



**Institute of  
Applied Physics**

Friedrich-Schiller-Universität Jena

# Imaging and Aberration Theory

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Lecture : Introduction

2018-10-19

Herbert Gross

- Time: Friday, 10.00 – 11.30
- Location: ACP, auditorium, Beutenberg
- Web page on IAP homepage under ‚learning/materials‘ provides slides, exercises, solutions, informations
- Seminar: Exercises and solutions of given problems  
time: Friday 8.15 - 9.45  
location: SR 2 , ACP, Beutenberg  
starting date: 2018-11-02  
2-weekly  
  
Mentor : Johannes Stock
- Shift of some dates could be possible
- Written examination, 90‘, retake oral

# Schedule - Imaging and aberration theory 2018

1	19.10.	Paraxial imaging	paraxial optics, fundamental laws of geometrical imaging, compound systems
2	26.10.	Pupils, Fourier optics, Hamiltonian coordinates	pupil definition, basic Fourier relationship, phase space, analogy optics and mechanics, Hamiltonian coordinates
3	02.11.	Eikonal	Fermat principle, stationary phase, Eikonals, relation rays-waves, geometrical approximation, inhomogeneous media
4	09.11.	Aberration expansions	single surface, general Taylor expansion, representations, various orders, stop shift formulas
5	16.11.	Representation of aberrations	different types of representations, fields of application, limitations and pitfalls, measurement of aberrations
6	23.11.	Spherical aberration	phenomenology, sph-free surfaces, skew spherical, correction of sph, aspherical surfaces, higher orders
7	30.11.	Distortion and coma	phenomenology, relation to sine condition, aplanatic systems, effect of stop position, various topics, correction options
8	07.12.	Astigmatism and curvature	phenomenology, Coddington equations, Petzval law, correction options
9	14.12.	Chromatical aberrations	Dispersion, axial chromatical aberration, transverse chromatical aberration, spherochromatism, secondary spectrum
10	21.12.	Sine condition, aplanatism and isoplanatism	Sine condition, isoplanatism, relation to coma and shift invariance, pupil aberrations, Herschel condition, relation to Fourier optics
11	11.01.	Wave aberrations	definition, various expansion forms, propagation of wave aberrations
12	18.01.	Zernike polynomials	special expansion for circular symmetry, problems, calculation, optimal balancing, influence of normalization, measurement
13	25.01.	Point spread function	ideal psf, psf with aberrations, Strehl ratio
14	01.02.	Transfer function	transfer function, resolution and contrast
15	08.02.	Additional topics	Vectorial aberrations, generalized surface contributions, Aldis theorem, intrinsic and induced aberrations, reverbability

- [1] H. Buchdahl, An Introduction to Hamiltonian Optics, Dover, 1970
- [2] A. E. Conrady, Applied Optics and Optical Design, Part one and two, Dover, 1985
- [3] H. Buchdahl, Optical Aberration Coefficients, Dover 1968
- [4] Y. Matsui / K. Nariai, Fundamentals of practical aberration theory, World Scientific, 1993
- [5] A. Walther, The ray and wave theory of lenses, Cambridge University Press, 1995
- [6] V. Lakshminarayanan / A. Ghatak / K. Thyagarayan, Lagrangian optics, Kluwer 2002
- [7] M. Berek, Grundlagen der praktischen Optik, de Gruyter, 1970
- [8] W. T. Welford, Aberrations of optical systems, Adam Hilger, 1986
- [9] K. Luneburg, Mathematical theory of optics, University of California Press, 1964
- [10] J. Palmer, Lens aberration data, Adam Hilger, 1971
- [11] G. Slyusarev, Aberration and optical design theory, Adam Hilger, 1984
- [12] D. Malacara / Z. Malacara, Handbook of optical design, Marcel Dekker, 2004
- [13] A. Cox, A system of optical design, The Focal Press, 1967
- [14] V. Mahajan, Optical imaging and aberrations I, Ray geometrical optics, SPIE Press, 5 1998
- [15] V. Mahajan, Optical imaging and aberrations II, Wave diffraction optics, SPIE Press, 2001
- [16] J. Sasian, Aberrations in optical imaging systems, Cambridge University Press, 2013

- Paper from 2010:

## **In the era of global optimization, the understanding of aberrations remains the key to designing superior optical systems**

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### **ABSTRACT**

Historically, a thorough grounding in aberration theory was the only path to successful lens design, both for developing starting layouts and for design improvement. Modern global optimizers, however, allow the lens designer to easily generate multiple solutions to a single design problem without understanding the crucial importance of aberrations and how they determine the full design potential. Compared to pure numerical optimization, aberration theory applied during the lens design process gives the designer a much firmer grasp of the overall design limitations and possibilities. Among other benefits, aberrations provide excellent insight into tolerance sensitivity and manufacturability of the underlying design form. We explore multiple examples of how applying aberration theory to lens design can improve the entire lens design process. Example systems include simple UV, visible, and IR refractive lenses; much more complicated refractive systems requiring field curvature balance; and broadband zoom lenses.

**Keywords:** optical design, aberrations, aberration theory, optimization, global optimization