Introduction

The German Agenda "Optical Technologies for the 21st Century" describes optical technologies as enabling technologies for other technical fields and their applications in the future [1], which has just recently been confirmed by a study of the German Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF, [2]). Already at the very beginning of this twenty-first century, optical sensors play a vital role in virtually every technical application: from simple light barriers to complicated white-light interferometers, from automotive rain sensors to high-resolution scanning near-field optical microscopes, there are sensors to measure a wide variety of measurement properties.

Optical sensors offer various advantages over their electronic and/or mechanical counterparts. Apart from their wide dynamic range and lower noise levels, optical sensors react on any change in the measurement properties literally with the speed of light. Also, the noncontact nature of the optical measurement avoids all systematic errors that come with tactile techniques. Consider the measurement of brake path lengths in vehicle testing: a well-established technique employs a combination of a so-called fifth wheel with an incremental encoder. To calculate the measurement result with sufficient measurement uncertainty, the wheel diameter must be known with the same precision. Here, the wheel slip will introduce systematic measurement errors. This is why the majority of automobile manufacturers relies on sensors that determine dynamic measurement properties from the optical cross-correlation between an image of the road surface and an optical grating [3].

Much effort is taken to miniaturize optical sensors and to integrate them into electrooptical chip designs. Not only the wide availability of megapixel-size imaging sensors, for example, for mobile phones, notebook computers, and miniaturized surveillance cameras, but also the ubiquitous optical computer mouse with its highly integrated sensor chip and optics are well-known examples. It is interesting to note that this high integration of state-of-the-art optical systems can also be found in biological systems, for example, in the optical system that is most important for all of us: the human eye. In a first approximation, it works like a simple hole camera with a layer of photoreceptors in its image plane. However, the "inverted" design of the retina seems quite strange from an optical designer's point of view: the light receptors are arranged behind several tissue layers and

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should therefore actually be subject to significant light scattering. It has just recently been revealed that the so-called Müller cells are the crucial functional elements inside the retina: They form an effective image-guiding optical fiber plate and, thus, transport the received image without significant losses across the cell layers directly to the light receptors [4].

Regardless of their working principles and purposes, all optical sensors have a common set of components: light sources, photodetectors, and optical components to guide the light in between. Somewhere along this light path, there will be the measurement object whose static and dynamic properties will determine the signal on the photodetector and, thus, the sensor reading. In order to understand the working principles of different optical sensors, it is therefore necessary to learn about the possible types of illumination and detection hardware, and about the various optical components that may be used. This will be discussed in Part One of this book. In Part Two, setups of different optical sensors are presented. They will be arranged according to the physical or chemical quantities that the sensors are intended to measure. Due to the large variety of optical sensors available today, this collection will not claim completeness, but will illustrate the state-of-the-art in optical sensor technology. Part Three will shed some light on the role of optical sensors in physics – it describes a laser-spectroscopic experiment from the author's physical background and its elaborate experimental setup. Some of the components employed in this setup have also been discussed in Part Two. The third part tries to give some brief introduction to the physical principles behind the experiment, but it does in no way want to ask too much from the reader.

The idea of this book is to bridge the gap between classical optical textbooks and monographies on particular optical sensor technologies. While the former cover all aspects of physical optics with sometimes only basic descriptions of applications, the latter delve deep into singular applications without detailed descriptions of the physical and optical basics. This leaves room for an introductory textbook, which is both aimed at students of all relevant engineering and scientific disciplines, and at interested professionals in all industries in which optical sensors are employed. It is intended to cover both aspects to an extent that gives the reader not only an idea about how different optical sensors work, but also about the possible fields of application and their respective limits.

No textbook that covers a topic like this can avoid to give references to commercially available sensors and sensor systems. The reader should note that any company and brand names are properties of their respective owners. Although the author has and had affiliations with at least one of the companies mentioned in the text, all examples are mere snapshots of the market situation and do not express recommendations for particular products or manufacturers. Similarly, the specifications listed up in the various tables are intended to give "typical" sensor data. The reader is strongly encouraged to do some research on his or her own, for example, on the Internet, in case an optical sensor shall be employed for a measurement task.

References

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