

*Michael Kaschke,
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**Optical Devices in
Ophthalmology and Optometry**

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and Michael Stefan Rill*

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Michael Kaschke

To Christel for her abundance of understanding all the time.

Karl-Heinz Donnerhacke

To my family and friends for their steady support.

Michael Stefan Rill

Contents

Preface XV

Part One 1

1	Structure and Function	3
1.1	Anatomy of the Human Eye	4
1.2	Retina: The Optical Sensor	10
1.2.1	Retinal Structure	10
1.2.2	Functional Areas	12
1.3	Recommended Reading	14
	References	14
2	Optics of the Human Eye	15
2.1	Optical Imaging	15
2.1.1	Entrance and Exit Pupils	17
2.1.2	Cardinal Points	19
2.1.3	Eye Axes	20
2.1.4	Accommodation	21
2.1.5	Resolution	23
2.1.6	Adaption	26
2.1.7	Stiles–Crawford Effect	28
2.1.8	Depth of Field	29
2.1.9	Binocular Vision	30
2.1.10	Spectral Properties	32
2.2	Schematic Eye Models	33
2.2.1	Paraxial Model: The Gullstrand Eye	34
2.2.2	Finite Wide-Angle Models	38
2.2.3	Applications of Eye Models	44
2.3	Color Vision	45
2.4	Recommended Reading	47
	References	47

3	Visual Disorders and Major Eye Diseases	49
3.1	Refractive Errors	49
3.1.1	Axial-Symmetric Ametropia: Myopia and Hyperopia	51
3.1.2	Astigmatism	51
3.1.3	Notations of Spherocylindric Refraction in Astigmatic Eyes	53
3.1.4	Anisometropia	54
3.1.5	Distribution of Refractive Errors	54
3.1.6	Refractive Errors Caused by Diseases	55
3.2	Cataract	56
3.3	Glaucoma	57
3.4	Age-Related Macular Degeneration	60
3.4.1	ARM	60
3.4.2	Dry AMD	60
3.4.3	Wet AMD	61
3.5	Diabetic Retinopathy	64
3.6	Retinal Vein Occlusions	65
3.7	Infective Eye Diseases	66
3.7.1	Trachoma	66
3.7.2	Onchocerciasis	67
3.8	Major Causes for Visual Impairment	67
3.9	Major Causes of Blindness	68
3.10	Socio-Economic Impact of Eye Diseases	70
3.11	Recommended Reading	72
	Problems to Chapters 1–3	72
	References	76

Part Two 79

4	Introduction to Ophthalmic Diagnosis and Imaging	81
4.1	Determination of the Eye's Refractive Status	82
4.2	Visualization, Imaging, and Structural Analysis	82
4.3	Determination of the Eye's Functional Status	85
4.3.1	Global Functional Status	85
4.3.2	Local Functional Status	86
4.4	Light Hazard Protection	86
	References	87
5	Determination of the Refractive Status of the Eye	89
5.1	Retinoscopy	91
5.1.1	Illumination Beam Path	92
5.1.2	Observation Beam Path	93
5.1.3	Measurement Procedure	96
5.1.4	Accuracy in Retinoscopy	98
5.1.5	Applications	99

5.2	Automated Objective Refractometers (Autorefractors)	100
5.2.1	Common Characteristics of Autorefractors	100
5.2.2	Measuring Methods	102
5.2.3	Measurement Accuracy and Limitations of Automatic Refractometers	120
5.3	Aberrometers	121
5.3.1	Fundamentals of Aberrometry	121
5.3.2	General Measurement Principles for Aberrometers	126
5.3.3	General Remarks on Aberrometry	127
5.3.4	Hartmann–Shack Wavefront Aberrometer (Outgoing Light Aberrometer)	127
5.3.5	Ingoing Light Aberrometers	131
5.3.6	Commercial Aberrometers	133
5.4	Wavefront Reconstruction and Wavefront Analysis	133
5.4.1	From Wavefront to Refraction (Wavefront Analysis)	135
5.4.2	Applications of Wavefront Analysis	140
5.5	Excursus: Refractive Correction with Eye Glasses and Contact Lenses	141
5.6	Recommended Reading	143
5.7	Problems	143
	References	144
6	Optical Visualization, Imaging, and Structural Analysis	147
6.1	Medical Magnifying Systems	147
6.1.1	Optics of a Single Loupe	148
6.1.2	Medical Loupes	149
6.2	Surgical Microscopes	151
6.2.1	Requirements for Surgical Microscopes	152
6.2.2	Functional Principle	154
6.2.3	Modular Structure of Surgical Microscopes	160
6.2.4	Prospects	176
6.3	Reflection Methods for Topographic Measurements	177
6.3.1	Keratometer	178
6.3.2	Placido Ring Corneal Topographer	187
6.4	Slit Lamp	200
6.4.1	Functional Principle	201
6.4.2	Modular Structure	202
6.4.3	Types of Illumination for Various Applications	205
6.4.4	Accessories for Other Examinations and Measurements	208
6.4.5	Prospects	212
6.5	Scanning-Slit Projection Devices	212
6.5.1	Lateral Scanning-Slit Projection Techniques	213
6.5.2	Scheimpflug Imaging of Rotating-Slit Projections	217
6.5.3	Clinical Relevance and Applications	223
6.6	Ophthalmoscope	225

6.6.1	Functional Principle	226
6.6.2	Direct Ophthalmoscope	227
6.6.3	Indirect Ophthalmoscope	230
6.7	Fundus Camera	236
6.7.1	Requirements for a Fundus Camera	237
6.7.2	Functional Principle	238
6.7.3	Field of View and Magnification	241
6.7.4	Wide-Field Imaging	241
6.7.5	Color and Monochrome Imaging	241
6.7.6	Fluorescence Angiography	242
6.7.7	Fundus Autofluorescence	244
6.7.8	Stereoscopic Imaging and Analysis	246
6.7.9	Equipment Solutions	248
6.7.10	Prospects	248
6.8	Scanning-Laser Devices	249
6.8.1	Confocal Scanning-Laser Ophthalmoscope	250
6.8.2	Confocal Scanning-Laser Tomograph	259
6.8.3	Scanning-Laser Polarimeter	261
6.9	Recommended Reading	267
6.10	Problems	267
	References	273
7	Optical Coherence Methods for Three-Dimensional Visualization and Structural Analysis	277
7.1	Introduction to Optical Coherence Tomography	278
7.2	Development of OCT and LCI as an Example of Modern Medical Technology Innovation	280
7.2.1	Academic Research – Conception of OCT (until 1993)	281
7.2.2	First Generation of Commercial OCTs (1993–2002)	281
7.2.3	Second Generation of OCTs – ZEISS Stratus OCT (2002–2006)	283
7.2.4	Third Generation of OCTs – Frequency-Domain OCT (2007–current)	283
7.3	Principles of Low-Coherence Interferometry and Optical Coherence Tomography	285
7.3.1	Michelson Interferometry with Coherent Light	285
7.3.2	Michelson Interferometry with Low-Coherence Light	286
7.3.3	Time-Domain OCT	289
7.3.4	Frequency-Domain OCT	291
7.3.5	Swept-Source OCT	295
7.3.6	Overview and Comparison of OCT Systems	297
7.4	Elements of OCT Theory	300
7.4.1	Theory of Time-Domain OCT – Axial Resolution	301
7.4.2	Theory of Frequency-Domain OCT	304
7.4.3	Effect of Group Velocity Dispersion in OCT Systems	309
7.4.4	Sensitivity and Signal-To-Noise Ratio in TD-OCT and FD-OCT	311

7.5	Device Design of OCTs	313
7.5.1	Light Sources	313
7.5.2	Commercial Systems	315
7.6	Ophthalmic Applications of OCT	316
7.6.1	Posterior Segment of the Eye	317
7.6.2	Anterior Part of the Eye	320
7.7	Optical Biometry by Low-Coherence Interferometry	324
7.7.1	Dual-Beam Low-Coherence Interferometry	327
7.7.2	Applications of Optical Biometry	329
7.8	Prospects	334
7.9	Recommended Reading	338
7.10	Problems	338
	References	341
8	Functional Diagnostics	345
8.1	Visual Field Examination	346
8.1.1	Physiological Aspects and Functional Principles	346
8.1.2	Basic Perimeter Design	351
8.1.3	Alternative Perimetric Concepts	357
8.1.4	Prospects	362
8.2	Metabolic Mapping	363
8.2.1	Microcirculation Mapping	363
8.2.2	Fluorophore Mapping	366
8.2.3	Prospects	367
8.3	Recommended Reading	367
8.4	Problems	368
	References	368
	Part Three	371
9	Laser–Tissue Interaction	373
9.1	Absorption	374
9.2	Elastic Scattering	375
9.2.1	Rayleigh Scattering	376
9.2.2	Mie Scattering	376
9.3	Optical Properties of Biological Tissue	376
9.4	Interaction of Irradiated Biological Tissue	378
9.4.1	Photochemical Response	379
9.4.2	Photothermal Response	380
9.4.3	Photoablation	383
9.4.4	Plasma-Induced Ablation and Photodisruption	384
9.5	Propagation of Femtosecond Pulses in Transparent Media	391
9.5.1	Self-Focusing	392
9.5.2	Self-Phase Modulation	392

9.5.3	Group Velocity Dispersion	393
9.6	Ophthalmic Laser Safety	394
9.6.1	Laser Classes	396
9.6.2	Safe Use of Ophthalmic Laser Systems	399
9.7	Recommended Reading	401
9.8	Problems	402
	References	403
10	Laser Systems for Treatment of Eye Diseases and Refractive Errors	405
10.1	Laser Systems Based on Photochemical Interactions	406
10.1.1	Basics of Photodynamic Therapy	408
10.1.2	Technical Equipment Concepts	409
10.1.3	Treatment Procedure	411
10.1.4	Prospects	411
10.2	Laser Systems Based on Photothermal Interactions	412
10.2.1	Functional Principle	412
10.2.2	Process Parameters	412
10.2.3	Treatment Modes	415
10.2.4	Technical Equipment Concepts	418
10.2.5	Clinical Applications	426
10.2.6	Prospects	430
10.3	Laser Systems Based on Photoablation	431
10.3.1	Basics of Photoablation Treatments	432
10.3.2	Technical Equipment Concepts	441
10.3.3	Surgical Ablation Techniques	446
10.3.4	Prospects	450
10.4	Laser Systems Based on Photodisruption with Nanosecond Pulses	450
10.4.1	Functional Principle	451
10.4.2	Process Parameters	451
10.4.3	Technical Equipment Concepts	454
10.4.4	Clinical Applications	457
10.4.5	Prospects	460
10.5	Laser Systems Based on Plasma-Induced Ablation with Femtosecond Pulses	460
10.5.1	Functional Principle	460
10.5.2	Process Parameters	461
10.5.3	Technical Equipment Concepts	463
10.5.4	Clinical Applications	466
10.5.5	Prospects	472
10.6	Recommended Reading	473
10.7	Problems	473
	References	476
Appendix A	Basics of Optics	481
A.1	Geometric Optics and Optical Imaging	482

A.1.1	Refraction and Dispersion	483
A.1.2	Imaging by Spherical Surfaces	486
A.1.3	The Ray Tracing Approach to Paraxial Optical Systems	492
A.1.4	Aperture Stops, Field Stops, and Pupils	496
A.1.5	Limitations of the Paraxial Beam Approximation	499
A.1.6	Aberrations	501
A.1.7	Wavefront Aberration and Image Quality	506
A.1.8	Classification and Expansion of the Wave Aberration Function	510
A.1.9	Chromatic Aberration	518
A.2	Wave Optics	518
A.2.1	Monochromatic Harmonic Waves	519
A.2.2	Paraxial Solutions of the Wave Equation	530
A.2.3	Monochromatic Superposition of Harmonic Waves	535
A.2.4	Polychromatic Superposition of Waves	537
A.3	Recommended Reading	543
A.4	Problems	543
	References	547

Appendix B Basics of Laser Systems 549

B.1	Einstein's Two-Level Model of Light-Atom Interaction	550
B.1.1	Absorption	551
B.1.2	Spontaneous emission	551
B.1.3	Stimulated emission	551
B.1.4	Relation of Einstein Coefficients	552
B.2	Light Amplification by Stimulated Emission	552
B.2.1	Conditions for Population Inversion	553
B.2.2	Multilevel Optical Pumping	555
B.3	Laser Oscillator	558
B.3.1	Inversion Threshold	558
B.3.2	Standing Wave Condition	561
B.4	The Gaussian Oscillator	563
B.4.1	Resonator Stability Condition	563
B.4.2	Divergence	565
B.4.3	Polarization	566
B.4.4	Pulsed Laser Operation	567
B.5	Technical Realization of Laser Sources	571
B.5.1	Gas Lasers	572
B.5.2	Semiconductor Lasers	577
B.5.3	Solid-State Lasers	580
B.6	Recommended Reading	583
B.7	Problems	583
	References	588

Appendix C Summary of Used Variables and Abbreviations 591

C.1	Chapters 1–3	591
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XIV | Contents

C.2	Chapters 4 and 5	593
C.3	Chapter 6	594
C.4	Chapter 7	597
C.5	Chapter 8	599
C.6	Chapters 9 and 10	600
C.7	Appendix A	603
C.8	Appendix B	605
Index		607

Preface

This book is based on lectures “Optical Systems in Medical/Ophthalmic Technology” held by two of the authors since 2007 at the Karlsruhe Institute of Technology (Germany) and since 2003 at the Ernst Abbe University of Applied Sciences in Jena (Germany). The idea behind these lectures was to create a link between fundamental physical methods in optics, photonics, and measurement technology on the one hand, and to communicate their applications in medical sciences, in particular ophthalmology and optometry, to graduate students in physics and in electrical and mechanical engineering on the other. As this book is essentially based on these lectures, the structure, motivation, and target group of readers for this is quite similar. However, this book is intended as a textbook and compendium for the engineer and physicist in academic and industrial research and development. It will also be useful for the teaching and practicing ophthalmologist and optometrist with an interest in optical technology. To cover the broad spectrum of readers, we have not only described the application of optical methods to the design of ophthalmic diagnostic and laser treatment systems, but have also discussed clinical applications in such a way that the advantage of using a particular optical system and design becomes evident.

A large number of excellent reference books and textbooks exist on ophthalmology and optometry. The same applies to applied and technical optics. However, most of these books focus on a certain aspect (e.g., disease diagnosis, treatment procedures, etc.) or distinct optical and photonics techniques (e.g., OCT, aberrometry, etc.). Consequently, they often address experts with a certain scientific background. Students looking for a systematic and relatively complete introduction to the topic of optical methods and systems in ophthalmology and optometry are thus confronted with a number of books from which the necessary information has to be extracted with considerable effort. The situation is actually very similar for engineers and scientists of academic and research institutions, who often look for a compendium or reference book which gives them a general overview of available solutions in medical technology associated with their area of expertise. To close this gap, we provide an interdisciplinary overview of the currently most relevant (and most often used) techniques and technologies in ophthalmology and optometry, their underlying optical principles, as well as their corresponding diagnostic and therapeutic application.

The eye is our most important sensory organ and any reduction or loss of vision is a major impairment of our quality of life. Although the eye is quite accessible for optical examination methods, the diagnostic options available to the ophthalmologist were very limited until the middle and end of the nineteenth century. It was not until 1850 that Herrmann von Helmholtz invented the ophthalmoscope affording a view of the inside of the living eye for the very first time. This can be considered as the advent of modern ophthalmology and the birth of ophthalmic equipment making. Over the years, it has been demonstrated that no other organ necessitates the use of as many different optical-medical devices as the eye. It is also no surprise that ophthalmology has become by far the most successful application area of lasers in medicine since the invention of the laser in the 1960s. Ophthalmic and optometric methods and technologies have rapidly grown and matured during the last couple of decades and have actually seen an acceleration, but this is still a very active field of research today. Presenting an in-depth coverage of all the ongoing activities is certainly beyond the scope of this book. Consequently, we will try to walk the line between covering the more general and principal approaches in design, development and application of ophthalmic systems, and providing detailed background information on exciting current research topics.

As this book is intended to bridge technology and clinical domains, we will discuss modern optical technologies alongside their clinical deployment. In this way, it addresses graduate and postgraduate students in physics, electrical, mechanical, and biomedical engineering who want to gain a general insight into the principles and concepts of ophthalmic systems. We have also added some topic-related application-oriented “Problems” at the end of each chapter. The problems are presented with fully elaborated solutions, which can be downloaded from the reserved website of Wiley (<http://www.wiley.com>). These problems demonstrate how basic design parameters of an ophthalmic device are calculated.

Ophthalmologists and optometrists who want to gain a profound understanding of how the diagnostic and therapy systems work will also greatly benefit from the application oriented approach used in our book. We also give references to the most current and relevant literature throughout the chapters and in corresponding “Recommended Reading” sections. These references might be particularly useful for specialists or students who want to acquire further expertise in a special subject.

The book has a modular structure so that it can be used by readers with different backgrounds and interests. In the first part, a basic introduction to key aspects of ophthalmology and optometry is given, including a brief introduction to anatomy, optical properties, as well as refractive errors and diseases of the human eye. The second part is dedicated to ophthalmic diagnosis and imaging devices and techniques. Within this part, Chapter 4 gives as an overview of the link-up between common eye diseases and clinical conditions as well as relevant ophthalmic devices and methods. In the third part of this book, we focus on the therapeutic aspects of ophthalmology in which the use of laser systems is of particular importance. The appendix of this book provides the basics of optics and lasers, which are relevant to understanding the physical concepts of the presented ophthalmic and optometric systems. Here, the intention was not to present the entire content of textbooks on

Table 1 Examples of structured courses.

Background	Electrical Engineer	Biomedical Engineer	Physicist	Engineer/Scientist in practice	Ophthalmologist/Optometrist
Chapter 1	2	R	1	R	R
Chapter 2	3	R	2	R	R
Chapter 3	4	R	3	R	R
Chapter 4	5	2	4	R	1
Chapter 5	6	3	5	1	2
Chapter 6	7	4	6	2	3
Chapter 7	8	5	7	3	4
Chapter 8	9	6	8	4	5
Chapter 9	11	8	9	5	6
Chapter 10	12	9	10	6	7
Appendix A	1	1	R	R	X
Appendix B	10	7	R	R	X

optics and lasers, but rather to focus on the topics relevant to ophthalmic devices and to provide a consistent reference base and notation.

The chapters of this book may be combined in various ways for use in semester courses. Representative examples of such structured courses are shown in Table 1 in which we also suggest a potentially beneficial sequence for reading the chapters of this book. Topics which should have already been treated during a previous course or are considered to be already known are marked with an “R”, standing for “revision”.

Commonly accepted notation and symbols have been used whenever possible. However, as this book covers a number of different topics, a number of symbols exist that have multiple meanings. To avoid confusion, we have added an overview of abbreviations and symbols to the Appendix C.

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