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# Characterization of a novel mask imaging algorithm based on the Extended Nijboer-Zernike (ENZ) formalism

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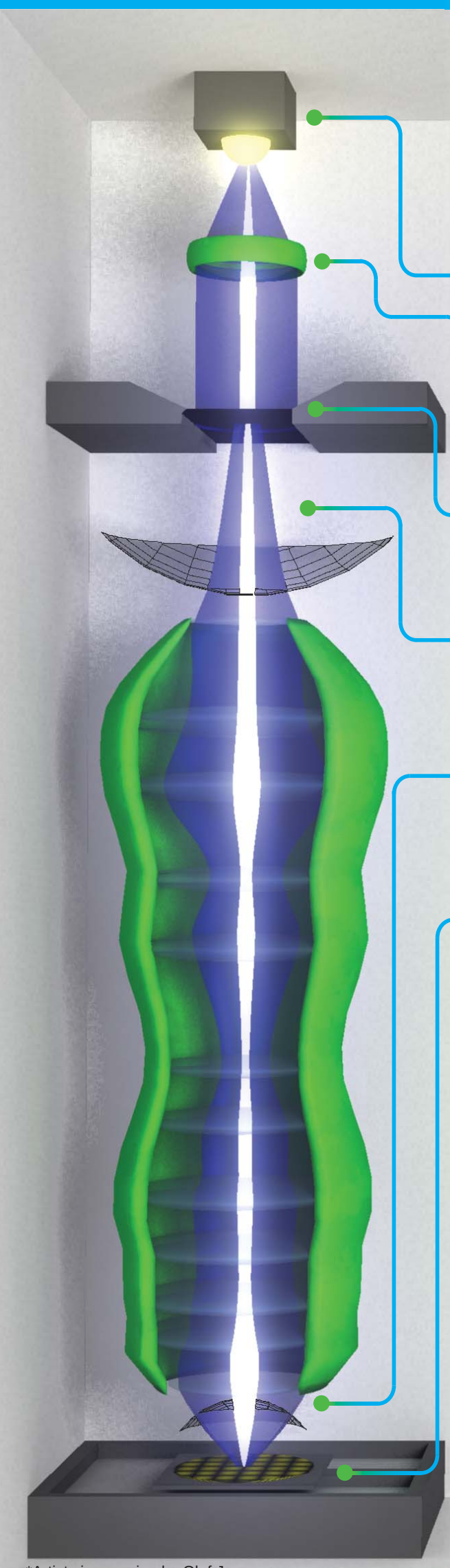


*Artists impression by Olaf Janssen

## Introduction:

We present details of a recently developed mask imaging algorithm based on the Extended Nijboer-Zernike (ENZ) formalism [1][2]. Convergence properties of the various computational steps are discussed and a comparison with the more conventional tool Dr. Litho [3] is presented.

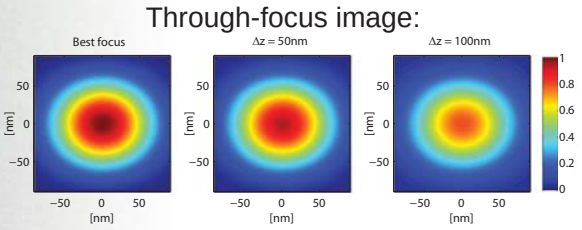
## ENZ imaging scheme:

- Discretize extended source
- Generate plane wave for every source element through Kohler illumination scheme
- Rigorously compute the near-field at the mask due to plane wave illumination
- Propagate near-field to the entrance pupil and represent it as a Zernike expansion
- Include aberrations and transmission changes and generate Zernike coefficients of exit pupil field
- Construct through-focus image contribution using the Zernike coefficients of the exit pupil and ENZ basic functions
- Final image is obtained as the incoherent sum of all source element contributions

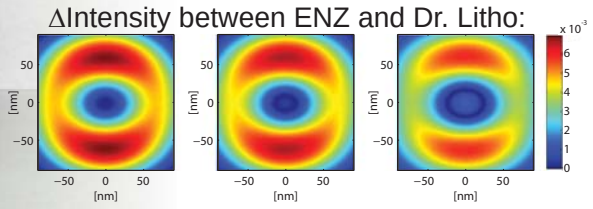
## Comparison with Dr. Litho:

90nm square contact hole is imaged by an immersion lithographic system (NA = 1.1, λ=193nm, im. fl. water).

Through-focus image:




ΔIntensity between ENZ and Dr. Litho:



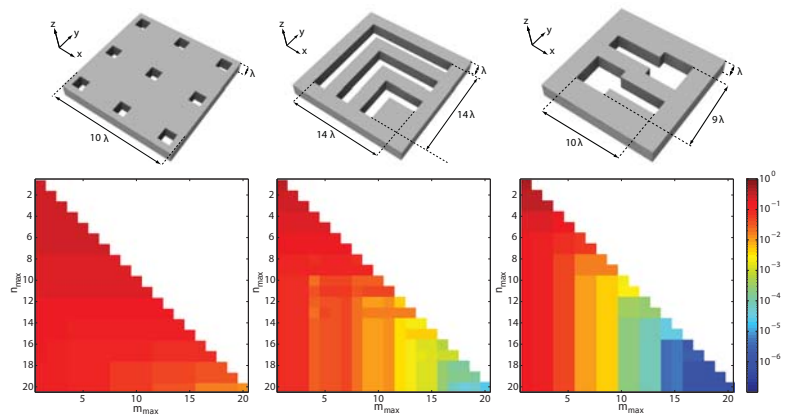

## Convergence properties:

### Rigorous solver:

Convergence considerations on the in-house developed FDTD tool and near-to-far field propagation can be found in Refs. [4] and [5].

### Least-square pupil fit convergence:

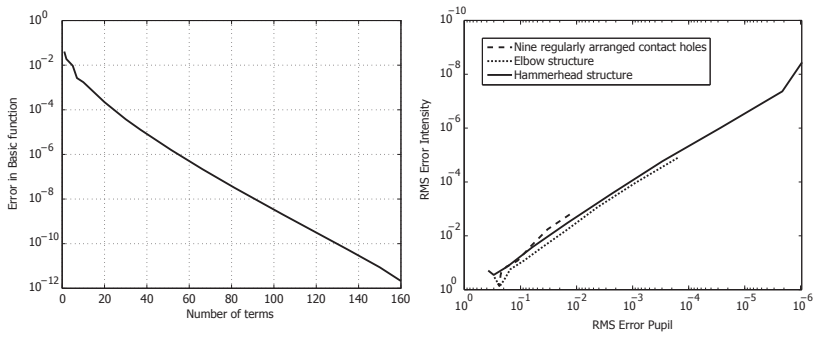
Maximum radial and azimuthal order of Zernike functions required for an accurate fit strongly depends on the object.




Fitting accuracy in entrance pupil versus ($N_{max}$, $M_{max}$)

### ENZ basic functions and final image:

The ENZ basic functions are computed using a well converging series expansion (see lefthand graph). They are independent of the object and can therefore be computed and stored in advance. As a result, the image accuracy is in practice only limited by the quality of the Zernike expansion in the entrance pupil. The righthand graph shows the RMS error in the image versus the RMS error in the expansion for the objects introduced above.




## References:

[1] S. van Haver, et al., Proc. SPIE **6924,** 69240U (2008)
[2] ENZ website: http://www.nijboerzernike.nl
[3] Dr. Litho software tool, http://www.drlitho.com
[4] P. Lalanne, et al., J. Eur. Opt. Soc. Rap. Publ. **2**, 07022 (2007)
[5] O.T.A. Janssen, et al., Proc. SPIE **6924,** 692410 (2008)

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