



Infrared Signatures, Sensors and Technologies

Kamal Nain Chopra

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Defence Research and Development Organisation

Ministry of Defence, New Delhi – 110 011

2023

DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES
INFRARED SIGNATURES, SENSORS AND TECHNOLOGIES

Dr Kamal Nain Chopra

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Chopra, Kamal Nain

Infrared Signatures, Sensors and Technologies

DRDO Monographs/Special Publications Series

1. Infrared Rays	2. Radar Technology	3. Modern Warfare
I. Title	II. Series	
621.384.3		

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ISBN 978-93-94166-10-3

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Cover Design
Rajesh Kumar

Printing
SK Gupta

Marketing
Tapesha Sinha

Published by Director, DESIDOC, Metcalfe House, Delhi – 110 054.

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Foreword

It is a matter of great pleasure for me to express that Dr Kamal Nain Chopra has made a tremendous and commendable effort in writing this monograph on Infrared Signatures, Sensors and Technologies, a topic, on which the availability of literature, especially at one place, is the need of the hour for the scientists engaged in Infrared Signatures, Sensors and Technologies in particular, and the researchers and academicians in general. Practically, all types of the IR Signatures, Sensors, and Technologies have been discussed in reasonable detail in this monograph, thereby making it very useful indeed for the scientific community in the world. Prior to this, very few attempts seem to have been made in presenting the different aspects of the subject at one place, and therefore, this effort will certainly bridge the gaps between the various types of research papers and technical reports at different places. The monograph should especially be useful for the designers and engineers of the infrared devices and sensors, as the topic has been presented and discussed at length. In addition, the monograph is expected to be of immense utility for the budding researchers and scientists in the field, since it provides a large number of theoretical and experimental results available in the literature for them to have a clear understanding of the subject, and also to choose the direction in which to move for carrying out research in this fascinating field. It is my sincere hope that this monograph serves the researchers in enhancing their inputs on the subject, and also is instrumental in growing of their interest for making more concentrated efforts in carrying out research in this rapidly evolving field.

Prof (Dr) Vipin Kumar Tripathi
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Preface

Infrared Signatures, Sensors and Technologies, have an important role to play in the modern warfare equipment including Infrared (IR) Imaging and IR seekers, and some other fields like space research, continuous wave functional near-infrared spectroscopy, and imaging instrumentation and methodology. The IR signatures are able to measure a target's apparent infrared brightness as a function of wavelength, and give information about its appearance to sensors under varying conditions of standoff distance and atmosphere. IR signatures are now well established as valuable tools in the design of vehicles, sensors, and camouflage systems.

A large number of studies have been conducted by researchers at several different universities, governmental agencies, and organisations; and they have reached very useful and promising conclusions regarding the utility of these technologies. Some of the very important studies are: Thermal and Radar Signature Management, Modeling of IR Signatures and Countermeasures, Detector Technology, and IR Threats.

In view of the underlying utility of the Infrared Technologies, Sensors and Countermeasures, for which not much literature is available especially at one place, an attempt has been made in this monograph to give a fair idea of the subject to the readers from both sections – new researchers, and also the designers of the devices based on these technologies. The monograph is certainly expected to be of immense utility for the budding scientists and technical officers of the DRDO laboratories including GTRE, Bengaluru, and ADE, Bengaluru; in addition to ADA, Bengaluru.

Dr Kamal Nain Chopra

Acknowledgements

The author is really grateful to the some faculty members of the Department of Physics, Indian Institute of Technology Delhi, especially, Prof Vipin Kumar Tripathi; and some DRDO scientists, for useful discussions leading to the creation of his interest in the evolving subject of the 'Infrared Signatures, Sensors and Technologies'. A large number of presentations and discussions on the complexities and technicalities of some of these sources have been immensely helpful in writing of this monograph.

The author is also thankful to Dr SA Vasudev, Scientist G of Gas Turbine Research Establishment (GTRE), Bengaluru, and Dr Heragu Srinath, Senior Scientist of the Aeronautical Development Agency (ADA), Bengaluru for very stimulating discussions on the subject during the visits to their laboratories for the invited Talks; and also various experts on the topics during the (GATET) programme, GTRE, Bengaluru March 2012 at the Aeronautical Society of India, Bengaluru; for igniting his interest in this important topic. In addition, the inputs obtained during the various Sessions of the Assessment Boards for evaluating the performance of the Technical officers, and also from the Directors of the concerned laboratories including GTRE, Bengaluru, and ADE Bengaluru, were very helpful in the further growth of the interest of the author in undertaking this important task of writing a monograph on this unconventional topic of 'IR Signatures, Sensors and Technologies', with a view to present the scattered available literature at one place for the scientists of DRDO in particular, and the academicians and scientists in general.

The author is highly grateful to Prof Vipin Kumar Tripathi, for various suggestions, and encouragement during the course of writing this monograph, which helped in greatly improving the contents; and more importantly, the presentation and readability of the monograph.

The author is thankful to Shri G Krishna Rao, Director, Electro Optical Instruments Research Academy (ELOIRA), Hyderabad for useful discussions, suggestions, and encouragement while finalising this monograph. The author is also thankful to Shri Hari Babu, DS and Director, LASTEC, for inviting to the Review Meetings, and thus providing opportunities to interact with various scientists of LASTEC, and other DRDO labs.

Thanks are also due to two anonymous reviewers of the monograph for their encouraging comments, and very important suggestions, incorporation of which has resulted in great improvement in the readability and contents of the Monograph.

The author is especially thankful to Dr Alka Suri, former Director, DESIDOC, for providing an opportunity to bring out this monograph, and giving encouragement and guidance at various stages of its compilation. The special thanks are also due to Ms Alka Bansal, Group Head, Publications Division, and Shri NK Chawla, former Head, Monographs for their constant support in completing this project.

Dr Kamal Nain Chopra

CHAPTER 1

Infrared Spectrum and Sensors

1.1 INTRODUCTION

Infrared (IR) radiation is Electromagnetic (EM) radiation of a wavelength longer than that of visible light, shorter than that of radio wave. It covers a long range of wavelengths - three orders of magnitude and has wavelengths between ~ 750 nm and ~ 1 mm. Thus, IR is just a certain region in the light spectrum, and is broken into three parts near IR, mid IR, and far IR. As is widely reported in the literature, it is shown in the Fig. 1.1.

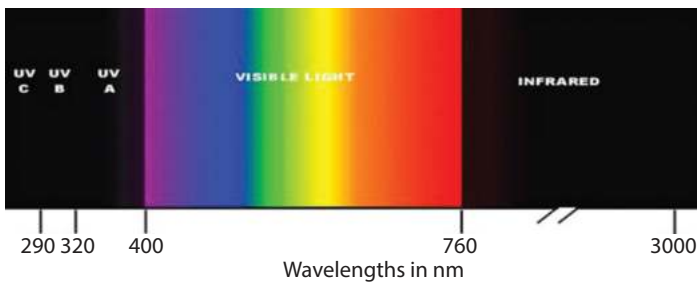


Figure 1.1. UV, Visible, and IR parts of the EM spectrum, in terms of the wavelengths in nm.

Clearly, it is one step up on the light spectrum from visible light. Presently, IR detector technologies are very important, both in military and civilian applications, and have been extensively investigated during the last century. Commercial applications of IR Focal Plane Arrays (FPAs) cover astronomy, art history and archaeology, biological and medical systems, spectroscopy, fire control, surveillance and driver's vision enhancement. The military applications include night vision, rifle sight, surveillance,

missile guidance, tracking, and interceptors. The IR signatures of the objects in space or earth, are useful as measure of heat; and are used in measuring the spectral radiance of the objects.

1.1.1 IR Interactions with Matter

- (i) Reflection: The IR wave is reflected from a surface, the angle of reflection being equal to the angle of incidence.
- (ii) Refraction: The IR wave refracts bends when passing between two transparent media with different propagation speeds based on Snell's law.
- (iii) Scattering: The IR waves are scattered upon interaction with particles of size of the order of the length of the wave.
- (iv) Diffraction: The IR waves are diffracted around the edges of an obstruction.
- (v) Interference: The IR waves interfere both constructively and destructively.
- (vi) Absorbtion: The IR waves are absorbed by matter.
- (vii) Emission: The IR radiation is emitted from matter.
- (viii) Transmission: The IR rays propagatate through a transparent medium or vacuum.
- (ix) Polarisation: The IR rays are partially polarised by reflection from dielectric.

The atmospheric transmittance depends on the wavelength, and is shown in the Fig. 1.2 (a & b).

As seen (Fig. 1.2 (a)), in the (i) visible region (0.3-1.0 μm), CCDs are used as sensors; (ii) near-IR region (1.0-5.2 μm) InSb is used as sensor; (iii) mid-IR region (8-25 μm) Si and As, are used as sensors; and (iv) far-IR

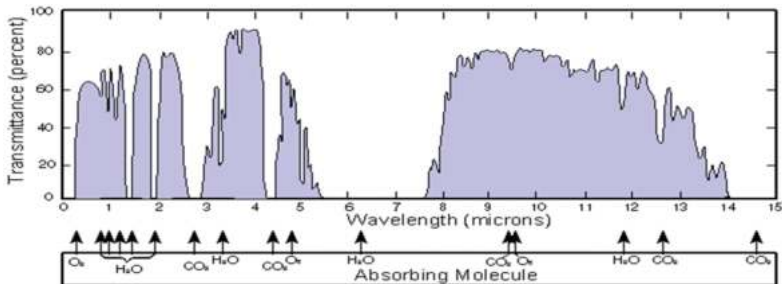


Figure 1.2. (a) Atmospheric transmittance in the IR region.

About the Monograph

This monograph on 'Infrared Signatures, Sensors, and Technologies', a topic, on which the availability of literature, especially at one place, is the need of the hour for the scientists engaged in Infrared Signatures, Sensors and Technologies in particular, and the researchers and academicians in general. Practically, all types of the IR Signatures, Sensors, and Technologies including Infrared Spectrum and Sensors, Infrared (IR) Signatures, Deceiving Technologies - Types, Analysis and Modeling of IR Signatures and Countermeasures, Thermal and Radar Signature Management, Fabrication of IR Sensors, Detector Technology and Discussion on QWIPs and QDIPs IR Detectors, IR Threats - RADAR Technology, and IR Seekers, have been discussed in reasonable detail in this monograph, thereby making it very useful indeed for the scientific community in the world. This monograph presents the different aspects of the subject at one place, and therefore, this effort will certainly bridge the gaps between the various types of research papers and technical reports at different places. This monograph should especially be useful for the designers and engineers of the IR devices and sensors, as the topic has been presented and discussed at length. In addition, the monograph is expected to be of immense utility for the budding researchers and scientists in the field, since it provides a large number of recent theoretical and experimental results available in the literature for them to have a clear understanding of the subject.

About the Author



Dr Kamal Nain Chopra has done BSc (University of Delhi), MSc (Physics- IIT, Delhi), MTech (Opto-Electronics - IIT, Delhi), and PhD (Applied Physics- IIT, Delhi). He has served DRDO for a period of 33 years and superannuated as Scientist G, from Laser Science and Technology Centre (LASTEC), Delhi, in the year 2005. Subsequently, he has also served as Professor (Physics) in NSIT (DU) and MAIT (GGSIPIU), and as Project Scientist in IIT, Delhi, in various projects, on topics including Photonics, Thin Films, and Optical Testing.

He has about 390 publications including about 330 in peer reviewed international journals, 15 Invited talks; 15 Technical reports; and 30 papers in International Conference Proceedings.

He has authored three monographs titled, 'Thin Films and their Applications in Military and Civil Sectors', 2010; 'Unconventional Lasers: Design and Technical Analysis', 2017 and 'Spintronics Theoretical Analysis and Designing of Devices Based on Giant Magnetoresistance' published by DESIDOC, DRDO, Ministry of Defence, India; four books 'Conventional and Unconventional Sources of Renewable Energy: Renewable Energy Sources', 2017; 'Novel Emerging Techniques of Business Management', 2021; 'Optoelectronic Instrumentation for Research in Oceanography', 2021; published by Lambert Academic Publishing, LAP, Germany; and 'Optoelectronic Gyroscopes and Applications', 2021 has been published by Springer Nature.

He has undertaken visits to foreign universities and industries including: School of Thin Film Coatings, Department of Physics, St Jerome University, Marseille, France (1984-85); Department of Physics, Innsbruck University, Austria; M/s Balzers, Liechtenstein, Switzerland (1995); and M/s Elettrovava, Torino, Italy (2000).

He has vast experience of serving the Recruitment and Assessment Boards of DRDO (RAC and CEPTAM), as Chairman as well as Expert Board Member.

Price: ₹ 1000/-
US \$25
UK £20

978-93-94166-10-3

