

Contents

Preface	xiii
Chapter 1 Analytic Fourier Theory Review	1
1.1 A Little History and Purpose	1
1.2 The Realm of Computational Fourier Optics.....	2
1.3 Fourier Transform Definitions and Existence.....	3
1.4 Theorems and Separability	3
1.5 Basic Functions and Transforms.....	5
1.6 Linear and Space-Invariant Systems.....	7
1.7 Exercises	10
1.8 References.....	12
Chapter 2 Sampled Functions and the Discrete Fourier Transform 13	
2.1 Sampling and the Shannon–Nyquist Sampling Theorem	13
2.2 Effective Bandwidth	15
2.3 Discrete Fourier Transform from the Continuous Transform.....	18
2.4 Coordinates, Indexing, Centering, and Shifting.....	20
2.5 Periodic Extension	21
2.6 Periodic Convolution	24
2.7 Exercises	26
2.8 References.....	27
Chapter 3 MATLAB Programming of Functions, Vectors, Arrays, and Fourier Transforms	29
3.1 Defining Functions	29
3.2 Creating Vectors	32
3.3 Shift for FFT	34
3.4 Computing the FFT and Displaying Results.....	36
3.5 Comparison with Analytic Results	38
3.6 Convolution Example	39
3.7 Two Dimensions	41
3.8 Miscellaneous Hints.....	43
3.9 Exercises	45

Chapter 4 Scalar Diffraction and Propagation Solutions	47
4.1 Scalar Diffraction.....	47
4.2 Monochromatic Fields and Irradiance	48
4.3 Optical Path Length and Field Phase Representation	50
4.4 Analytic Diffraction Solutions.....	51
4.4.1 Rayleigh–Sommerfeld solution I.....	51
4.4.2 Fresnel approximation.....	53
4.4.3 Fraunhofer approximation.....	55
4.5 Fraunhofer Diffraction Example.....	56
4.6 Exercises	59
4.7 References.....	61
Chapter 5 Propagation Simulation	63
5.1 Fresnel Transfer Function (TF) Propagator	63
5.2 Fresnel Impulse Response (IR) Propagator	64
5.3 Square Beam Example.....	66
5.4 Fresnel Propagation Sampling	69
5.4.1 Square beam example results and artifacts.....	69
5.4.2 Sampling regimes and criteria.....	72
5.4.3 Criteria applied to square beam example	74
5.4.4 Propagator accuracy	75
5.4.5 Sampling decisions.....	77
5.4.6 Split-step simulation, windowing, and expanding grids.....	78
5.5 Fraunhofer Propagation	79
5.6 Coding Efficiency	83
5.7 Exercises	83
5.8 References.....	86
Chapter 6 Transmittance Functions, Lenses, and Gratings	89
6.1 Tilt.....	89
6.2 Focus.....	93
6.3 Lens.....	96
6.4 Gratings and Periodic Functions.....	98
6.4.1 Cosine magnitude example	99
6.4.2 Square-wave magnitude example.....	102
6.4.3 One-dimensional model	105
6.4.4 Periodic model.....	106
6.5 Exercises	108
6.6 References.....	111
Chapter 7 Imaging and Diffraction-Limited Imaging Simulation ...	113
7.1 Geometrical Imaging Concepts.....	113
7.2 Coherent Imaging	116

7.2.1	Coherent imaging theory	116
7.2.2	Coherent transfer function examples.....	117
7.2.3	Diffraction-limited coherent imaging simulation.....	119
7.2.4	Rough object	124
7.3	Incoherent Imaging	127
7.3.1	Incoherent imaging theory.....	127
7.3.2	Optical transfer function examples.....	128
7.3.3	Diffraction-limited incoherent imaging simulation.....	129
7.4	Exercises	132
7.5	References.....	139
Chapter 8 Wavefront Aberrations		141
8.1	Wavefront Optical Path Difference	141
8.2	Seidel Polynomials	142
8.2.1	Definition and primary aberrations	142
8.2.2	MATLAB function.....	144
8.3	Pupil and Transfer Functions	146
8.3.1	Pupil function	146
8.3.2	Imaging transfer functions.....	147
8.4	Image Quality	147
8.4.1	Point spread function.....	147
8.4.2	Modulation transfer function.....	148
8.5	Lens Example—PSF and MTF	148
8.6	Wavefront Sampling	153
8.7	Superposition Imaging Example.....	157
8.7.1	Image plane PSF map.....	157
8.7.2	Image simulation	160
8.7.3	Practical image simulation	163
8.8	Exercises	163
8.9	References.....	168
Chapter 9 Partial Coherence Simulation.....		169
9.1	Partial Temporal Coherence	170
9.1.1	Quasi-monochromatic light.....	170
9.1.2	Partial temporal coherence simulation approach.....	172
9.1.3	Partial temporal coherence example.....	173
9.2	Partial Spatial Coherence.....	177
9.2.1	Stochastic transmission screen	177
9.2.2	Partial spatial coherence simulation approach	178
9.2.3	Partial spatial coherence example	182
9.3	Reducibility, Number of Spectral Components, and Phase Screens.....	186
9.4	Exercises	187
9.5	References.....	189

Appendix A Fresnel Propagator Chirp Sampling	191
A.1 Fresnel Transfer Function Sampling.....	191
A.1.1 Oversampled transfer function	192
A.1.2 Critically sampled transfer function	194
A.1.3 Undersampled transfer function	194
A.2 Fresnel Impulse Response Function Sampling	195
A.2.1 Undersampled impulse response	196
A.2.2 Critically sampled impulse response	196
A.2.3 Oversampled impulse response	197
A.3 Summary	198
A.4 References.....	198
Appendix B Fresnel Two-Step Propagator	199
B.1 Approach.....	199
B.2 Sampling Considerations	202
B.2.1 Similar side lengths.....	203
B.2.2 Significantly different side lengths.....	203
B.2.3 Comments and recommendations.....	204
B.3 MATLAB Code	204
B.4 References.....	205
Appendix C MATLAB Function Listings	207
C.1 Circle.....	207
C.2 Jinc	207
C.3 Rectangle.....	207
C.4 Triangle	208
C.5 Unit Sample "Comb"	208
C.6 Unit Sample "Delta"	208
Appendix D Exercise Answers and Results	209
D.1 Chapter 1	209
D.2 Chapter 2.....	210
D.3 Chapter 3.....	211
D.4 Chapter 4.....	212
D.5 Chapter 5.....	214
D.6 Chapter 6.....	217
D.7 Chapter 7.....	220
D.8 Chapter 8.....	223
D.9 Chapter 9.....	225
Index.....	229