VOLUME 6
Active Electro-Optical Systems
Clifton S. Fox, Editor
Active
Electro-Optical
Systems

The Infrared and Electro-Optical Systems Handbook
The Infrared and Electro-Optical Systems Handbook

Joseph S. Accetta, David L. Shumaker, Executive Editors

**VOLUME 1.** Sources of Radiation, George J. Zissis, Editor
Chapter 1. Radiation Theory, William L. Wolfe
Chapter 2. Artificial Sources, Anthony J. LaRocca
Chapter 3. Natural Sources, David Kryskowski, Gwynn H. Suits
Chapter 4. Radiometry, George J. Zissis

**VOLUME 2.** Atmospheric Propagation of Radiation, Fred G. Smith, Editor
Chapter 1. Atmospheric Transmission, Michael E. Thomas, Donald D. Duncan
Chapter 2. Propagation through Atmospheric Optical Turbulence, Robert R. Beland
Chapter 4. Nonlinear Propagation: Thermal Blooming, Frederick G. Gebhardt

**VOLUME 3.** Electro-Optical Components, William D. Rogatto, Editor
Chapter 1. Optical Materials, William L. Wolfe
Chapter 2. Optical Design, Warren J. Smith
Chapter 3. Optomechanical Scanning Applications, Techniques, and Devices, Jean Montagu, Herman DeWeerd
Chapter 4. Detectors, Devon G. Crowe, Paul R. Norton, Thomas Limperis, Joseph Mudar
Chapter 5. Readout Electronics for Infrared Sensors, John L. Vampola
Chapter 6. Thermal and Mechanical Design of Cryogenic Cooling Systems, P. Thomas Blotter, J. Clair Batty
Chapter 8. Photographic Film, H. Lou Gibson
Chapter 9. Reticles, Richard Legault
Chapter 10. Lasers, Hugo Weichel

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Chapter 2. Electro-Optical Imaging System Performance Prediction, James D. Howe
Chapter 3. Optomechanical System Design, Daniel Vukobratovich
Chapter 4. Infrared Imaging System Testing, Gerald C. Holst
Chapter 5. Tracking and Control Systems, Robert E. Nasburg
Chapter 6. Signature Prediction and Modeling, John A. Conant, Malcolm A. LeCompte

**VOLUME 5.** Passive Electro-Optical Systems,
Stephen B. Campana, Editor
Chapter 1. Infrared Line Scanning Systems, William L. McCracken
Chapter 2. Forward-Looking Infrared Systems, George S. Hopper
Chapter 3. Staring-Sensor Systems, Michael J. Cantella
Chapter 4. Infrared Search and Track Systems, Joseph S. Accetta

**VOLUME 6.** Active Electro-Optical Systems, Clifton S. Fox, Editor
Chapter 1. Laser Radar, Gary W. Kamerman
Chapter 2. Laser Rangefinders, Robert W. Byren
Chapter 3. Millimeter-Wave Radar, Elmer L. Johansen
Chapter 4. Fiber Optic Systems, Norris E. Lewis, Michael B. Miller

**VOLUME 7.** Countermeasure Systems, David Pollock, Editor
Chapter 1. Warning Systems, Donald W. Wilmot, William R. Owens, Robert J. Shelton
Chapter 2. Camouflage, Suppression, and Screening Systems, David E. Schmieder, Grayson W. Walker
Chapter 3. Active Infrared Countermeasures, Charles J. Tranchita, Kazimieras Jakstas, Robert G. Palazzo, Joseph C. O'Connell
Chapter 4. Expendable Decoys, Neal Brune
Chapter 5. Optical and Sensor Protection, Michael C. Dudzik
Chapter 6. Obscuration Countermeasures, Donald W. Hoock, Jr., Robert A. Sutherland

**VOLUME 8.** Emerging Systems and Technologies,
Stanley R. Robinson, Editor
Chapter 1. Unconventional Imaging Systems, Carl C. Aleksoff, J. Christopher Dainty, James R. Fienup, Robert Q. Fugate, Jean-Marie Mariotti, Peter Nisenson, Francois Roddier
Chapter 2. Adaptive Optics, Robert K. Tyson, Peter B. Ulrich
Chapter 3. Sensor and Data Fusion, Alan N. Steinberg
Chapter 5. Directed Energy Systems, Gary Golnik
Chapter 6. Holography, Emmett N. Leith
Chapter 7. System Design Considerations for a Visually-Coupled System, Brian H. Tsou
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The Infrared and Electro-Optical Systems Handbook

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Preface

The Infrared and Electro-Optical Systems Handbook is a joint product of the Infrared Information Analysis Center (IRIA) and the International Society for Optical Engineering (SPIE). Sponsored by the Defense Technical Information Center (DTIC), this work is an outgrowth of its predecessor, The Infrared Handbook, published in 1978. The circulation of nearly 20,000 copies is adequate testimony to its wide acceptance in the electro-optics and infrared communities. The Infrared Handbook was itself preceded by The Handbook of Military Infrared Technology. Since its original inception, new topics and technologies have emerged for which little or no reference material exists. This work is intended to update and complement the current Infrared Handbook by revision, addition of new materials, and reformatting to increase its utility. Of necessity, some material from the current book was reproduced as is, having been adjudged as being current and adequate. The 45 chapters represent most subject areas of current activity in the military, aerospace, and civilian communities and contain material that has rarely appeared so extensively in the open literature.

Because the contents are in part derivatives of advanced military technology, it seemed reasonable to categorize those chapters dealing with systems in analogy to the specialty groups comprising the annual Infrared Information Symposia (IRIS), a Department of Defense (DoD) sponsored forum administered by the Infrared Information Analysis Center of the Environmental Research Institute of Michigan (ERIM); thus, the presence of chapters on active, passive, and countermeasure systems.

There appears to be no general agreement on what format constitutes a “handbook.” The term has been applied to a number of reference works with markedly different presentation styles ranging from data compendiums to tutorials. In the process of organizing this book, we were obliged to embrace a style of our choosing that best seemed to satisfy the objectives of the book: to provide derivational material data, descriptions, equations, procedures, and examples that will enable an investigator with a basic engineering and science education, but not necessarily an extensive background in the specific technology, to solve the types of problems he or she will encounter in design and analysis of electro-optical systems. Usability was the prime consideration. In addition, we wanted each chapter to be largely self-contained to avoid time-consuming and tedious referrals to other chapters. Although best addressed by example, the essence of our handbook style embodies four essential ingredients: a brief but well-referenced tutorial, a practical formulary, pertinent data, and, finally, example problems illustrating the use of the formulary and data.
The final product represents varying degrees of success in achieving this structure, with some chapters being quite successful in meeting our objectives and others following a somewhat different organization. Suffice it to say that the practical exigencies of organizing and producing a compendium of this magnitude necessitated some compromises and latitude. Its ultimate success will be judged by the community that it serves. Although largely oriented toward system applications, a good measure of this book concentrates on topics endemic and fundamental to systems performance. It is organized into eight volumes:

Volume 1, edited by George Zissis of ERIM, treats sources of radiation, including both artificial and natural sources, the latter of which in most military applications is generally regarded as background radiation.

Volume 2, edited by Fred Smith of OptiMetrics, Inc., treats the propagation of radiation. It features significant amounts of new material and data on absorption, scattering, and turbulence, including nonlinear propagation relevant to high-energy laser systems and propagation through aerodynamically induced flow relevant to systems mounted on high-performance aircraft.

Volume 3, edited by William Rogatto of Santa Barbara Research Center, treats traditional system components and devices and includes recent material on focal plane array read-out electronics.

Volume 4, edited by Michael Dudzik of ERIM, treats system design, analysis, and testing, including adjunct technology and methods such as trackers, mechanical design considerations, and signature modeling.

Volume 5, edited by Stephen Campana of the Naval Air Warfare Center, treats contemporary infrared passive systems such as FLIRs, IRSTs, IR line scanners, and staring array configurations.

Volume 6, edited by Clifton Fox of the Night Vision and Electronic Sensors Directorate, treats active systems and includes mostly new material on laser radar, laser rangefinders, millimeter-wave systems, and fiber optic systems.

Volume 7, edited by David Pollock, consultant, treats a number of countermeasure topics rarely appearing in the open literature.

Volume 8, edited by Stanley Robinson of ERIM, treats emerging technologies such as unconventional imaging, synthetic arrays, sensor and data fusion, adaptive optics, and automatic target recognition.

Acknowledgments

It is extremely difficult to give credit to all the people and organizations that contributed to this project in diverse ways. A significant amount of material in this book was generated by the sheer dedication and professionalism of many esteemed members of the IR and EO community who unselfishly contributed extensive amounts of precious personal time to this effort and to whom the modest honorarium extended was scarcely an inducement. Their contributions speak elegantly of their skills.
Directly involved were some 85 authors and editors from numerous organizations, as well as scores of technical reviewers, copyeditors, graphic artists, and photographers whose skill contributed immeasurably to the final product.

We acknowledge the extensive material and moral support given to this project by various members of the managements of all the sponsoring and supporting organizations. In many cases, organizations donated staff time and internal resources to the preparation of this book. Specifically, we would like to acknowledge J. MacCallum of DoD, W. Brown and J. Walker of ERIM, and J. Yaver of SPIE, who had the foresight and confidence to invest significant resources in the preparation of this book. We also extend our appreciation to P. Klinefelter, B. McCabe, and F. Frank of DTIC for their administrative support during the course of this program.

Supporting ERIM staff included Ivan Clemons, Jenni Cook, Tim Kellman, Lisa Lyons, Judy Steeh, Barbara Wood, and the members of their respective organizations that contributed to this project.

We acknowledge Lorretta Palagi and the publications staff at SPIE for a professional approach to the truly monumental task of transforming the manuscripts into presentable copy and the patience required to interact effectively with the authors.

We would like to pay special tribute to Nancy Hall of the IRIA Center at ERIM who administrated this at times chaotic project with considerable interpersonal skill, marshaling the numerous manuscripts and coordinating the myriad details characteristic of a work of this magnitude.

We properly dedicate this book to the people who created it and trust it will stand as a monument to their skills, experience, and dedication. It is, in the final analysis, a product of the community it is intended to serve.

January 1993

Joseph S. Accetta
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Notices and Disclaimer

This handbook was prepared by the Infrared Information Analysis Center (IRIA) in cooperation with the International Society for Optical Engineering (SPIE). The IRIA Center, Environmental Research Institute of Michigan, is a Defense Technical Information Center-sponsored activity under contract DLA-800-C-393 and administrated by the Defense Electronics Supply Center, Defense Logistics Agency.

This work relates to the aforementioned ERIM contract and is in part sponsored by the Department of Defense; however, the contents do not necessarily reflect the position or the policy of the Department of Defense or the United States government and no official endorsement should be inferred.

The use of product names does not in any way constitute an endorsement of the product by the authors, editors, Department of Defense or any of its agencies, the Environmental Research Institute of Michigan, or the International Society for Optical Engineering.

The information in this handbook is judged to be from the best available sources; however, the authors, editors, Department of Defense or any of its agencies, the Environmental Research Institute of Michigan, or the International Society for Optical Engineering do not assume any liability for the validity of the information contained herein or for any consequence of its use.
## Contents

Introduction

<table>
<thead>
<tr>
<th>CHAPTER 1</th>
<th>Laser Radar, Gary W. Kamerman</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Laser Radar Range Equation</td>
<td>9</td>
</tr>
<tr>
<td>1.3 Transmitter Characteristics</td>
<td>12</td>
</tr>
<tr>
<td>1.4 Atmospheric Propagation</td>
<td>20</td>
</tr>
<tr>
<td>1.5 Target Laser Cross Section</td>
<td>28</td>
</tr>
<tr>
<td>1.6 Receiver Characteristics</td>
<td>35</td>
</tr>
<tr>
<td>1.7 Signal Detection in Noise</td>
<td>44</td>
</tr>
<tr>
<td>1.8 Heterodyne Efficiency</td>
<td>50</td>
</tr>
<tr>
<td>1.9 Laser Radar Measurements</td>
<td>52</td>
</tr>
<tr>
<td>1.10 Measurement Characteristics</td>
<td>61</td>
</tr>
<tr>
<td>1.11 Transmitter Modulation Techniques</td>
<td>65</td>
</tr>
<tr>
<td>1.12 Receiver Demodulation Techniques</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 2</th>
<th>Laser Rangefinders, Robert W. Byren</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction</td>
<td>79</td>
</tr>
<tr>
<td>2.2 Theory of Operation</td>
<td>79</td>
</tr>
<tr>
<td>2.3 Laser Rangefinder Applications</td>
<td>82</td>
</tr>
<tr>
<td>2.4 Laser Range Equation</td>
<td>87</td>
</tr>
<tr>
<td>2.5 Probability of Ranging and False Alarm Rate</td>
<td>99</td>
</tr>
<tr>
<td>2.6 Ranging Accuracy</td>
<td>106</td>
</tr>
<tr>
<td>2.7 Characteristics of Common Laser Rangefinders</td>
<td>109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 3</th>
<th>Millimeter-Wave Radar, Elmer L. Johansen</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
<td>117</td>
</tr>
<tr>
<td>3.2 Radar Fundamentals</td>
<td>118</td>
</tr>
<tr>
<td>3.3 Millimeter-Wave Phenomenology</td>
<td>150</td>
</tr>
<tr>
<td>3.4 Millimeter-Wave Components</td>
<td>178</td>
</tr>
<tr>
<td>3.5 Applications</td>
<td>208</td>
</tr>
<tr>
<td>CHAPTER 4</td>
<td>Fiber Optic Systems, Norris E. Lewis, Michael B. Miller</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>4.2</td>
<td>Fiber and Cable</td>
</tr>
<tr>
<td>4.3</td>
<td>Optical Sources and Transmitters</td>
</tr>
<tr>
<td>4.4</td>
<td>Optical Detectors and Receivers</td>
</tr>
<tr>
<td>4.5</td>
<td>Multiplexing Techniques</td>
</tr>
<tr>
<td>4.6</td>
<td>System Components</td>
</tr>
<tr>
<td>4.7</td>
<td>System Analysis</td>
</tr>
<tr>
<td>Index</td>
<td></td>
</tr>
</tbody>
</table>
Introduction

This volume is devoted to the technology of "active" electro-optical systems, which employ an artificial source of optical radiation (typically a laser) and a receiver that collects and detects some fraction of that radiation either directly or after reflection from a target scene. This is as opposed to "passive" systems, which sense naturally emitted radiation or reflected sunlight or moonlight. In most cases, it is preferable to use a passive sensor for a particular application if the need can thereby be met. Frequently, however, active sensors, with their unique capabilities, are needed to satisfy the requirement at hand. Accurate determination of target range, range rate, three-dimensional geometry, vibrational characteristics, spectral reflectance, and many other attributes is possible using the appropriate active sensor. Active sensors are also frequently used in conjunction with passive sensors to take advantage of the best features of both. A simple example of this is the use of a laser rangefinder with a thermal imaging system.

Although millimeter-wave (MMW) radiation is not in the optical portion of the electromagnetic spectrum, MMW radar is also addressed in this volume due to the current strong interest in the use of that technology in conjunction with electro-optical sensors and in order to highlight the similarities and differences between laser and MMW radars.

In some cases (for example, fiber optic communication systems), a signal is encoded on the transmitted beam and routed as directly as practical to a receiver at a remote location where it is detected. In other cases (for example, laser and MMW radars and rangefinders), the beam is transmitted to a target and a small portion of the reflected radiation is collected and detected by the receiver, which in most cases is collocated with the transmitter. In these cases, the desired information to be sensed by the receiver is one or more characteristics of the target. This information is impressed on the reflected radiation by the target itself. In most of these cases, a specific waveform (for example, pulsed, cw, AM, or FM) is used on the outgoing beam in order to most effectively extract the desired information from the target.

Chapter 1 addresses laser radar. Coherent detection is emphasized since so many laser radars now employ coherent (heterodyne) detection receivers. Laser radars are currently being developed and used for a wide variety of applications, from short-range sensors employing low-power solid-state or semiconductor diode-type laser transmitters and direct detection receivers (for example, airborne wire and obstacle detectors with typical ranges to hundreds of meters or less) to very long-range sensors employing relatively high-power gas lasers and coherent detection receivers (for example, laser radars for strategic target discrimination with ranges to hundreds of kilometers). In many cases, coherent
detection provides substantially higher sensitivity and versatility than a direct
detection sensor of equal transmitter power. Coherent detection provides excel­
lent capability to sense radial motion, including both gross target motion
(Doppler shift) and vibration (micro-Doppler).

Chapter 2 addresses laser rangefinders and emphasizes direct detection since
most laser rangefinders employ direct detection receivers. Laser rangefinders
are currently being developed and used for a very wide range of military and
civilian applications. Military use is primarily in fire control systems for combat
vehicles, aviation platforms, and air defense systems as well as a wide variety
of manportable weapons systems. Pulsed solid-state lasers are the most common
type of radiation source used in currently fielded laser rangefinders, although
some semiconductor diode and gas laser types also exist. Most of the currently
fielded devices operate at a wavelength of 1.06 μm or less and are not eyesafe.
However, increasing numbers of eyesafe varieties operating at wavelengths
longer than 1.4 μm are expected to be fielded in larger numbers in the near
future.

Chapter 3 addresses millimeter-wave radar. Recent advances in component
and systems level technology, especially at 35- and 95-GHz frequencies, have
created a strong interest and substantial system development activities for
military target acquisition and fire control applications. The generally superior
foul weather penetration capability of radiation at millimeter-wave frequencies
compared to optical radiation, combined with the much better angular resolution
achievable with millimeter-wave compared to microwave radars of a given
aperture size, make this type of radar an attractive candidate for a variety of
applications.

Chapter 4 addresses fiber optic systems. Fiber optic communication systems
provide tremendous improvement in bandwidth and, therefore, information
handling capacity, compared to conventional conductive wire communication
systems. Substantial improvements in the optical and mechanical quality of
fiber optic cable, improved performance of diode laser transmitters and receiv­
ers, and the reduced cost of componentry have made fiber optic communication
systems the preferred choice for closed-channel applications.

January 1993

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