Preface to the first edition

We started the project for this book some years ago. During our laboratory work, in particular, with students of Engineering Physics in the field of lasers and optics, we encountered various situations where the imaging of objects was required at different levels of quality. Examples included the imaging of laser-produced plasmas, imaging of microstructures fabricated by laser radiation, mask projection in lithographic applications, and profiles and focal spot distributions of laser beams, to imaging large objects such as complete breadboard setups and even converting images taken with conventional light microscopes for archival storage. In all cases, optical systems were required, often in combination with modern digital electronic sensors or cameras. With the continuous development of powerful and complex digital camera systems, however, we found that basic concepts, handling and requirements for achieving the desired quality of imaging should be conveyed as well to all people working with such systems. This has to be done at least in a condensed way, incorporating all necessary steps in the imaging process chain-like imaging optics, electronic detection and image processing. Our goal was that not only students, but also experienced engineers should become capable of understanding the requirements for a given imaging problem and finding the appropriate optical system for scientific and technical applications. Moreover, being passionate amateur photographers, we discovered that also for those interested in classical photography, a physical background and technical information could be helpful.

In a more general view, imaging belongs to the most important processes in human life. The human eye is usually the reference, and images are taken in daily life and displayed on TV, computer screens, smartphone screens and so on. Thus, we can regard imaging as an important subject in general. The present book treats this subject from a technological and scientific point of view and discusses nearly all aspects of imaging in general and still imaging in particular. Here, by "still imaging," we understand taking single images in contrast to imaging on video films. The intention is to show "what is behind" taking images and what information is contained in the images themselves.

The main title of the present book is "Optical imaging and photography" and indeed, emphasis is put on the topic of photography since photography is a topic that is demonstrative and easily accessible. This may also be of large interest for people with a bias in photography. However, imaging is treated universally, and this is indicated by the subtitle "Introduction to science and technology of optics, sensors and systems," which shows the much broader base of the topic. This book comprises a discussion of modern image detectors as used for science and technology. Imaging and imaging technology is also essential for a lot of modern technologies such as automation, robotics and autonomous vehicles, medical applications, etc. The goal of the present book is to take those into account, too. Thus, the intention to treat the important background for imaging in a more general way relates to applications in science and technology, and in particular, for industrial purposes. Indeed, during the proofreading our manuscript, we came across the

https://doi.org/10.1515/9783110789966-203

Edmund Optics booklet "2018 Imaging Optics, A Technical Resource for Imaging Solutions," which briefly touches on a lot of the topics discussed in the present book, and thus clearly shows that the contents of the present book are well- adapted to the mentioned goal and of interest for many technical applications.

There might arise the question: what are the unique features of the present book compared to the multitude of books on related topics on the market? There are a lot of books on photography. There are standard books on optics and/or optical sensors, and for instance, on technical and industrial imaging. And there are books going very deeply into specific topics such as lens design or sensor and semiconductor technology. However, we became aware that to the best of our knowledge there is a lack of available books that cover all relevant aspects of imaging and photography in total and in compact form, comprising aspects of the optical system and the electronic sensor parts. To some extent, the recommended book "Image Sensors and Signal Processing for Digital Still Cameras" edited by J. Nakamura, may be an exception. We like it very much, but there, emphasis is put on the topics of the title and, what is more, a complete discussion, for instance of Fourier optics, is missing. In addition, the book is more than 10 years old.

On the other hand, the internet may be regarded as a good source. There are excellent websites on specific topics. A short selection of recommended links is provided at the end of this book. But also here concatenation of the relevant subtopics is often missing, which means that imaging as an integrated whole has not been available. Even more, there exists also a lot of misleading information on dubious websites. The unexperienced reader cannot discriminate. This may often lead to a smattering of information, which consequently introduces errors. There are a lot of examples; in particular, sometimes good lenses designed for analogous cameras are wrongly judged when tested in cameras with digital sensors; or the rash opinion that a larger number of camera pixels is always better; or the immature judgment of exposure corrections by ±10 EV by a specific raw converter; or the idea of an enhancement of the dynamic range of an image by usage of smaller brightness steps, and so on. Here, we would like to stimulate the reader to be very critical when reading literature and articles on popular websites, even when written by "experts."

Based on our interest in photography and maybe even more on our general experience in optics and optical imaging sensors, which we teach in lectures and which we apply in scientific experiments and technical solutions, our goal has been to write a book that closes the gap between these very special topics. We present many details and, for instance, discuss lens system constructions, lens parameters like aspheric coefficients or special and advanced imaging sensors. Of course, the latter makes sense for scientific and technical imaging. But also for everyday imaging this may be important as the example of the development of the backside illuminated CCD sensor shows. Approximately 30 years ago, we belonged to the first users of those at that time purely scientific detectors. But today this technology is implemented in standard devices such as compact and smartphone cameras.

Although the book should provide a comprehensive and consistent description of (still) imaging and be a single unit, it cannot be fully complete because this would have been out of scope for a more or less compact book. But, in particular, we emphasized cross-linking the subtopics, such as lenses, sensors, Fourier optics and so on. The book restricts to the optical, or more generally, the physical and technical background of imaging, imaging process, imaging devices, etc. In that sense, the book should also provide the essential background information for understanding the further handling of images, especially image processing. But it does not provide a workflow of image and data processing, not even partially, because there are a lot of good books on that particular topic and our intention is not to add another one. Moreover, excluded are also details of color management, which are so extensive that they would fill a separate book. Excluded is also imaging for videos, a topic that requires a lot of additional and very special discussions. Excluded is also enhanced image processing. We also do not provide much information on norms, as they are predicated on what is described in the book and as they are subject to changes. Finally, the present book is not a book of photography in the sense of being a manual on taking good pictures in the artistic sense.

Thus, as a whole, the present textbook does not only serve as a tutorial suitable for beginners and advanced learners. It may also be used as a work of reference for scientists, engineers and photographers. Photographers should be encouraged to enlarge their technical understanding that subsequently may influence their photoshooting. Even more generally, the book may be useful for those employing and assessing imaging systems including industrial or machine vision cameras and for anyone interested in imaging. Thus, we hope that the book may be of interest for a wide audience. As we concentrate mostly on the physical background, we hope that even with future progress in the field of optical imaging, the book will still be up to date for a long time given the fact that for instance sensor chips, pixel size and so on may change within the next few years, but not principal relations such as photon conversion and tone curves.

Finally, we would like to give some remarks on the book's structure. The strong concatenation of the different subtopics within the book makes it sometimes necessary to use some knowledge in anticipation of a more detailed description later on. Chapters 1 and 2 have a kind of introductory character to imaging, also with a focus to photography and examples of modern camera systems. Chapter 3 presents the basics of imaging optics that are required to understand the complexity of optical systems like modern camera lenses. Their historical evolution during the last two centuries as well as their differentiation today is given in Chapter 6, mostly based on examples of the photographic full format. Background information for sensors and detectors is given in Chapter 4 to comprehend their characteristics like noise, resolution, speed, etc., illustrated by many practical examples. We keep the discussion on electronics rather short and refer to special literature or books with a different emphasis. In Chapter 5, Fourier optics is considered in order to make out the overall transfer function of complete optical systems. Examples show how the overall quality of a system can be assessed and influenced. Chapter 8 describes some practical methods by which a multitude of different optical systems can

be experimentally investigated. Some data sheets of commercially available lenses are presented, which describe their technical properties based on the investigations. In the closing Chapter 9, we dare some outlook of modern trends in optical imaging.

It is common in most textbooks that known basics are presented without detailed reference to sources. Hence, we forgo a detailed reference list. However, some selected books and articles that aid in orientation with the topics in a broader sense are compiled in the reference list at the end of the book. In cases where a singular reference is helpful, we inserted a footnote.

During the compilation of the present book, we got many valuable comments and hints directly or indirectly from various people who have influenced the progress of this book. Representatively, we would like to express our thanks to our long-time colleague, Prof. Dr. Bert Struve, for many fruitful discussions. We are also much indebted to Dr. Vladan Blahnik from the Corporate Research and Technology of Carl Zeiss AG for his kind support and valuable comments on our manuscript. We would like to thank Eberhard Dietzsch for discussions and William Claff for information on sensor data. Hartmut Jesch and the ProxiVision team, Uwe Artmann and all companies providing us with images, are given thanks. Furthermore, we are most grateful for technical support given by many staff members, our PhD students and students of our universities in Emden and Oldenburg, among which we would like to mention particularly, Volker Braun, Johannes Diekhoff, Malte Ennen, Lars Jepsen, Arno Hinrichs, Brian Holt, Gregor Indorf, Christian Menninger, James Napier, Markus Schellenberg and Sabine Tiedeken. Their help is greatly appreciated. We also extend our gratitude to Walter de Gruyter Verlag for the opportunity to present our understanding of optical imaging to an international audience. In particular, we would like to thank Konrad Kieling for the support at the initial phase of this book and Nadja Schedensack and Anett Rehner for their commitment and patience during the realization of this book.

The warmest thanks go to our families for their valuable backing and understanding during all phases of this demanding project.

Emden, September 2018

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