

Contents

1	Principles of Optical Heterodyning	1
1.1	Heterodyne Detection of Regular Signals	1
1.1.1	Interference of Optical Fields at the Detector Sensitive Area	1
1.1.2	Spectrum of the Output Signal Under Regular Modulation of Optical Fields	4
1.1.3	Optimal Conditions for Wavefronts	7
1.1.4	Siegman Antenna Theorem	11
1.1.5	Practical Schemes of Wavefront Matching	15
1.1.6	Tolerances on Aberrations of Optical Systems	23
1.2	Heterodyne Detection of Random Signals	30
1.2.1	Spectrum of the Photocurrent	30
1.2.2	Heterodyning with Partial Spatial Coherence of Optical Waves	36
1.3	Sensitivity of an Ideal Heterodyne Receiver	40
1.3.1	Sensitivity of an Ideal Heterodyne Receiver to Narrow-Band Laser Signals	40
1.3.2	Sensitivity of an Ideal Heterodyne Receiver to Wide-Band Optical Signals	45
	References	48
2	Laser Heterodyne Spectroscopy	51
2.1	Laser Heterodyne Spectroscopy of Scattered Radiation	51
2.1.1	Historical Introduction	51
2.1.2	The Principles of Heterodyne and Homodyne Spectroscopy	52
2.1.3	Basics of Single Scattering	58
2.1.4	Finite Width of Laser Spectrum	65
2.1.5	Signal-to-Noise Ratio in Spectroscopic Measurements	71
2.1.6	Some Experimental Results	77

2.2	High-Frequency Heterodyne Spectroscopy	81
2.2.1	Historical Introduction	81
2.2.2	Secondary Frequency Standards with CO ₂ -Lasers	82
2.2.3	High-Frequency Mixing Devices	85
2.2.4	Measuring Frequencies of Molecular Transitions	90
2.2.5	Optical Frequency Synthesis Spectroscopy	90
2.3	Frequency-Modulation Spectroscopy	94
	References	101
3	Laser Heterodyne Radars and Lidars	105
3.1	Introduction	105
3.2	Heterodyne Photoreceivers	106
3.2.1	Basic Types of Heterodyne Photodetectors	106
3.2.2	Sensitivity of Photoresistors and Photodiodes in the Heterodyne Mode	108
3.3	Laser Heterodynes	122
3.4	Atmospheric Turbulence	124
3.5	Probability of Detection and False Alarm	132
3.5.1	Signal Statistics and Input Circuits of Heterodyne Receivers	132
3.5.2	Detection of Regular Continuous Gaussian Signals without Accumulation	136
3.5.3	Detection of Regular Continuous Gaussian Signals with Accumulation	138
3.5.4	Non-Gaussian Signals	144
3.5.5	Experimental Results	148
3.6	Retrieving Information from Heterodyne Signals	150
3.6.1	Measuring Target Velocity	150
3.6.2	Synthetic Aperture Method	155
3.6.3	Synthetic Aperture: Experimental Results	170
3.6.4	Linear Frequency Modulation Method	175
3.6.5	Linear Frequency Modulation: Experimental Results ..	179
3.7	Lidars	180
3.7.1	Range Selectivity in Heterodyne Lidars	181
3.7.2	Wind Speed Vector Measurement	186
	References	188
4	Laser Heterodyne Radiometers	191
4.1	Principles of Laser Heterodyne Radiometers	191
4.1.1	Basic Scheme of a Laser Heterodyne Radiometer	191
4.1.2	Equivalent Noise Temperature of a Radiometer	193
4.1.3	Sensitivity and Resolution of a Radiometer	200
4.1.4	Basic Types of Laser Heterodyne Radiometers	209
4.2	Characteristics of Laser Heterodyne Radiometers	213
4.2.1	Sensitivity and Signal-to-Noise Ratio	213

4.2.2	Resolution	217
4.2.3	Applications of Laser Heterodyne Radiometers	218
4.3	Laser Heterodyne Interferometers	220
4.3.1	Introduction	220
4.3.2	Interference Method of Measuring Angular Dimensions of Astrophysical Objects	221
4.3.3	Principle of Operation and Sensitivity of Laser Heterodyne Interferometer	226
4.3.4	Phase-Modulation Interferometer	231
4.3.5	Laser Heterodyne Correlation Interferometer	235
4.3.6	Some Experimental Results	238
	References	240
5	Laser Heterodyne Interferometry and Polarimetry	243
5.1	Laser Heterodyne Interferometry	245
5.1.1	Precise Position Measurements	245
5.1.2	Surface Profilometry	248
5.1.3	Glass Thickness Measurements	251
5.2	Heterodyne Polarimetry of Glass Birefringence	255
5.2.1	Introduction	255
5.2.2	Principles of the Cross-Polarized Technique	256
5.2.3	Experimental Results	262
5.3	Kerr Polarimetry	265
5.3.1	Introduction	265
5.3.2	Theoretical Basics of the Magneto-Optical Kerr Effect	268
5.3.3	Experimental Results	273
5.3.4	Laser Heterodyne Kerr Microscopy	275
5.4	Surface Polarimetry	279
5.4.1	Introduction	279
5.4.2	Principle of Surface Polarimetry	280
5.4.3	Principle of Measuring Critical Dimensions	282
5.4.4	Experimental Results	287
5.4.5	Measuring Critical Dimensions of Sub-Wavelength Structures	290
	References	303
6	Heterodyne Imaging and Beam Steering	307
6.1	Heterodyne Scanning	307
6.1.1	Introduction	307
6.1.2	Theory of Heterodyne Scanning	308
6.1.3	Laser Heterodyne Scanning Microscopy	316
6.1.4	Laser Heterodyne Differential Microscopy	320
6.1.5	Laser Heterodyne Phase-Contrast Microscopy and Super-Resolution	326

6.2	Adaptive Heterodyne Imaging	332
6.2.1	Principle of Adaptive Imaging	332
6.2.2	Adaptation with the Heterodyne Receiver Signal	333
6.3	Laser Heterodyne Phase Arrays	342
6.3.1	Adaptive Focusing	342
6.3.2	Beam Steering	347
	References	350
Index		353