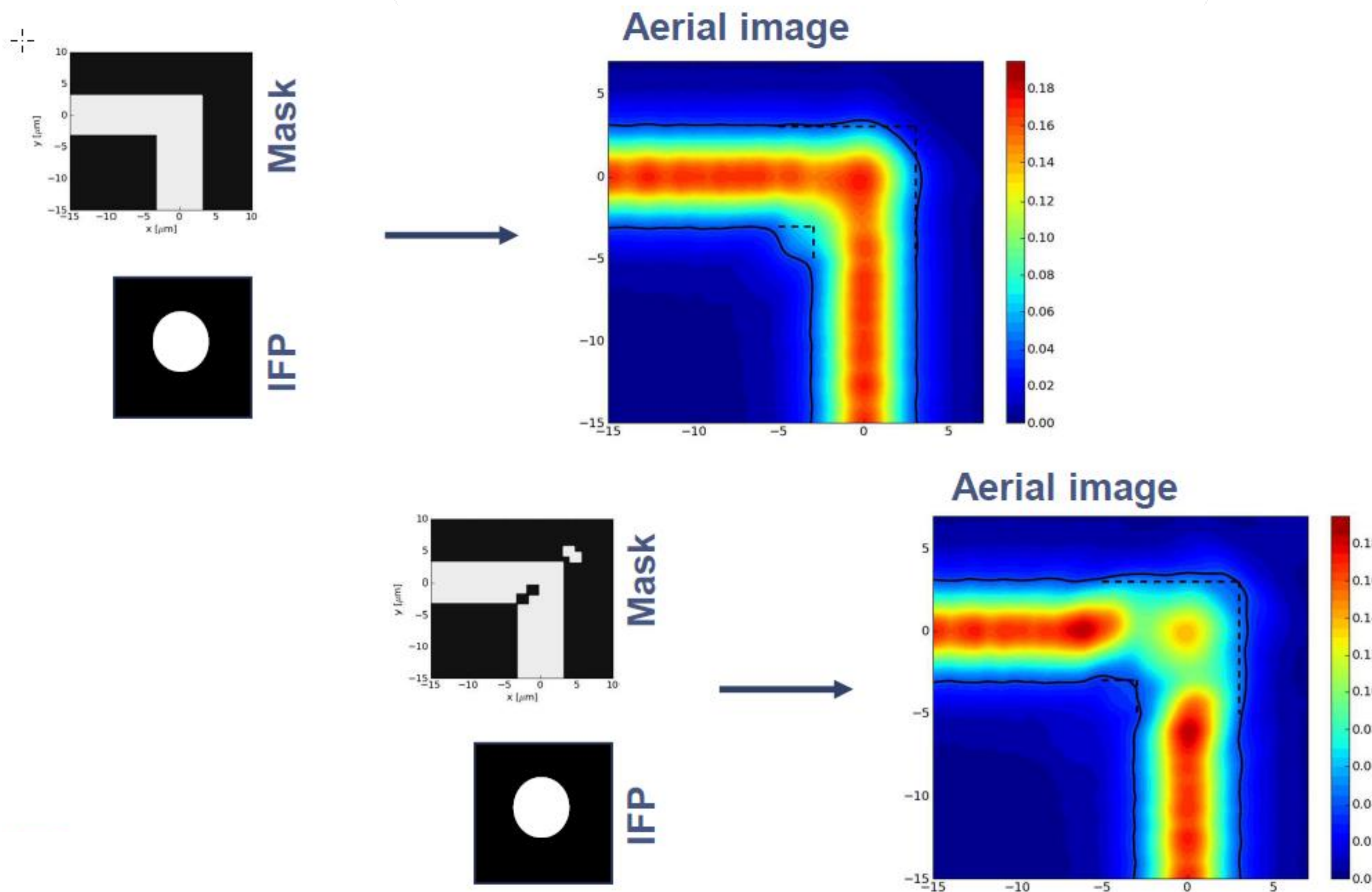
Mask Correction

- Optical proximity correction (OPC) is important to improve the pattern fidelity.
- The example shows the application of OPC to enhance corner sharpness.



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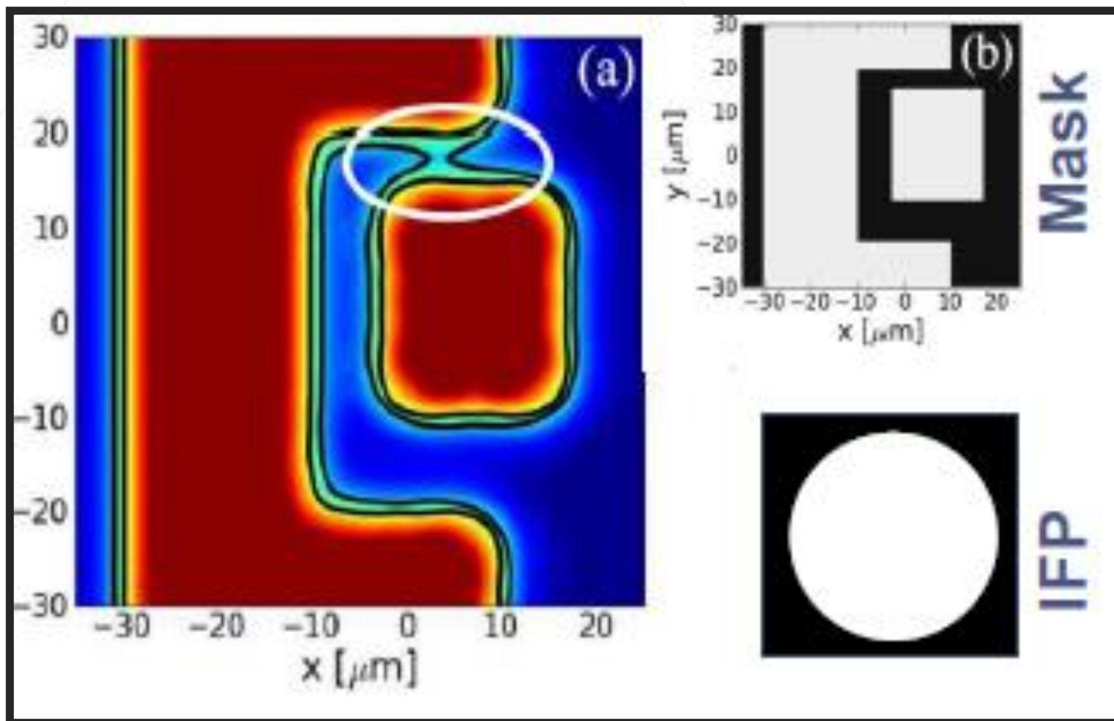
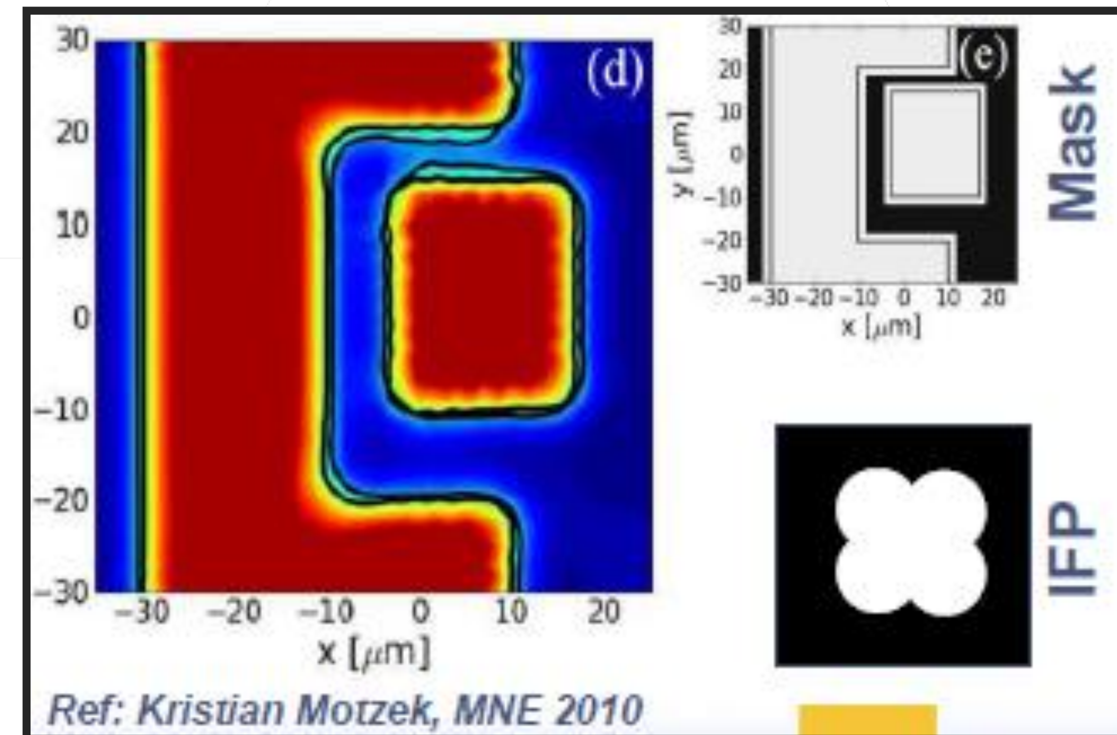
Source Mask Optimisation

- Combination of source shaping and OPC of the mask is critical to improve the pattern fidelity.
- The example shows the application of SMO to expose small features.





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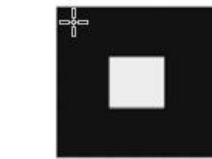
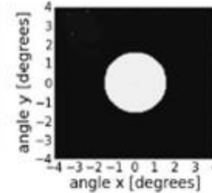
Source Mask Optimisation - Squares

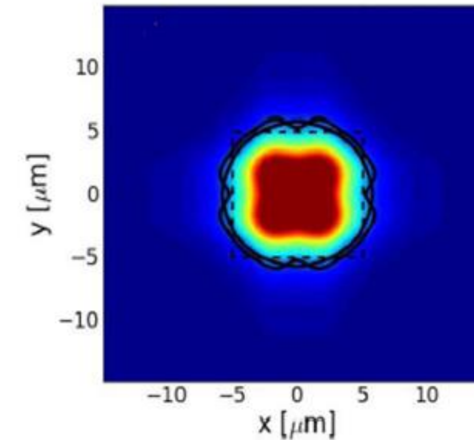
- Different sources impact the final shape of simple layouts.



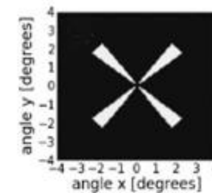
Simple mask pattern



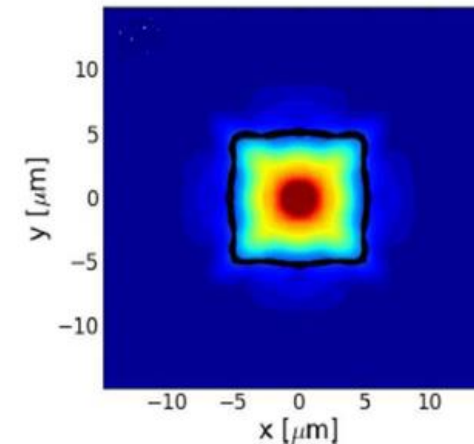
Conventional source



Optimized mask layout



Optimized angle distribution



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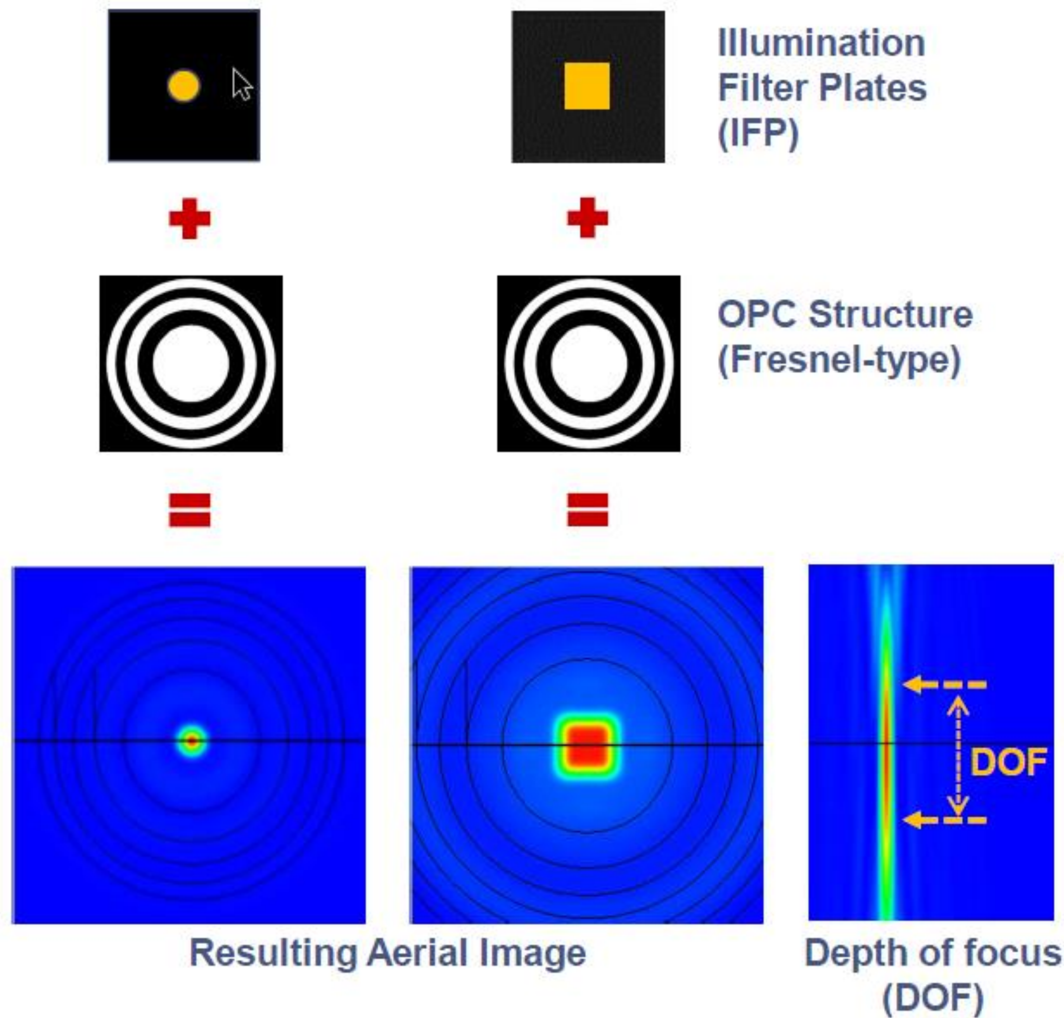
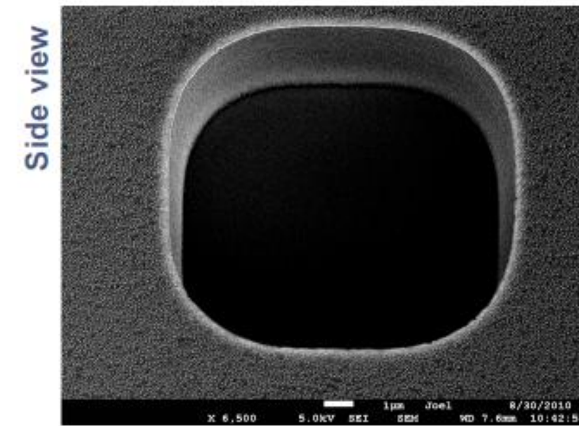
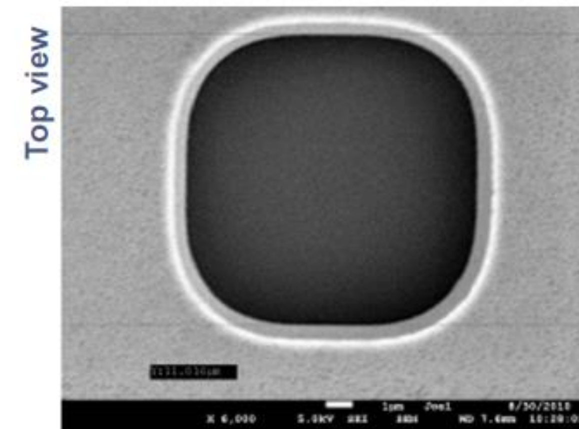
Source Mask Optimisation – Fresnel Mask

- The Fresnel-type mask can focus the light on a very large proximity gap with an extended depth of focus. The exposure shape is defined by the source.





11µm via at 800 µm proximity gap



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Summary

- **LAB** can simulate full exposure processes from light sources including its illumination shape to the 3D resist profile after development. The **process window** analysis and **loop** function show their flexibility to analyse the feasibility of pattern printing.

- With the embeded source shaping, the SÜSS mask aligner user has access to do „unlimited" pre-exposure simulations, thus saving time and costs.

- The source mask optimisation has been demonstrated to be powerful to enhance pattern fidelity.

References

- References:

  - R. Voelkel, U. Vogler, etc., Advanced Mask Aligner Lithography (AMALITH), SPIE 8326-69, SPIE Advanced Lithography, San Jose, Feb 12 - 16, 2012.
  - R. Voelkel, U. Vogler, etc., Lithographic process window optimisation for mask aligner proximity lithography, SPIE Advanced Lithography 2014, 9052-15 Opt. Microlithography XXVII, February 25, 2014.
  - K. Motzek, A. Erdmann, etc., Using computational methods for mask aligner lithography, SPIE Newsroom, January 2012. DOI: 10.1117/2.1201201.003955.
  - K. Motzek, U. Vogler, etc., Computational algorithm for optimising mask layouts in proximity printing, Microelectronic Engineering 88, 2066-2069, 2011.

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