

## **Unit 157: Optical Fibre Communications Systems**

**Unit code:** T/615/4153

**QCF level:** 4

**Credit value:** 15

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- **Aim**

The aim of this unit is to develop an understanding of the principles of the operation of optical fibre transmission lines, light sources and detectors and their application to communication systems.

- **Unit abstract**

The unit covers the principles of light transmission in optical fibres, the differing modes of propagation and the types of fibre in common use. The physical properties and operating principles of a range of light sources and detectors are also covered. The performance of complete fibre optic communication systems is considered, as are the applications of optical fibres to other fields such as medical electronics.

- **Learning outcomes**

**On successful completion of this unit a learner will:**

- 1 Understand optical fibre transmission lines
- 2 Understand sources and modulating devices used for fibre optic communication systems
- 3 Understand optical detectors used for fibre optic communication systems
- 4 Be able to determine the overall performance of typical optical fibre communication systems.

## Unit content

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### 1 Understand optical fibre transmission lines

*Operation of optical fibres:* the physics of light, e.g. light as a wave, ray and a particle (photon), the electromagnetic spectrum, frequency and wavelength of light – visible and infra-red; behaviour of light, eg reflection, refraction, dispersion, diffraction, absorption and scattering; refractive index, eg refractive indices of typical materials used for optical fibres, calculations involving Snell's law; total internal reflection, critical angle, acceptance angle, numerical aperture, dispersion and attenuation; fibre termination techniques, eg splicing and connectors; polishing; typical losses

*Advantages of optical fibres:* bandwidth; security; lack of interference; cost

*Three modes of operation:* multi-mode (stepped index and graded index); single-mode (mono-mode); refractive index profiles of optical fibres; materials used for the manufacture of optical fibres; choice of wavelength

### 2 Understand sources and modulating devices used for fibre optic communication systems

*Characteristics of light sources:* requirements in terms of output power, efficiency, coupling, operating wavelength, line width, response time, stability, principles of emission (spontaneous, stimulated); calculations to determine the wavelength of emission (given the operating temperature and the band gap energy of the semi-conductor material)

*Light-emitting diodes:* semi-conductor materials; structure (simple, surface emitting, edge emitting); characteristics, eg line width, angle of radiation, response time, wavelength, bandwidth, output power, radiation pattern, coupling efficiency, stability, cost

*Semi-conductor laser diode:* simple structure, heterostructure; characteristics, eg line width, angle of radiation, response time, wavelength, bandwidth, output power, radiation pattern, coupling efficiency, stability, cost; drive electronics and temperature control

### 3 Understand optical detectors used for fibre optic communication systems

*Photo detectors:* photo detector requirements, eg sensitivity, response times, linearity, noise; principles of photo detection, eg electron-hole generation, energy gap, spectral response; operation and characteristics of photo diodes, eg PN junction, PIN, APD, PINFET; design and construction of photo diodes, eg PN junction, PIN, APD, PINFET; calculations to determine values for the responsivity of photo detectors

*Optical receivers:* detector circuits; receivers, eg trans-impedance, integrating, APD, high impedance, detectability, noise, and bandwidth

**4 Be able to determine the overall performance of typical optical fibre communication systems**

*Performance of optical fibre systems:* factors affecting choice of transmitter, type of fibre, receiver; coupling (between transmitter and fibre and fibre and receiver); calculation of link budgets; modulation, multiplexing and coding; repeaters and regenerators; bandwidth and rise time budgets; noise, bit error rate, eye patterns; coherent optical communication systems; integrated optical amplification; optical time domain reflectometers

*Applications:* long-haul communication links; fibre-based local area networks; cable television system

## **Learning outcomes and assessment criteria**

| <b>Learning outcomes</b>  | <b>Assessment criteria for pass</b>   |
|---|---|
| <b>On successful completion of this unit a learner will:</b>  | <b>The learner can:</b>   |
| <p>LO1</p> <p>Understand optical fibre transmission lines</p>   | <p>1.1 investigate the operation of optical fibres when used as communication links</p> <p>1.2 discuss the advantages of optical fibres over copper-based transmission lines</p> <p>1.3 compare and contrast the three modes of operation for different types of optical fibres</p>   |
| <p>LO2</p> <p>Understand sources and modulating devices used for fibre optic communication systems</p>        | <p>2.1 discuss the characteristics of suitable light sources for optical fibre transmission lines</p> <p>2.2 compare and contrast light-emitting diodes (LEDs) and semi-conductor laser diodes (SLDs)</p> <p>2.3 explain how LEDs and SLDs may be modulated, using practical demonstrations</p>   |
| <p>LO3</p> <p>Understand optical detectors used for fibre optic communication systems</p>                     | <p>3.1 explain the principles of operation of a range of semi-conductor devices used as photo detectors</p> <p>3.2 discuss the design of optical receivers</p> <p>3.3 explain the principle of operation of coherent detection receivers</p>  |
| <p>LO4</p> <p>Be able to determine the overall performance of typical optical fibre communication systems</p> | <p>4.1 appraise the performance of optical fibre systems used for analogue and digital communication systems</p> <p>4.2 perform link budget calculations to estimate system performance from given component parameters for typical applications</p> <p>4.3 explain the principles of wavelength division multiplexing</p> <p>4.4 explain the principles of operation, and relevant advantages of integrated optical amplifiers</p> |

## Information for tutors

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### Essential requirements

Learners will need access to the internet.

### Delivery guidance

This unit can be delivered as a stand-alone package or integrated into other appropriate programme units. If it is delivered in an integrated way, care must be taken to provide tracking of evidence for the outcomes. Centres should be aware that study and assessment at individual outcome level could lead to assessment overload. Wherever possible, a practical approach should be adopted. Learning and assessment can be across units, at unit level or at individual outcome level. Effort should be made to identify the relevance of the principles covered to engineering applications and system design.

Appropriate software packages should be used to verify solutions to problems and the behaviour of optical fibres. Learners could be asked to terminate optical fibres in a laboratory/workshop situation. Access to suitable laboratory equipment and test instrumentation is desirable but not essential.

### Assessment guidance

Evidence of outcomes can be in the form of assignments, reports of practical activities, computer printouts, solutions to applied problems and/or the results of unseen tests/examinations. Evidence can be accumulated by learners building a portfolio of activities or through a tutor-led combination of tests and assignments. In either case, the evidence must be both relevant and sufficient to justify the grade awarded.