

CONTENTS

<i>Preface</i>	xv
<i>Historical Remarks</i>	xvii

Chapter 1. Radiometric Considerations

1.1	Introduction.....	1
1.2	Basic Optical Relations	1
1.3	Signal-to-Noise Ratio.....	2
1.4	Extended Simplified Radiometric Performance Equation.....	4
1.5	Thermal Radiation Laws	4
1.5.1	Blackbody radiation and Planck's law.....	5
1.5.2	The Stefan-Boltzmann law.....	6
1.5.3	Wien's displacement law	7
1.5.4	Kirchhoff's law and emissivity	7
1.6	Transmission through the Atmosphere.....	8
1.6.1	Permanent constituents of dry atmosphere.....	9
1.6.2	Variable constituents.....	9
1.6.3	Approximation (assumption)	9
1.6.4	Precipitable water (definition)	10
1.6.5	Humidity	11
1.6.6	Precipitable water (calculation)	11
1.6.7	Atmospheric transmission (calculation).....	12
1.6.8	Computer models.....	13
1.7	Typical IR Detectors	14
1.7.1	Thermal detectors	14
1.7.2	Photon or quantum detectors	14
1.7.3	Photoconductive detectors	14
1.7.4	Specific detectivity and noise equivalent bandwidth	15
1.7.5	Detector configurations.....	16
	References.....	17

Chapter 2. Basic Optics

2.1	Introduction.....	19
2.2	Snell's Law and the Prism	20
2.3	The Transition from a Prism to a Lens.....	20
2.4	Image Formation	21
2.5	Object-Image Relations	23
2.6	Stops, Pupils, and Windows.....	24
2.7	Throughput.....	26
2.8	Energy Transfer.....	28
2.8.1	Signal-to-noise calculations	28

2.9	Differential Changes	29
2.10	Optical Gain	30
2.10.1	Immersion lenses	30
2.10.2	Light pipes	33
2.10.3	Field lens.....	34
2.11	Field of View for Staring Arrays.....	34
	References.....	35

Chapter 3. Primary Aberrations

3.1	Introduction.....	37
3.2	Primary Aberrations	37
3.2.1	Spherical aberration	37
3.2.2	Coma.....	38
3.2.3	Astigmatism	39
3.2.4	Field curvature	40
3.2.5	Distortion	41
3.2.6	Axial chromatic aberration	41
3.2.7	Lateral chromatic aberration.....	42
3.3	Calculations of Primary Aberrations	42
3.3.1	Spherical aberration	44
3.3.2	Coma.....	46
3.3.3	Astigmatism	47
3.3.4	Field curvature	47
3.3.5	Astigmatism and field curvature combined.....	48
3.3.6	Axial chromatic aberration	49
3.3.7	Numerical example	50
3.4	General Aberration Correction Methods.....	53
3.5	Doublets	53
3.5.1	Two elements, same material	53
3.5.2	Two elements, different materials.....	55
3.5.3	The achromat	56
3.6	Two Thin Air-spaced Elements.....	57
3.6.1	The Petzval objective.....	57
3.6.2	Refractive beam expanders	59
3.6.3	Telephotos	62
3.7	Reflective Optics.....	62
3.7.1	The spherical mirror	63
3.7.2	The Mangin mirror.....	65
3.7.3	Classical two-mirror configurations.....	67
3.7.4	The two-sphere Cassegrain system	68
3.7.5	The two-sphere Gregory system	71
3.7.6	Schwarzschild, a very special case.....	72
3.7.7	Reflective beam expanders	73
3.8	Diffraction Limit	74
3.9	Resolution of Imaging Systems	75
	References.....	76

Chapter 4. Wave Aberrations

4.1	Introduction.....	77
4.2	Diverging and Converging Waves	77
4.3	Optical Path Length OPL.....	78
4.4	Optical Path Difference OPD (Wave Front Aberration)	78
4.5	Spherical Aberration	78
	4.5.1 Numerical example	79
	4.5.2 Best focus position.....	81
4.6	Third-Order Spherical Aberration.....	82
4.7	Depth of Focus	82
	References.....	82

Chapter 5. Special Optical Surfaces and Components

5.1	Introduction.....	83
5.2	The Plane-Parallel Plate	83
	5.2.1 Displacements.....	83
	5.2.2 Optical micrometer	85
	5.2.3 Aberration contributions	86
	5.2.4 Application remarks.....	87
	5.2.5 The wedge (thin prism).....	90
5.3	Domes	91
5.4	The Ball Lens.....	93
	5.4.1 Spherical aberration	94
	5.4.2 An aspherized ball lens	94
5.5	Gradient Index Lens.....	95
5.6	Conic Sections and General Aspheres.....	97
	5.6.1 Mathematical expressions	98
	5.6.2 Reflectors with conic section surfaces	99
	5.6.3 Lenses with conic section surfaces	100
	5.6.4 Common two-mirror configurations using conic section surfaces	103
	5.6.5 General aspheres (surfaces of rotation).....	103
	5.6.6 Two conic section mirrors with an aspheric corrector	104
	5.6.7 Three-mirror configurations.....	105
5.7	Diffraction (Binary) Optics	107
	5.7.1 The simple diffractive singlet	107
	5.7.2 The hybrid achromat.....	109
	5.7.3 Numerical examples.....	111
	5.7.4 Diffraction efficiency.....	114
	5.7.5 "Useful" spectral bandwidth	115
	5.7.6 Diffraction efficiency for a particular order.....	115
	5.7.7 The hybrid achromat, corrected for chromatic and spherical aberrations	116
	5.7.8 Binary optics.....	117
	References.....	119

Chapter 6. Design Examples

6.1	Introduction.....	121
6.2	Basic Assumptions for the High-and Low Temperature Applications	121
6.2.1	Optics for high-temperature system (3–5 μm)	122
6.2.2	Optics for low-temperature system #1 (8–12 μm)	122
6.2.3	Optics for low-temperature system #2 (8–12 μm)	123
6.2.4	Optics for low-temperature system #3 (8–12 μm)	123
6.3	The Improved Petzval Objective.....	125
6.3.1	Numerical example for a LWIR application.....	126
6.3.2	Manufacturing remarks	128
6.4	Instantaneous Field of View.....	128
	References.....	129

Chapter 7. Thermal Effects

7.1	Introduction.....	131
7.2	Changing Parameters.....	131
7.3	Defocus with Change of Temperature.....	132
7.4	Defocus of Singlet.....	132
7.5	Athermalization with a Doublet	133
7.6	The Athermalized Achromat.....	135
7.6.1	The all-refractive athermal achromat	136
7.6.2	The hybrid athermal achromat	137
7.7	Cold Stop and Cold Shield.....	138
7.7.1	Cold stop.....	138
7.7.2	Cold shield.....	138
	References.....	139

Chapter 8. Optical Coatings

8.1	Introduction.....	141
8.2	Effects at a Single Surface	141
8.3	Two Plane-Parallel Surfaces	142
8.4	Antireflection Coatings	143
8.5	Reflective Coatings	145
8.6	Typical Interference Filters	146
8.6.1	Angular sensitivity of filters	148
8.6.2	Thermal sensitivity of filters	149
	References.....	150

Chapter 9. Image Evaluation

9.1	Introduction.....	151
9.2	Blur Spot Measurements	151
9.2.1	Circular mask.....	151
9.2.2	Slit	152
9.2.3	Knife Edge.....	152
9.3	Energy Distribution.....	154

9.4	Modulation Transfer Function	154
9.4.1	Overview.....	155
9.4.2	Contrast and resolving power	157
9.4.3	Diffraction MTF	160
9.4.4	Geometric MTF	161
9.4.5	Numerical example	161
	References.....	163

Chapter 10. Diamond Turning

10.1	Introduction.....	165
10.2	Overview.....	165
10.3	Surface Finish	166
10.4	Scattering	168
10.5	Shape Correction.....	169
10.6	Optical Surface Testing.....	169
10.6.1	Surface roughness	169
10.6.2	Surface shape	171
10.7	Machining Time	171
10.8	Further Progress and Developments.....	172
	References.....	172

Appendix

A.1	Paraxial Ray Tracing.....	173
A.1.1	Surface equations.....	173
A.1.2	Power equations (ray tracing through thin lenses)	175
A.2	Spherical Aberration of a Thin Lens	176
A.2.1	Derivation of expression.....	176
A.2.2	Blur spot size	178
A.3	Optical and Thermal Data for Some Infrared Materials.....	178
A.3.1	Selected materials for the 3–5- μm spectral band	179
A.3.2	Selected materials for the 8–12- μm spectral band	179
	References.....	181

Index	181
--------------------	-----