

# Chapter 1

## Introduction

**Abstract** In the introductory chapter, we first give an overview of the evolution of optical and laser metrology. Then we outline the wide range of laser measurement technology. Finally, we point to the fact, that laser metrology is a non-contact measurement with high flexibility, high measuring speed and high precision.

### 1.1 Optical Metrology and Laser Measurement Technology

Today there are plenty of different measurement technologies available that one single scientist or engineer can hardly overlook. Hence measurement technologies are divided into different sub-disciplines. Besides electrical metrology a very important discipline is physical metrology. It was developed in need of special measurement instruments—such as thermometers, clocks, scales or microscopes—for physics and engineering. Nowadays physical metrology is divided into very different autonomous areas such as nuclear physics metrology, acoustic measurement technology or optical metrology.

Optical measurement methods have gained a prominent importance for metrology. Although optical measurement technology is a rapidly growing area, it is not a new discipline. The development of physical sciences has been affected from the very beginning by optical measurement techniques. With the invention of the microscope in the late 16th century and the telescope in the early 17th century, optical measurement technology has contributed significantly to the study of micro- and macrocosm. Other milestones in optical metrology have been the development of photography and spectroscopy in the 19th century. The latter offers important insights into the structure of matter. In the 20th century optical metrology has provided significant contributions to the development of science. This is evidenced inter alia by the awarding of Nobel Prizes for the development of interferometric precision instruments for spectroscopic and metrological studies

(A. Michelson), of Raman scattering (C. Raman), of phase contrast microscopy (F. Zernike), of holography (D. Gabor), nonlinear optics with lasers (N. Bloembergen, A. Schawlow), of ultraprecise laser spectroscopy (J. Hall, T. Hänsch) and CCD sensors (charged coupled devices to detect optical radiation; W. Boyle, G. Smith).

In 1960 Theodore Maiman realized the first laser. Lasers are currently used for various applications, e.g. in communication technology, material processing and medicine. With the compact disc, the laser is to be found even in many households. Due to the laser, some conventional methods were substituted by novel technologies. Laser ablation or laser additive manufacturing (LAM) are examples: These processes are capable to produce shapes of workpieces, which cannot be realized with conventional machining. Generally, laser technology is now considered to be a key technology, comparable to microelectronics.

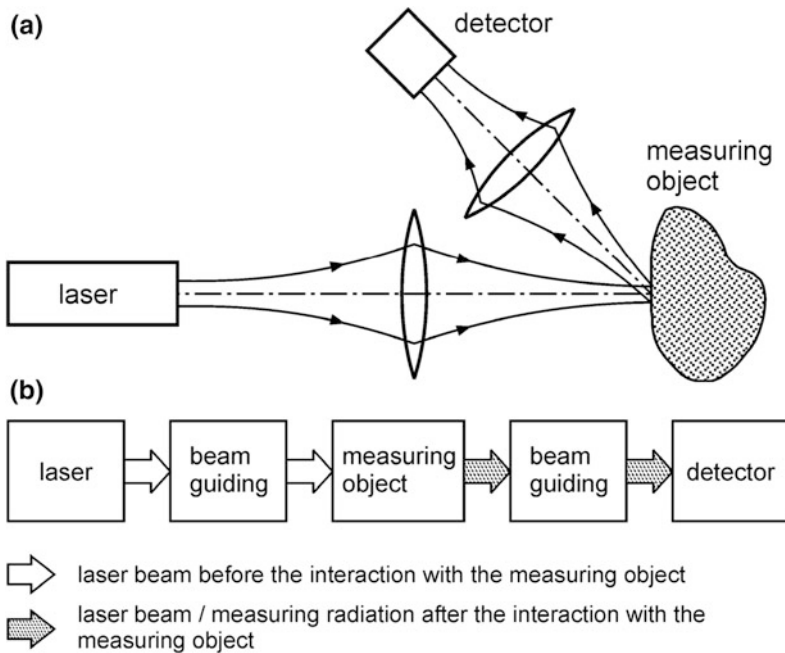
Due to its special characteristics, laser beams are also versatile measurement tools. Immediately after the invention of the laser, a new branch of measurement technology was established: laser measurement technology. Laser measurement technology has developed dynamically in recent years. Its applications range from production engineering via process engineering, quality assurance, recycling technology, environmental protection, biotechnology up to medical technology. The characteristics of laser measurement technology are:

- non-contact measurement,
- high flexibility,
- high measuring speed and
- high precision.

Laser-based measurement methods are increasingly used in manufacturing processes where a routine testing of each produced good is required. The growing importance of process and quality control in manufacturing has accelerated sustainably the development of laser measurement technology in many areas.

The capability of non-contact measurements is often decisive to deploy laser measuring systems in production lines. Lasers are measuring quality-critical features without interrupting the production flow, thus providing in realtime data for direct process control. Utilization of this inline capability enables to automate test procedures straightforwardly, to optimize production processes and to improve product quality significantly in a variety of applications.

The aim of this book is to present the basics of laser measurement technology. In Chaps. 1–5, the physical principles of laser technology are discussed. Chapters 6–14 are dedicated to different laser measurement techniques. From the variety of methods used today, we have made a selection. The selection criteria are technological maturity and commercial availability. For each laser measurement method described, we present typical applications. The Appendix offers supplemental information on the topics interference visibility and spectral radiance as well as some derivations of formulas. A list of abbreviations and symbols completes the Appendix.



**Fig. 1.1** Laser measuring system: **a** principal set-up, **b** block diagram

## 1.2 Schematic Set-up

Figure 1.1a shows the basic set-up of a typical laser measuring system. The three main components are:

- laser,
- measuring object and
- detector.

The radiation of the laser interacts with the object to be measured. During this interaction, information of the measuring object is impressed to the laser radiation. A part of the radiation reaches the detector, which converts the information stored in the light into a recognizable form for the observer. Between laser and measuring object and between measuring object and detector, elements for beam shaping and guiding are arranged in general. Examples of such elements are focusing optics, beam expanders or optical fibers.

The components shown in Fig. 1.1b are described in Chaps. 2–5. Chapter 2 provides an overview of the properties of laser radiation. The different possibilities of interaction between laser radiation and measuring object are discussed in the third chapter. In Chap. 4, the main elements of beam shaping and guiding are presented. Chapter 5 describes the most common radiation detectors. The

knowledge gained in the first part of the book, is necessary to understand the laser measurement methods treated in Chaps. 6–14. In addition, it provides the necessary basic knowledge to follow competently the latest developments in laser measurement technology.

Laser Measurement Technology

Fundamentals and Applications

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