Foreword

With photography over the past quarter century, digital imaging has changed the way we share information and how we preserve memories in unprecedented ways. Gone are the days when you drop off 24 frames on a film roll at your local photoshop and wait a week for the prints, eventually only to find the shots are blurry or overexposed. Digital photography has created endless possibilities because the images are immediately available and transferable and can also be modified, combined and processed.

The doubts before the beginning of the millennium as to whether digital image sensors could ever achieve the resolution of high-resolution film while remaining affordable have dissipated just as quickly as questions about compact storage media that could process and store the huge amounts of data. In the 1980s and 1990s, around 20 million cameras were sold annually, ranging from the compact camera to the professional SLR camera. Today alone, 100 times as many smartphones with cameras are sold each year, i. e., almost 2 billion annually. In the 1990s, who would have thought the image quality of modern smartphone cameras that fit in a thimble, weigh just a few grams and cost less than €30 as a system component? This image quality and the linking of image data to communication networks have made digital photography so widespread today that most people around the world always carry a digital camera, constantly preserving and communicating their experiences with images. The functions of the camera have long since expanded from snapshots with friends and family to personal authentication for access to money, document scanning or data transfer via QR scan. In the future, the number of digital camera systems will continue to multiply, which will further be integrated seamlessly into our everyday lives. Billions of development funds are being invested in the development of AR glasses, autonomous driving or mobile healthcare systems.

A book on “Optical Imaging and Photography” that provides the physical fundamentals of these applications, and their technical solutions is therefore highly topical. Ulrich Teubner and Hans Josef Brückner, two professors of physics as well as enthusiastic photographers, fill a gap by comprehensively treating all aspects of digital (and analogue) photographic imaging in a single book. This is unique in the compilation. Until now, you would have had to get many different books respectively about photography and optics, optical design, Fourier optics, camera and image sensor technology and image processing. In addition, for this compilation of state-of-art technology you would have to research masses of information and data on specific camera systems, lenses, camera qualification metrology as well as the rapidly advancing developments of modern CCD or CMOS sensors from magazines, Internet sources and directly from manufacturers in the industry over many years.

Digital imaging, particularly the interplay between optics and image sensors, is the focus of the book. Nevertheless, the presentation is more fundamental: Ulrich Teubner and Hans Josef Brückner comprehensively introduce the reader to the physical basics of

https://doi.org/10.1515/9783110789966-201

all aspects of optical imaging for photography, the technical implementation of modern photo-optical systems and their performance metrics and the associated test setups from manufacturers or test institutes for the measurement of MTF curves, straylight, dynamic range, etc.

The fundamentals of “optical imaging” include the paraxial imaging equations and, for the calculation of intensity distributions, a wave-optical modeling. Wave-optical modeling, namely “Fourier optics,” includes the fundamental limitation of image resolution due to diffraction as well as lens aberrations. Practical photography requires many more aspects of optical imaging, which only very rarely all occur simultaneously for industrial applications under laboratory conditions.

The imaging is essentially three-dimensional and requires lenses that can focus over a large depth range. On the other hand, there is limited depth-of-field, which depends on basic parameters such as f-number, focal length and object distance. In turn, the “blurring in depth,” which the photographer calls “bokeh,” exhibits special properties of the lens such as vignetting due to field diaphragms or various types of aberrations. Premium manufacturers, in addition to achieve good performance in best-focus, spend considerable effort to optimize lenses also for an appealing bokeh.

Practical photography often extends over a large dynamic range, i. e., the simultaneous presence of bright objects or light sources and dark areas. Irradiance variations of over 5 orders of magnitude or more in the scene requires image sensors as well as “HDR” imaging methods that can display these light and dark areas simultaneously. They should be displayed in such a way that fine nuances of brightness or color deviations can be distinguished by the viewer and the depiction of the scene appears natural to the human viewer at the same time. If this high dynamic range is enabled by the image sensor, then there are still the lenses, which might limit the image performance by producing disturbing ghost images or stray light haze in the image depending, e. g., on the quality of antireflective coatings.

Photographic lenses have to support the very high resolution of modern image sensors right up to “high speeds,” i. e., high apertures, and this over the entire wavelength range of visible light. In addition, lenses should often be as flexible as possible, i. e., “zoomable” over a large field-of-view and focusable for a large distance range. All this is practically not compatible in one type of lens, at least not for a practical, portable system. That is why there are many different lens types such as “zoom,” “macro,” “tele” or “wide angle.” In addition to many examples of current photo lenses on the market, Ulrich Teubner and Hans Josef Brückner also present various classic optical designs such as Double-Gauss, retrofocus type, telephoto lens, etc. and discuss the connections between the layout and optical aberrations and camera space constraints.

In addition, there are many other aspects of optical imaging for photography such as relative movements and image stabilization, environmental dependencies such as different temperatures or underwater photography, the use of comprehensive image processing including digital aberration correction, etc. This makes it clear that a representation like this one by Ulrich Teubner and Hans Josef Brückner on the optical imaging of practical photography must be very versatile, and of course, contain many other applications such as machine vision in large parts automatically.

Current digital camera systems on the market are discussed, some with interesting cross-comparisons, example.g., between smartphone cameras and large-format system cameras. For this comparison of "small" and "big" imaging systems, there are immutable physical laws: The étendue, which shrinks with the miniaturization of the optics, requires either longer exposure times or higher ISO sensitivity with a side effect on image noise. The latter reintroduces texture artifacts into the image using software-based noise reduction. Other fundamental physical effects of the miniaturization of image sensors are the increased depth of field or the limited resolution due to diffraction. These and many other complex mechanisms are described concisely with their impact on image quality. Image imperfections such as due to optics, e. g., aberrations, scattered light, ghost images, etc. or due to the image sensor such as noise, pixel sampling, rolling shutter, blooming, image lag, etc. are not only explained for themselves, but also the cause of their occurrence. At the end of the digital imaging chain, there is the representation on the display and the perceived image quality of the human observer. Accordingly, the authors also discuss perceived quality for common viewing conditions, e. g., depending on whether the images are viewed on the camera or smartphone display or enlarged on a computer screen. Sometimes their analysis concludes critically, as not all technical specifications and developments in the consumer camera market led to actual improvements of perceived image quality but were sometimes rather driven by marketing. The book is full of excellent illustrations, tabular data overviews and image comparisons for reference.

In a rapidly changing field, the blessing of application orientation presentation is always accompanied by the curse of no longer being up to date for the newest developments after a few years. Many new developments were added to the new edition, such as the multicamera systems and their multicell image sensors for smartphones, miniaturized 3D acquisition systems, the use of computational imaging or the digital correction of image errors in the optics among many other topics. However, despite all those new developments, most of the presentation will remain up to date for many years.

In the research and development of digital image systems, the entire digital image chain must be considered today when optimizing camera systems: Do all parts of the image chain, i. e., the optics, the image sensor and the image processing, harmonize? How can I improve the weakest part? Can I compensate for hardware deficits computationally by software? With what side effects? You have to ask yourself this for a huge number of camera settings, external conditions and image motifs, whether bright sunshine, twilight and darkness or high dynamic range, i. e., very bright and dark image parts at the same time, as well as different image motifs, whether finely structured, high-contrast or with fine brightness or color nuances.

So, this book is of interest to a great many, especially to those with a technical or physical education who are interested in photography. But it is also a reference book that should be on the desk of scientists and engineers of digital optical imaging systems or setups using those, whether for photographic or industrial applications.

Oberkochen, March 15, 2023 Vladan Blahnik