SPIE Optical Systems Design

SÜSS MicroOptics

Simulation Tools for Advanced Mask Aligner Lithography (AMALITH)

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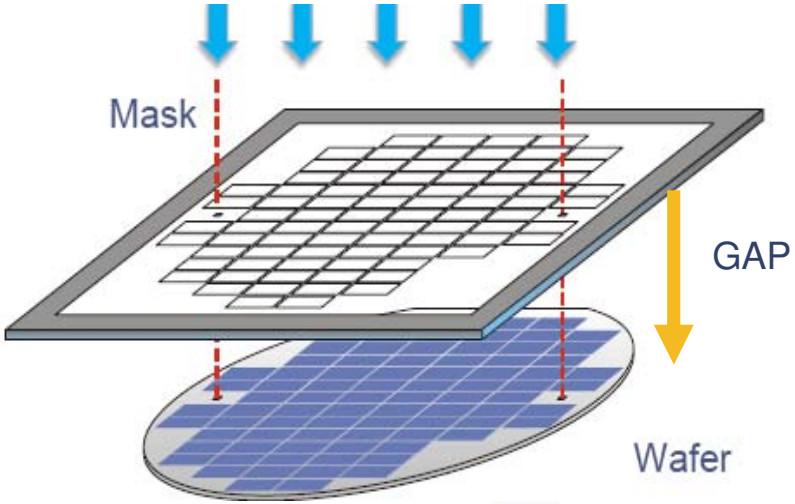
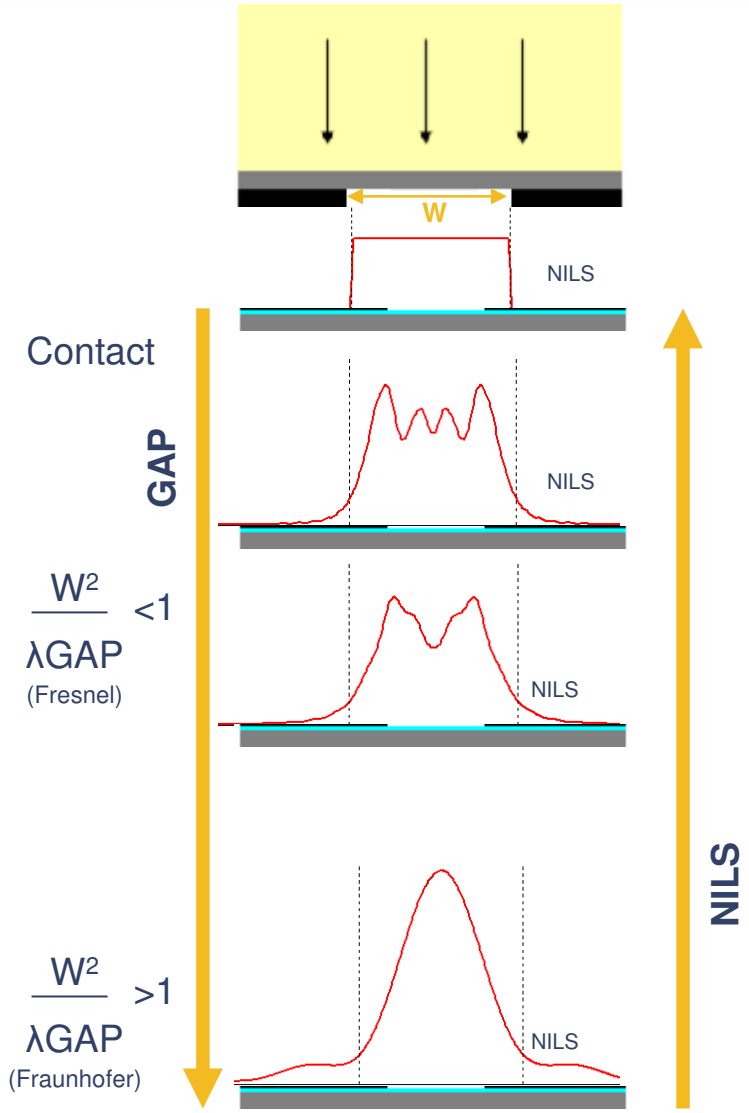
Michael Hornung, Reinhard Voelkel

Contact/Proximity Lithography





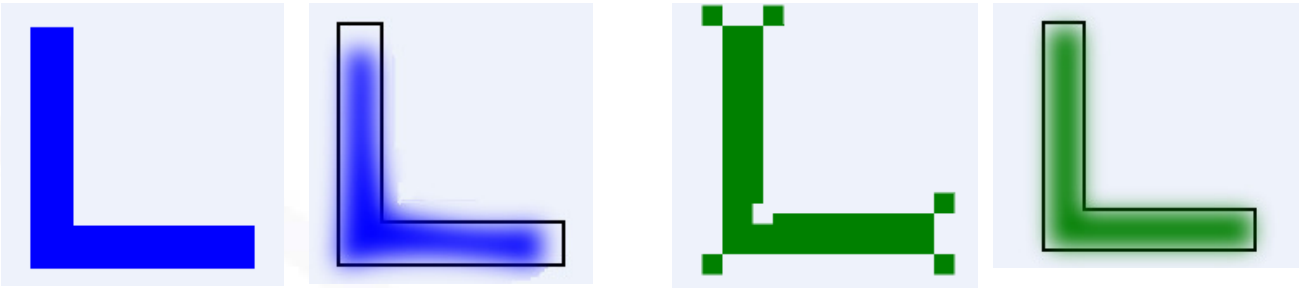
Diffraction affects the printing results:

- Intensity depends on the Gap
- Normalized Image log-slope (NILS) depends on the Gap
- Resolution is limited
- **W** on the wafer can be different than on the mask

Resolution Enhancement Technologies

+ Optimization of the mask pattern shape (Optical Proximity Correction, OPC)

Source: Wikipedia



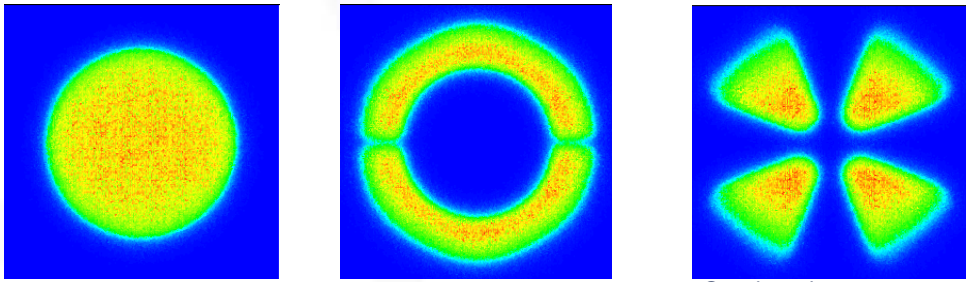
Mask Layout without OPC features

Resist Profile

Mask Layout with OPC features

Resist Profile

+ Optimization of angles of incoming light (off-axis illumination, OAI)



Conventional

Annular

Quadrupole (Malt 45°)

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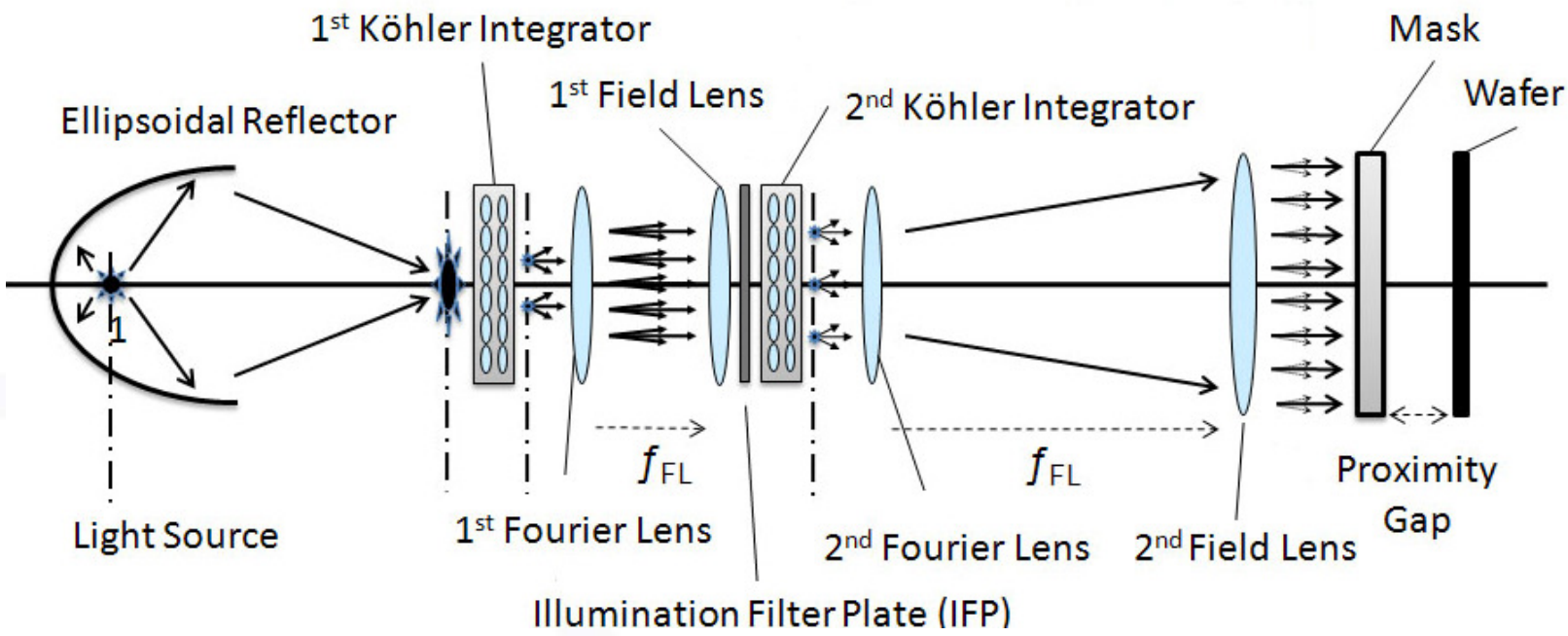
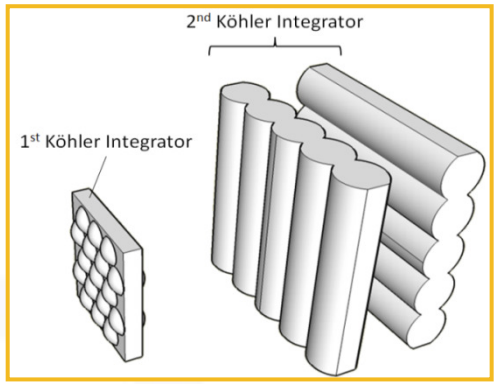
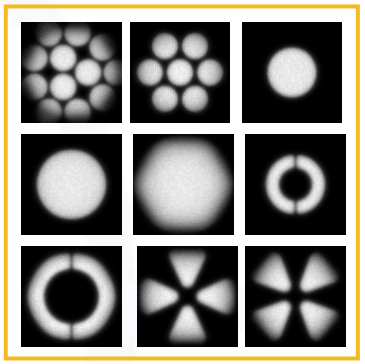
MO Exposure Optics





Uniformity in Angular Spectrum and Irradiance

+



Determination of **Angular Spectrum**

Precise modeling for simulations

Preselection Illumination

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Simulations

+ Manufacturing Tool

Reduction of the number of experimental test, troubleshooting of problems in the fab

+ Research Tool

Improvement in lithography based on simulation results (PSM and Off axis illumination)

+ Process Development Tool

Development of new lithographic process or equipment (top bottom antireflection coatings)

+ Learning Tool

Possibility to see intermediate parts of imaging sequence, like aerial image and latent images

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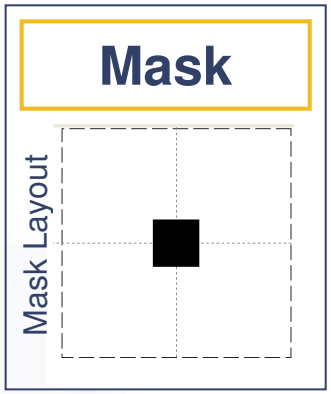
Lithography Simulation: LayoutLab

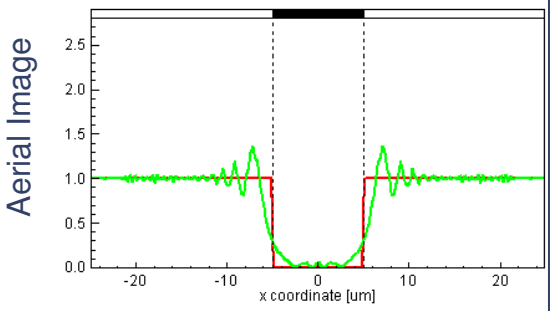
Input

Mask



INTERMEDIATE RESULTS

Exposure

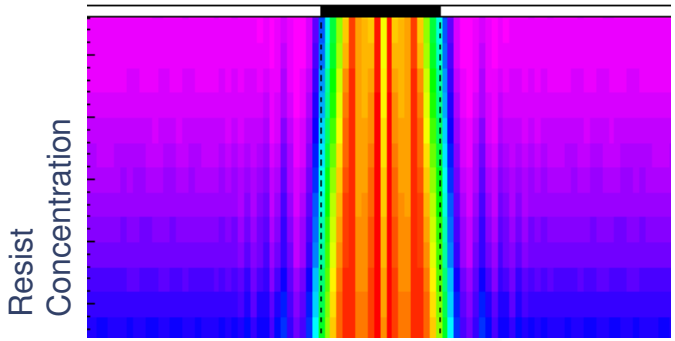


Output

NILS; contrast, DoF

RESULTS

Resist

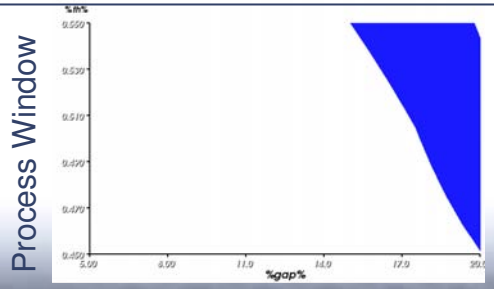


Output

Resist profile; CD; Sidewall slope

ANALYSIS VALUE

Export; Metrology



Output

Process Window CD vs Gap/Dose

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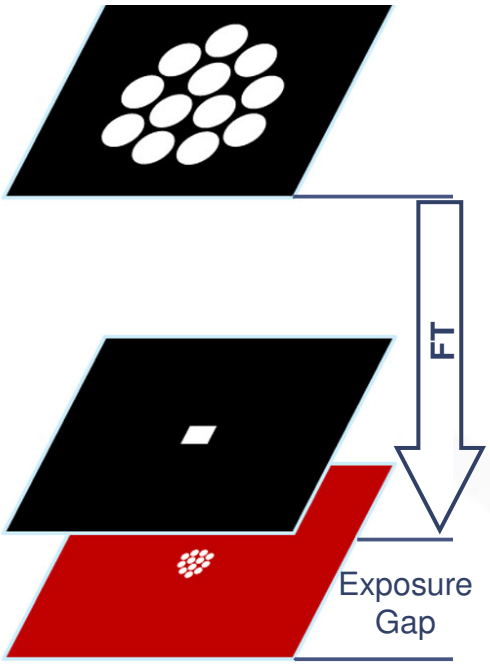
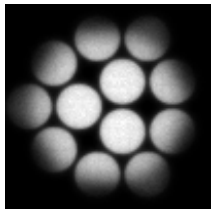
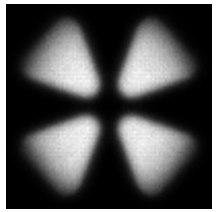
Source Optimization

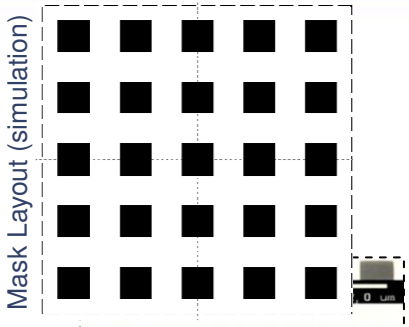


A-IFP

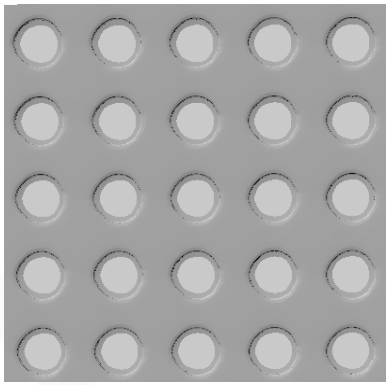


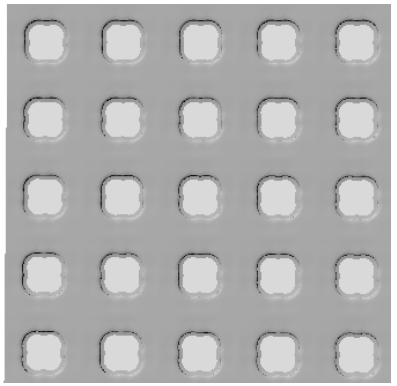
MALT 45°-IFP



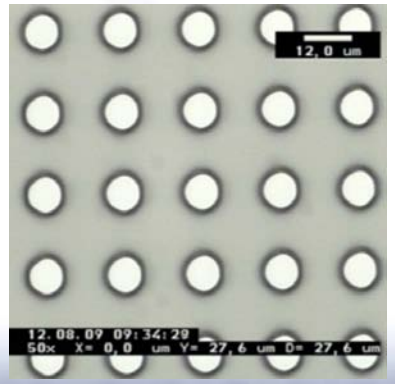


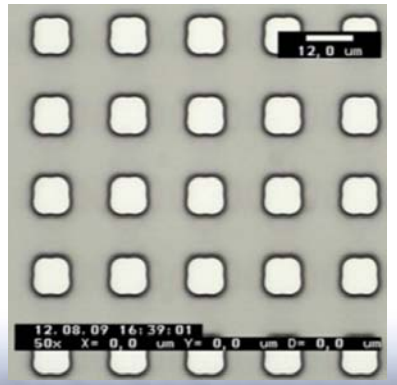
3D Simulated resist profile





Experimental resist profile





Simulation and experimental setting

- Photomask: 10 µm x 10 µm
- 1.2 µm thick photoresist (AZ1518)
- 100 µm Exposure Gap

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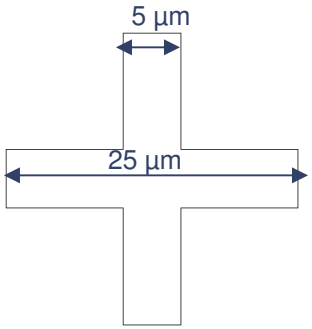
Source Optimization

Simulation setting

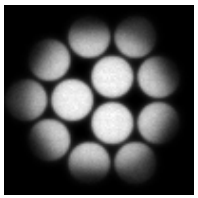
- Photomask: cross shape
- 0.1 µm thick photoresist (AZ1518)
- 0, 20, 50, 100, 200 µm Exposure Gap

MASK

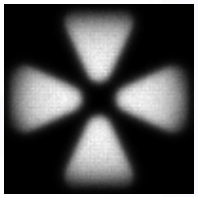


Simulated Resist Profile (LayoutLAB, GenISys);

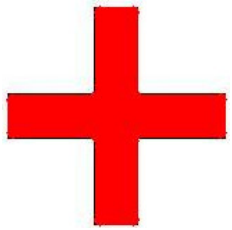
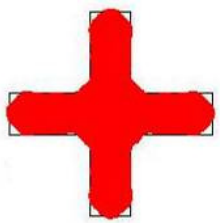
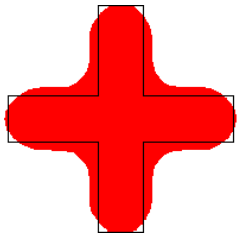
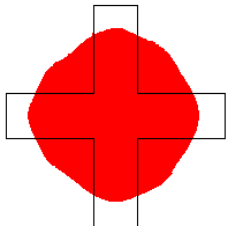
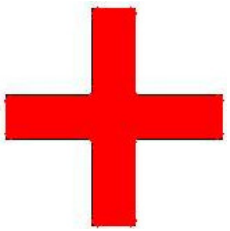
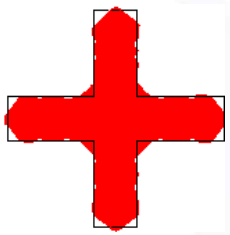
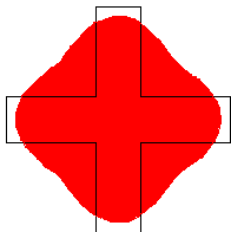
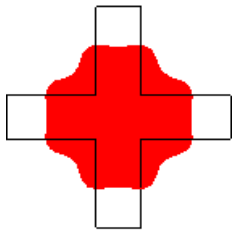
SOURCE



A-IFP



MALT-IFP 0°

Contact	20 µm	50 µm	100 µm	200 µm
				
				

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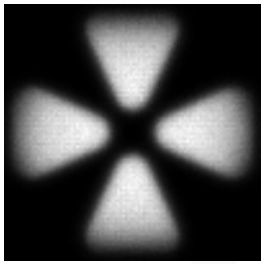
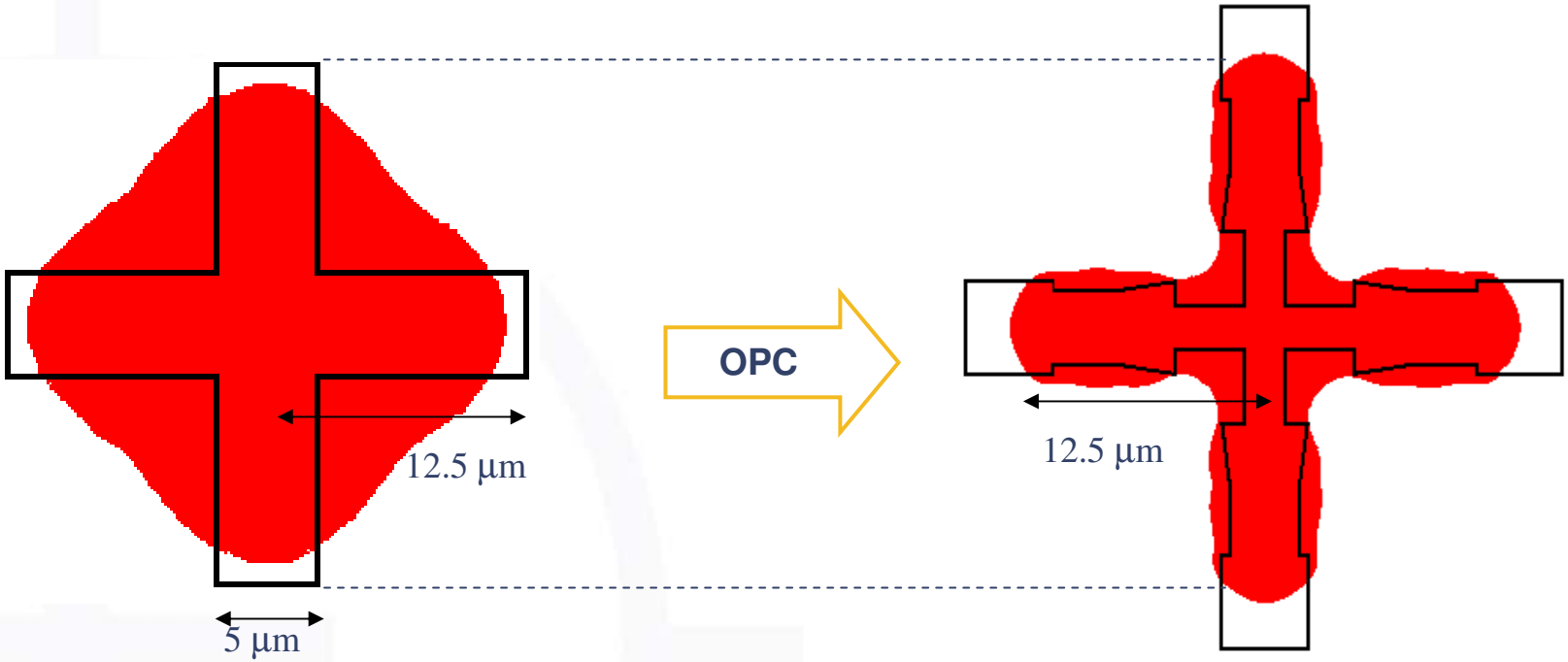
Source Mask Optimization (SMO)



MALT-IFP 0°

SOURCE OPTIMIZATION + OPC = SMO

- **Simulation setting**
- Photomask: cross shape and OPC mask
- 0.1 µm thick photoresist (AZ1518)
- 100µm Exposure Gap



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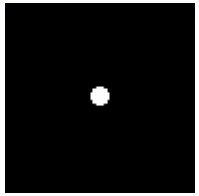
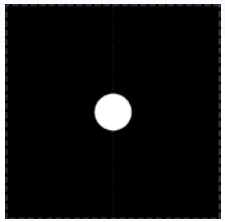
Fresnel type mask optimization



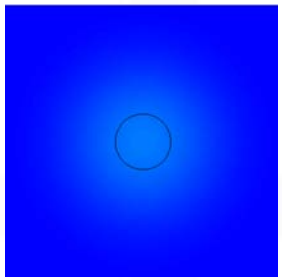
Circular Illumination (IFP)

+

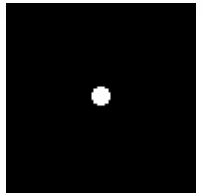


Dark Field Mask

=



2D Aerial Image

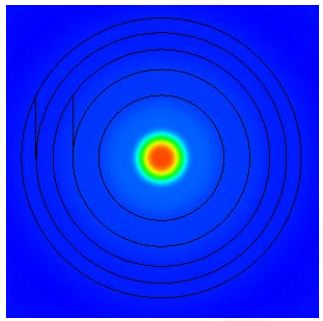


Circular Illumination (IFP)

+

OPC Structure (Fresnel-type)

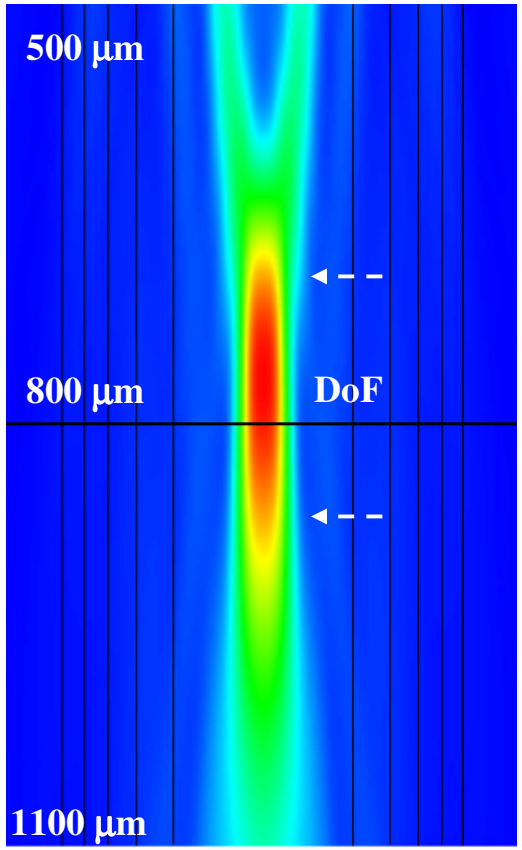
=



2D Aerial Image

Simulation setting

- Photomask: Fresnel Zone Plate (FZP)
- 5 µm thick photoresist (AZ1518)
- 800 µm Exposure Gap



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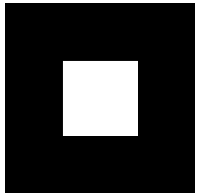
Square IFP

Simulation and experimental setting

- Photomask: Fresnel Zone Plate (FZP)
- 5 µm thick photoresist (AZ1518)
- 800 µm Exposure Gap

Illumination Filter Plates (IFP)



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OPC Structure (Fresnel-type)

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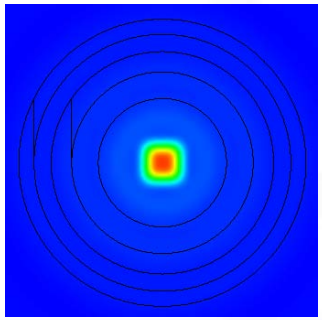
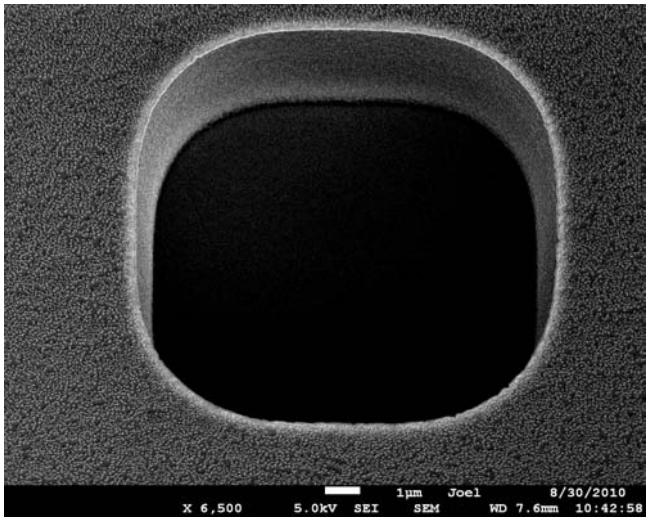
Resulting Aerial Image

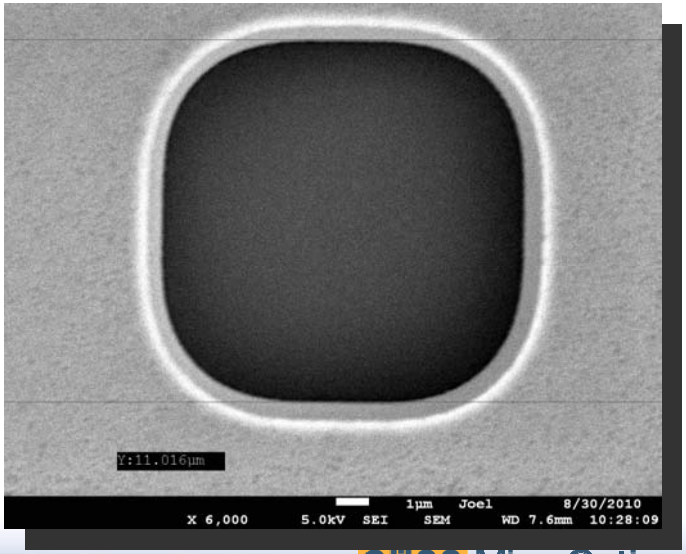


11µm via at 800 µm proximity gap

Side view



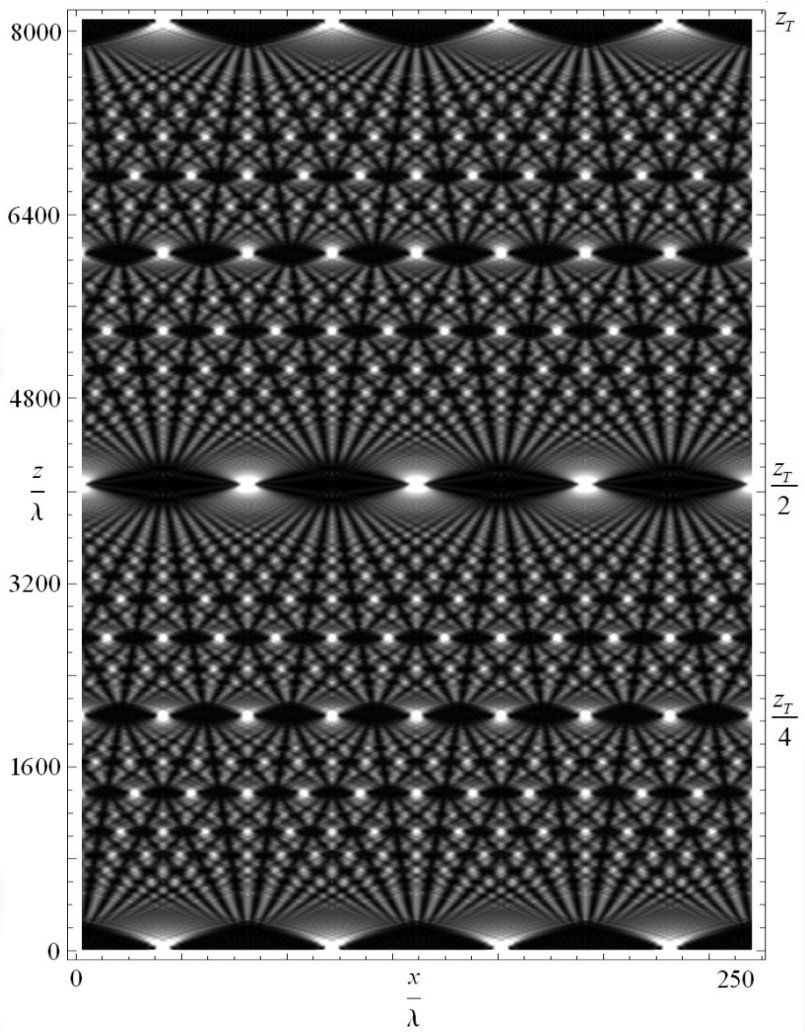
Top view



SUSS MicroOptics

Talbot Effect

Source: Wikipedia



- Near-field **diffraction effect** observed when a plane wave is transmitted through a grating or other periodic structure
- At multiples of a certain defined distance the structure is replicated. At smaller regular fractions of this gap, sub-images can also be observed
- This distance is known as the **Talbot Length** and is found by these formulas:
  - $Z_T=2d^2/\lambda$ [Quadratic array]
  - $Z_T=3d^2/2\lambda$ [Hexagonal array]
- Exactly halfway between these locations, the structures with half the spatial period of the original structure are reproducted

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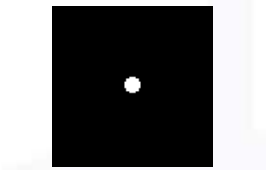
Talbot Effect in Proximity Lithography

Hexagonal Array → $Z_T = 3d^2/2\lambda$ → $Z_T \approx 102\ \mu m$ (d= 5µm; λ= 365µm)



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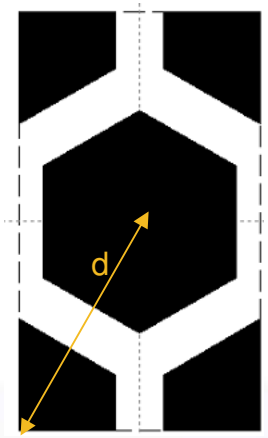

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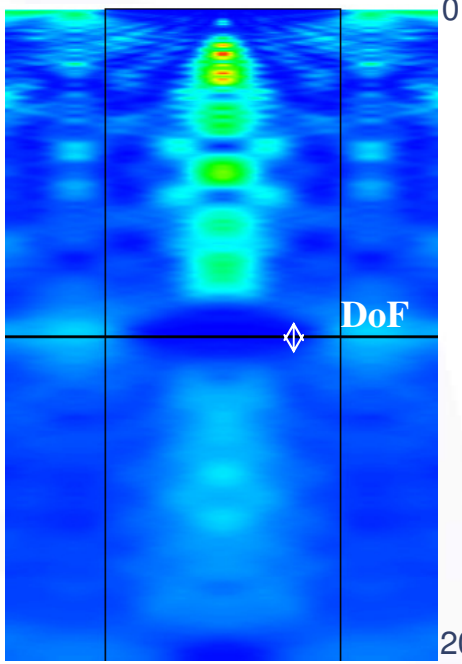
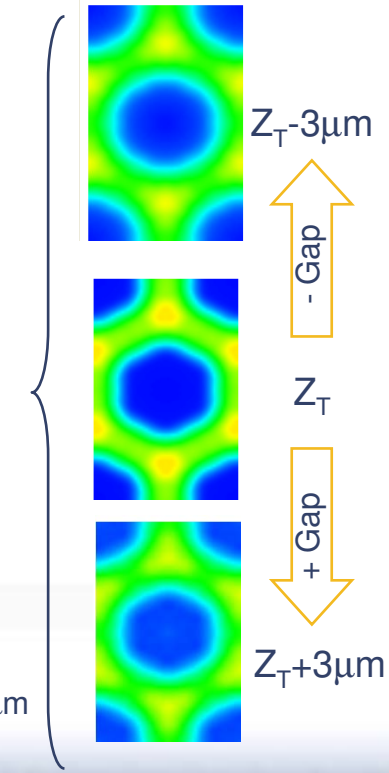
Aerial Image for Gap between 0µm and $2Z_T$ (Cross Section)



Aerial Image, Gaps: $Z_T \pm 3\mu m$



Simulation Setting

- Photomask: Hexagonal Array (d= 5µm; size= 4µm)
- 102µm ± 3µm Exposure Gap

DoF > 6µm

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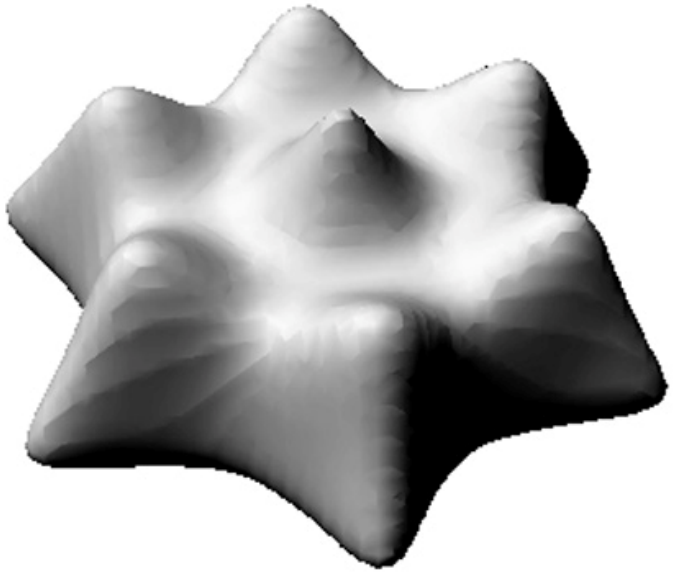
Comparison between Simulation and Experiment

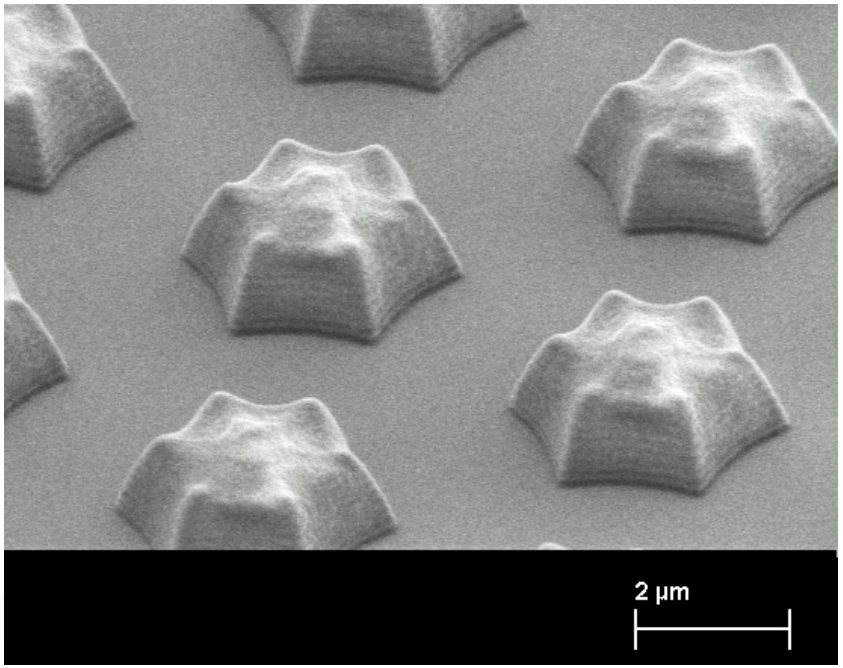
Simulation and experimental setting

- Photomask: Fresnel Zone Plate (FZP)
- 5 µm thick photoresist (AZ1518)
- 102 µm Exposure Gap

Simulation 3D Resist Structure
(LayoutLab, GenISys)



Printed resist structures



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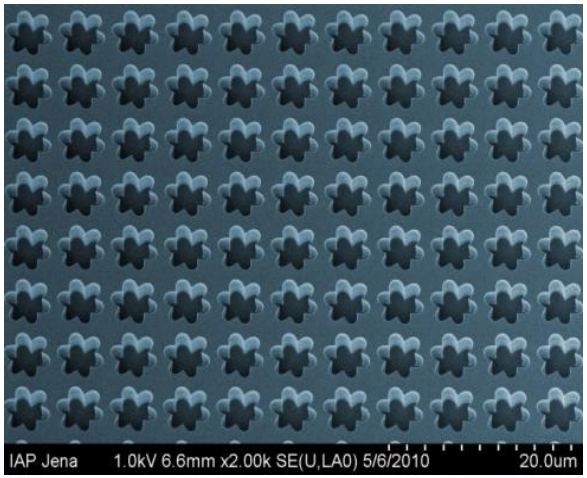
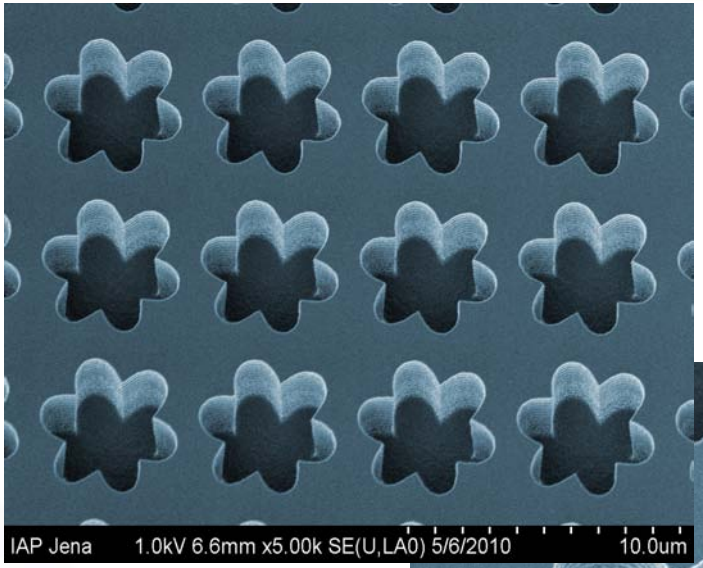
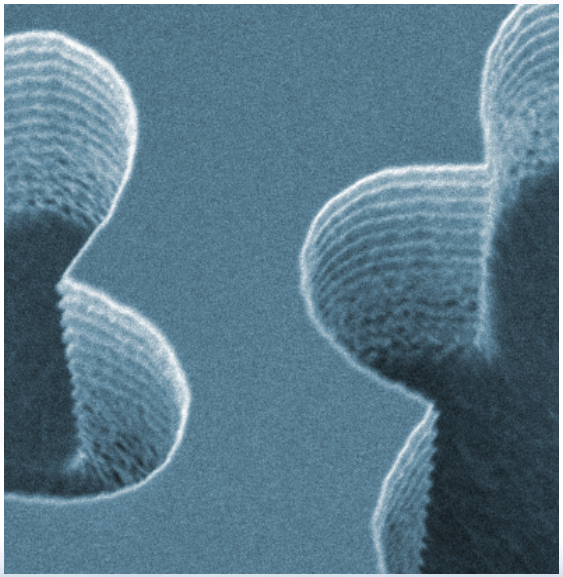
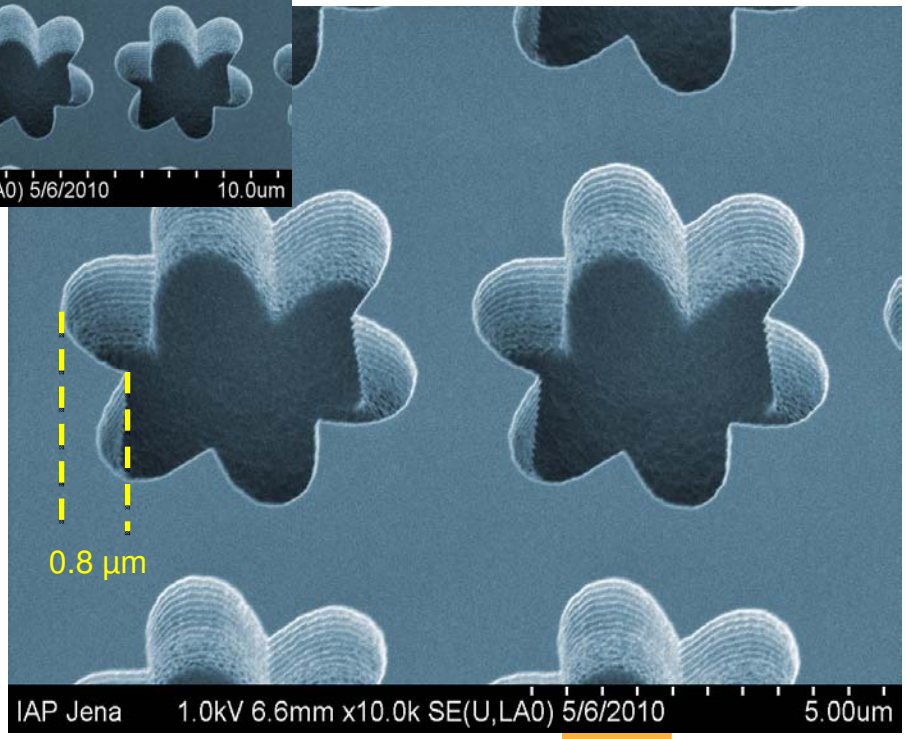
MO Talbot Lithography (Periodic Structures/PSS)





Flowers	*4 µm*
Pitch	*6 µm*
Resist	*2 µm thick*
Etching	*RIE (Bosch, Si)*
Proximity Gap	*102 µm*
Mask Aligner	*MA8/BA6*





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Conclusion

- Two simulation tools LayoutLab [GenISys] and Dr.LITHO [Fraunhofer IISB] were presented
- MO Exposure Optics allows the employment of simulation
- Simulations allow to find the most promising illumination and mask setting
- Experimental results and simulations correspond well

Outlook

- Resist model parameter require fitting experimental data with actual resist process
- More accurate physical description at the molecular level is needed to allow a rigorous and improved photoresist modeling

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