SPIE Optical Systems Design

SÜSS MicroOptics

Mask Aligner Process Enhancement by Spatial Filtering

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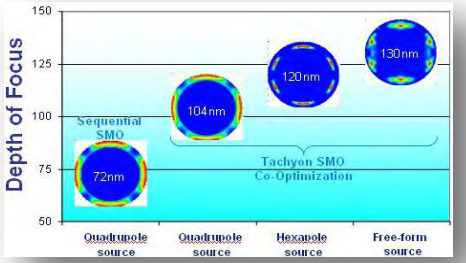
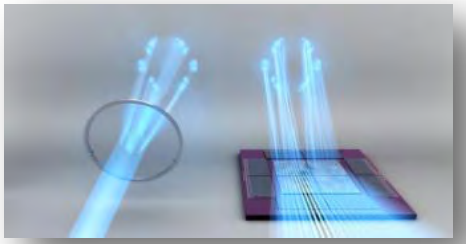
Micro-Optics in Front-End Lithography

Customized Illumination
Pupil Shaping (DOE)
Now: FlexRay™
programmable illumination
technology from ASML

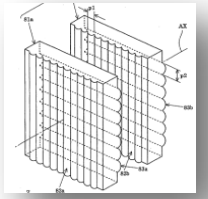
Excimer Laser (193nm)
Laser Beam Shaping
Laser Beam Homogenizing

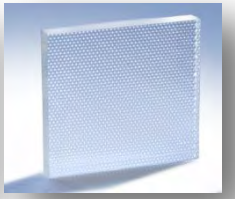


Customized Illumination



Diffractive Optical Elements (DOE)
MEMS Mirror Arrays (FlexRay™)





Microlens Köhler Homogenizer

Micro-Optics is Key Enabling Technology in Front-End Lithography

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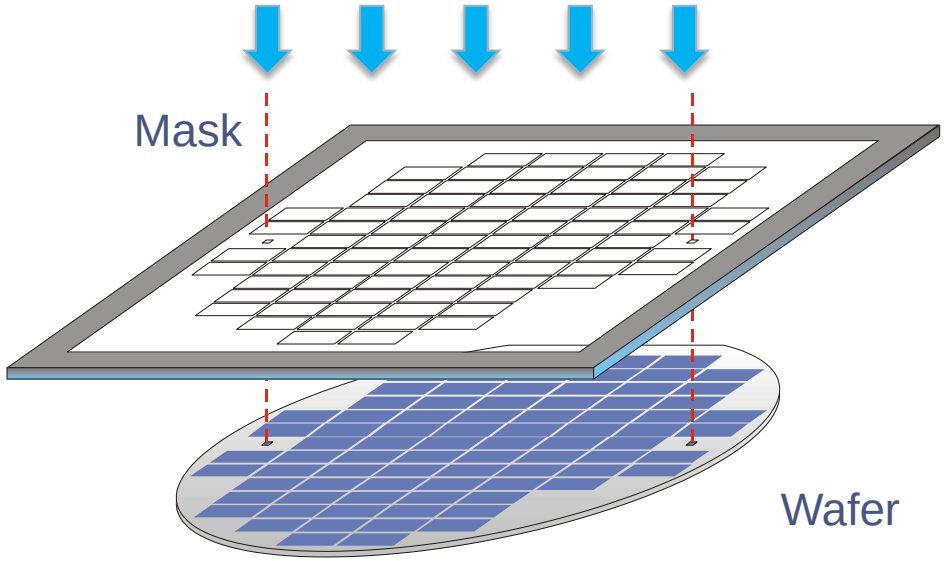
Back End Lithography: Mask Aligner

Mask Aligners Lithography is „Shadow Printing“

+ Mask illumination using UV light (High Pressure Mercury)
+ Resolution <=> proximity gap



Mode	Gap (µm)	Min. Resolution
Contact	→ 0	> λ
Proximity	10 < gap < 200	$> \frac{3}{2}\sqrt{\lambda \bullet \left(gap + \frac{ResistTh}{2}\right)}$

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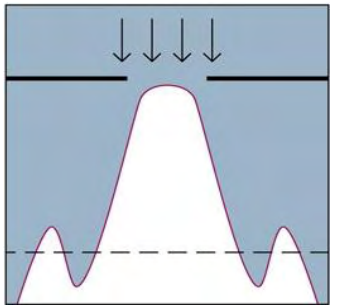
Mask Aligner Lithography

All about illumination!

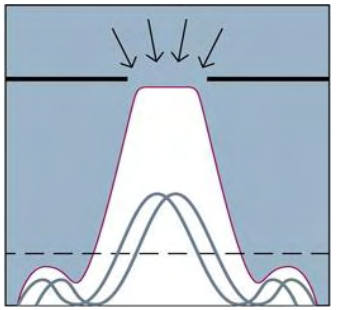
- Diffraction effects
- Partial coherence
- Side lobes
- Apodization

Parallel Light

Diffuse Light



Parallel Light



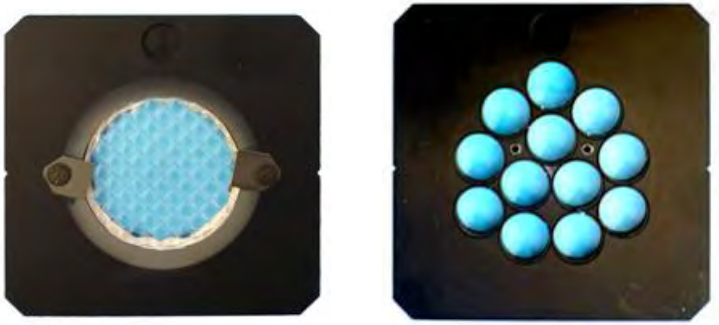
Apodization

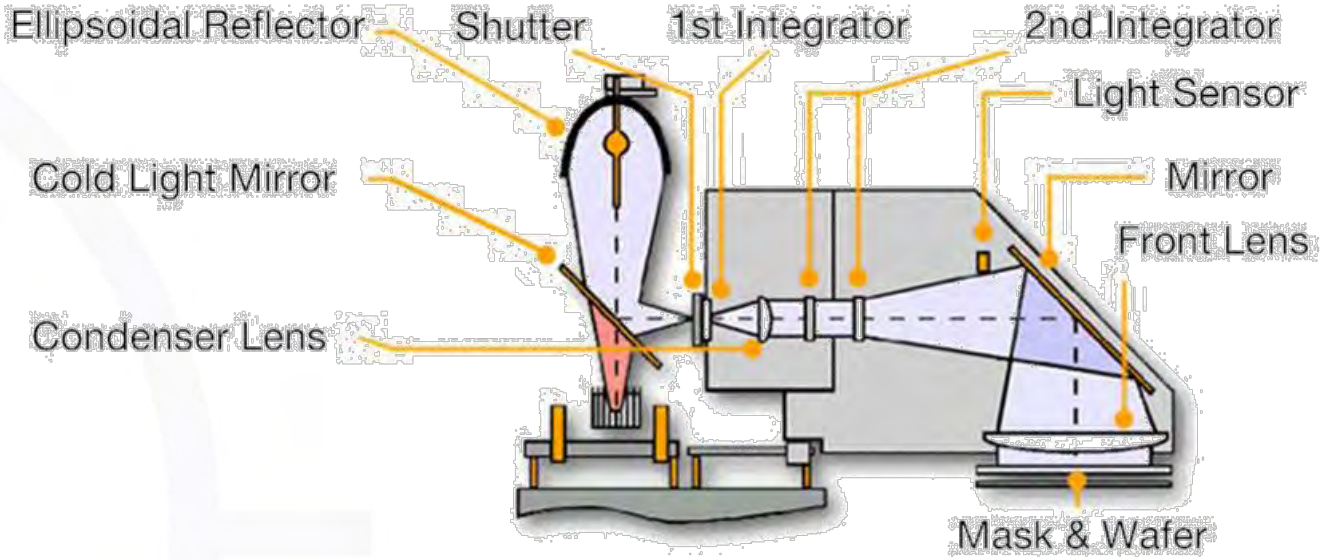
Customized Illumination?

Mask Aligner Illumination System

Requirements

+ Good Uniformity < 3% (5%)
+ Max. irradiance intensity
+ Long term stability
+ Diffraction reduction





Standard Mask Alginer Illumination System

Feature

+ Off-axis Illumination
+ fixed illumination angles

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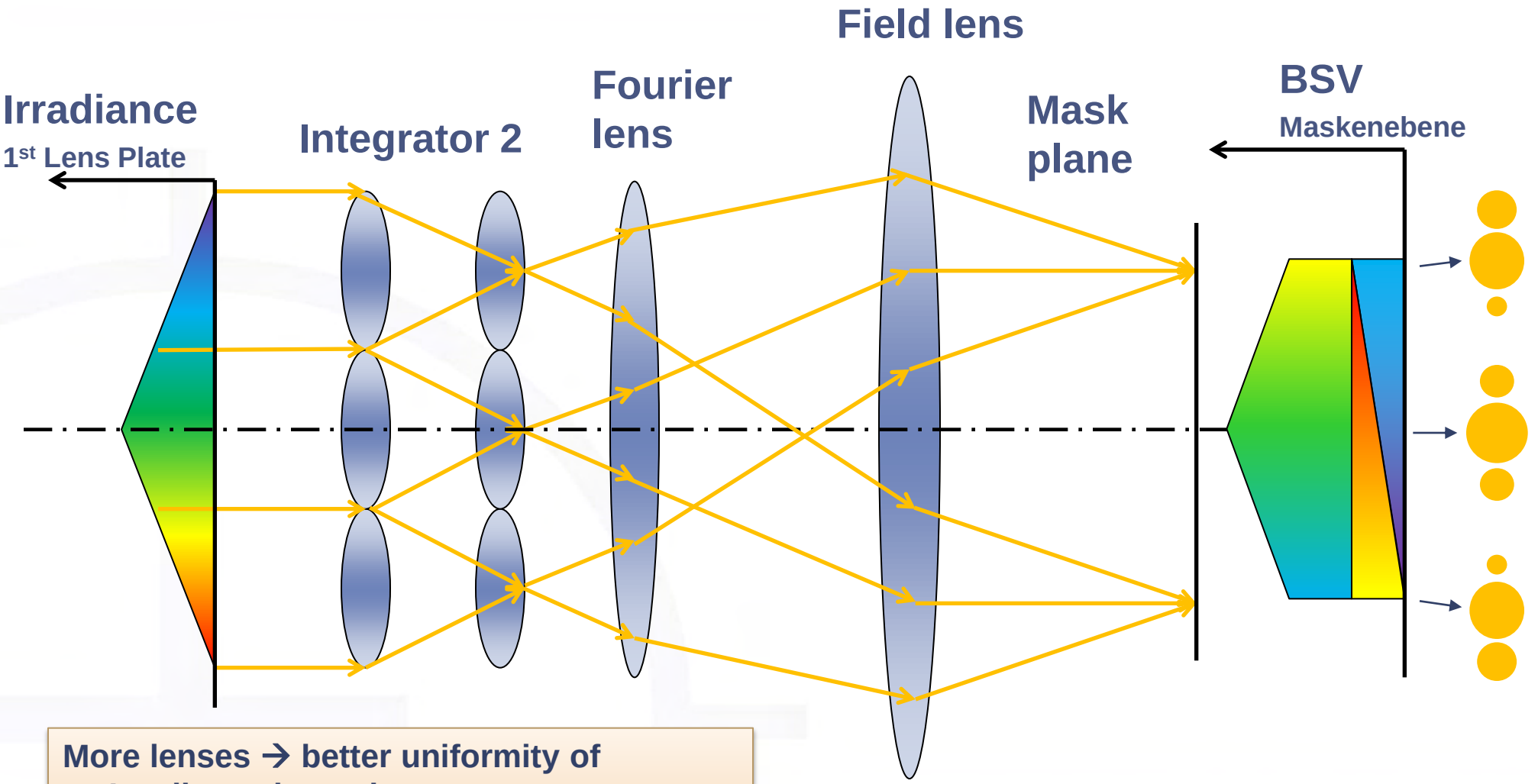
Mask Illumination



More lenses → better uniformity of
- Irradiance intensity
- Angular spectrum

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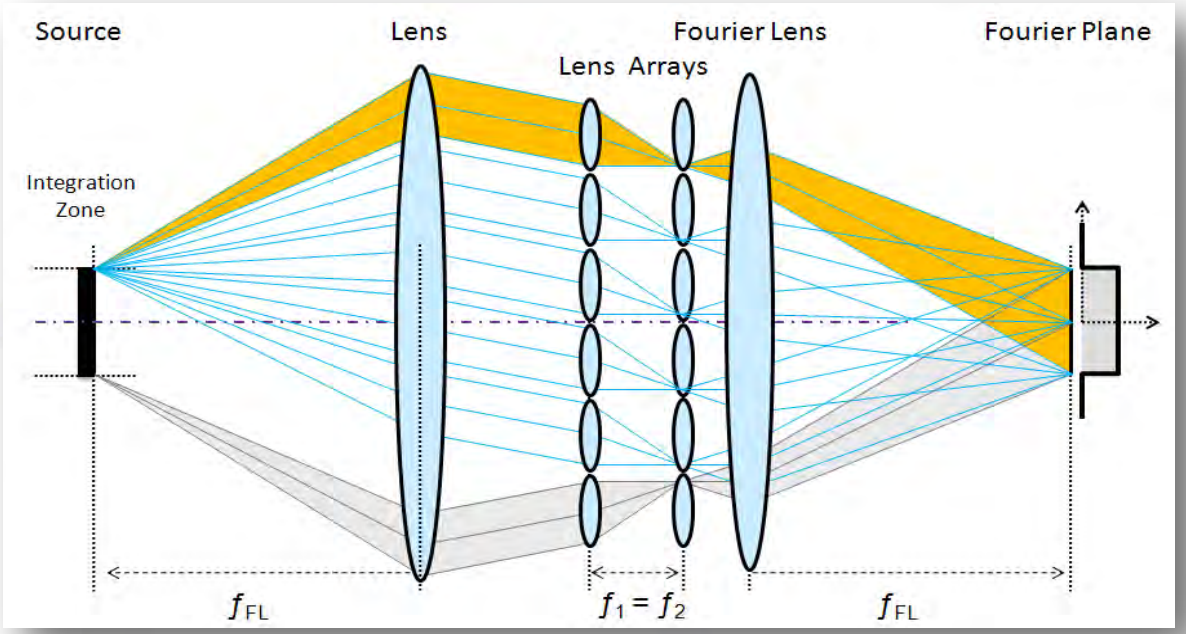
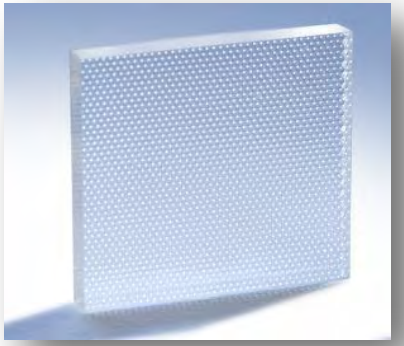
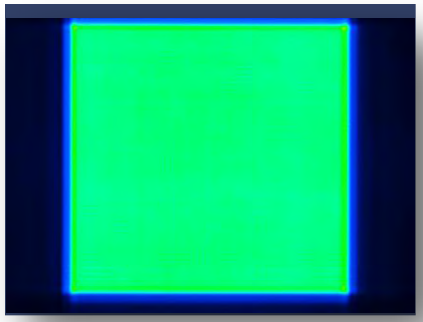
Microlens Optical Integrator (Köhler)





Microlens Array



Flat-Top Intensity Profile

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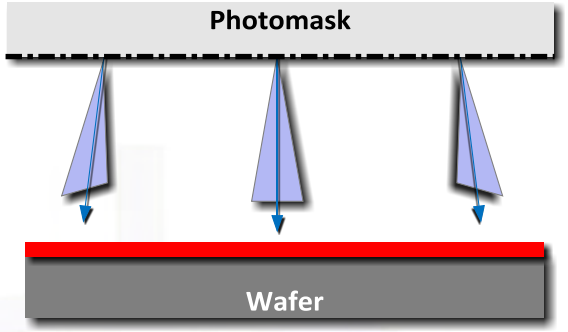
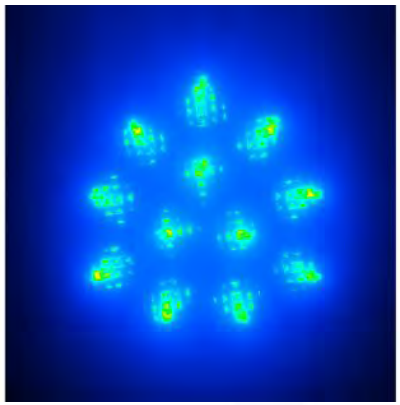
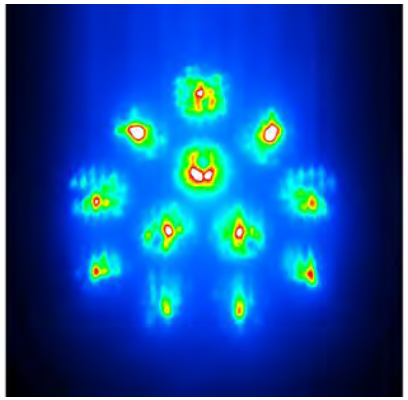
Microlens Arrays → Stability / Telecentricity

Standard Mask Illumination



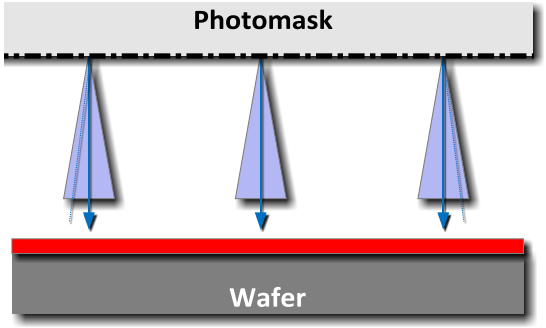


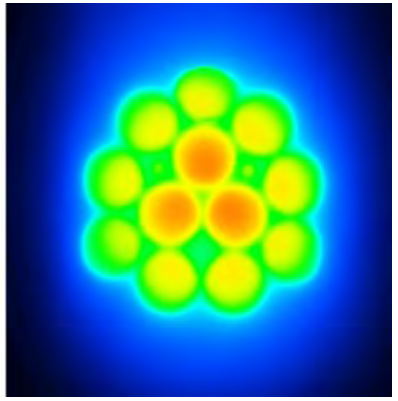


centre rim

Anglular spectrum at the mask plane

Telecentric Mask Illumination





Uniform angular spectrum over the entire mask plane

Features

+ Stable Light Source
+ Excellent Uniformity
+ Telecentric Illumination

Benefits

+ Reduced Maintenance
+ Improved CD Uniformity
+ Larger Process Window
+ Higher Yield

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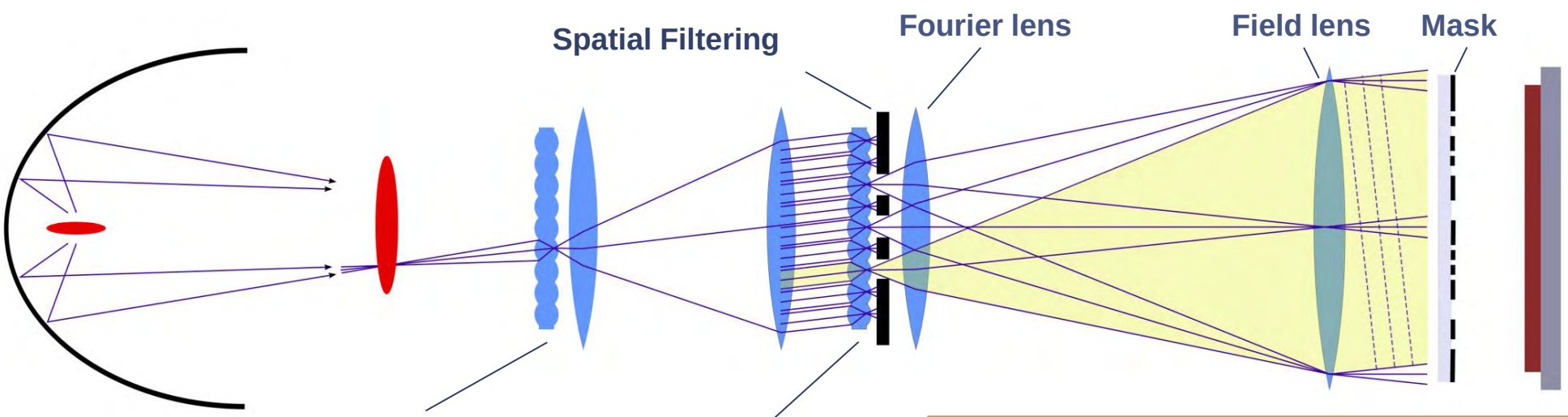
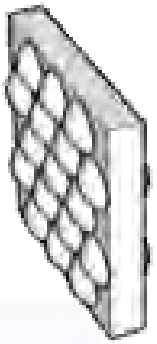
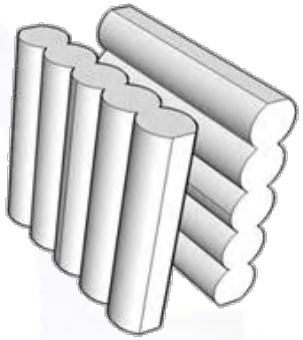
Funktion IFP's





Monolithic: Doulbe-sided round lenses



Two crossed lens plates: double sided cylindric lenses

Variabel Spacial filtering Concepts

- Axicon telescope
- Zoom lenses
- liquid crystal displays (LCD),
- micro-mirror arrays (DLP)
- variable membranes (MEMS, MOEMS)
- spatial light modulators (SLM)
- variable diaphragms

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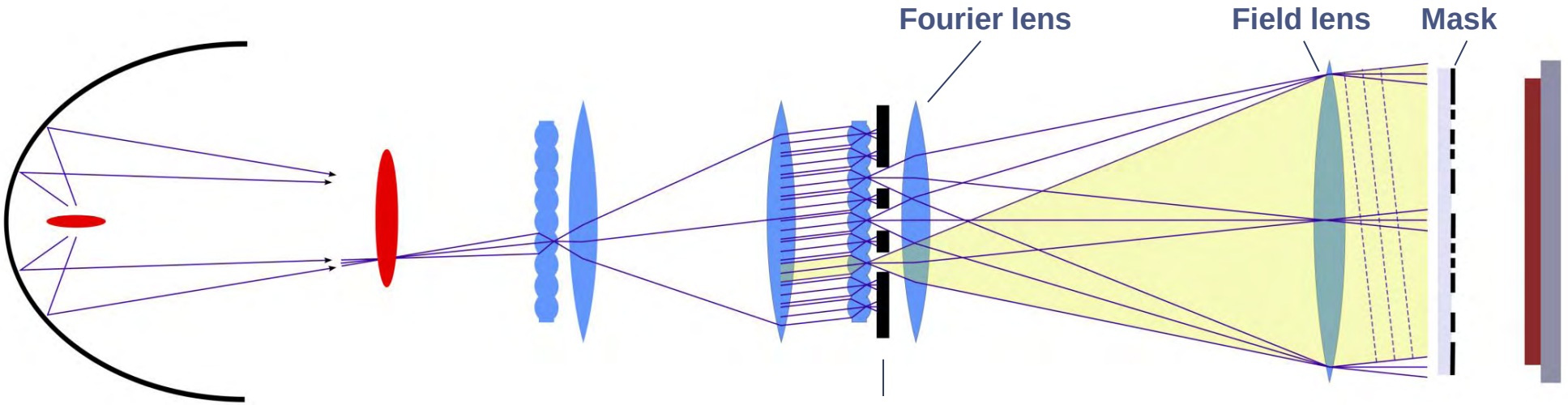
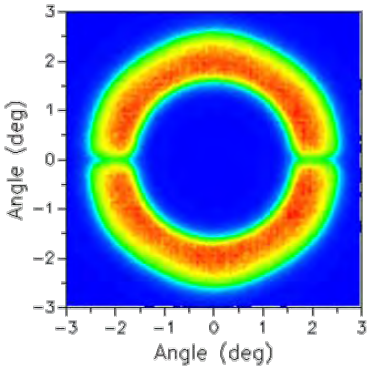
Illumination Filter Plates (IFP's)



IFP's

- Free form illumination
- Quick and easy changeover
- Self-made customized illumination
- Long term stability
- Downward compatible (no software moddifications)

Angular spectrum at the mask plane



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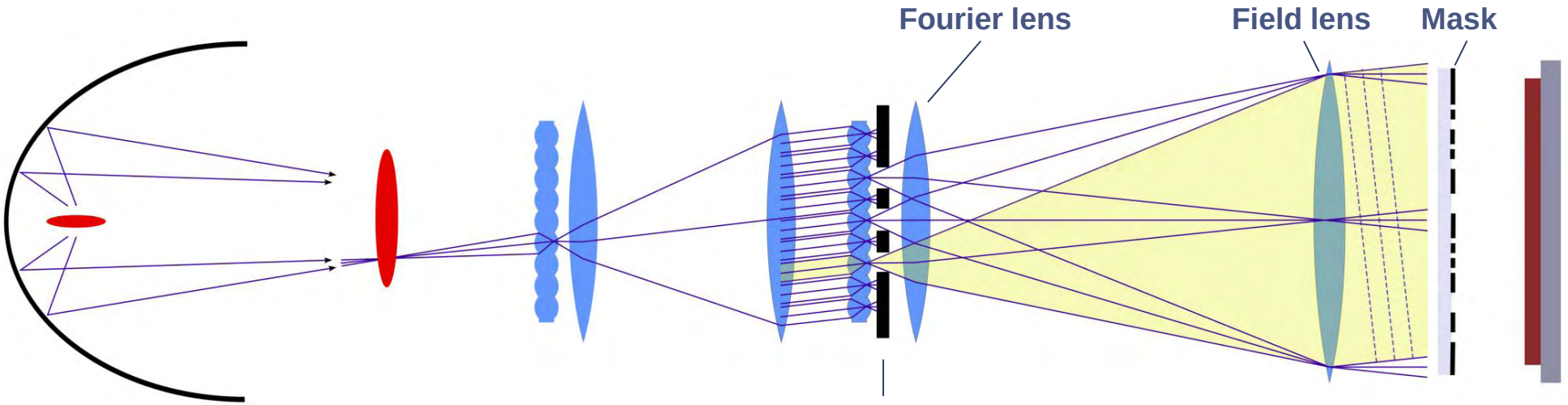
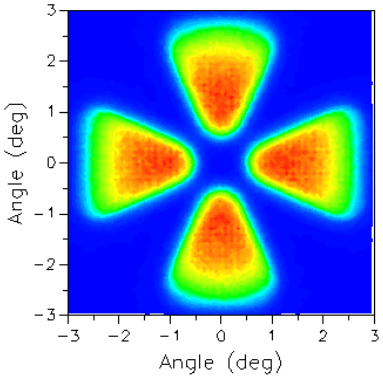
Illumination Filter Plates (IFP's)



IFP's

- Free form illumination
- Quick and easy changeover
- Self-made customized illumination
- Long term stability
- Downward compatible (no software moddifications)

Angular spektrum at the mask plane



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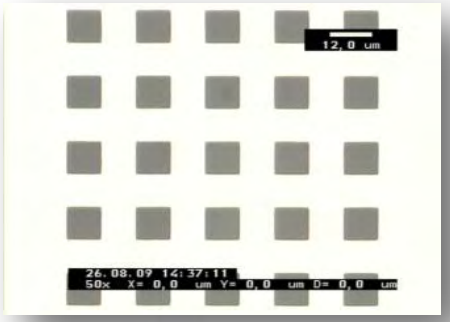
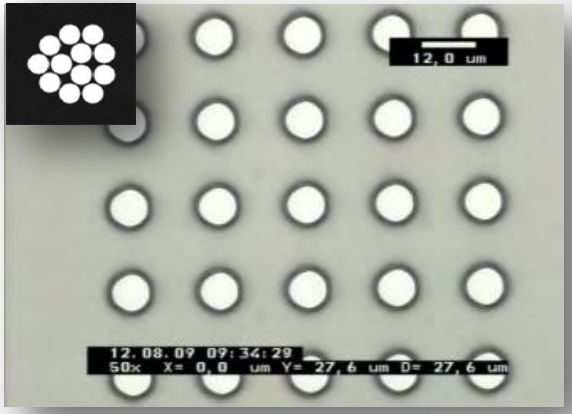
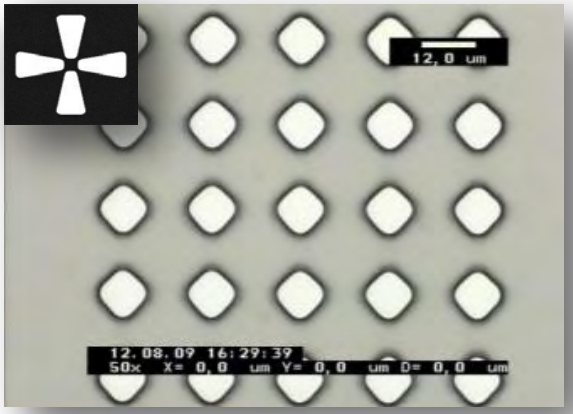
Customized Illumination - Optimize Pattern



Photomask Pattern
Square 10x10µm²





Prints in Photoresist, 1.2µm thick resist (AZ 4110), 100µm Proximity Gap, SUSS MA8

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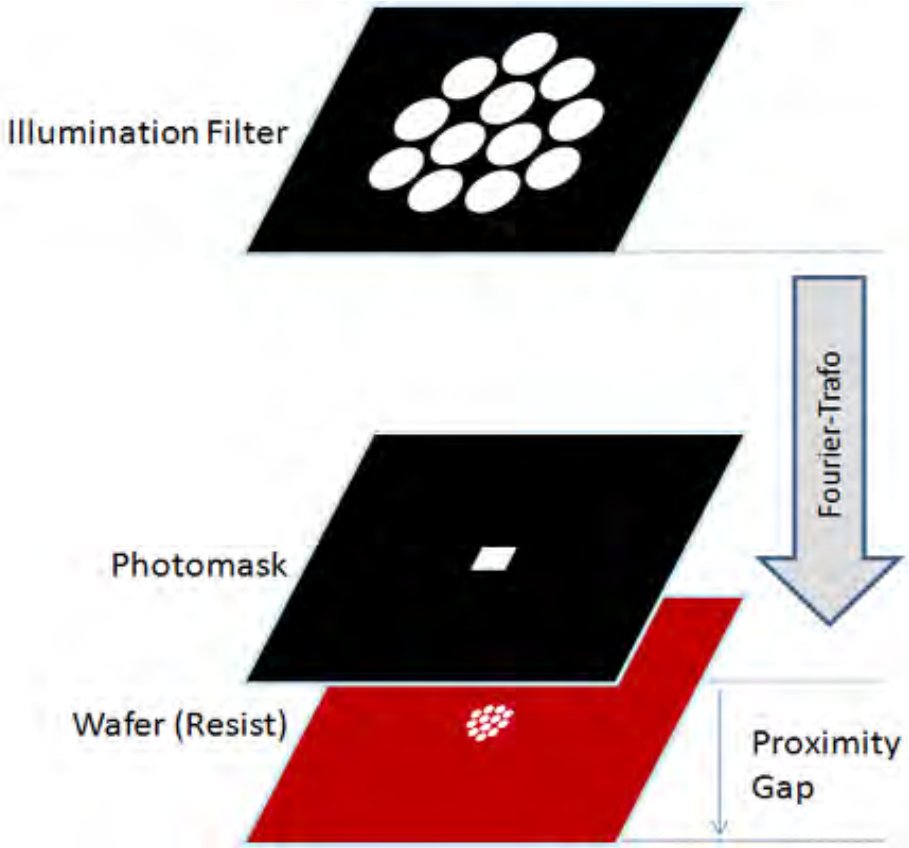
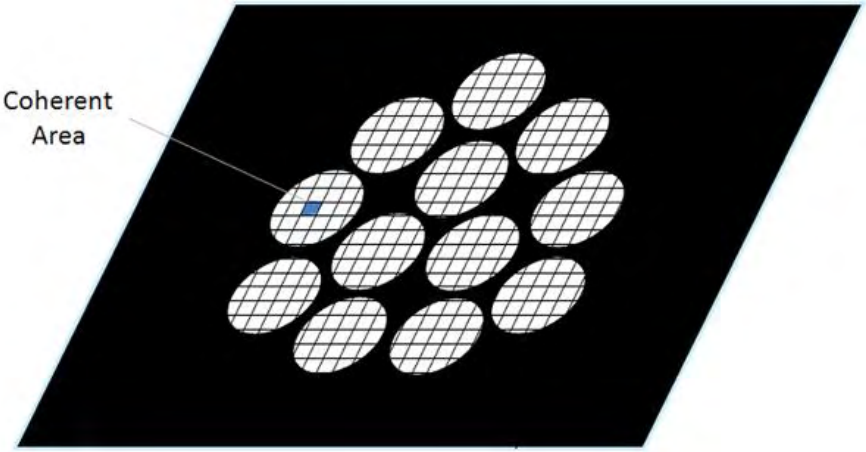
Image formation





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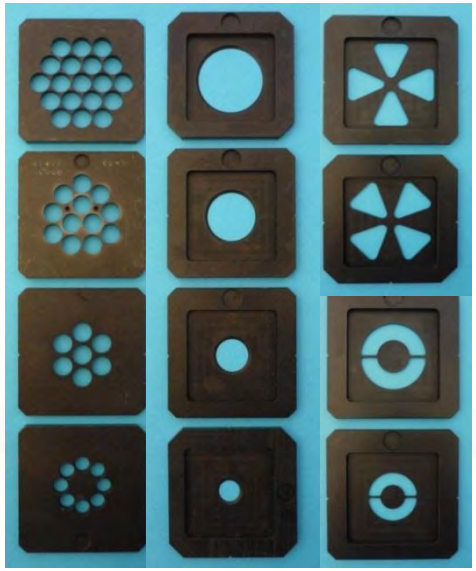
IFPs: Trail or calculation?



Evaluation of the perfect in the laboratory can consume a lot of resources.

Simulation needed for the preselection of illumination settings. ↔ A stable, telecentric illumination is needed to get reliable simulation results

Challenges:

+ Calculation time for big areas
+ Analyses of resist parameters
+ Stability of resist parameters

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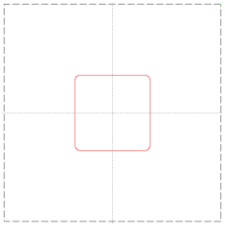
Lithography Simulation: LayoutLab

Input

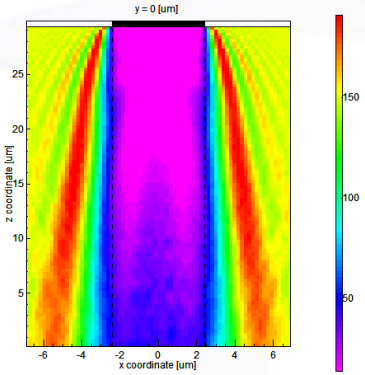
Mask Design
Amplitude
Phase

Mask design

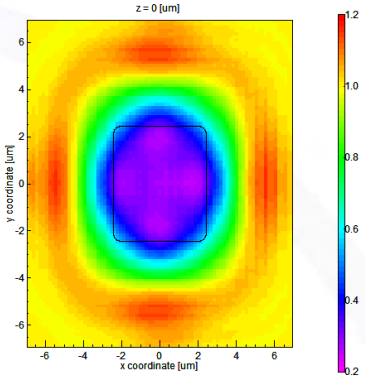


Stack configuration
Substrate
Resist Parameter
Topography

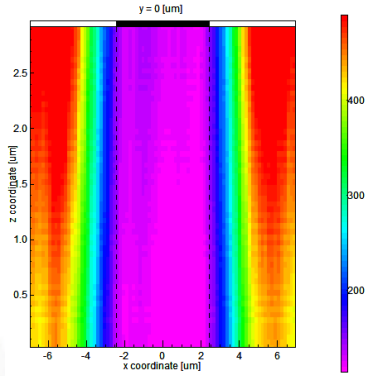
Exposure Configuration
Wavelength spectrum
Gap
Angular spectrum



Cross section of the irradiance distribution within the gap



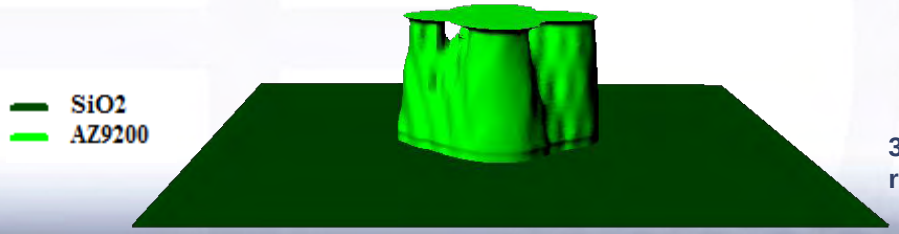
Aerial image on top of the resist



Cross section of irradiance in resist

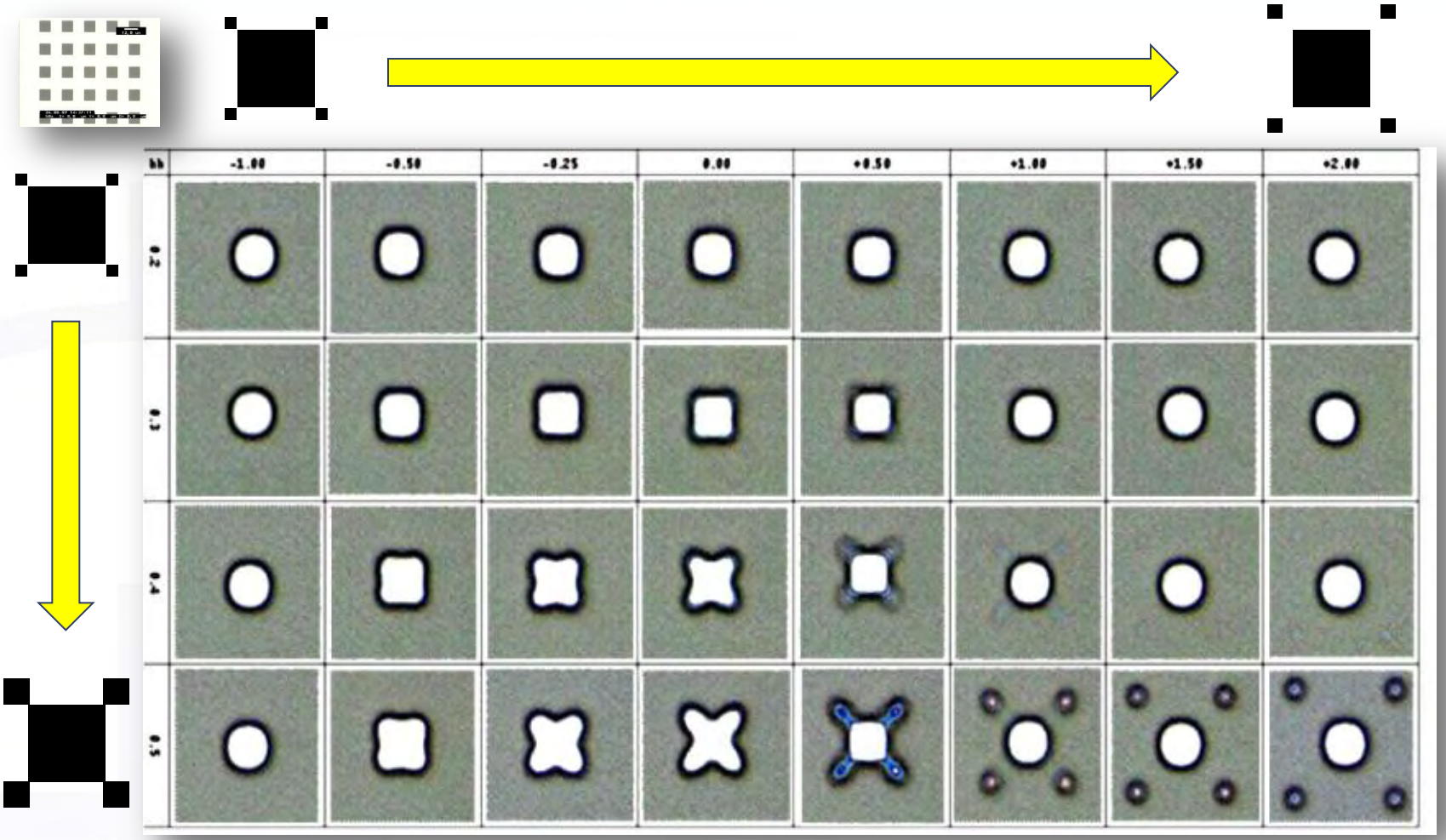
Intermediate Data
Aerial Image
3D-Energy Spread
Resist Image

Analyses Values
Process Window
Sidewall shape
CD vs. Gap
CD vs. Dose
Normalized Image Log Slope (N.I.L.S.)



3D- Image of the resulting resist cylinder

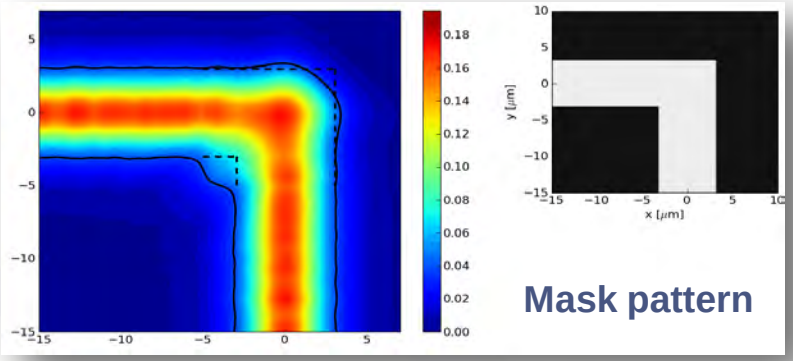
Source-Mask Optimization: Mask Optimization

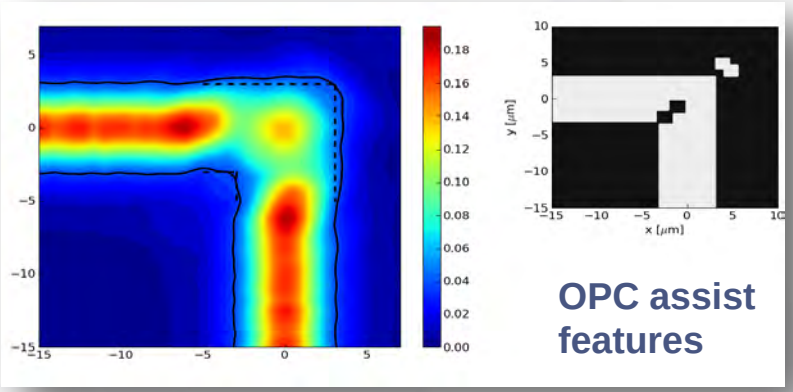


Square10µm x 10µm, Proximity Gap 50µm, Photoresist AZ4110, 1.2um thick

Optical Proximity Correction (OPC)

Aerial image (simulation)





Ref: Kristian Motzek, FhG-IISB, SUSS Report Sept 2010

- 6µm line
- Aerial image
- 40µmProximity gap
- OPC assist features

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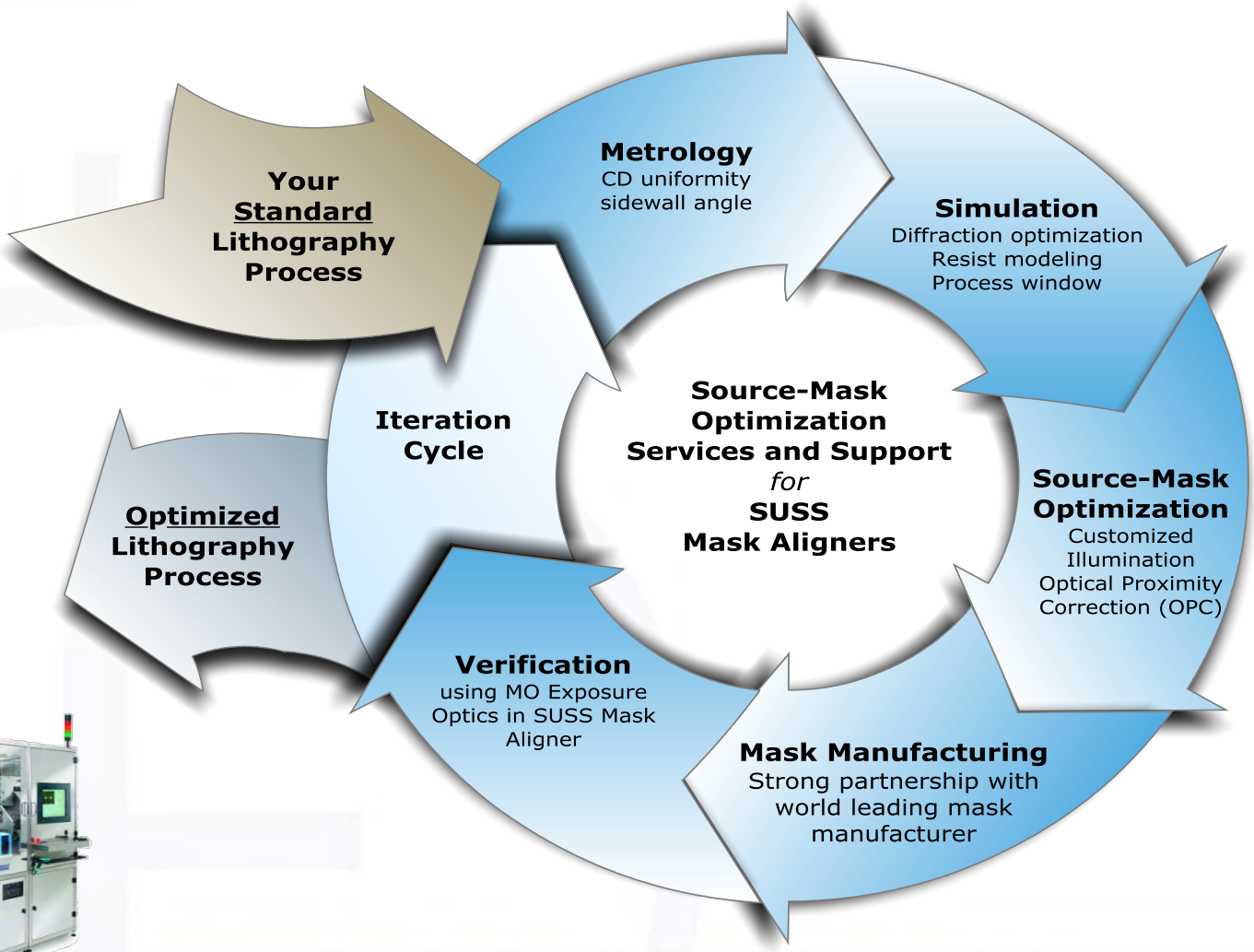
Source-Mask Optimization Service



TOPPAN
TOPPAN PHOTOMASKS, INC.

Fraunhofer
IISB

GenISys

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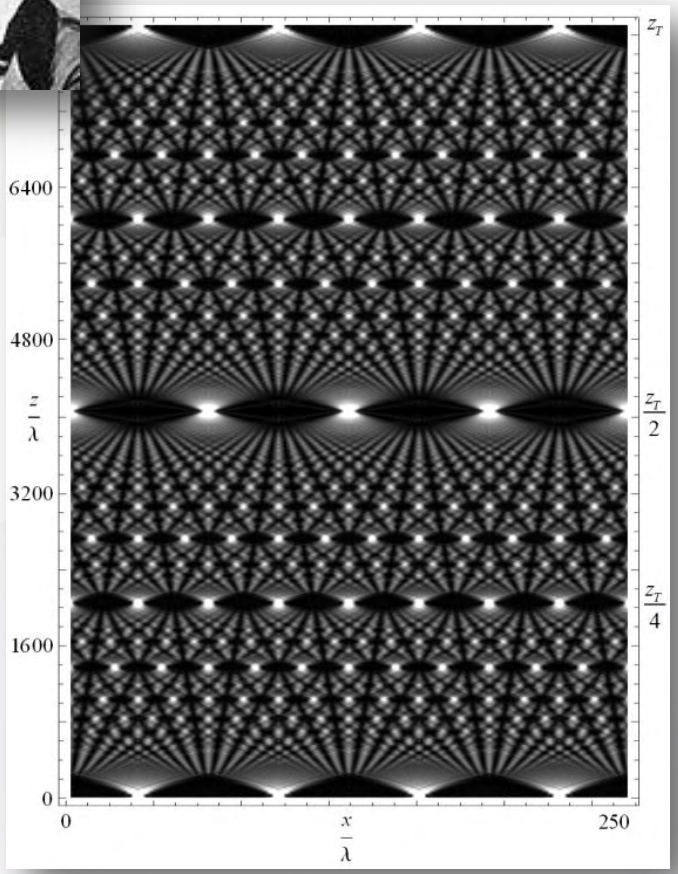
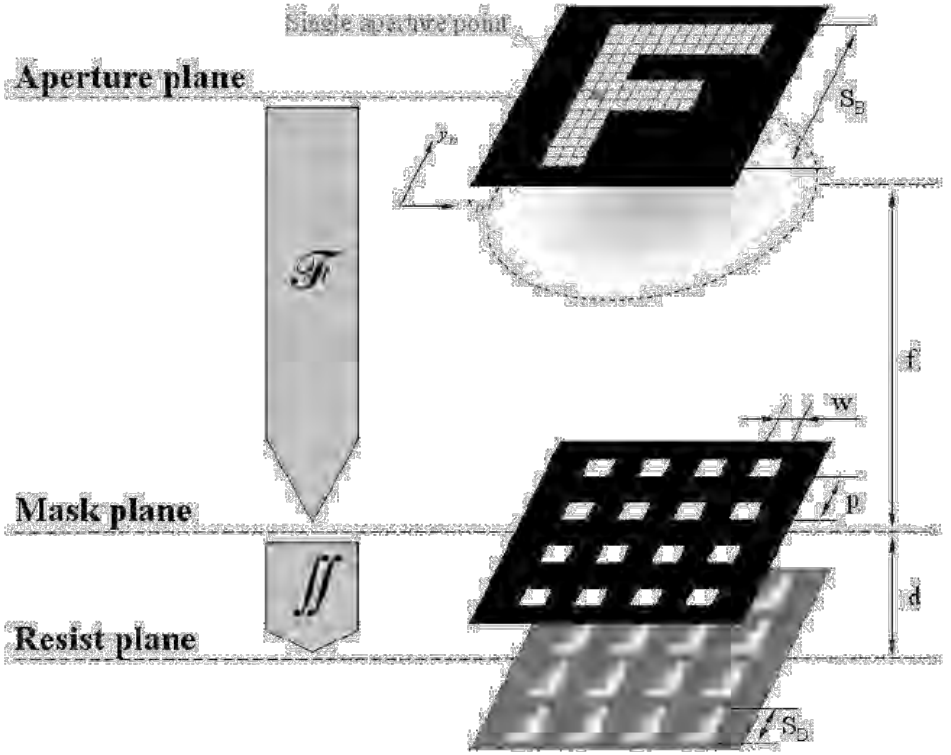
Application Example: Tablot effect



Talbot carpet

(Source: Ben Goodman, Wikipedia)



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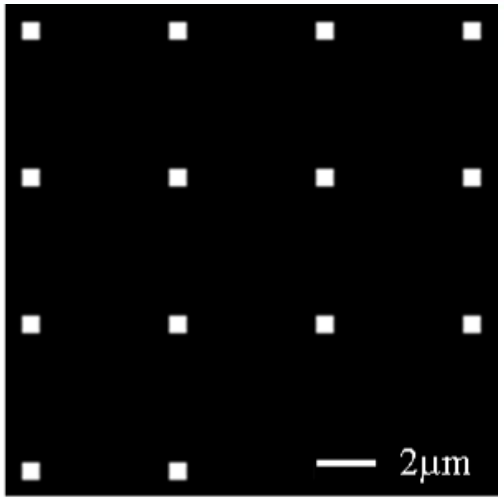
Application Example: Talbot Effect

Features

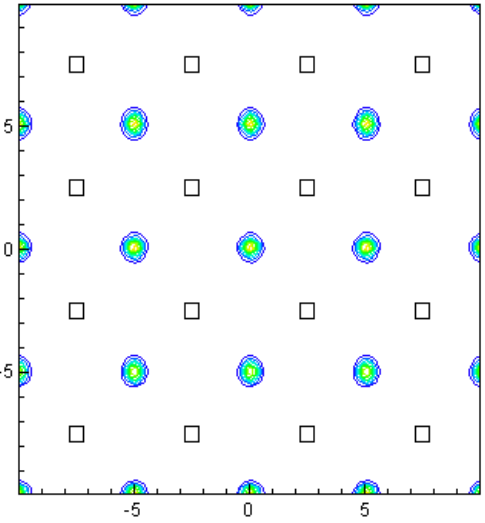
- For periodic structures
- Information transfer for big gaps and small resolution

Simple pattern change with pixelated Illumination Filter Plate (IFP)

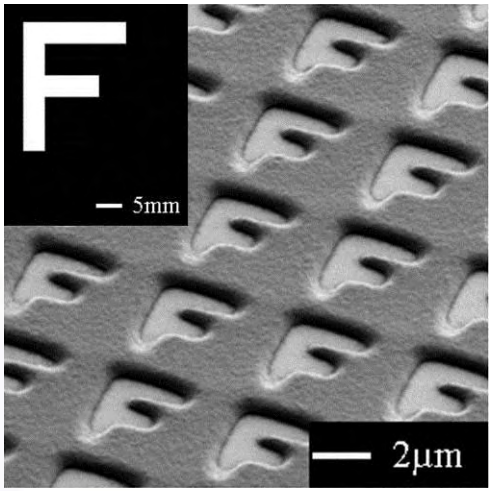
Mask



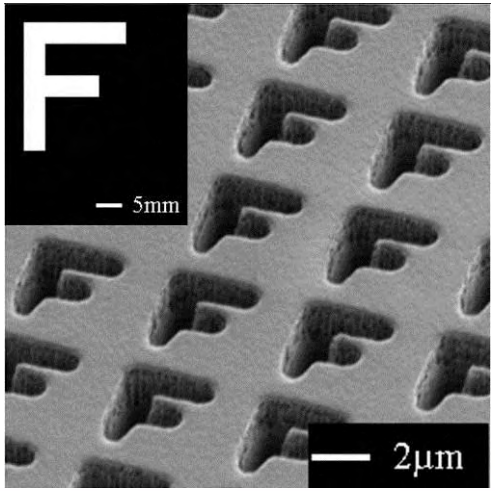
Simulation of self imaging (pinhole IFP)



SEM Reist



SEM after RIE



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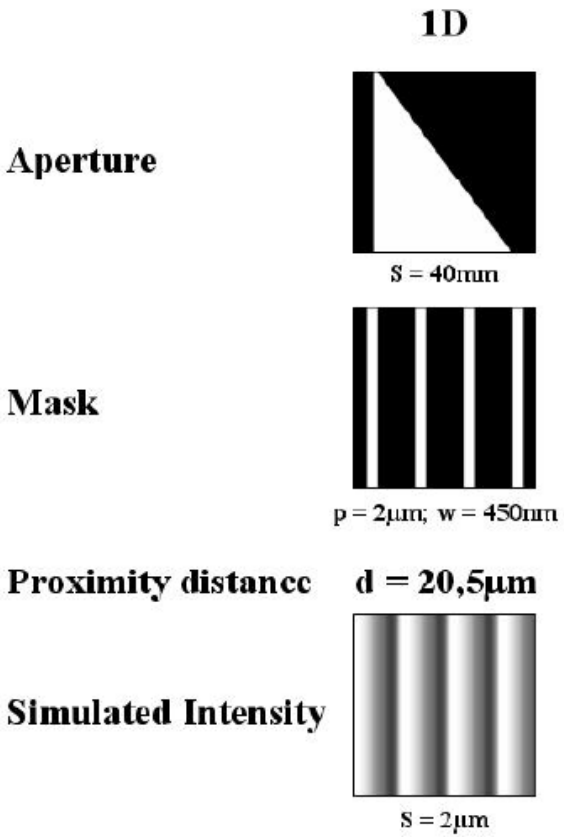
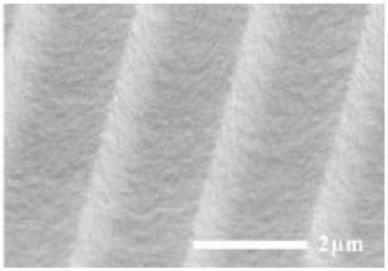
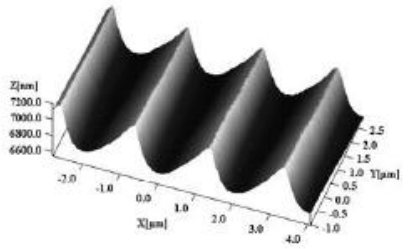
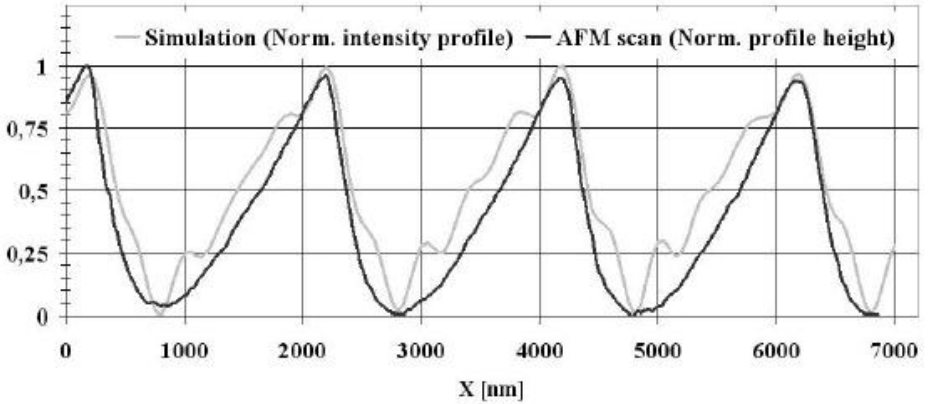
Grey-Level Structures Printed on Full Wafer in MA6









SE micrograph and atomic force scan of a realized blazed grating structure in photo resist AZ 4562. The normalized profile scan of the resist structure (height: 580nm) and the normalized intensity profile are shown together

T. Harzendorf, L. Stuerzebecher, U. Vogler, U.D. Zeitner, R. Voelkel, “Half-tone proximity lithography”, Photonics Europe, Conf. on Micro-optics Fabrication Technologies, 7716-34, April 12-16, 2010

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Summary / Outlook

Summary

+ Increase of uniformity, telecentricity → higher yield
+ Enables lithography simulation
+ Enables Customized Illumination, Source-Mask-Optimization,

Outlook

+ Create further optimization rules

SÜSS MicroOptics

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Thank you for your attention!!

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Our Solutions Set Standards

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