

Table of Contents

PRINCIPLES OF OPTICAL WAVEGUIDING

LECTURE NOTES

1. INTRODUCTION TO OPTICS.....	1
1.1. <i>Introduction</i>	1
2. HISTORICAL BACKGROUND	3
2.1 <i>The seventeenth century</i>	3
2.2 <i>The nineteenth century</i>	4
2.3 <i>The twentieth century</i>	4
3. ELECTROMAGNETIC THEORY.....	6
3.1 <i>Electromagnetic phenomena</i>	6
3.2 <i>The wave equation in free space</i>	6
4. ELECTROMAGNETIC WAVES	8
4.1 <i>Solutions for the electric field</i>	8
4.2 <i>Transverse nature of the electric field</i>	9
4.3 <i>Solutions for the magnetic field</i>	10
4.4 <i>Why no 'luminiferous aether'?</i>	10
4.5 <i>Electromagnetic waves in materials</i>	11
4.6 <i>Plane waves and other forms</i>	12
4.7 <i>Power flow and the Poynting vector</i>	12
4.8 <i>Standing waves</i>	13
4.9 <i>Group velocity</i>	14
5. POLARISATION	16
5.1 <i>Linear states of polarisation</i>	16
5.2 <i>Circular and Elliptical States of Polarisation</i>	16
5.3 <i>Birefringence</i>	18
5.4 <i>Polarisers</i>	19
6. OPTICAL SOURCES AND THE PARTICLE PROPERTIES OF LIGHT.....	21
6.1 <i>The Particle Properties of Light</i>	21
6.2 <i>The Electromagnetic Spectrum</i>	21
6.3 <i>Generation of Electromagnetic Radiation</i>	22
6.4 <i>Electromagnetic Properties of Atoms</i>	23
6.5 <i>Radiation From Atoms and Molecules</i>	24
6.6 <i>X-rays and Gamma Rays</i>	26
6.7 <i>Linewidth</i>	26
6.8 <i>Coherence</i>	27
7. REFLECTION AND REFRACTION.....	30
7.1 <i>Introduction</i>	30
7.2 <i>Geometrical laws of reflection and refraction</i>	31
7.3 <i>A wave-picture of reflection and refraction</i>	32
7.4 <i>Boundary conditions for the electric and magnetic field vectors</i>	32
7.5 <i>Relationship between the continuity conditions and the laws of reflection and refraction</i>	36
7.6 <i>The Fresnel Equations</i>	38
7.7 <i>The Brewster angle</i>	42
7.8 <i>Total internal reflection</i>	43
7.9 <i>Energy associated with the evanescent wave</i>	45
7.10 <i>Form of the evanescent wave</i>	46
7.11 <i>Phase changes on reflection</i>	48
7.12 <i>The Goos-Haenchen shift</i>	50
8. INTERFERENCE.....	53
8.1 <i>Young's slits</i>	53
8.2 <i>The Mach-Zehnder interferometer</i>	54

<i>8.3 Visibility of interference</i>	57
<i>8.4 Effect of polarisation on visibility</i>	58
<i>8.5 Effect of coherence on visibility</i>	60
9. DIFFRACTION	61
10. OPTICAL WAVEGUIDES	63
<i>10.1 Total internal reflection.....</i>	63
<i>10.2 The two-dimensional slab waveguide.....</i>	64
<i>10.3 The formation of waveguide modes.....</i>	65
<i>10.4 Number of allowed waveguide modes</i>	66
<i>10.5 Field distributions for the guided modes.....</i>	67
<i>10.6 The waveguide parameters.....</i>	67
<i>10.7 Mode cut-off conditions.....</i>	69
<i>10.8 Normalised effective index and normalised film thickness.....</i>	70
<i>10.9 TE and TM modes</i>	71
<i>10.10 The asymmetric slab waveguide</i>	72
<i>10.11 The eigenvalue equation.....</i>	74
<i>10.12 Graded index slab waveguides.....</i>	75
<i>10.13 Prism coupling</i>	79
11. OPTICAL FIBRES	82
APPENDIX A.....	84
<i>Tutorial 1 - Wave And Particle Properties Of Light</i>	84
<i>Tutorial 2 - Optical Waveguides</i>	85
APPENDIX B	86
<i>Tutorial Solutions 1 - Wave And Particle Properties Of Light.....</i>	86
<i>Tutorial Solutions 2 - Optical Waveguides</i>	87

Table of Contents

OPTICAL WAVEGUIDING

STUDENT MANUAL

1. INTRODUCTION.....	1
2. THEORY.....	2
<i>2.1 Planar step index waveguides</i>	2
<i>2.2 Graded index waveguides.....</i>	4
<i>2.3 Prism coupling.....</i>	6
3. APPARATUS.....	8
4. LASER SAFETY	9
<i>4.1 Operational Hazard - Semiconductor laser diodes</i>	9
5. THE EXPERIMENTAL SYSTEM.....	10
<i>5.1 Aims and Objectives</i>	10
<i>5.2 Assembly and operating instructions for the experimental system.....</i>	10
5.2.1 Assembly of the system.....	10
5.2.2 Establishment of the required polarisation state	10
5.2.3 Operation of the system.....	11
6. EXPERIMENTS AND EXERCISES.....	12
<i>6.1 Investigation of Step Index Waveguides</i>	12
6.1.1 Determination of the mode structure of a step index planar waveguide.....	12
6.1.1.1 Observation of the substrate modes.....	12
6.1.1.2 Coupling to the waveguide modes	13
6.1.1.3 Observation and investigation of the m-lines (mode lines)	13
6.1.1.4 Measurement of the coupling angles and mode effective indices for the TE polarisation state ...	14
6.1.1.5 Measurement of the mode structure of the waveguide for the TM polarisation state.....	14
6.1.1.6 Determination of the mode structure of the second step index waveguide provided (optional - on instructions from the laboratory supervisor)	14
6.1.2 Determination of the step index waveguide parameters (i.e. the waveguide refractive index and thickness) from the measured mode spectrum.....	15
6.1.3 Establishing the design of a single mode step index waveguide.	15
6.1.4 Confirmation of your design of a single mode waveguide	15
<i>6.2 Investigation of Graded Index Waveguides.....</i>	16
6.2.1. Determination of the mode structure of the graded index waveguide	16
6.2.2. Determination of the waveguide parameters of the graded index waveguide (the surface index and thickness) from the measured mode spectrum.....	16
6.2.3. Establishing the design of a single mode graded index waveguide	16
6.2.4 Confirmation of single mode operation.....	17
APPENDIX WAVE: OPTICAL WAVEGUIDING SET-UP.....	18
<i>WAVE1: Basic Assembly Procedure.....</i>	18
<i>WAVE2: Practical Guide to Achieving Waveguiding.....</i>	21
<i>WAVE3: Angular Measurement Technique Using Micrometer.....</i>	24
APPENDIX LA&C: LASER ALIGNMENT & COLLIMATION	25
<i>LA&C1: Centralising the Laser Beam.....</i>	25
<i>LA&C2: Collimating or Focusing The Laser Beam.....</i>	25