The problems involved in designing optimal infrared (IR) measuring systems under given conditions are commensurately complex. The optical set-up and radiation conditions, the interaction between sensor and irradiation and the sensor itself, determine the operation of the sensor system. Simple calculations for solving these problems without any understanding of the causal relationships are not possible.

*Thermal Infrared Sensors* offers a concise explanation of the basic physical and photometric fundamentals needed for the consideration of these interactions. It depicts the basics of thermal IR sensor systems and explains the manifold causal relationships between the most important effects and influences, describing the relationships between sensor parameters such as thermal and special resolution, and application conditions.

This book covers:
- various types of thermal sensors, like thermoelectric sensors, pyroelectric sensors, microbolometers, micro-GOLAY cells and bimorphous sensors
- basic applications for thermal sensors
- noise – a limiting factor for thermal resolution and detectivity – including an outline of the mathematics and noise sources in thermal infrared sensors
- the properties of IR sensor systems in conjunction with the measurement environment and application conditions
- 60 examples showing calculations of real problems with real numbers, as they occur in many practical applications

This is an essential reference for practicing design and optical engineers and users of infrared sensors and infrared cameras. With this book they will be able to transform the demonstrated solutions to their own problems, find ways to match their commercial IR sensors and cameras to their measurement conditions, and to tailor and optimise sensors and set-ups to particular IR measurement problems. The basic knowledge outlined in this book will give advanced undergraduate and graduate students a thorough grounding in this technology.

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THERMAL INFRARED SENSORS
THERMAL INFRARED SENSORS
THEORY, OPTIMISATION AND PRACTICE

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For Prof. Dr. Ludwig Walther, founder of the Dresden Infrared School
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Preface

Until only a few decades ago, infrared technology was mainly the domain of military technology. In recent times, though, it has invaded an increasing number of new applications in our everyday lives. Examples are motion and fire detectors, ear thermometers, sensors that register the degree of browning in toasters, hand pyrometers for the contactless measuring of temperatures and thermal imaging devices. Infrared sensors are even the basis for new areas of application such as technical diagnosis, non-destructive evaluation methods, environmental monitoring, gas sensors and remote sensing.

The technical interest in infrared radiation is due to the fact that it can be used both to determine the temperature without contact and thus the presence of bodies as well as the characteristics of bodies themselves including their structures:

- At room temperature, the maximum specific spectral radiation of blackbodies amounts to an approximate wavelength of 10 μm. This radiation wavelength range is therefore of fundamental importance for detecting real objects and determining their characteristics.
- The bond between the atoms of organic and anorganic molecules show resonance frequencies that almost always correspond to wavelengths in the infrared spectral range. If we can determine the frequency – or wavelength-related reflecting, transmitting and absorbing characteristics of substances and mixtures of substances – we can also determine the atomic or molecular structure of materials.

The increasing technical utilisation of infrared radiation in the mentioned areas of application is also related to central development trends in infrared measuring technology:

- Improved characteristics of infrared detectors. Research focuses particularly on increasing detectivity and improving the temperature resolution of such sensors as well as the transition to uncooled sensor principles.
- Development of highly integrated sensor arrays. Large pixel numbers of detector arrays require the miniaturisation of components and thus also the transition to semiconductor technology and the integration of sensor element and evaluation electronics. Thin layers on silicon substrates, the use of standard circuitry for evaluation electronics and the development of improved circuit technologies are of particular importance.
- Optimisation of infrared measuring systems. Here, the research focus is on the improvement of all system components and the optimisation of the characteristics of the total system.
Analysis and development of new applications: contactless, emissivity-independent temperature measurements, spectroscopic applications, miniaturised spectroscopy, multicolour sensors, recognition systems and many more.

Thermal infrared sensors, in particular, are very important for civil applications as they can be used – as opposed to quantum detectors – in a non-cooled state and are therefore suitable for small and cost-efficient solutions and thus for large quantities.

Today, we do not only have a vast number of applications of thermal infrared sensors, but also the technological requirements regarding size, design, optical conditions, thermal and spatial resolution and many other framework conditions have diversified. This has resulted in very complex issues that users have to solve when trying to design optimum measuring arrangements or conditions. Each individual part of the measuring chain affects the relation between the source of the infrared radiation and the output signal of the measuring system. For this reason there are no simple rules and the problems cannot be solved without a basic understanding of the correlations.

There is a very limited number of textbook-like presentations available that summarise these issues. The present book intends to fill this gap by providing explanations of the essential basics of thermal infrared sensors and the correlation between the diverse effects. Using a large number of examples we will systematically show how this basic knowledge can be applied to the solution of specific tasks. Although the authors start with introducing the physical basics, they will only develop them to the point where they are necessary for real-life, recalculable ups with specific characteristics.

The goal of this book is to create a basic manual for users. It is intended to provide engineers, technicians, technical management, purchasers, and equipment suppliers with practical knowledge regarding the usage of modern infrared sensors and measuring systems. The book focuses on thermal infrared sensors. This way, we want to avoid exceeding the scope and keep it handy. The authors agreed that this would not constitute any serious restriction. On the one hand, it is mainly the uncooled, thermal sensors that represent the largest increases in commercial sales and determine the major part of new applications. On the other hand, it is possible to transfer major parts of the information to quantum detectors.

The present book is based on lectures on infrared measuring technology that the authors have held during many years at the Technische Universität Dresden, Germany. This book, however, was designed in a completely different way in order to turn the information into a basic user manual. This means this publication has been a new experience for us, too. We are aware that it will not be complete right away, and would therefore appreciate corrections, ideas, and suggestions for improvements (Helmut.Budzier@tu-dresden.de; Gerald.Gerlach@tu-dresden.de).

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Helmut Budzier, Gerald Gerlach
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