Extended Nijboer-Zernike (ENZ) based evaluation of amplitude and phase aberrations on scaled and annular pupils

[1]S. van Haver, [2]A.J.E.M. Janssen, [2]P. Dirksen, [1]J.J.M. Braat
[1]Delft University of Technology, TNW-IST Optics Research Group, Lorentzweg 1, 2628 CJ Delft, The Netherlands
[2]Philips Research Europe, HTC-36 & HTC-4, 5656 AE Eindhoven, The Netherlands
Email: S.vanHaver@tudelft.nl

1. Abstract

We present an ENZ-retrieval method that obtains perfect re-construction for aberrated pupil functions on an annular set from through-focus intensities under high-NA conditions. This is based on a recently developed formalism [1] to describe a numerical-aperture reduced pupil in terms of Zernike coefficients.

2. Reduced & annular pupils

Full   Reduced   Annular
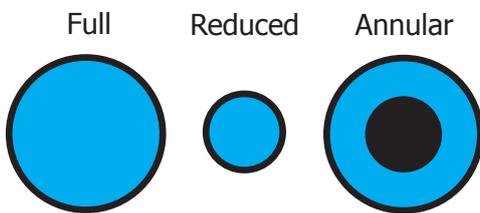
- Full pupil: maximal attainable pupil, determined by the optical system.

- Reduced pupil: subset of the full pupil. For instance, selected by means of a diaphragm.

- Annular pupil: ring-shaped (or centrally obstructed) pupil. Constructed by substracting a reduced pupil from a full pupil.

## 3. Through-focus point-spread function (high-NA)

The formalism in [1] for the computation of Zernike expansions of scaled pupils in terms of those of full pupils allows ENZ-computation of point-spread functions of reduced or annular pupils. This requires adjusting the ENZ-basic functions appro-priately, which can be done also under high-NA conditions, as in [2].

best focus Δfocus $\neq$ 0

Full

Reduced

Annular
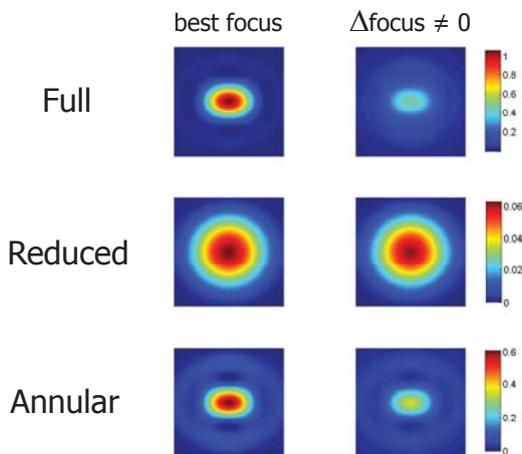
4. ENZ-aberration retrieval

With the adjusted basic functions available, aberration retrieval can be practised in the same way as was done for full pupils in [3,4]. The high-NA case and the iterative Predictor-Corrector scheme for perfect reconstruction can be incorporated as well.

Observed Intensity vs. analytic expression
$\approx$ linearized analytic expression
$= \sum \beta(m,n) \times \{$ENZ-basic functions$\}$

Focus

Exp.

match

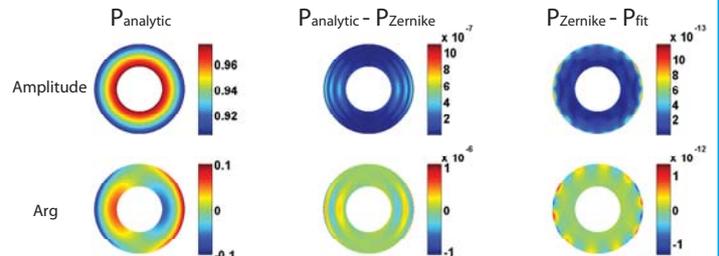Theory
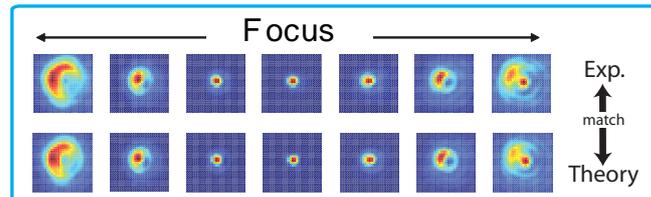
5. Retrieval of an annular aberrated pupil (high-NA)

As an example we reconstruct an annular pupil with a Gaussian transmission function and a comatic phase aberration in simulation. Thus we let

$P_{analytic}$ = analytically given pupil function,
$P_{Zernike}$ = Zernike expansion of $P_{analytic}$,
P_{fit} = ENZ-retrieved pupil function.

P_{fit} is the result of ENZ-retrieval, using the Predictor-Corrector ap-proach, performed on the through-focus intensity distribution con-stituted by $P_{Zernike}$ (for details see [5]).

$P_{analytic}$ $P_{analytic} - P_{Zernike}$ $P_{Zernike} - P_{fit}$

Amplitude

Arg

6. Summary & Conclusion

We have shown that an appropriate adjustment of the basic func-tions occurring in ENZ-theory allows the perfect reconstruction of aberrated pupil functions on scaled and annular pupils under high-NA conditions.

[1]   A.J.E.M. Janssen, P. Dirksen, Journal of Microlithography, Microfabrication, and Microsystems 5 (2006), 030501, pp. 1-3.
[2]   J.J.M. Braat, et al., J. Opt. Soc. Am. A 20 (2003), pp. 2281-2292.
[3]   S. van Haver, et al., J. Eur. Opt. Soc. -RP 1 (2006), 06004, pp. 1-8.
[4]   S. van Haver, et al., J. Eur. Opt. Soc. -RP 2 (2007), 07011e, pp. 1-1.
[5]   A.J.E.M. Janssen, et al., submitted to J. Mod. Opt., March 2007.

http://www.nijboerzernike.nl

PHILIPS   nano ned   TUDelft

Delft University of Technology