Detection of Light

Detection of Light provides a comprehensive overview of the important approaches to photon detection from the ultraviolet to the submillimeter spectral regions. This expanded and fully updated second edition discusses recently introduced types of detector such as superconducting tunnel junctions, hot electron bolometer mixers, and fully depleted CCDs, and also includes historically important devices such as photographic plates. Subject matter from many disciplines is combined into a comprehensive and unified treatment of the detection of light, with emphasis on the underlying physical principles. Chapters have been thoroughly reorganized to make the book easier to use, and each includes problems with solutions as appropriate. This self-contained text assumes only an undergraduate level of physics, and develops understanding as it is needed. It is suitable for advanced undergraduate and graduate students, and will provide a valuable reference for professionals in astronomy, engineering, and physics.

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Detection of Light

From the Ultraviolet to the Submillimeter

SECOND EDITION

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Preface

This book provides a comprehensive overview of the important technologies for photon detection from the millimeter-wave through the ultraviolet spectral regions. The reader should gain a good understanding of the similarities and contrasts, the strengths and weaknesses of the multitude of approaches that have been developed over a century of effort to improve our ability to sense photons. The emphasis is always upon the methods of operation and physical limits to detector performance. Brief mention is sometimes made of the currently achieved performance levels, but only to place the broader physical principles in a practical context.

Writing is a process of successive approximations toward poorly defined goals. A second edition not only brings a book up to date, it also allows reconsideration of the goals and permits a new series of approximations toward them. Specific goals for this edition are to:

- Provide a bridge from general physics into the methods used for photon detection;
- Guide readers into more detailed and technical treatments of individual topics;
- Give a broad overview of the subject;
- Make the book accessible to the widest possible audience.

Based on the extensive survey of the literature that accompanied preparation of this edition, these goals have led to a unique book. It combines subject matter from many disciplines that usually have little interaction into a comprehensive treatment of a unified topic (in preparing the book, I frequented at least a dozen distinct areas in the library!).

I have restricted the physics assumed in the book very strictly to the level attainable after only a semester or two of college-level physics with calculus. To supplement this minimal background, the first chapter includes overviews of radiometry and solid state physics. Although many readers may want to skim this material, it gives others with less preparation a reasonable chance of understanding the rest of the book. Although the required preparation is modest, the subject matter is carried to a reasonably advanced level from the standpoint of the underlying physics. Because the necessary physics is developed within the discussion of detectors, the book should be self-contained for those who are outside a classroom environment.

The discussion is designed to interface smoothly with the specialized literature in each area. In fact, since the writing of the first edition many books and review articles have appeared on specific topics in photon detection. The possibilities for further exploration of the subjects introduced here are therefore much richer than before. This book is designed to bridge between general physics and these other books and reviews with their focus on advanced topics and their assumption of a substantial specialized knowledge of the relevant physics. Each chapter ends with a short listing of recommended sources for further reading, details of which are given in References. I have followed the suggestions of some reviewers of the first edition and separated the bibliography into sections for each chapter to help readers move even further into the literature on topics of interest to them.

Although restricting the level of assumed physics is a first step toward a widely accessible book, it is not sufficient. As with most books, this one is probably best read from beginning to end in the order of presentation. Doing so will reward the reader with a broad and self-consistent understanding of photon detection that would be difficult to obtain from any other source. However, I am aware that very few readers will take this approach. A number of features should help one read the book in a more normal if less organized fashion.

- Each chapter begins with a single-paragraph overview of its contents. These paragraphs are a bit like abstracts of the chapter and should be of interest to readers who will skip reading the chapter but would like a short summary of its contents.
- The first major section of each chapter gives a more detailed summary, but still a summary. This section will help place the more detailed discussions in the following sections into context.
- Each chapter is reasonably self-contained. An exception is that Chapter 1, on background matters, and Chapter 2, which introduces many basic concepts, are recommended as general reading. Otherwise, the book is analogous to a series of interrelated short stories rather than to an elaborately plotted novel.
- Any unique symbols in equations are defined near the equation, not in some preceding chapter, even if the result is a small amount of repetition. Symbols are also included in the index (except for standard physical constants and parameters used only once in the text), which will lead readers to their initial

introductions in the book. As a result, it should be possible to pick an isolated topic and develop a reasonable understanding of it without assimilating all the preceding material.

Because of these features, there are many ways to read the book. Chapters 1, 2, 5, and 6 provide a focused text on solid state detectors and arrays for the visible. If desired, the treatment can be expanded to photodiodes by adding Chapter 4, to photomultipliers and image intensifiers with Chapter 7, and/or to photography with Chapter 8. A focus on near-infrared detectors and arrays can be obtained from Chapters 1, 2, 4, 5, and the first and last sections of Chapter 6. Mid- and far-infrared devices can be added by reading Chapter 3. Submillimeter approaches are discussed fully in Chapters 1, 9, 10, and 11. The book also will serve readers who want to sample broadly but not deeply, for whom simply reading the first section of each chapter should provide a largely nontechnical overview of all the detection approaches discussed.

Finally, an accessible book needs to be carefully organized and written, and I have paid very careful attention to these attributes. Technical books should be considered works of serious nonfiction, nothing more daunting. It is my hope that this book can be approached in a manner readers might use with other works of nonfiction, particularly if they leave the equations to provide deeper levels of meaning on a second reading.

So far as seemed reasonable, MKS (meter, kilogram, second) units have been used. There are some cases, however, in which some other unit is predominant in usage, frequently because it has a "natural" size for the application. In these cases, the commonly employed system has been used in tabulations of parameters to maintain continuity with other literature. However, formulas are in MKS. Errors can be easily avoided by rigorously carrying units through all calculations. A table of the important physical constants is included as Appendix A; it also includes selected conversions from "conventional" units to MKS.

I am indebted to many people for making me aware of resources and for assistance in reviewing the material for the first edition, including John Bieging, Mike Cobb, Rich Cromwell, John Goebbel, Art Hoag, Jim Kofron, Michael Kriss, Frank Low, Craig McCreight, Bob McMurray, Harvey Moseley, Paul Richards, Fred, Marcia, and Carol Rieke, Gary Schmidt, Bill Schoening, Michael Scutero, Ben Snavely, Chris Walker, and Erick Young. They have been augmented by Jason Glenn, Nancy Haegel, George Jacoby, Gerry Neugebauer, Cynthia Quillen, and Tom Wilson for the second one. I thank Karen Visnovsky and Karen Swarthout for their assistance with the first edition, much of which is carried over into the second one. I also thank a number of classes of students at the University of Arizona for their comments on the lecture notes that evolved into this text.

Any corrections, suggestions, and comments will be received gratefully. They can be addressed to the author at grieke@as.arizona.edu.

George Rieke