

Table of Contents

FIBRE OPTIC COMMUNICATIONS

LECTURE NOTES

CHAPTER 1 : INTRODUCTION TO OPTICAL FIBRE COMMUNICATIONS	1
1.1 Introduction	1
1.2 Historical perspective	1
1.3 Fibre optic communications systems	3
1.4 Why fibre optics	5
CHAPTER 2 : THE OPTICAL COMMUNICATIONS CHANNEL	7
2.1 Introduction	7
2.2 Optical fibre for communications systems	7
2.3 Attenuation and link length limits in fibre optic channels	8
2.3.1 Attenuation in optical fibre	8
2.3.2 Fibre attenuation mechanisms	8
2.3.2.1 Absorption	8
2.3.2.2 Scattering	9
2.3.4 The wavelength dependence of attenuation in silica fibre	10
2.3.5 Fibre cable losses - radiation/ bend loss	11
2.3.6 Other sources of loss in optical fibre channels	12
2.3.7 Implications of attenuation	12
2.4 Pulse spreading, dispersion and bit rate/ distance limits in optical fibre links	14
2.4.1 Introduction	14
2.4.2 Pulse spreading/ dispersion in single mode optical fibre	14
2.4.3 Physical origins of intramodal dispersion	16
2.4.3.1 Material dispersion	16
2.4.3.2 Waveguide dispersion	17
2.4.4 The total magnitude of pulse spreading in single mode optical fibres	17
2.4.5 Pulse spreading in multimode optical fibre - intermodal time delay effects	18
2.4.5.1 Multimode step index fibre	19
2.4.5.2 Multimode graded index fibre	20
2.4.5.3 Multiple sources of pulse spreading	21
2.4.6 Implications of pulse spreading	21
2.5 Analogue transmission	25
2.6 Summary	25
CHAPTER 3 : OPTICAL SOURCES FOR FIBRE OPTIC COMMUNICATIONS SYSTEMS	26
3.1 Introduction	26
3.2 Structures & operating principles of semiconductor optical sources for telecommunications ...	26
3.2.1 Light generation in a simple p-n junction	26
3.2.2 Double hetero-junctions for efficient light generation and collection	27
3.2.3 Material systems and fabrication	29
3.2.4 Lasers and LEDs - the differences	30
3.3 Characteristics of LEDs	30
3.3.1 Power/ current characteristics	30
3.3.2 Output power and launched power	31
3.3.3 Modulation Bandwidth/ Maximum bit rate	31
3.3.4 Wavelength characteristics	32
3.4 Laser diode characteristics	34
3.4.1 Power/ current characteristics	34
3.4.2 Output power and launched power	35
3.4.3 Modulation bandwidth/ maximum bit rate	35
3.4.4 Wavelength characteristics	35
3.4.4.1 Fabry Perot Cavity (FPC) Lasers	36

3.4.4.2 Distributed Feedback (DFB) Lasers	39
3.5 Summary	40
CHAPTER 4 : OPTICAL DETECTION AND OPTICAL RECEIVERS	41
4.1 Introduction	41
4.2 Principles of p-n and pin diode structures	41
4.3 Principles of photodiode detection	43
4.4 Principles of avalanche photodiodes (APDs).....	44
4.5 Characteristics of photodiodes and photodiode receivers	45
4.5.1 Quantum efficiency and responsivity	45
4.5.2 Wavelength dependence of the responsivity	46
4.5.3 Response speed and bandwidth	46
4.5.4 Noise in photodiode detectors	48
4.5.4.1 Signal shot noise.....	49
4.5.4.2 The dark current shot noise	50
4.5.4.3 Thermal noise	50
4.5.5 Signal to noise ratio and detection sensitivity	51
4.5.5.1 Thermal noise limited detection	51
4.5.5.2.Dark current shot noise limits.....	52
4.5.5.3 Quantum or shot noise limited detection	53
4.5.6 Digital optical receivers.....	53
4.5.7 Avalanche photodiodes	55
4.5.8 Power penalties	56
4.6 Practical photodiode detector circuits	56
4.7 Summary.....	57
CHAPTER 5 : THE FIBRE OPTIC COMMUNICATIONS SYSTEM.....	59
5.1 Introduction	59
5.2 System performance	59
5.3 System design and analysis	62
5.4 Summary.....	66
REFERENCES	67
APPENDIX A: TUTORIALS	
APPENDIX B: TUTORIAL SOLUTIONS	

Table of Contents

FIBRE OPTIC COMMUNICATIONS

INSTRUCTOR MANUAL

1. INTRODUCTION	1
2. PRINCIPLES OF FIBRE OPTIC COMMUNICATIONS SYSTEMS.....	1
2.1 ATTENUATION LIMITS	2
2.2 DISPERSION LIMITS	3
3. PRINCIPLES OF FIBRE DISPERSION AND SYSTEM RESPONSE MEASUREMENTS	3
3.1 FREQUENCY DOMAIN RESPONSE MEASUREMENTS	3
3.2 TIME DOMAIN RESPONSE MEASUREMENTS	4
3.3 CALCULATION OF THE BW.L AND BR.L PRODUCTS.....	4
3.4 MEASUREMENT OF THE MATERIAL AND INTERMODAL DISPERSION CONTRIBUTIONS.....	5
4. DESIGN OF THE EDUCATOR KIT.....	6
5. APPARATUS	6
5.1 EQUIPMENT SUPPLIED	6
5.2 ADDITIONAL EQUIPMENT TO BE SUPPLIED BY THE USER	7
6. LASER SAFETY	8
6.1 OPERATIONAL HAZARD - SEMICONDUCTOR LASER DIODE	8
7. OPERATING INSTRUCTIONS	9
7.1 FRONT PANEL LAYOUT	9
7.2 BEFORE SWITCHING ON	9
7.3 CARE OF OPTICAL FIBRES	9
7.4 SETTING THE BIAS POINTS FOR THE OPTICAL SOURCES	10
7.5 USE OF THE WAVEFORM GENERATOR.....	10
7.6 BEFORE SWITCHING OFF	10
8. EXPERIMENTS.....	12
8.1 COMPARISON OF LED AND LASER DIODE CHARACTERISTICS.....	12
8.1.1 <i>Optical Output Power against Drive Current</i>	12
8.1.2 <i>Launched Optical Power</i>	14
8.2 ATTENUATION IN OPTICAL FIBRE LINKS.....	14
8.2.1 <i>Optical Fibre Connector Loss</i>	14
8.2.2 <i>Attenuation of the Optical Signal over the Link Length</i>	15
8.2.3 <i>Determination of Fibre Link Length and Fibre Attenuation Coefficient</i>	15
8.2.4 <i>Determination of Attenuation Limited Link Lengths</i>	18
8.2.5 <i>Exercises</i>	20
8.3 BANDWIDTH AND FIBRE DISPERSION MEASUREMENTS.....	21
8.3.1 <i>Time domain measurements</i>	21
8.3.2 <i>Frequency Domain Measurement</i>	24
8.3.3 <i>Exercises</i>	26
APPENDIX A: DISPERSION PHENOMENA IN OPTICAL FIBRES.....	28
<i>The Origins of Dispersion</i>	28
<i>Step and Frequency Responses</i>	30
<i>Dispersion and Bit Error Rate</i>	32
<i>Dispersion Effects - A Brief Investigation</i>	35
APPENDIX B: EQUATING AN AMPLITUDE DIVIDED SIGNAL TRAVERSING TWO DIFFERENT PATHS.....	38
APPENDIX C: FIBRE LINK LENGTH MEASUREMENT USING BER(COM).....	39
C.1 <i>Theory</i>	39
C.2 <i>Measurement of Fibre Length with BER(COM) – Method 1</i>	39
C.3 <i>Measurement of Fibre Length with BER(COM) – Method 2</i>	41
C.4 <i>Calculation of the Fibre Attenuation per km for the Optical Sources</i>	43