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

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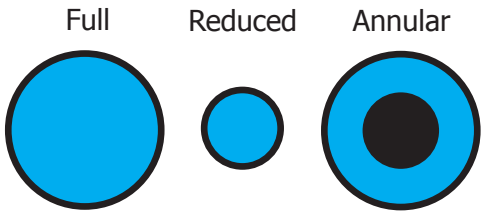
1. Abstract

We present an ENZ-retrieval method that obtains perfect reconstruction 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.

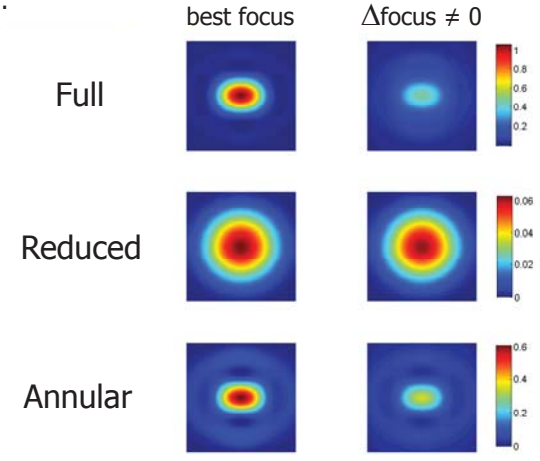
2. Reduced & annular pupils



- Full 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)

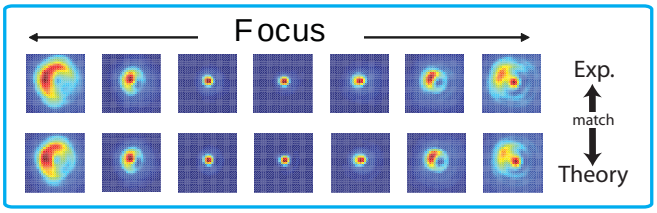
The formalism in [1] for the computation of Zernike expansions of scaled pupils in terms of those of full pupils allows ENZ-computation of point-spread functions of reduced or annular pupils. This requires adjusting the ENZ-basic functions appropriately, which can be done also under high-NA conditions,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



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
≈ linearized analytic expression
= Σ β(m,n) x {ENZ-basic functions}

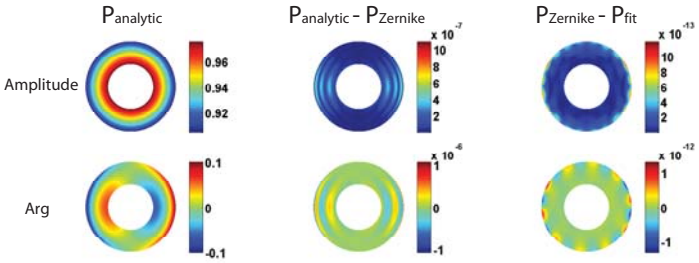


5. Retrieval of an annular aberrated pupil (high-NA)

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 approach, performed on the through-focus intensity distribution constituted by $P_{Zernike}$ (for details see [5]).



6. Summary & Conclusion

We have shown that an appropriate adjustment of the basic functions 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.

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