## Contents

PREFA	CE	ix
CHAPT	ER 1 INTRODUCTION	1
1.1	The Doppler Shift	1
1.2	Optical Beating	2
1.3	The Differential Doppler Technique	3
1.4	Survey of Applications	4
CHAPT	ER 2 OPTICS AND LASERS	
2.1	Light as Electromagnetic Radiation	6
2.2	Geometrical Optics	7
2.3	Wave Optics	8
2.4	Interference	10
2.5	Optical Path Length	11
2.6	The Michelson Interferometer	12
2.7	Interference Between Reflected Beams	13
2.8	The Fabry–Perot Interferometer	14
2.9	Diffraction	15
2.10	Diffraction at a Focus	16
2.11	Gaussian Beam Optics	18
2.12	Polarized Light	19
2.13	Polarizing Prisms	20
2.14	Retardation Plates	21
2.15	Polarization by Reflection	22
2.16	Lasers	24
2.17	Light Amplification	24
2.18	Laser Oscillator Systems	26
2.19	Laser Modes	27
2.20	Coherence Length of a Laser	30
2.21	Light Detectors for LDA	31
2.22	Photomultipliers	32
2.23	Photodiodes	32
2.24	Light Quantization	33
2.25	Statistics of Photoemission	34

	٠
* *	
v	н.
v	х.

## CHAPTER 3 THE DOPPLER SHIFT

	1 JOIT LER SHITT	
3.1	Derivation of the Doppler Shift	36
3.2	Doppler Shift with a moving source	37
3.3	Relativistic Doppler Shift	38
3.4	Doppler Shift on Scattering	40
3.5	Alternative Derivation of the Doppler Shift on Scattering	42
3.6	Geometrical Derivation of the Shift.	43
3.7	Energy and Momentum Conservation on Scattering	45
3.8	Doppler Shifting by Reflection	46
3.9	Doppler Shifting by Diffraction Gratings	47
3.10	Diffraction by Acoustic Waves	48
3.11	Brownian Movement and the Doppler Shift	50
3.12	The Measurement of the Doppler Shift by Optical Spectroscopy	50
СНАРТІ	ER 4 OPTICAL BEATING AND THE REFERENCE BEAM	
01111	TECHNIQUE	
41	The Principle of Optical Heterodyning	53
4.1	Signal to Noise Ratios in Ontical Beating	55
43	Coherence in Ontical Beating	55
4.5	Cone of Coherence	57
4.4	Competitical Illustration of Coherence	58
4.5	Leser Speekle	60
4.0		61
4.7	Contenence Factors	64
4.8	Reference Beam Heterodyning	65
4.9	Configurations for Reference Beam Experiments	67
4.10	A Useful Reference Beam Arrangement	68
4.11	Doppler Signals	70
4.12	Transit Time Broadening	70
4.13	Broadening Mechanisms	70
4.14	Limitation of Accuracy due to Line Broadening	75
4.15	Self-Aligning Optics	74
4.16	Back Scattering Experiments	15
4.17	Signal to Noise Ratios in Reference Beam Experiments	/0
4.18	Calculation of Signal to Noise Ratios	/8
4.19	Signal to Noise Ratio for Typical Experiments	/9
4.20	Signal to Noise Ratio in Back Scattering	81
4.21	Limits of Sensitivity $\ldots$ $\ldots$ $\ldots$ $\ldots$ $\ldots$ $\ldots$ $\ldots$	83
СПАРТ	THE DIFFERENTIAL DOPPLER TECHNIQUE	
5 1	Differential Donnler Besting	85
5.1	Interpretation in Terms of Interference Fringes	86
J.2 5 2	The Brobe Volume	87
5.5 5 A	Ontical Arrangements for the Differential Donnler Technique	88
5.4	Deem Sulitting by Delerization	91
<b>3.3</b>	Beam Splitting by Polarization	21
5.6	Self-aligning Prism Devices.	74

5.7	Light Collection Arrangements		92
5.8	The Dual Scatter Technique		95
5.9	Multi-particle Fringe Crossing Signals		97
5.10	Signal to Noise Ratios		97
5.11	Coherent and Non-coherent Signals	•	100
5.12	2 Analysis of the Differential Doppler Technique	•	101
5.13	Signals in Rudd's Technique	•	105
5.14	Accuracy in Velocity Measurements	•	107
5.15	5 Pedestal Removal		108
5.16	6 Optical Imperfections	•	110
5.17	7 The Problem of Spherical Aberration	•	110
5.18	Criteria for Lens Performance	•	114
5.19	Aberrations from Windows	•	116
5.20	Alignment of the Detector	•	117
5.20	Choice of Ontical System	•	118
0.21		•	110
СНАРТ	FER 6 SIGNAL PROCESSING TECHNIOLIES		
61	Types of I DA Signal		110
6.2	Spectrum Analysis	•	119
63	Measurement of Turbulence by Spectrum Analysis	•	121
64	Frequency Tracking	•	123
6.5	Autodyne Tracking	•	120
6.6	Random Phase Eluctuations	•	120
67	Spectral Applysis of Frequency Demodulated Simple	•	129
6.8	Phase Decorrelated Doppler Signals	•	130
6.0	Counting Techniques	•	131
6 10	Count Walidation	•	133
6 11	Velocity Piering	•	136
6 12	Correction for Dissing Emerge	•	136
6.12	E Correction for Blassing Errors	•	137
0.13	Director Consultting	•	142
6.14		•	145
6.15	Interpretation of Correlation Functions	•	149
6.16	Sensitivity of the Photon Correlation Technique	•	152
6.17	Computer Processing and Other Techniques	•	152
6.18	Choice of Signal Processor	•	153
СНАРТ	TER 7 DIRECTIONAL DISCRIMINATION AND FREQUENCY		
	SHIFTING		
7.1	Directional Ambiguity	•	156
7.2	Two Phase Detection		156
7.3	High Frequency Phase Modulation		161
7.4	Directional Discrimination of a Single Transit		162
7.5	Frequency Shifting		164
7.6	Techniques of Frequency Shifting		165
7.7	Rotating Diffraction Gratings.		166

vii

7.8	Acousto-optic Cells							168
7.9	Frequency Shifting by Electro-optic Techniques .						•	170
7.10	The Rotating Half-wave Plate							170
7.11	Multi-cell Electro-optic Frequency Shifting Devices							172
7.12	Electro-optic Phase Modulators						•	177
7.13	The Practical Application of Frequency Shifting .							180
7.14	Problems in the Use of Frequency Shifting		•	•	•	•	•	180
CHAPTI	ER 8 PROPERTIES OF SCATTERING PARTICLE	ES						
8.1	The Requirement for Scattering Particles							182
8.2	Fluid Dynamic Considerations							183
8.3	Light Scattering from Small Particles							184
8.4	Scattering from Spherical Particles							186
8.5	The Seeding of Liquid Flows							190
8.6	The Seeding of Gases							191
8.7	Polarization Changes on Scattering							194
8.8	The Effect of Particle Size on LDA Signals							195
CHAPT	ER 9 APPLICATIONS							100
9.1	Measurement of Velocity and Turbulence Profiles .	٠	•	•	·	٠	·	199
9.2	Multi-component Velocity Measurement	•	•	٠	•	•	·	201
9.3	Two-Component Differential Doppler Systems	•	•	•	•	·	·	203
9.4	Studies of Turbulence	•	•	•	•	•	·	207
9.5	Applications to Aerodynamics	•	•	•	•	•	·	210
9.6	The Measurement of Wind Speed	•	•	•	•	٠	•	211
9.7	Studies of Combustion	·	•	•	•	٠	•	214
9.8	Microscopic and Biological Measurements	•	•	•	•	٠	•	217
9.9	The Measurement of the Velocity of Solid Surfaces	·	•	•	·	•	٠	220
9.10	Laser Interferometry	·	•	·	·	•	•	222
9.11	Related Techniques	•	•	·	•	•	٠	225
9.12	$Conclusion \dots \dots$	•	٠	•	•	•	•	226
REFER	ENCES	•	•	•	•	•	•	228
BIBLIO	GRAPHY	•	•					231
INDEX								233

viii