The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6217 OPTICAL COMMUNICATION DEVICES & SYSTEMS

Credits: 15

Course Description including Aims

The course examines the behaviour of the components in a communications system and the way in which their design and individual performance is determined by that of the system requirements. The course is delivered as a set of 30 one hour lectures and includes a visit to the Central Facility. Copies of incomplete OHP transparencies are distributed to students and these are supplemented by additional notes taken during the lecture. The module aims are

1. To study the characteristics of the device components used in optical fibre communication systems and to examine their dependence on design.
2. To study the dependence of the system performance on device design.

Outline Syllabus

Introduction to optical fibre communications.

Optical fibres; structure, fabrication, ray and wave optics, attenuation and dispersion, bit-rate, bit-error-rate, acceptance angle, NA. Optical mode, single-model fibres, multimode fibres, modal dispersion, cutoff. Graded index fibres. Fibre amplifiers. Eye diagram. Fibre optical sensor. Visible light communication. Non line-of-sight communication. System design and power budget. Loss and Dispersion Limits for System. Detailed System Analysis. Network Architecture WDM systems and components

III-nitride semiconductors, LEDs including white LEDs, spontaneous emission, surface and edge emitters, linewidth and speed, internal quantum efficiency, extraction efficiency, radiative recombination, non-radiative recombination, recombination life-time.

Semiconductor lasers; structure, material growth, device fabrication, gain and feedback, materials, heterostructures, carrier and optical confinement. Threshold gain and Fabry-Pérot mode separation. Dependence of gain on n, λ and T, lasing emission spectrum. DBR and DFB, VCESL, I_{th}, turn-on delay, dynamic response. Advanced laser structures. Advanced semiconductor growth technologies.

Detectors; photoconductor, pin diodes, responsivity, absorption, Si photodiodes. Quantum efficiency, transit-time, current gain, structure. APD, impact ionisation, field dependence, multiplication, noise and breakdown. APD design.

Time Allocation

30 hours of lectures plus 6 hours of additional support material.

Recommended Previous Courses

Students are required to have a background which covers basic semiconductor device structure, electronic and optical properties together with some previous knowledge of semiconductor technology. Sheffield undergraduates should have taken the s modules EEE118 “Electronic Devices” and passed in previous years. PGT students or have taken external courses with equivalent learning outcomes (see module description for this course)

Assessment

Assessment is primarily in the form of a 2 Hour Examination the end of semester 2. Candidates must choose any three out of four questions (75% total marks)
Students will be requested to complete course work which will account for 25% of the module score.

Recommended Books

Senior, J.M.	*Optical Fibre Communications*	Prentice-Hall
Battacharya, P.	*Semiconductor Optoelectronic Devices*	Prentice-Hall
Gowar, G.	*Optical Communications Systems*	Prentice-Hall
Singh, J.	*Semiconductor Optoelectronics*	McGraw-Hill

Objectives

By the end of the module successful students will be able to

1. Understand the major application areas of modern optical communication
2. Understand the present market and future development in optical communication
3. Have knowledge of the basic structural and optical properties of semiconductor materials of relevance to optical communication
4. Understand the principles of semiconductor LEDs, lasers, detectors and optical fibres.
5. Describe the basic structure and electronic properties of solid-state devices
6. Understand each component and its operation mechanism
7. Appreciate the dependence of device performance on design.
8. Understand how device design and performance feeds through into system performance.
9. Understand the principles of semiconductor light emitting diodes, lasers, detectors and optical fibres and apply this knowledge to the design of a lightwave system.
10. Calculate the limits to bandwidth distance product in a fibre-optic system and recognize methods to improve system operation.
11. Calculate the light collection and data transmission properties of a fibre-optic system.

Detailed Syllabus

1. Introduction: history and current status of optical communication, plane wave, phase velocity, group velocity
2. Fibres: waveguide, optical fibre modes, NA, acceptance angle, single mode fibres, mutiple mode fibres
3. Dispersion: intermodal dispersion, intramodal dispersion, material dispersion, waveguide dispersion, chromatic dispersion
4. Loss: loss mechanisms in fibres; optical fibre manufacture
5. Loss and dispersion limits: review of fibre properties, repeater spacing, bandwidth; limit due to attenuation, limit due to dispersion; power budget
6. Bit-error: receiver; mechanisms for error regeneration; bit-error-rate; eye diagram; power penalties
7. Optical amplifiers: classification of optical amplifiers; EDFA & PDFA; operational mechanism of EDFA; gain saturation; cross-talk; semiconductor optical amplifiers
8. WDM: structure, principles of operation; optical coupler; WDM coupler; DWDM Components
9. System design: communication system structure and components; optical power budgeting
10. Fibre optic sensor
11. Visible light communication system

12. Non line-of-sight communication
13. Revision of Semiconductor device physics
14. LEDs-1: basic concepts; structures; characteristic of LEDs; modulation dynamics
15. LEDs-2: Burrus surface emitter; edge emitter; coupling to fibre; fabrication of LEDs; modern LEDs
16. Introduction of III-nitride semiconductors and devices
17. III-nitride semiconductor based solid state lighting
18. White LEDs with ultra short response time
19. Ultraviolet-LEDs for non line-of-sight communication
20. Laser diodes-1: requirements for a laser diode; laser structure; gain and loss; optical confinement and threshold; design of laser diodes
21. Characteristics of laser diodes: estimation of threshold current; temperature effect; phase conditions and laser modes; lateral confinement lasers; coupling light to a fibre
22. Introduction of different type of laser diodes: short-cavity FP; DBR; DFB; VCSEL; wavelength tuning
23. Laser diodes-2: laser rate equations, carrier density rate equation, photon density rate equation; laser turn on delay; dynamic response above threshold; frequency modulation response; chirp
24. Low dimensional laser diodes: basic theory for low dimensional semiconductors, Quantum Mechanics; MQW; QWire; QD for laser; advanced growth technologies of MQW, QWire and QDs; lattice mismatch and strain; strained layer lasers
25. Photo-detectors: classification of photodetectors; quantum efficiency; responsivity; transit time; modulation frequency; bandwidth; photoconductor, operational mechanism; current gain; noise performance
26. Photodiodes: pin diodes; operational mechanism; noise performance
27. APD: operational mechanism, impact ionization, multiplication factor; device design; noise performance
28. Worked examples.

29-30 Practical sessions: Tour of National Centre; Demonstration of device operation

UK-SPEC/IET Learning Outcomes

Outcome Code	**Supporting Statement**
SM1p	The physics ideas of semiconductor devices and optical fibres are brought together in this module to provide a basis for design of an optical communication system. The ability to exploit these ideas is tested in the exam. History and future development of semiconductor devices and optical fibres are included.
SM1m / SM1fl	Students will develop a comprehensive understanding of the underlying scientific principles and methodology behind different kinds of optical communication systems. Students are also requested to have a comprehensive understanding of the underlying scientific principles and concepts for semiconductor devices which are the key components for optical communication systems. This module also details that the development of semiconductor optoelectronics has major impact on the development of optical communication systems.
SM2m	The application of mathematical tools to engineering problems is a fundamental aspect of application of semiconductor devices in designing an optical communication system, such as the limits in terms of distance and bit-rate. It is tested in the exam.
SM3m	This module contains a large number of concepts in semiconductor devices (such as line-width of laser or LED, recombination lifetime, detector limit) and optical

fibres (such as optical dispersion and optical loss, signal broadening, etc). Understanding of these concepts is essential for designing an optical communication system. It is tested in the exam.

SM4m	The technologies for the fabrication of advanced semiconductor devices and latest progress in the field of optical communication are introduced.
SM6m	This module requires application of the concepts mentioned in SM3p and a number of semiconductor physics concepts which are beyond engineering (such as density of states in a low dimensional structure, quantization energy in semiconductor quantum structures, etc.) in designing optoelectronics as components for an optical communication system. It is tested in the exam.
SM3fl	This module requires application of the concepts mentioned in SM3p and a number of semiconductor physics concepts which are beyond engineering (such as density of states in a low dimensional structure, quantization energy in semiconductor quantum structures, etc.) in designing optoelectronics as components for an optical communication system. It is tested in the exam.
EA1p	The essence of this module is the process of defining models that describe an optical communication system to allow predictions of performance to be made. It is tested in the exam.
EA1m	Students will develop a comprehensive understanding of engineering principles behind different kinds of optical communication systems and the ability to apply them to perform critical analysis on the performance of these optical communication systems.
EA2m / EA2fl	This module introduces the latest developments in modern optical communications, where analytical methods and modelling techniques are crucial for identifying, classifying and describing the performance of the optical communications systems and the semiconductor devices.
EA2m	Students are taught the mathematical tools to design an optical communication system. It is tested in the exam.
EA3p	Student will develop an ability to apply quantitative and computational methods to resolve practical problems in designing optical communication systems with good reliability, such as maximal transmission distance, power budget of transmitter, etc.
EA3m / EA3fl	Students are taught the mathematical tools to analyse and evaluate the fundamental limitations in designing an optical communication system, such as optical loss and optical dispersion limitations of optical fibres used. Students will develop an ability to use alternative approaches to resolve these issues. It is tested in the exam.
EA4m	Basic structures and requirements for fibre optical communication are introduced. Performance of different kinds of semiconductor devices and optical fibres is introduced. Student will develop an ability to integrate these two different kinds of components with matching performance to each other in order to design optical communication systems which can meet different requirements.
EA5m	Latest progress on developing new semiconductor devices and optical fibres is introduced, which however is still based on the fundamental concepts and the existing theory. This is tested in the exam.
EA6m	Students are taught the mathematical tools to extract data of semiconductor devices and apply these data to design new structures of semiconductor devices which student may not be familiar with. It is tested in the exam.
D2p / D2m	This module introduces issues on environmental and sustainability limitation, security, health, safety, and risk assessment of employing semiconductor devices

in designing some new kinds of optical communication, in particular, non-line-of-sight communication sustems which are important for short-range optical communications that request high security, where deep ultraviolet emitters as optical transmitters are the key components.

D2fl	Students will develop knowledge and comprehensive understanding of fundamental processes and methodologies of optical communication systems and apply these to design new kinds of optical communications which students may not be familiar with.
D5p / D5m	Issues on a system design and component manufacturing costs for building up an optical communication system including semiconductor devices and optical fibres are introduced.
D5p	Issues on manufacturing costs of optical fibres and semiconductor devices which are related to their performance for different purposes are introduced.
D7m	Students will develop knowledge and comprehensive understanding of fundamental processes and methodologies of optical communication systems and apply these to design new kinds of optical communications which students may not be familiar with.
ET2m / ET2fl	Safety, environmental and IP requirements of manufacturing semiconductor devices and optical fibres are introduced. The development of optical fibre and optical components is introduced in terms of commercial, economic and social aspects.
ET4m	Issues on developments of semiconductor devices in both a sustainable and a cost-effective manner are introduced.
ET4fl	Issues on developments of semiconductor devices in both a sustainable and a cost-effective manner are introduced.
ET6p	This module introduces issues on risk assessment and risk management of employing semiconductor devices in designing some new kinds of optical communication systems, in particular, non-line-of-sight communication systems, where deep ultraviolet emitters as optical transmitters are the key components.
EP1p / EP1m	Historical and latest developments in optical communications are introduced in terms of understanding of context in which engineering knowledge can be applied.
EP2p / EP2m	Students will develop knowledge of characteristics of semiconductor materials including emerging semiconductors, advanced facilities which are used to produce these semiconductor materials, and final devices fabricated from these semiconductor materials.
EP2m	A large number of semiconductor materials, final devices fabricated from these semiconductors and the whole manufacturing process from producing these materials to the final fabrication of devices including cutting-edge techniques are introduced. Students will develop extensive knowledge and understanding of characteristics of semiconductor materials including emerging semiconductors, advanced facilities which are used to produce these semiconductor materials, and final devices fabricated from these semiconductor materials.
EP9m	Limits in performance of current laser diodes, detectors, optical fibres and optical amplifiers are introduced. These have to be taken into account in designing an optical communication system. Future development of technology for fabrication of new semiconductor devices and optical fibres are introduced.
EP10m	Devices reliability and optical power budgeting are introduced for the design of practical fibre optical communication systems. It is tested in the exam.
EP1fl	Students will develop knowledge of characteristics of semiconductor materials

including emerging semiconductors, advanced facilities which are used to produce these semiconductor materials, and final devices fabricated from these semiconductor materials. A large number of semiconductor materials, final devices fabricated from these semiconductors and the whole manufacturing process from producing these materials to the final fabrication of devices including cutting-edge techniques are introduced. Students will develop extensive knowledge and understanding of characteristics of semiconductor materials including emerging semiconductors, advanced facilities which are used to produce these semiconductor materials, and final devices fabricated from these semiconductor materials.

EP2fl	Limits in performance of current laser diodes, detectors, optical fibres and optical amplifiers are introduced. These have to be taken into account in designing an optical communication system. Future development of technology for fabrication of new semiconductor devices and optical fibres are introduced.