European Optical Society Biennial Meeting (EOSAM) 2018, Delft, Netherlands

Adaptation of Gerchberg-Saxton algorithm to aberration measurement of high-aperture optical systems

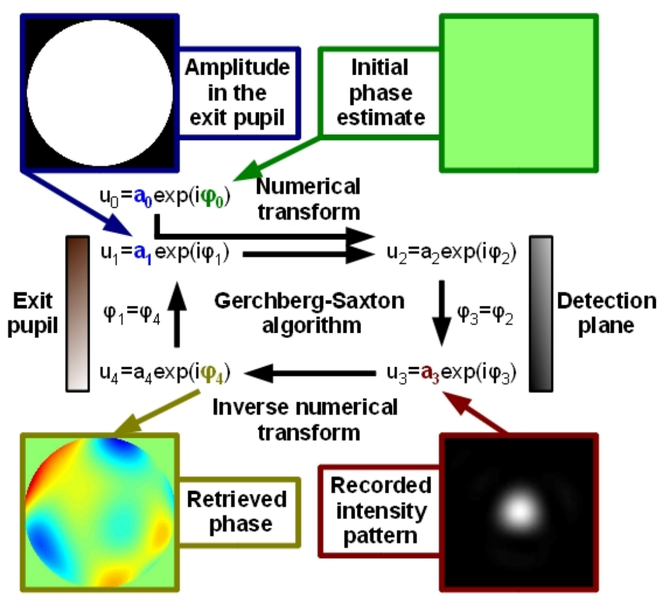
Michal Baranek
Department of Optics, Palacky University, 17. listopadu 1192/12, 771 46 Olomouc, Czech Republic
baranek@optics.upol.cz

Introduction: Gerchberg-Saxton (GS) algorithm allows the phase reconstruction of light from detected intensity patterns without using any additional optics. In this paper, various adaptations of GS algorithm applicable to the aberration measurement of high-aperture objectives are discussed.

Methods

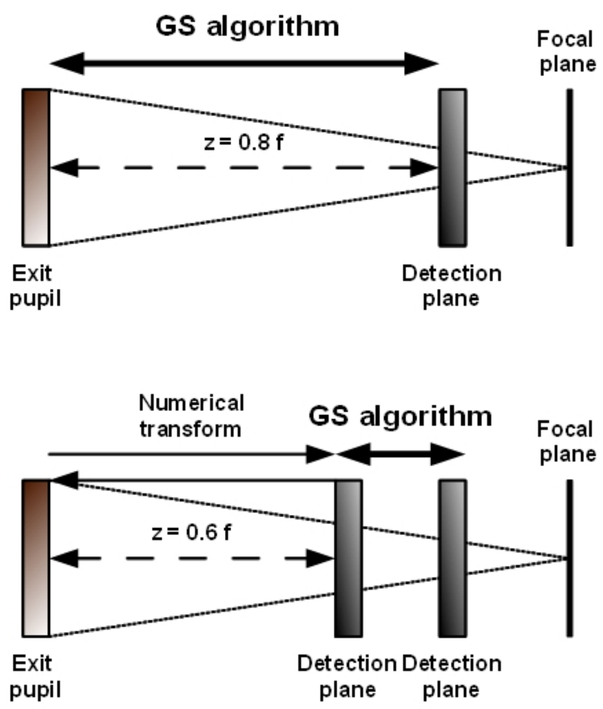
Principle of the GS algorithm

The GS algorithm uses the intensity spot acquired in the detection plane and the retrieved phase in the exit pupil of the tested objective is obtained as the result of the iteration process [1].



Paths of the GS algorithm

Two different paths of the GS algorithm are studied.



Numerical transform

Fast Fourier transform is used for calculation of free space propagation of light. The angular spectrum is multiplicated by transfer function H [2].

$$u_2 = \mathrm{IFFT}\{H \cdot \mathrm{FFT}\{u_1\}\}$$

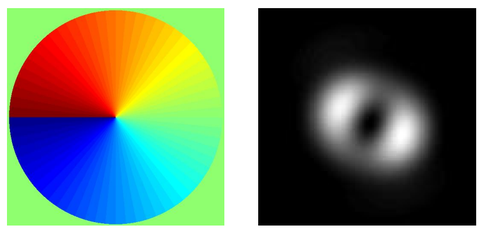
$$u_4 = \mathrm{IFFT}\{H \cdot \mathrm{FFT}\{u_3\}\}$$

$$H = \exp\left[\mathrm{i}2\pi\frac{z}{\lambda}\sqrt{1-\lambda^2\left(f_x^2+f_y^2\right)}\right]$$

Spiral phase modulation

Spiral phase modulation in the exit pupil was examined as the initial phase constraint [3].

$$t(\varphi) = \exp(im\varphi)$$



Zernike polynomials

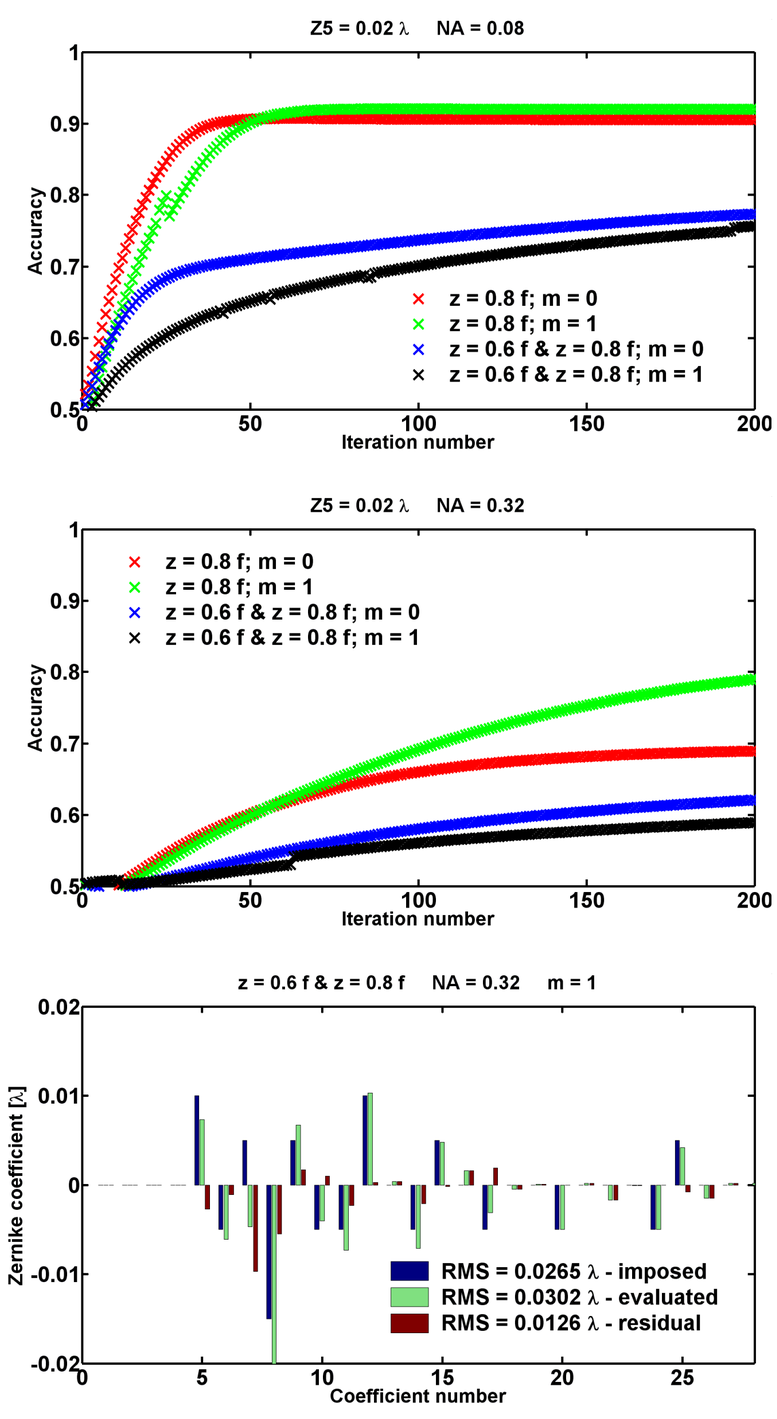
Zernike polynomials are used for the quantification of wavefront deformation [4]. Accuracy coefficient E is defined for the evaluation of the iteration process.

$$E = \frac{\sqrt{\sum_{j=1}\left|Z_j^1\right|^2}}{\sqrt{\sum_{j=1}\left|Z_j^1\right|^2}+\sqrt{\sum_{j=1}\left|Z_j^2-Z_j^1\right|^2}}$$

$$W(\rho,\varphi) = \sum_{j=1}^{28} Z_j Zp_j(\rho,\varphi)$$

$$RMS = \sqrt{\sum_{j=1}\left|Z_j\right|^2}$$

Results



Conclusions: The aberration measurements of high-aperture lenses based on the adapted GS algorithm are presented. The defocused diffraction patterns and the initial spiral phase constraint are examined as modification of the GS algorithm used for the wavefront reconstruction.

References:
[1] R.W. Gerchberg, W.O. Saxton, A practical algorithm for the determination of phase from image and diffraction plane pictures, Optik 35, 237246 (1972).
[2] J.W. Goodman, Introduction to Fourier optics, Mc Graw-Hill (1996).
[3] A. Jesacher, A. Schwaighofer, S. Furhapter, C. Maurer, S. Bernet, M. Ritsch-Marte, Wavefront correction of spatial light modulators using an optical vortex image, Opt. Express 15, 5801-5808 (2007).
[4] D. Malacara, Optical shop testing, Wiley (2007).

Acknowledgments:
This work was supported by the project No. 18-01396S of the Grant Agency of the Czech Republic and the IGA project of the Palacky University PrF 2018-003 Modern optics and applications.