Determination of Zernike coefficients based on Line Spread Functions

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What are Zernike coefficients?

Zernike polynomials are a complete, orthonormal system of functions on the unit circle. Each polynomial can be assigned to an optical aberration, which makes them ideal for describing wavefronts. The Zernike coefficients indicate the quantitative part of the respective polynomial [1],[2].
There are different ways for indexing the polynomials. The FRINGE scheme is used here.

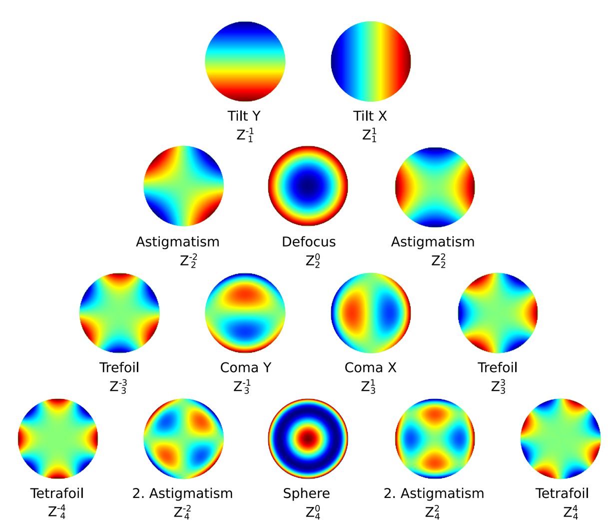


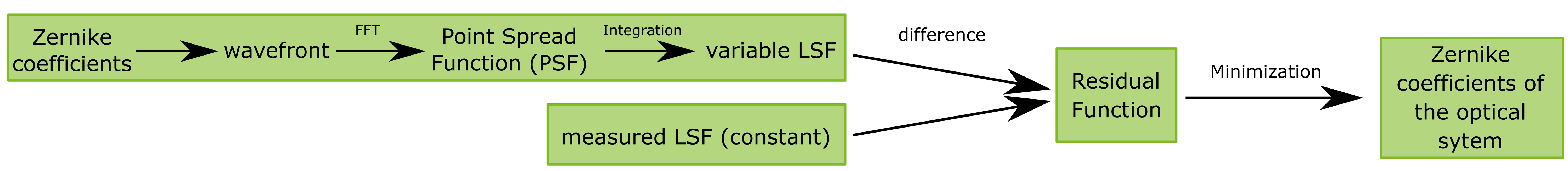
Fig. 1: Representation of the Zernike polynomials up to the 4th order.

Objective and Method

Motivation:
As the demands on the quality and precision of optical components continue to increase, an efficient strategy for assessing their manufacturing status will be presented here. In order to avoid complex and expensive interferometric measurements, an approach based on the experimentally easily accessible Line Spread Function (LSF) is made [3].

Approach:
A MATLAB-algorithm is created which minimizes the difference between the measurement signal and a calculated signal based on variable Zernike coefficients.
To test this algorithm, two lens systems are created with the help of the optics simulation program OSLO. Their LSFs are calculated as an artificial measurement signal. The advantage here is that the Zernike coefficients from OSLO are already known exactly.

How the algorithm works



Simulation and Test

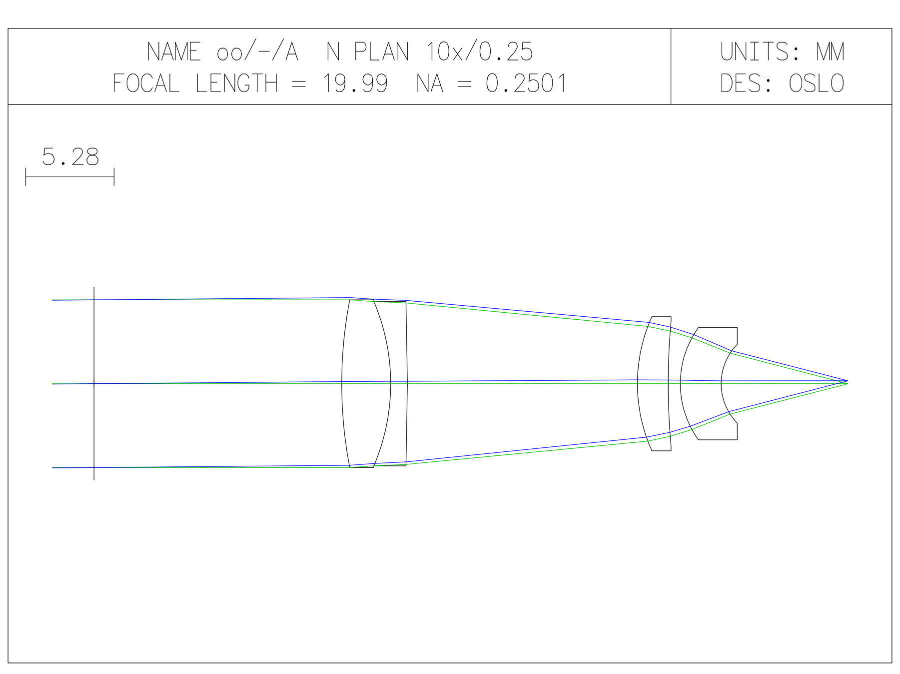


Fig. 3: Illustration of the microscope objective in OSLO.

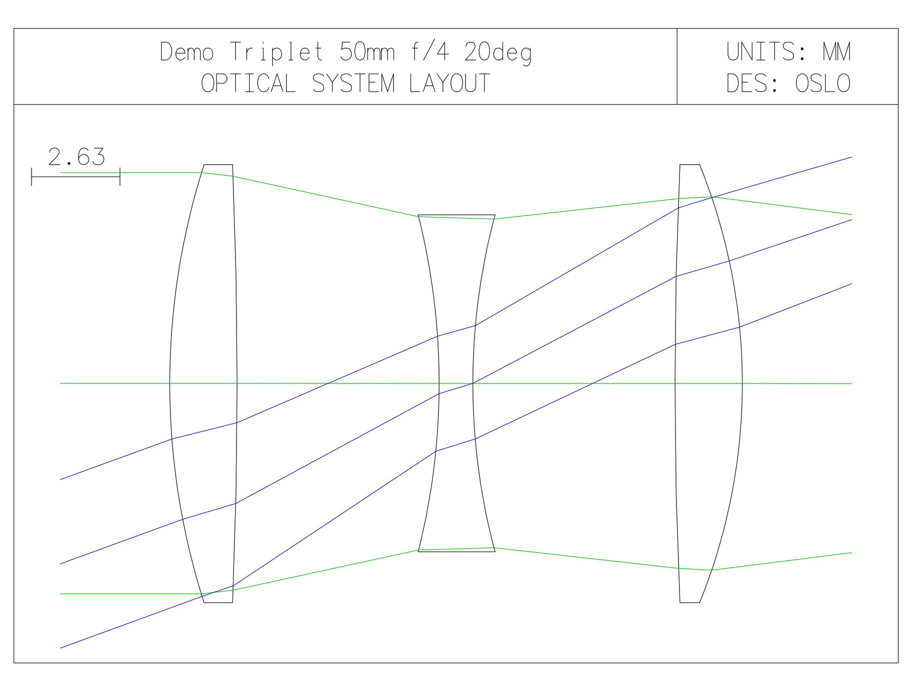


Fig. 4: Illustration of the triplet in OSLO.

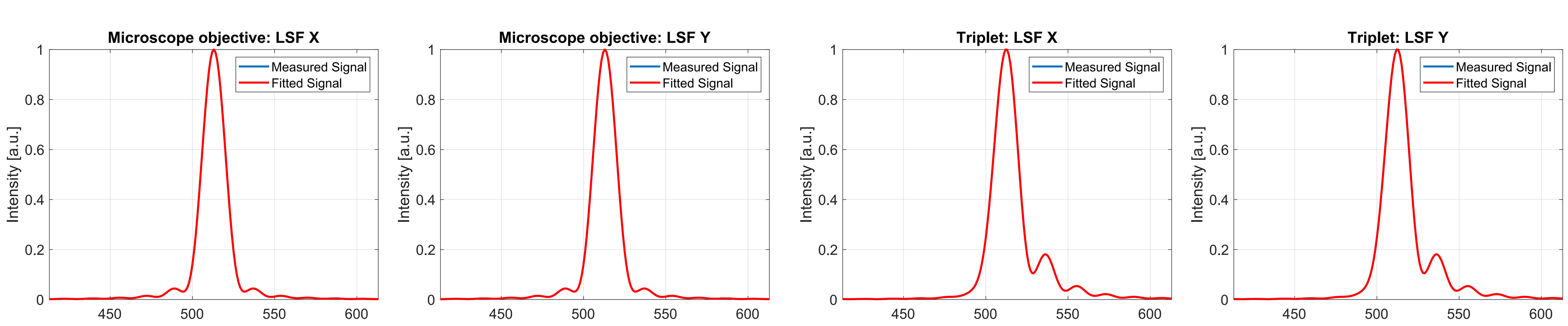
Results

Description	Coefficient-Nr.	OSLO	MATLAB
Piston	0	-0.010462	(0.0000)
X Tilt	1	0	0.0000
Y Tilt	2	0	0.0000
Defocus	3	0.005468	0.005436
X Astigmatism	4	0	-0.0001
Y Astigmatism	5	0	0.0000
X Coma	6	0	0.0000
Y Coma	7	0	0.0000

Fig. 5: Comparison of the coefficients for the microscope objective.

Coefficient-Nr.	OSLO	MATLAB
0	-0.123405	(0.0000)
1	-0.006471	-0.006515
2	-0.006471	-0.006516
3	0.009305	0.0000
4	0	0.0000
5	0.001197	0.0000
6	0.148566	0.148765
7	0.148566	0.148831

Fig. 6: Comparison of the coefficients for the Triplet.



- Results of the algorithm fit the simulated measurement signal, graphs of LSF-functions (measured and fitted) lie on top of each other
- Successful calculation of the Zernike coefficients, deviations may be due to the termination criteria and the fact that only the first eight coefficients were calculated

Conclusion

Successful calculation of the **Zernike coefficients based on only the LSF**, shown for two different lens systems using a theoretical simulation

Next steps

- Extension so that Edge Spread Function (ESF) signals can be used
- Validation of the algorithm through calculations with real measurement data
- Optimize computation time so that more Zernike coefficients can be calculated in a reasonable time

References

[1] Born and Wolf (1999). *Principles of Optics*. Cambridge University Press. p.986. ISBN 9780521642224.

[2] Qi, Chen, and Dong (2002)., "Wavefront fitting of interferograms with Zernike polynomials," in Optical Engineering; Jul2002, Vol. 41 Issue 7, p1565-1569,5p.

[3] Ke et al (2018)., "Wavefront reconstruction for multilateral shearing interferometry using difference Zernike polynomials fitting," in Optics and Lasers in Engineering July 2018 106:75-81.

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