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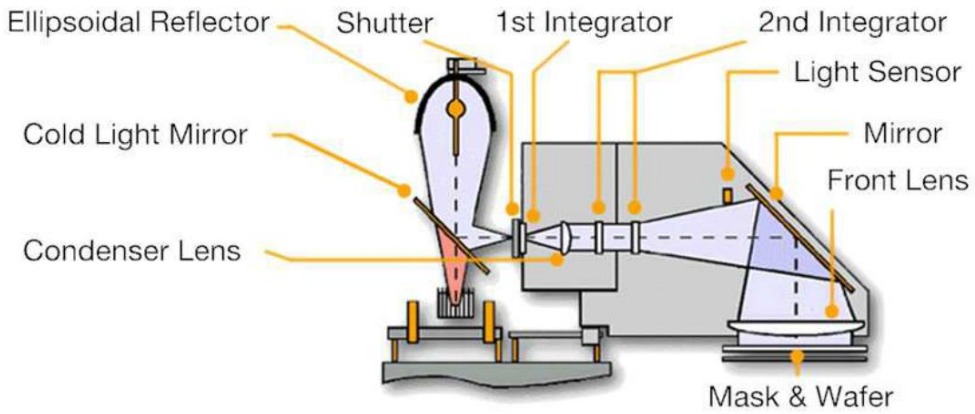
SÜSS MicroOptics Source Mask Optimisation

SÜSS MicroOptics (MO) is an illumination system introduced by *SÜSS MicroTech* for mask aligner lithography. The capability to allow shaping the angular spectrum of the illumination source enables Source Mask Optimisation (SMO) to enhance exposure resolution. Since the illumination condition (collimation angle and off-axis illumination) impacts the lithography result, the optimisation of those conditions improve resolution and process window.

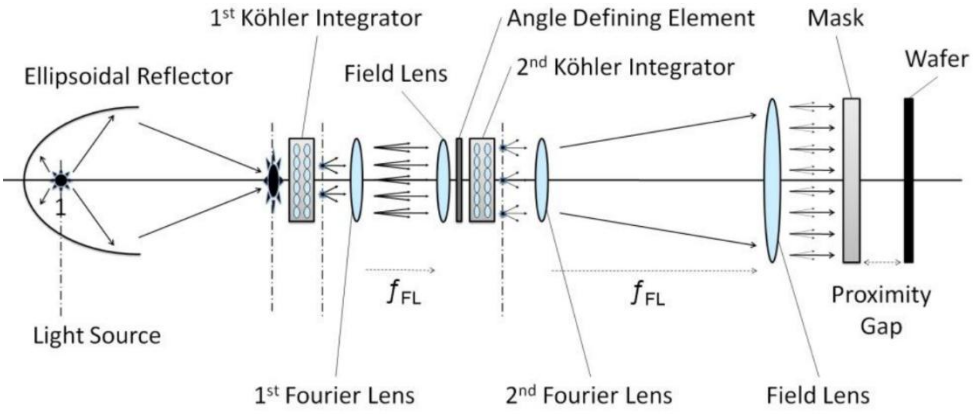
LAB can simulate full exposure process from light source, including its illumination shape, to the 3D resist profile after development. It is useful for process improvement with time and cost efficiency.

Mask Aligner Lithography

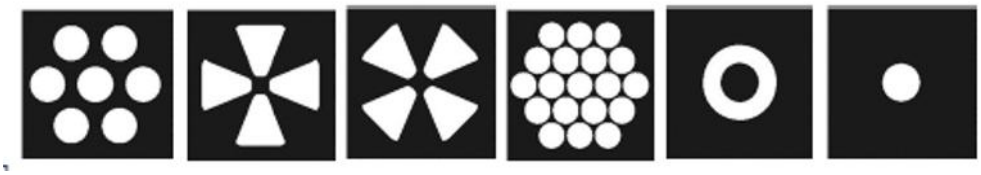
Mask aligner lithography is one of the main techniques in semiconductor industry. It has been widely applied in packaging, MEMS, microfluidics, etc. The schematic view of a standard illumination system is shown below, with contact or proximity printing without optical elements between mask and wafer.



SÜSS Mask aligner is specialised with its capability for source shaping. The SÜSS MO exposure stabilises the illumination against lamp misalignment using two high-quality arrays of microlenses immersed in fused silica (Köhler integrators). The scheme of the SÜSS MO illumination system is shown (*SÜSS report: Advanced mask aligner lithography (AMALITH)*).

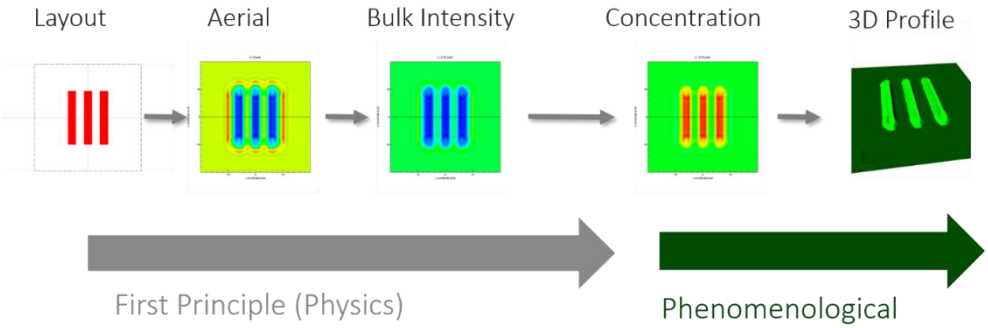


The MO exposure has its advantage in improved light uniformity and telecentric illumination. The shaping of the angular spectrum of the illumination is via angle definition element IFP (Angle Defining Element). Various angular source shapes are available in the MO systems.



LAB as a Modelling Tool

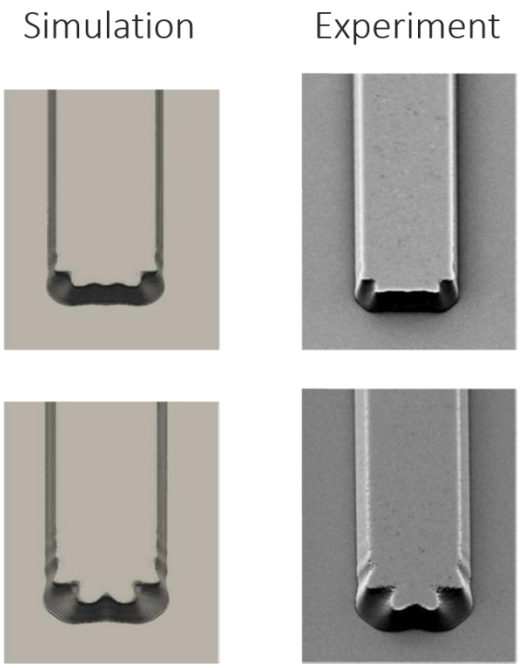
As a modelling tool, **LAB** allows 3D simulation of proximity lithography in mask aligners, including bulk intensity and 3D resist profile. The modelling procedure is described in the following image. Exposure modelling from light source to final resist profile bridges the gap between design and final exposure result. Pre-exposure simulation is cost and time effective for prediction and process improvement.



LAB simulation is module based, with each module performing sequential step in lithography. Typical simulation flow includes three modules. Import module is the import of a layout to be exposed. The Proximity module resolves the proximity optical exposure in resist. Both tool source and light interaction in material stack are considered in optical calculation. The Resist module mimics the resist development procedure using a resist development model.

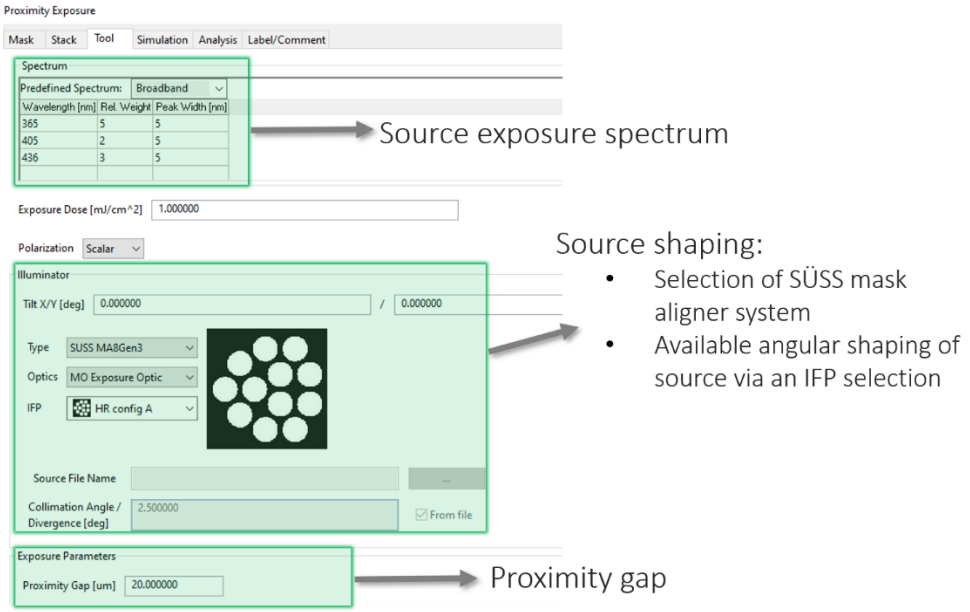
With a proper modelling setup, it is capable to predict the exposure procedure with accuracy. The 3D resist profile vs experimental resist shape proves this accuracy. In the example, top

and bottom exposure use two different source shapes (*GenISys BEAMeeting @ 38th International conference on Micro and Nano Engineering, Toulouse 2012*).

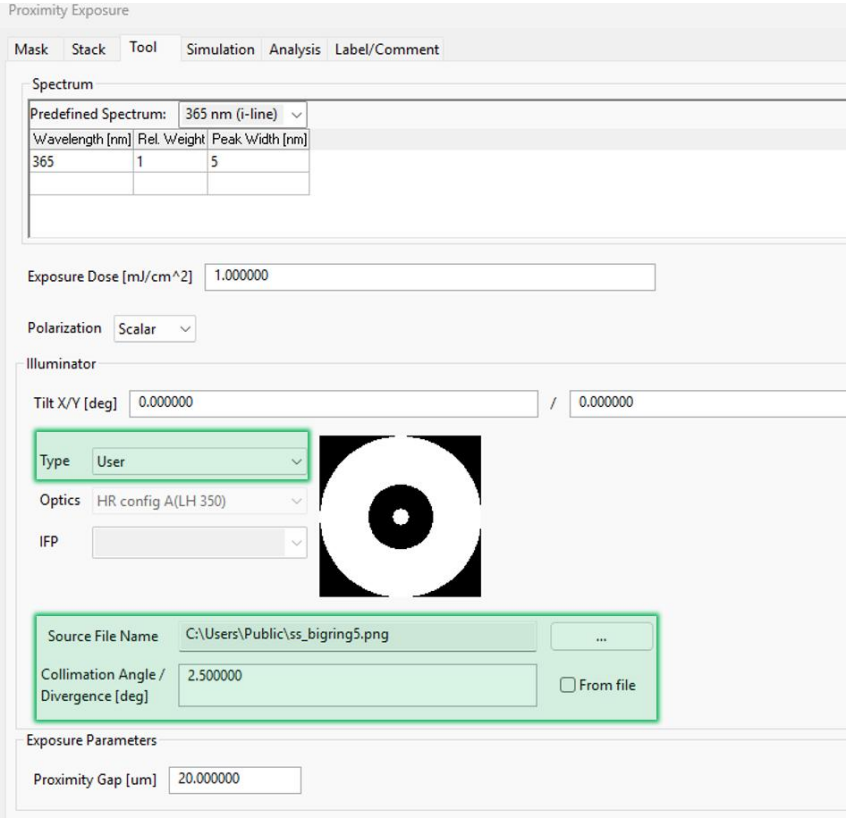


Simulation Setup Details

Proximity module provides simulation of intensity distribution in resist. The tool specifications are described in detail, including spectrum, source shaping and proximity gap.



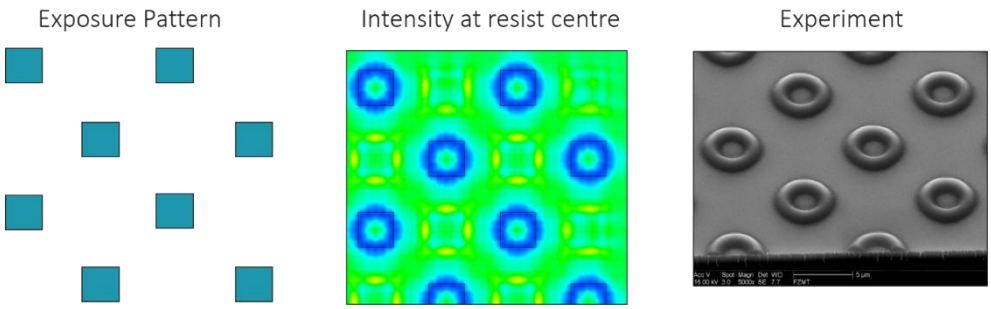
Except for the available source shaping in the tool, **LAB** is flexible for any tool or any sources. User can define any specified source as a “User” defined source in “Type” selection. Source shape file can be in SRC, MO and PNG format.



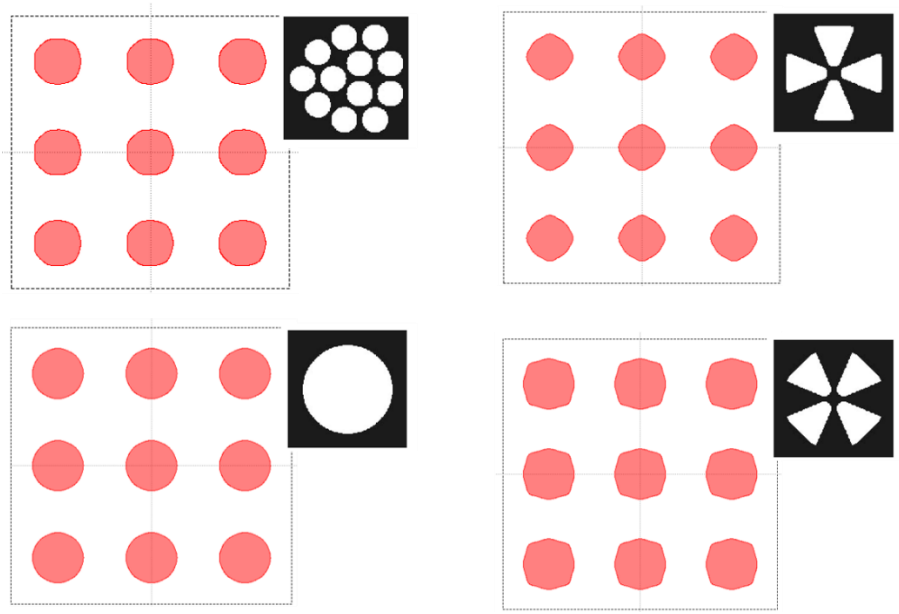
Intensity Image Analysis

Lithography is a pattern transfer from mask to resist. The final resist shape is a combination result of optical exposure and resist development. Proximity lithography enlarges the pattern fidelity issue when the proximity gap is increasing.

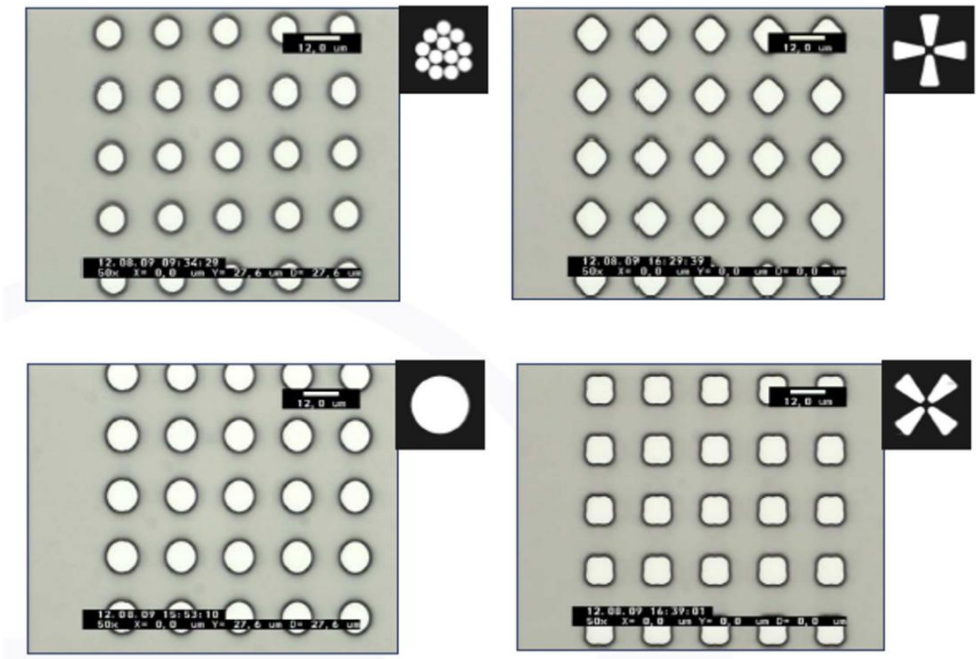
In most cases, the intensity in the resist is enough to analyse the exposure quality even if the resist development model is not calibrated. In the following example, the mask layout is 3 µm squares and exposed with proximity gap 20 µm. The material stack has a 2 µm resist AZ6624, which is deposited on silicon substrate. The intensity image fits the experimental result.



The imaging is an interaction of illumination with mask. The following example is an exposure of 10 µm square array at a proximity gap of 100 µm. The simulation shows *the resist profile (threshold on intensity) when different source shapes are applied for exposure (Ref.: R. Voelkel, U. Vogler, etc., Advanced Mask Aligner Lithography (AMALITH), SPIE 8326-69, SPIE Advanced Lithography, San Jose, Feb 12 - 16, 2012*).



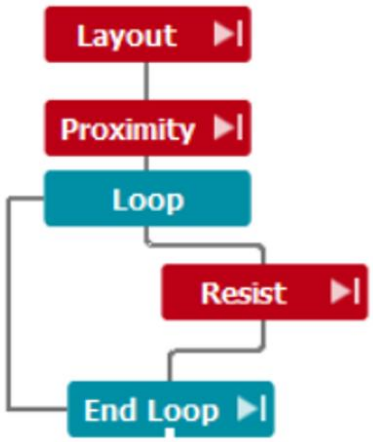
Corresponding resist shapes with SEM images prove the correspondence between simulation and lithography result.



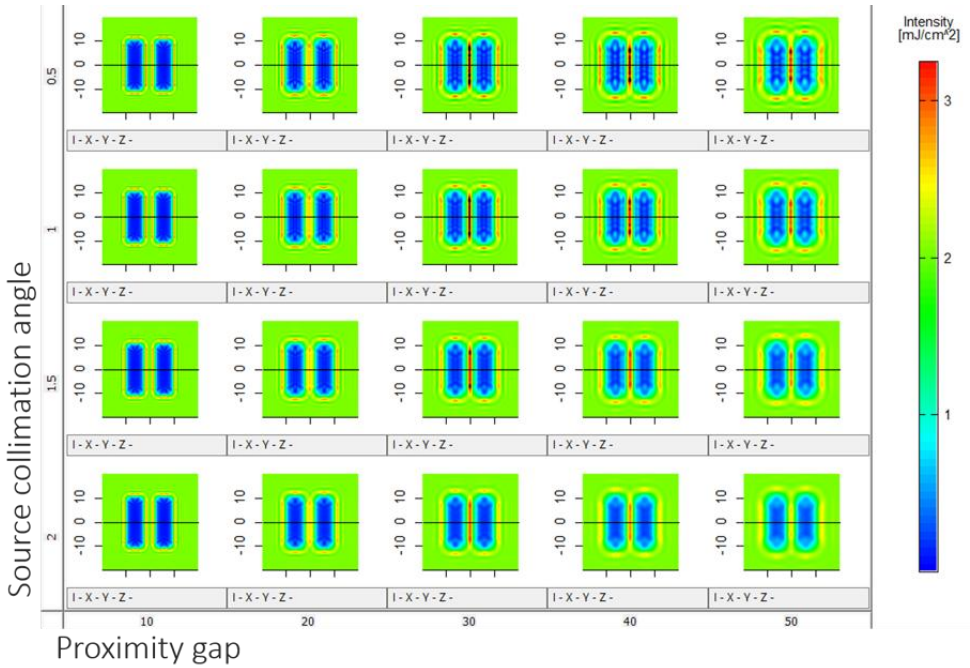
Simulation Flexibility

More than a single simulation, *Loop* module provides flexibility to visualise the influence of different parameters, e.g. proximity gap, dose and mask correction.

The typical workflow for *Loop* module is shown as follows.

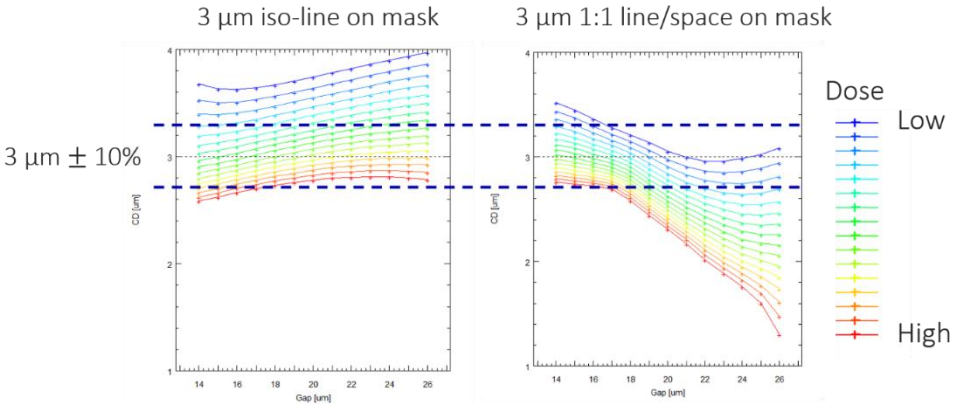


When the result is opened, a matrix of simulation intensity is shown, making side by side comparison visible.



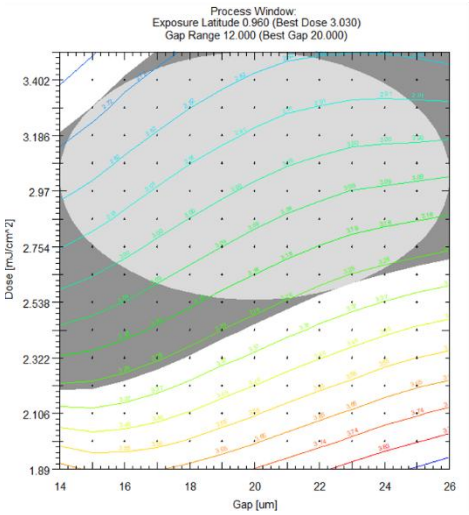
Moreover, **LAB** allows analysing the dose/gap-matrix simulation of the exposed layout. The simple example is patterning 3 µm iso- and 1:1 line/space.

The CD calculation for varying proximity gap and exposure dose is analysed, which is like Bossung curve in projection lithography.

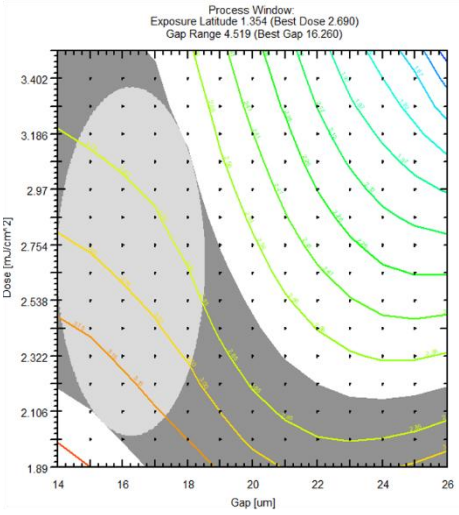


The dose/gap matrix can be converted to a process window. Following conversion shows the dependence of process window on pattern density.

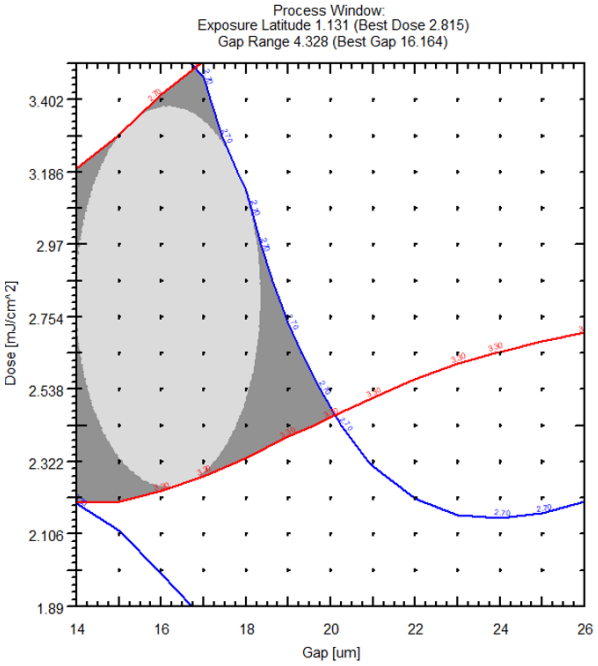
3 µm iso-line on mask



3 µm 1:1 line/space on mask



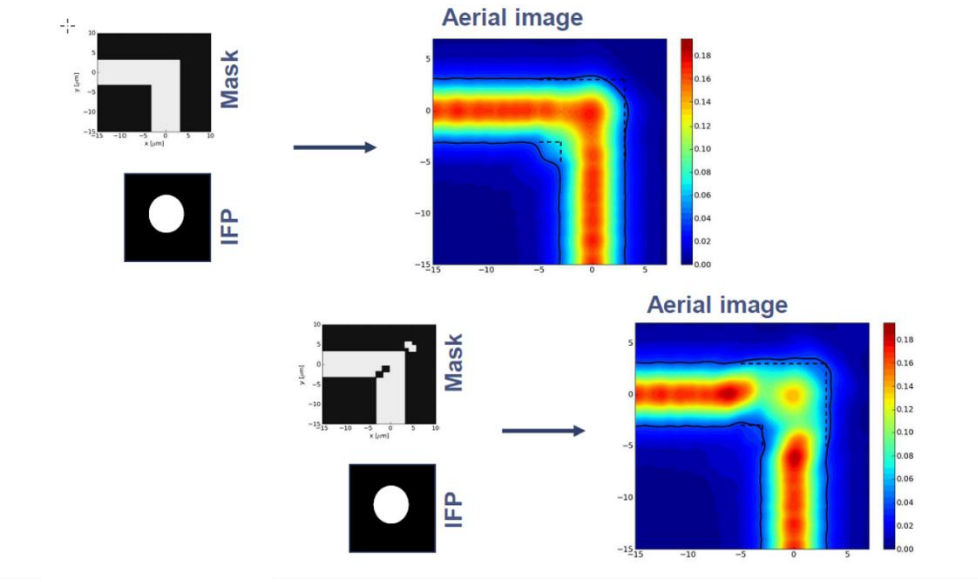
When both iso- and line/space pattern are fabricated on the same wafer, the overlap of process window demonstrates that it is impossible to print both iso and 1:1 line/space pattern at a proximity gap larger than 20 µm.



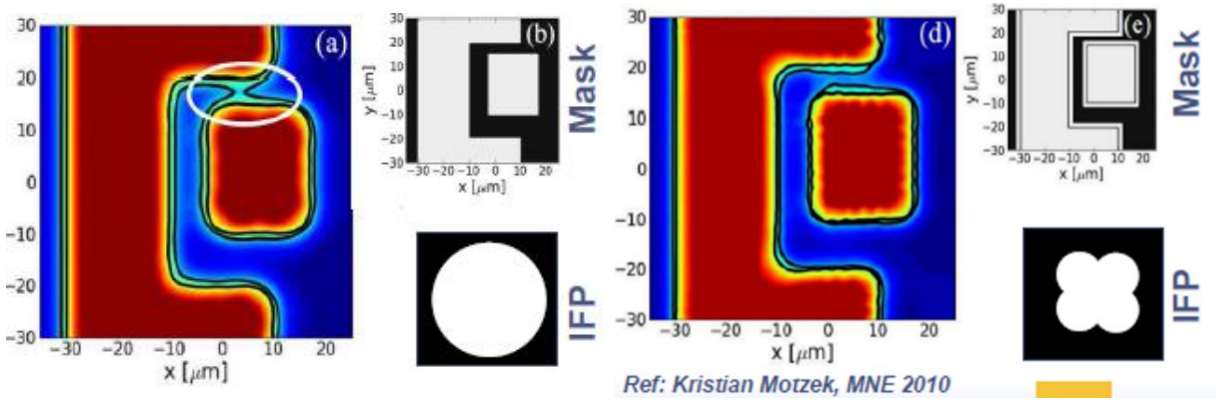
Source Mask Optimisation

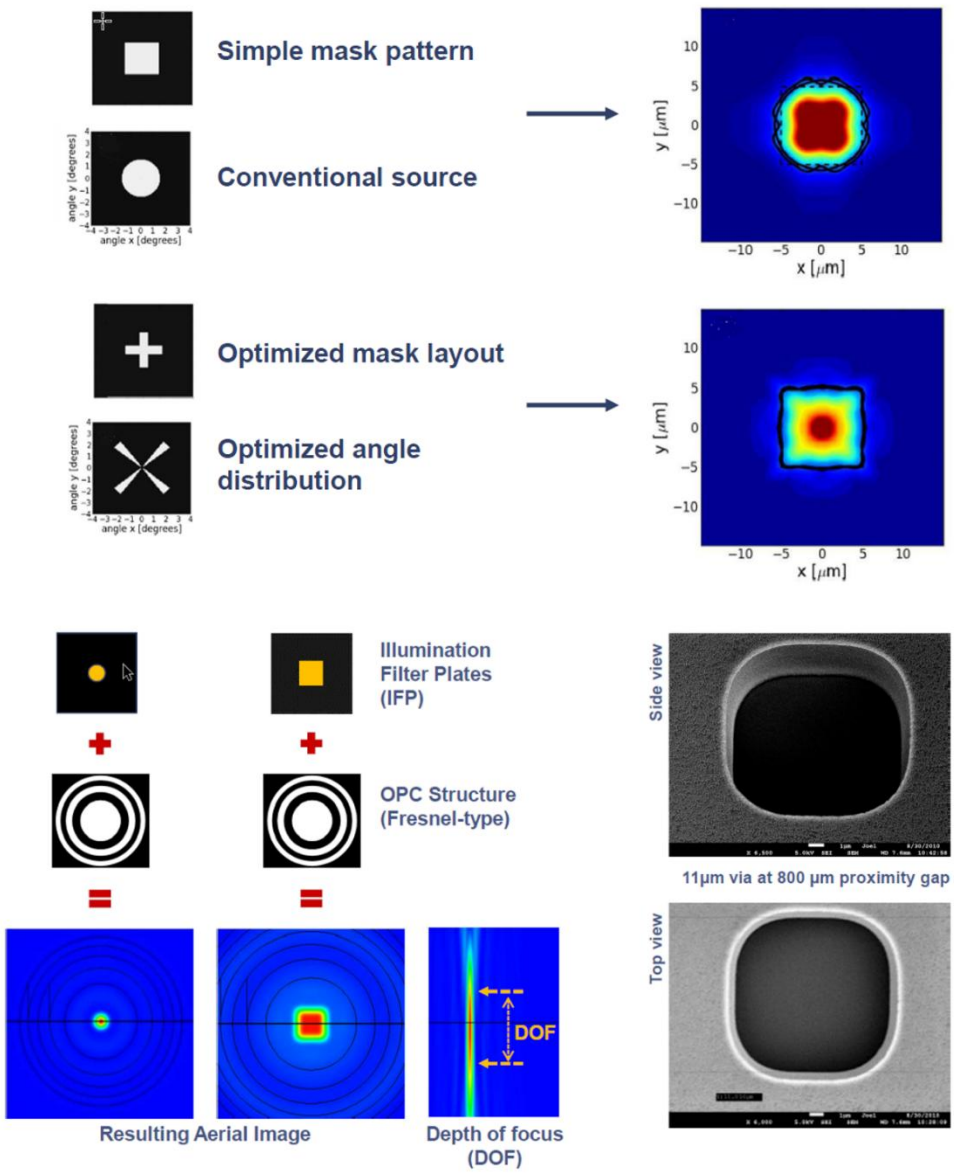
Optical proximity correction (OPC) is commonly used to improve the lithography quality. The example shows the application of OPC to improve the corner sharpness *(Ref.: K. Motzek, A.*

Erdmann, etc., Using computational methods for mask aligner lithography, SPIE Newsroom, January 2012. DOI: 10.1117/2.1201201.003955).



In addition to OPC, source mask optimisation (SMO) optimises source shaping and OPC at the same time. Due to the diffraction at the mask plane, pattern fidelity in proximity lithography is worse than projection lithography. The lithography result is even worse when the proximity gap is increased, making it difficult to resolve small features. The pattern fidelity with SMO can be enhanced better than only OPC. The examples below are applications of SMO to expose small features (*Ref.: K. Motzek, U. Vogler, etc., Computational algorithm for optimising mask layouts in proximity printing, Microelectronic Engineering 88, 2066-2069, 2011*). They are resolving a fine gap between large pads, printing a square shape. The Fresnel-type mask can focus the light on a very large proximity gap with an extended focus, while the exposure shape is defined by the source.





Above all, SMO is a pattern dependent on optimisation of source shaping and mask OPC at the same time. The optimisation is an iterative procedure to make improvement step by step. **LAB** modelling covers the optical source and optical effect through mask, which allows “unlimited” pre-exposure simulation for SMO, thus enabling time and cost efficiency.

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 embedded source shaping, the user has access to do “unlimited” pre-exposure simulations, thus saving time and costs. SÜSS mask aligner users have access to pre-defined source shapes, which are available in the tool.

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