Sub-Wavelength Holographic Lithography (SWHL) for Fabrication IC & MEMS Topologies on Non-Planar Surfaces by Single Exposure

NANOTECH SWHL

39th MNE, 16-19.09.2013, London

EXECUTIVE SUMMARY

- **SWHL uses newly developed mathematical apparatus that made possible digital synthesis of SWHM for aerial images of IC & MEMS topologies with CD's ≈ $\lambda/2$.**

- **SWHL is suitable for all range of technologies nodes covered by DUVL and even for smaller CD's using coherent light sources with a shorter wavelength**

- **SWHM combines main functions of a mask and projection lens, which allows to have radically simple optical scheme and significantly reduce the requirements to the quality of optical elements.**

- **SWHL allows during of SWHM 's manufacturing avoid of technologically complex operations using instead of PS and OPC their virtual counterparts HoloPS and HoloOPC.**

- **Aerial images of IC & MEMS topologies are not sensitive to SWHM local defects. Because of that SWHM has an unlimited (almost) lifetime and does not need any regular control and maintenance.**

- **SWHL is a new, alternative low cost approach to lithography and cut your costs for:**
  Masks - up to factor of 10
  Steppers - up to factor of 4.

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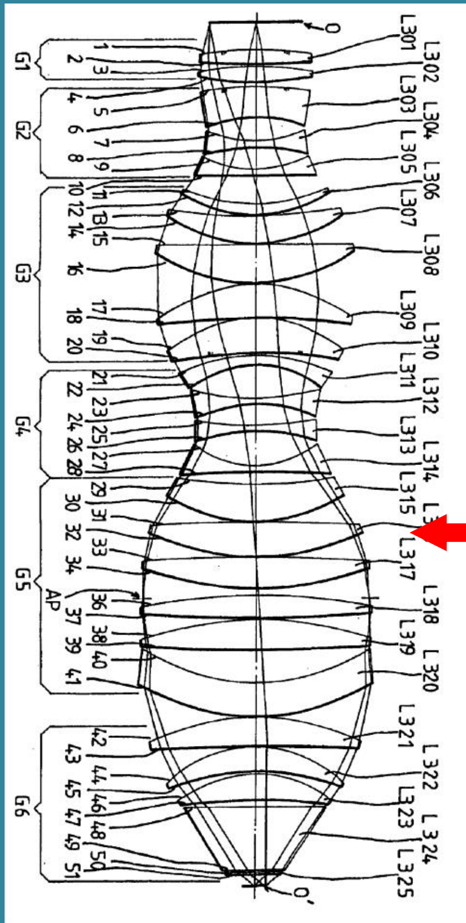
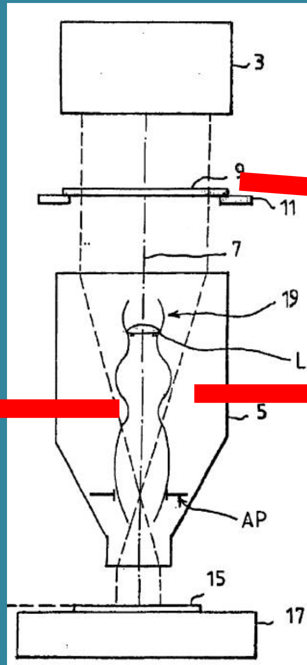
SIMPLE AND MORE EFFICIENT OPTICAL SCHEME

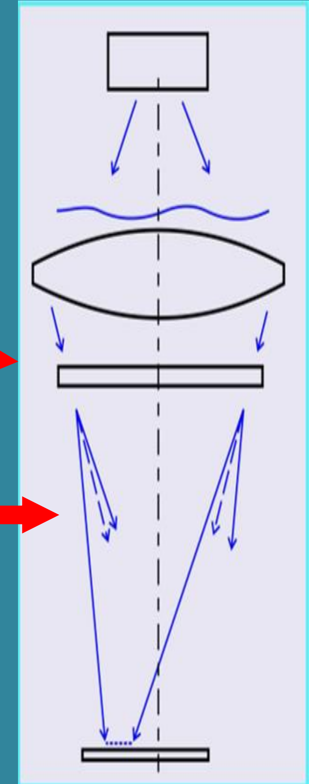




Exposure stage at traditional projective lithography
Carl Zeiss Patent, US6788387, 2004

Traditional mask is replaced with a hologram (Sub-wavelength Holographic Mask - SWHM)

No Projection Lens used



Exposure stage at sub-wavelength holographic lithography (SWHL)

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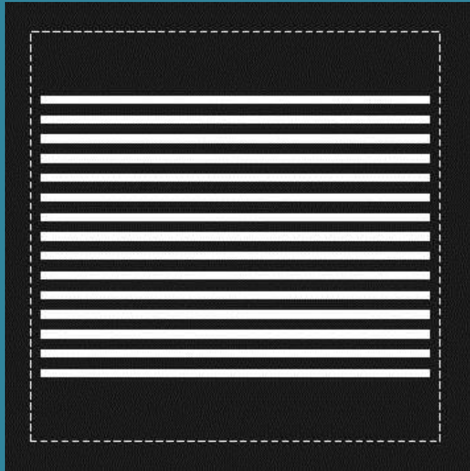
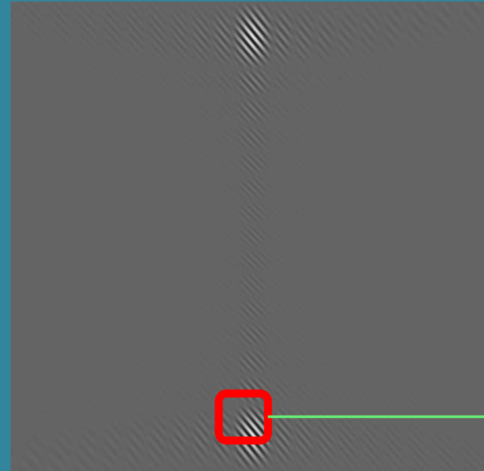
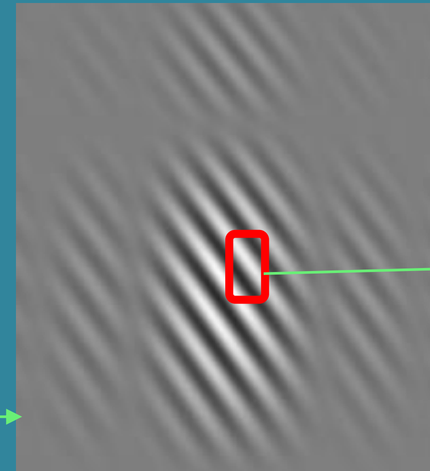
SWHM CONSISTS OF SIMPLE UNIFORM ELEMENTS



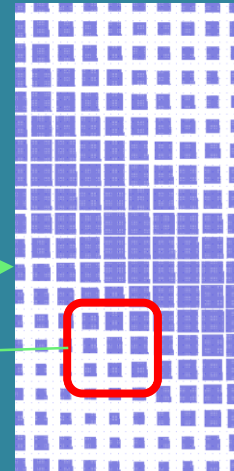
Desired topology in Si-wafer



Corresponding SWHM

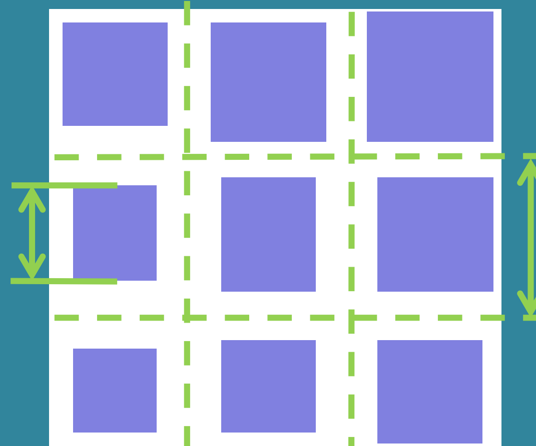


Small part of SWHM



Small part of band

The linear size of transmission areas varies from 1,7λ to the full size of cell.



9 cells with 9 transmission areas (TA)

The linear size of SWHM cell is constant and defined beforehand. It falls within the range $1{,}7 - 2{,}5\lambda$.

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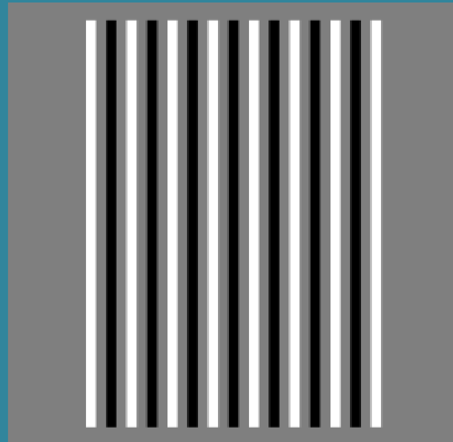
SWHM' LOCAL DEFECTS DO NOT AFFECT AERIAL IMAGE QUALITY

(computer simulation)

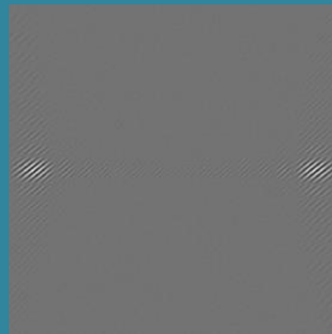
Dust area (in %) on the SWHM (each particle 1 μ^2)

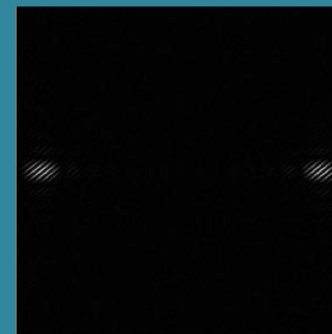
0% **45%** **98%**



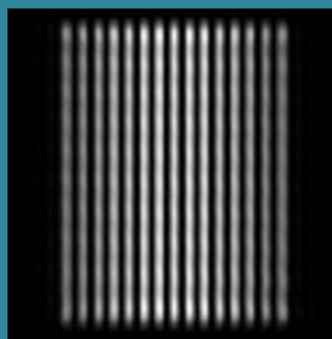
Initial topology

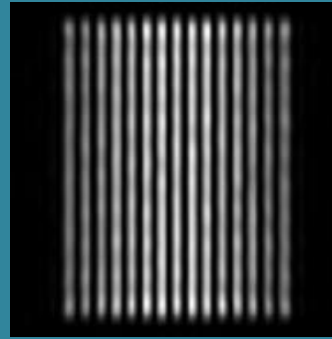
Black & white lines indicates strong Phase-Shift

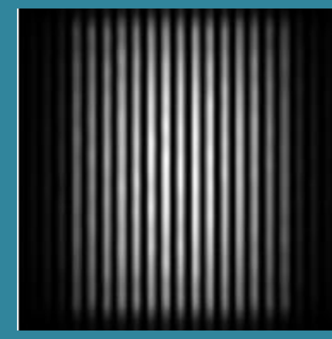




SWHM







Aerial images

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CONVENTIONAL OPC IS REPLACED WITH VIRTUAL HoloOPC

Conventional calculated & technologically produced OPC

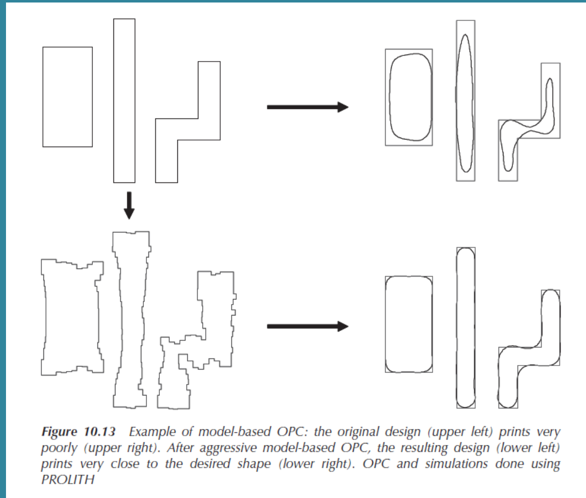
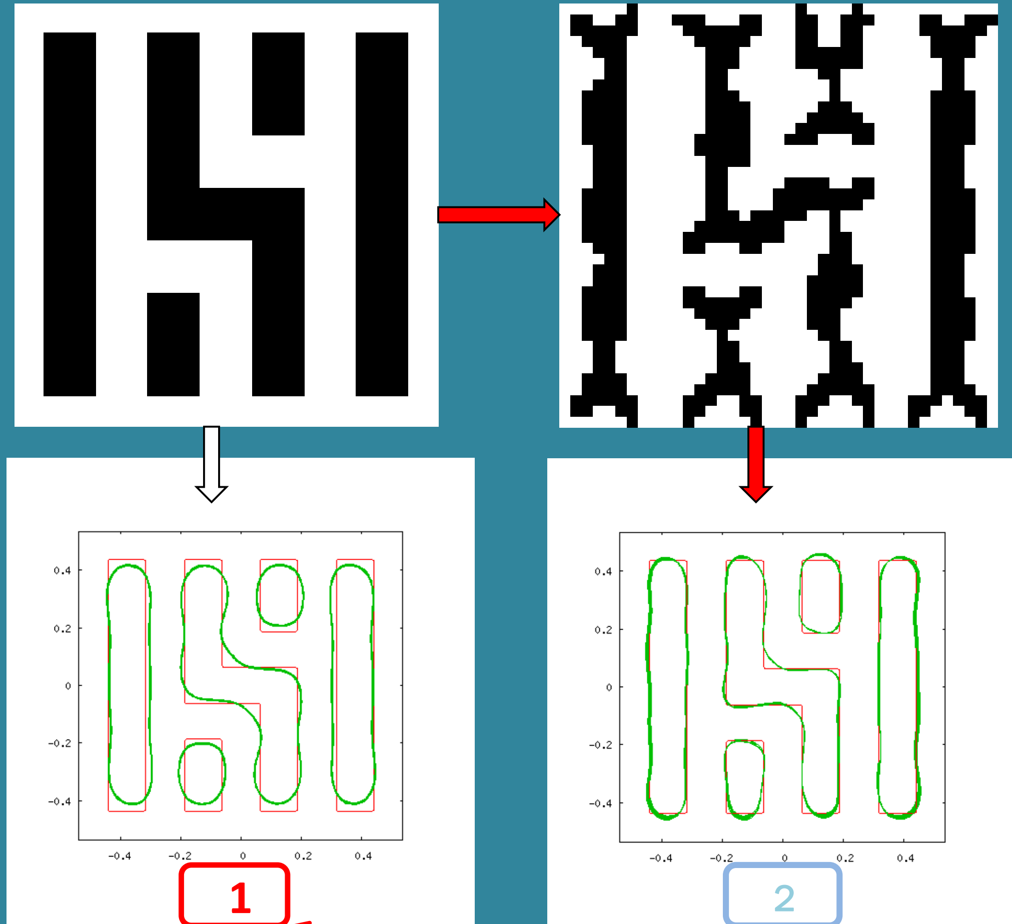


Figure 10.13 Example of model-based OPC: the original design (upper left) prints very poorly (upper right). After aggressive model-based OPC, the resulting design (lower left) prints very close to the desired shape (lower right). OPC and simulations done using PROLITH

Chris Mack,
«*Fundamental Principles of Optical Lithography:The Science of Microfabrication*»,
2009 John Wiley & Sons

HoloOPC is realized by computation and not produced technologically



Contours of aerial image **before (1)** and **after (2) HoloOPC**

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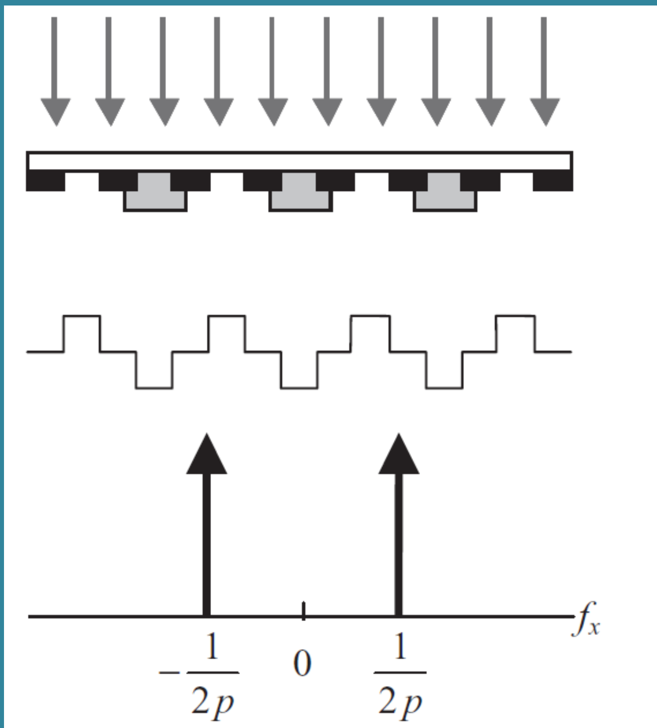
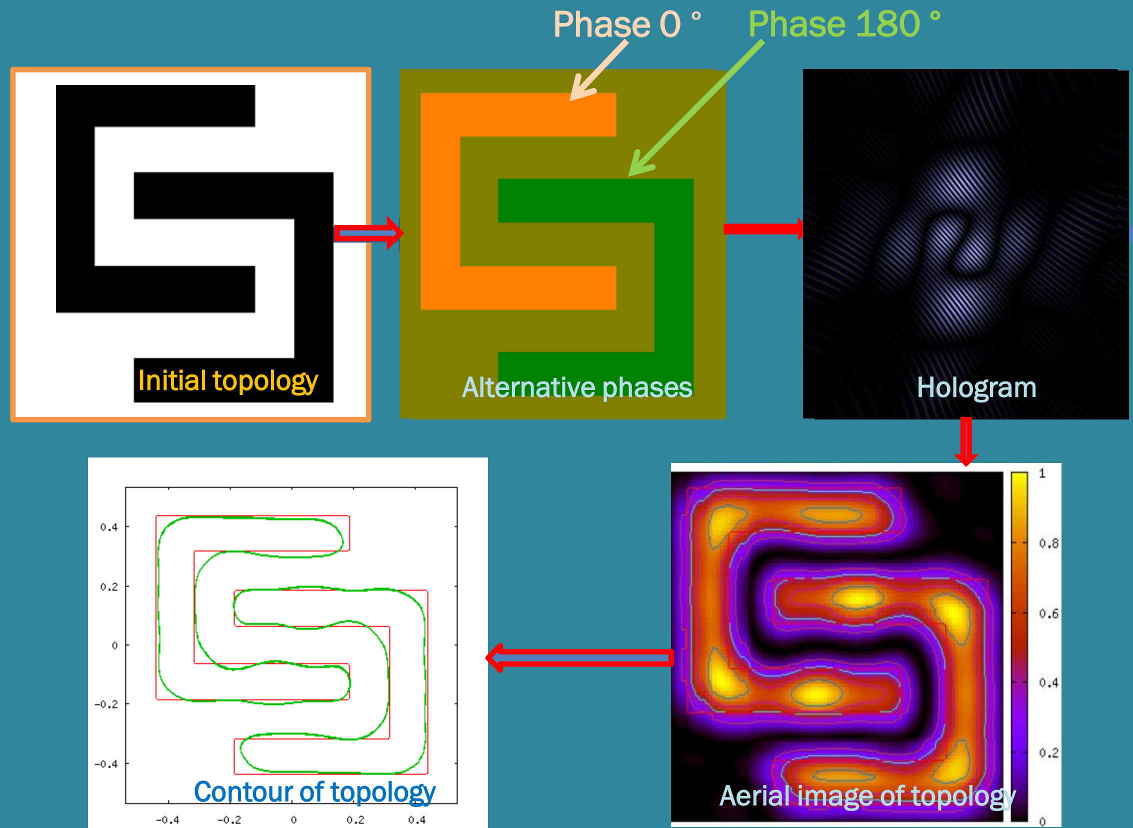
CONVENTIONAL ALTERNATIVE PhasE-Shift is REPLACED with ALTERNATIVE Holo-Phase SHIFT

Conventional alternative phase-shift is realized as a technological operation



Chris Mack,
«***Fundamental Principles of Optical Lithography:The Science of Microfabrication***»,
2009 John Wiley & Sons

Alternative holo phase-shift is realized by computation and does not need any technological operations



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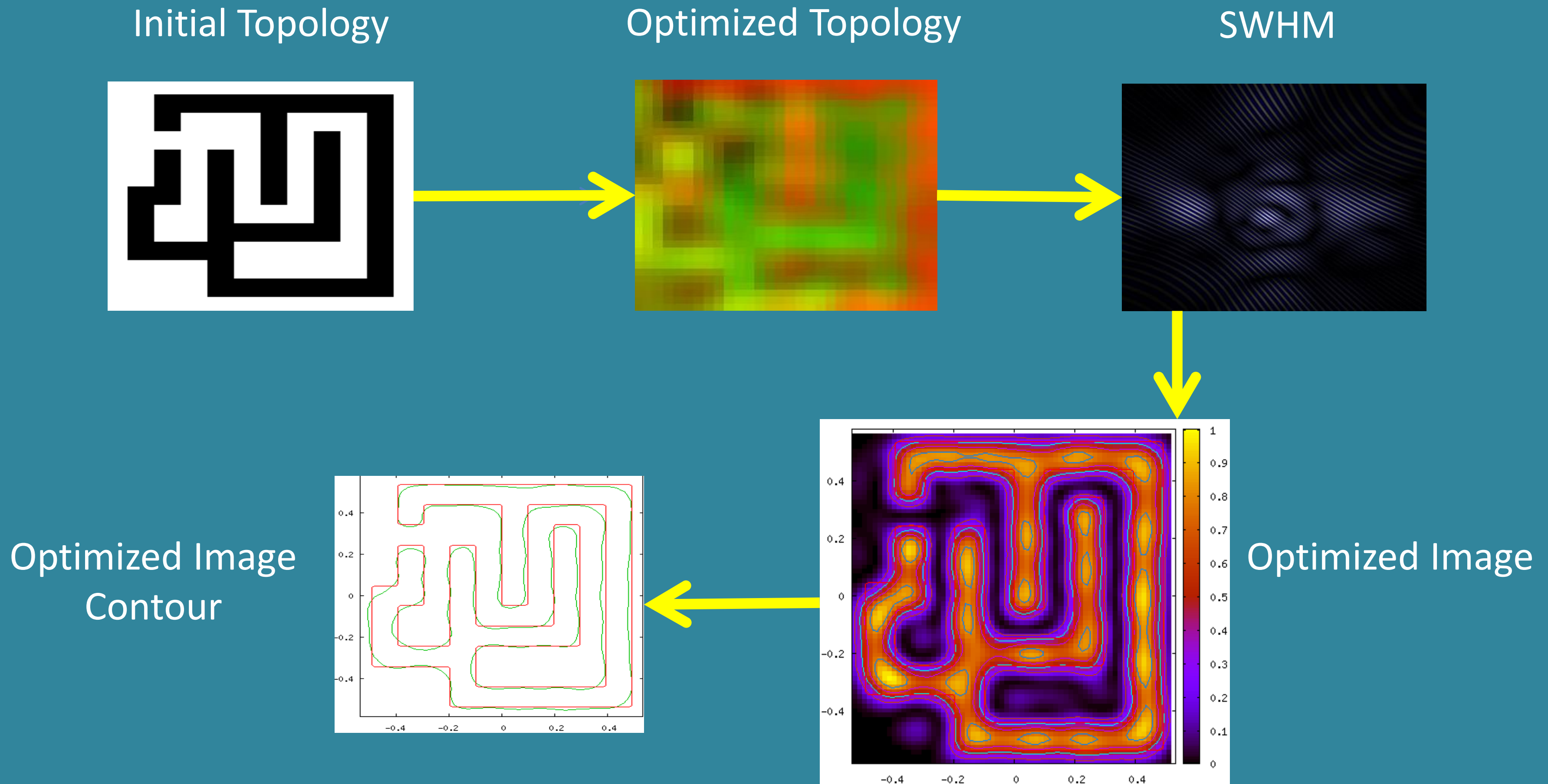
HoloOptimization

We can continuously change local values of phase & amplitude of radiation used for creation of aerial image on photo resist. With HoloOptimization' method we also can obtain topologies that are not possible to get with projection lithography.



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THREE PROBLEMS OF MEMS LITHOGRAPHY PRODUCING

1. *Micro-relief formation* (direct electron beam etching, grey scale lithography, laser scanning with alignment system modifications)

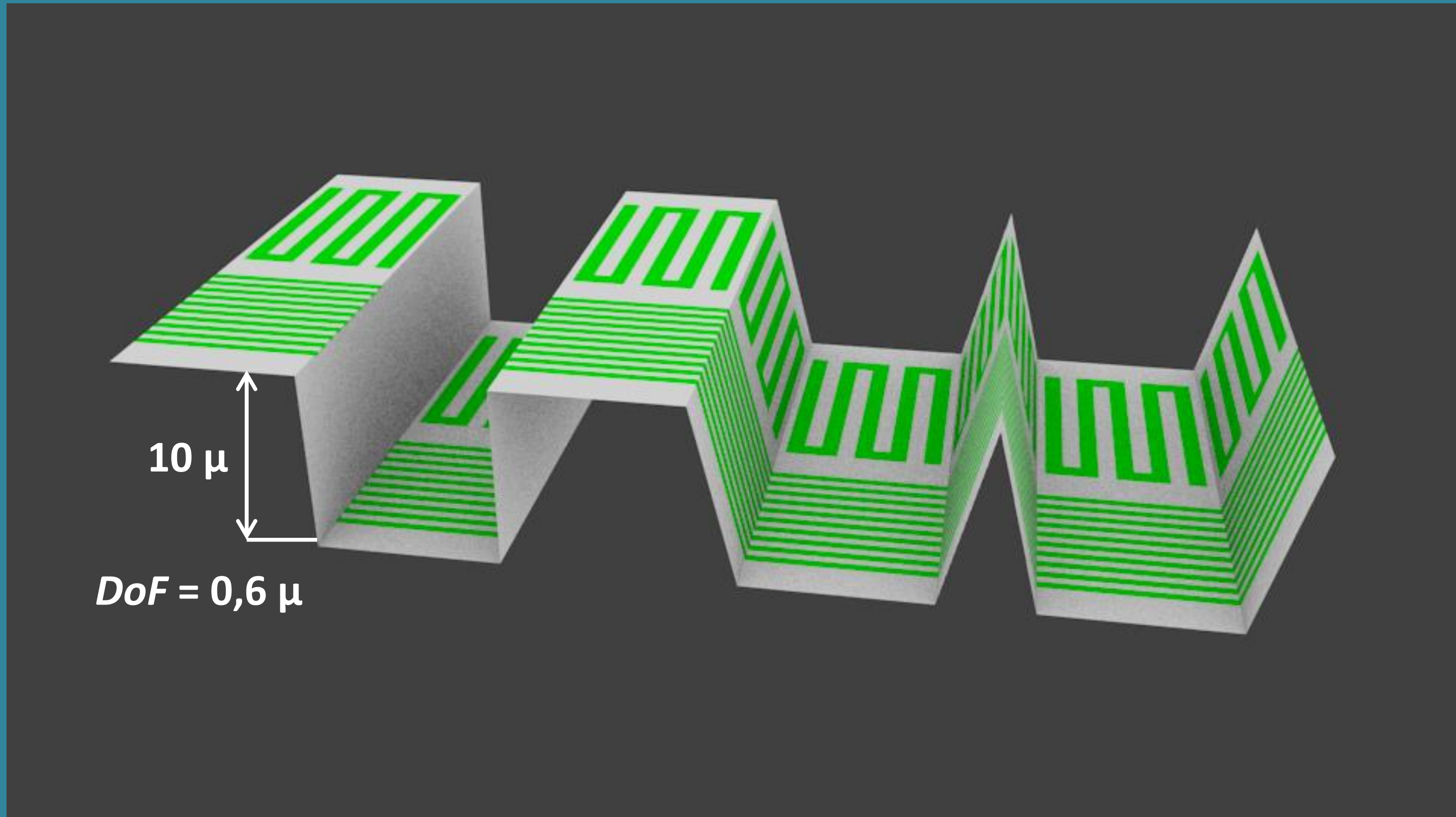
2. *Non-planar surfaces patterning* (laser scanning with alignment system modifications, glass blowing, flexible masking, flexible membranas)

3. *Sub-wavelength complex patterns lithography* (photomasks for IC & MEMS)

SWHL TECHNOLOGY CAN BE USEFUL IN ALL THREE PROBLEMS SOLUTION

3D-SWHL Lithography

(Computer simulation)



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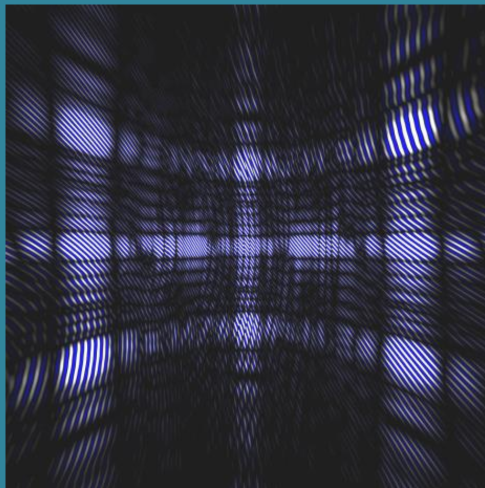
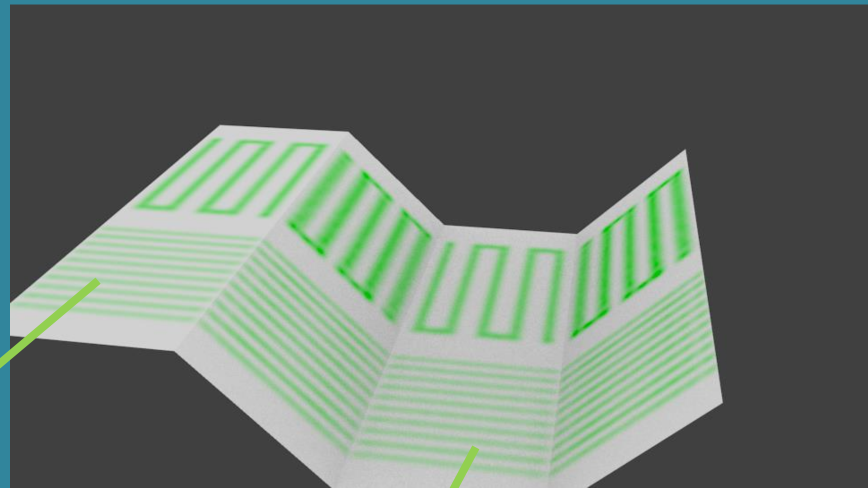
3d-Aerial image
(computer simulation)

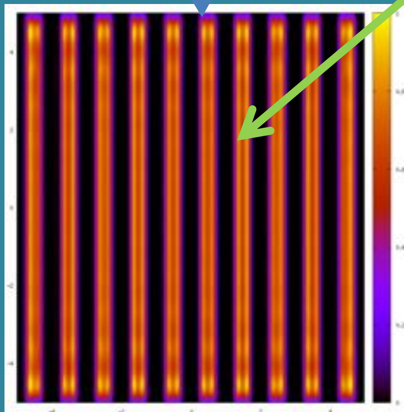


Plane hologram (SWHM)

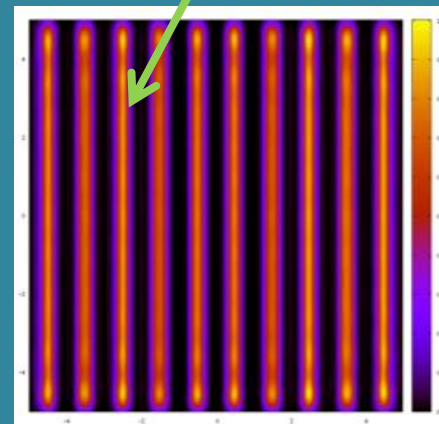
λ=193 nm
CD≈100 nm
NA=?



Reconstructed aerial image



Aerial image of the topology on upper plane



Aerial image of the topology on lower plane

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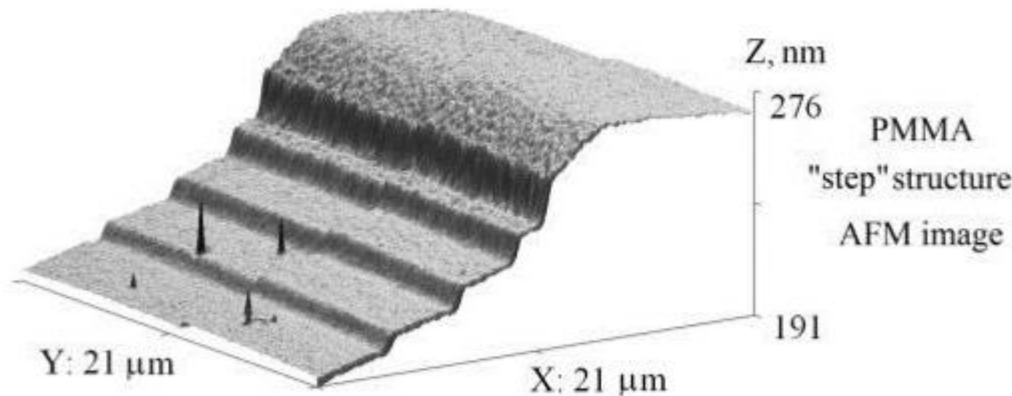
Comparison of E-Beam Lithography & SWHL lithography capabilities got by computer simulation



Relief in resist obtained with e-beam in scanning mode. Beam size is 10-15*nm*.

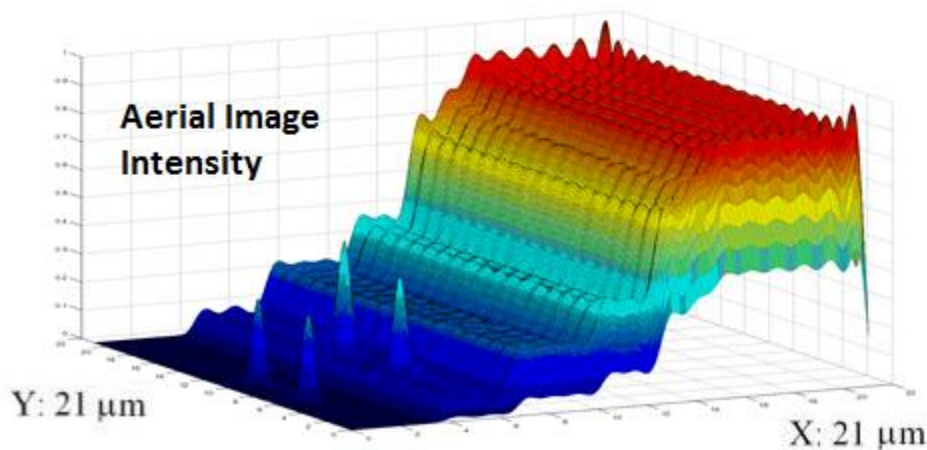
M.A. Bruk[a], E.N. Zhikharev[b], D.R. Streltsov[a], V.A. Kalnov[b], A.V. Spirin[a]

«The new dry method of mask (relief) formation by direct electron-beam etching of resist»

[a] Karpov Research Institute of Physical Chemistry, 6, Moscow 105064, Russia

[b] Physics and Technology Institute of Russian Academy of Sciences,

http://dx.doi.org/10.1016/j.mee.2013.06.03,



Aerial image obtained with

one exposure of SWHM

(computer simulation)

λ=193 nm, NA=0,2

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