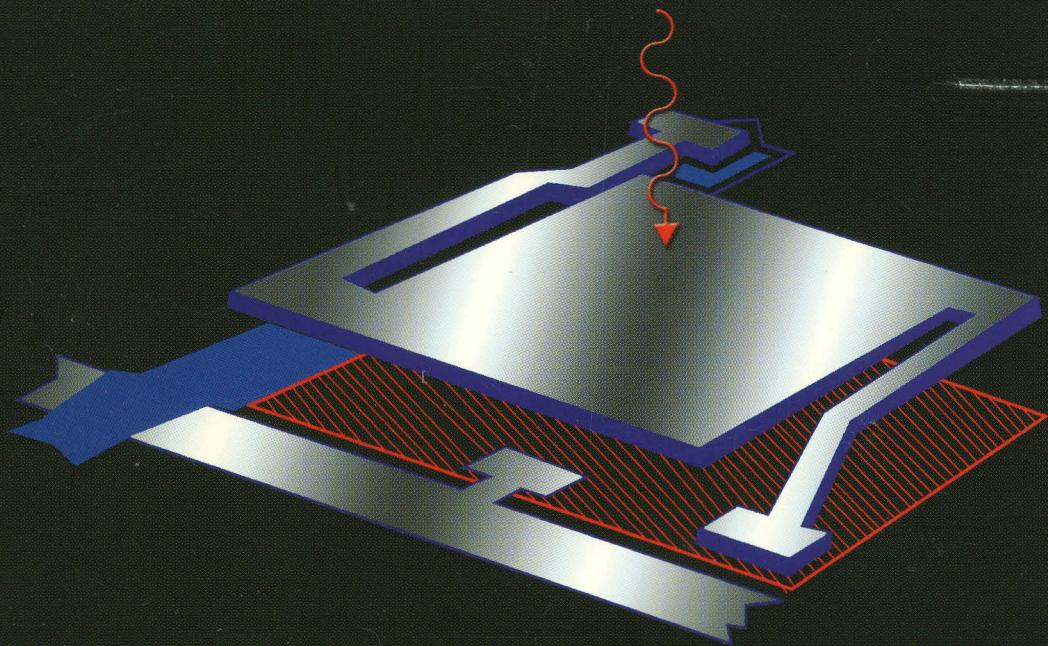


UNCOOLED THERMAL IMAGING

Arrays, Systems, and Applications



V 35

Paul W. Kruse

UNCOOLED THERMAL IMAGING

Arrays, Systems, and Applications

Paul W. Kruse

C IV 35

DK 551.508.25

Tutorial Texts in Optical Engineering
Volume TT51

Arthur R. Weeks, Jr., Series Editor
Invivo Research Inc. and University of Central Florida

343/4152

INSTITUT
FÜR METEOROLOGIE U. KLIMATOLOGIE
UNIVERSITÄT HANNOVER
HERRENHÄUSER STR. 2 - 30419 HANNOVER



SPIE PRESS

A Publication of SPIE—The International Society for Optical Engineering
Bellingham, Washington USA

Contents

List of Figures xiii

List of Tables xv

Preface xvii

Chapter 1 An Overview of Uncooled Thermal Imaging Detection Mechanisms and Their Figures of Merit / 1

- 1.1 Terminology / 1
 - 1.2 Detection Mechanisms / 2
 - 1.2.1 Photon detection mechanisms / 2
 - 1.2.2 Thermal detection mechanisms / 4
 - 1.2.2.1 Resistive bolometer / 4
 - 1.2.2.2 Pyroelectric effect / 5
 - 1.2.2.3 Field-enhanced pyroelectric effect/ferroelectric bolometer / 5
 - 1.2.2.4 Thermoelectric effect/radiation thermocouple / 5
 - 1.2.3 Wave interaction effects / 6
 - 1.3 Figures of Merit / 6
 - 1.3.1 Responsivity / 7
 - 1.3.2 Noise equivalent power and D^* / 7
 - 1.3.3 Noise equivalent temperature difference / 8
 - 1.3.4 Minimum resolvable temperature difference / 9
 - 1.3.5 Thermal response time / 9
- References / 10

Chapter 2 Fundamental Limits / 11

- 2.1 Introduction / 11
 - 2.2 Photon Noise Limitations of Thermal Detectors / 12
 - 2.3 Temperature Fluctuation Noise in Thermal Detectors / 14
 - 2.4 Temperature Fluctuation Noise Limit to Focal Plane Array Performance / 20
 - 2.5 Background Fluctuation Noise Limit to Focal Plane Array Performance / 20
 - 2.6 Discussion / 22
- References / 23

Chapter 3 Thermoelectric Arrays / 25

- 3.1 Introduction / 25
- 3.2 The Heat Flow Equation / 27
- 3.3 Responsivity / 29
- 3.4 Noise / 30
- 3.5 D^* / 30
- 3.6 Noise Equivalent Temperature Difference / 30
- 3.7 Pixel Design Optimization / 31
- References / 32

Chapter 4 Resistive Bolometers / 33

- 4.1 Introduction / 33
- 4.2 Responsivity / 34
 - 4.2.1 Case I: No Joulean heating; constant bias / 34
 - 4.2.2 Case II: Joulean heating; constant bias / 35
 - 4.2.3 Case III: Joulean heating; pulsed bias / 40
- 4.3 Noise / 42
- 4.4 Noise Equivalent Temperature Difference / 44
- 4.5 Choice of Resistive Materials / 45
 - 4.5.1 Vanadium oxide / 45
 - 4.5.2 Amorphous silicon / 46
 - 4.5.3 Thermistor materials / 47
 - 4.5.4 Titanium / 47
 - 4.5.5 P-N junction diodes / 47
- References / 48

Chapter 5 Pyroelectric Arrays / 49

- 5.1 Introduction / 49
- 5.2 The Heat Flow Equation / 51
- 5.3 Responsivity / 52
- 5.4 Johnson Noise / 54
- 5.5 Temperature Fluctuation Noise / 55
- 5.6 Noise Equivalent Temperature Difference / 55
- References / 56

Chapter 6 State of the Art and Technical Trends / 57

- 6.1 Introduction / 57
- 6.2 Resistive Bolometer Arrays and Their Applications in Thermal Imagers and Imaging Radiometers / 57
 - 6.2.1 The Honeywell silicon microstructure resistive bolometer array and thermal imager / 57

- 6.2.2 Improvements on the Honeywell VOx 240 × 332 pixel bolometer array / 63
 - 6.2.2.1 Increase in fill factor / 63
 - 6.2.2.2 CMOS ROIC / 63
 - 6.2.2.3 Smaller pixels / 63
 - 6.2.2.4 640 × 480 pixel arrays / 64
 - 6.2.2.5 160 × 120 pixel arrays / 64
 - 6.2.2.6 Removal of temperature stabilizer / 64
 - 6.2.3 Use of amorphous silicon rather than vanadium oxide as the resistive material / 64
 - 6.2.4 Use of diodes rather than resistive materials / 65
 - 6.2.5 Thermal imagers employing uncooled VOx bolometer arrays / 65
 - 6.2.6 Imaging radiometers based on 320 × 240 pixel uncooled VOx bolometers / 65
 - 6.2.7 Summary / 67
 - 6.3 Pyroelectric and Ferroelectric Bolometer Uncooled Arrays and Thermal Imagers that Employ Them / 67
 - 6.3.1 Introduction / 67
 - 6.3.2 The Texas Instruments (now Raytheon) hybrid ferroelectric bolometer array and imagers / 68
 - 6.3.3 Monolithic pyroelectric array development / 72
 - 6.4 Uncooled Thermoelectric Arrays and Thermal Imagers and Imaging Radiometers that Employ Them / 72
 - 6.4.1 Introduction / 72
 - 6.4.2 Monolithic linear arrays / 73
 - 6.4.3 Imaging radiometer employing linear thermoelectric arrays / 75
 - 6.5 Status and Trends of Uncooled Arrays / 77
 - 6.5.1 Status and trends of uncooled arrays for military systems / 77
 - 6.5.2 Status and trends of commercial uncooled arrays and systems / 78
- References / 79

Chapter 7 Choosing the Proper Technical Approach for a Given Application / 83

- 7.1 Introduction / 83
- 7.2 Thermal Imaging Applications / 83
- 7.3 Comparison of the Principal Types of Uncooled Thermal Detectors / 86

Index / 89