Module Name: **Optical Transmission and Networks**

Module Acronym: **OTN**

Module Manager: **Prof Polina Bayvel**

Course Lecturers: Prof Polina Bayvel, Dr Robert Killey, Dr Seb Savory, Dr Philip Watts  
*Guest lecturers:* OFDM Dr Steve Desbruslais, Xtera - *Submarine System Design*; Group exercise Dr Robert Maher/Dr Dom Lavery

### 1.1.1 Summary

This module provides the student with an advanced understanding of the physical layer of optical transmission systems and networks on different time- and length-scales. Optical networks include the description of optical networks as a set of optical links, including the principle of wavelength routing on different time-scales (static and dynamic). This part of the course also includes optical interconnects. On optical transmission the focus is on the elements of analysis and design of point-to-point optically-amplified transmission systems as well as access applications. This covers in-depth understanding of optical transmission system design, optical amplifiers and amplified systems and the operation of wavelength division multiplexed systems. Both linear and nonlinear sources of transmission impairments and their accumulation with distance and interaction with dispersion are analysed. The choice of modulation formats, fibre dispersion and electronic processing techniques are discussed with the aim of maximising the spectral efficiency, channel capacity and operating system margins.

### 1.1.2 Learning Outcomes

At the end of the course, students are expected to:

- Understand the principles of optically amplified optical transmission systems, power levels, noise accumulation and the trade-off between system capacity and reach
- Carry out power budget calculations for optically amplified links
- Understand signal transmission impairments: fibre dispersion, PMD, fibre nonlinearity
- Carry out calculations quantifying the effects of dispersion and nonlinearity on an optical link
- Understand the concept of spectral efficiency; appreciate the difference between symbol rate and bit rate, and describe the use of different modulation formats and other signal dimensions to increase capacity (such as polarization and phase)
- Clearly understand optical system performance metrics: signal-to-noise ratio, sources of noise, capacity and spectral efficiency
- Understand trade-offs between optical systems capacity and reach, choice of modulation and detection formats, and implications on system performance
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- Understand and apply the principles of electronic processing (transmitter and receiver based) and the basics of coherent detection
- Describe & analyse a variety of optical network architectures: access vs core, static vs dynamic operating on different time- and length-scales
- Analyse and design network topologies and calculate their capacities
- Have the knowledge and confidence to design optical communications links and networks on different time – and distance-scales
- Describe current research trends and explain expected future directions in optical communications with reference to key problems that need to be solved

1.1.3 Syllabus

Introduction to optical transmission networks

An introduction to optical transmission links and subsystems including transmitters, receivers, optical fibre and amplifiers. Introduction to optical networks as a set of optical transmission links and routing in the optical domain. Basics of optical network architectures.

Optically amplified and wavelength division multiplexed transmission systems

Here the physical properties that effect the propagation of optical signals on point-to-point links are explained and the techniques for modelling these are described. Design of optical amplifiers and optical amplifier chains, noise figure, overall signal to noise ratio, and different noise sources and impairments inc attenuation, dispersion and polarization mode dispersion.

New modulation formats and coherent detection

Use of different signal domains inc phase, amplitude, polarization and wavelength to increase overall system capacity. Introduction to capacity and spectral efficiency. Digital coherent receivers – key concepts and subsystems and their mathematical analysis, in terms of overall system performance metrics – Q-factor and bit error rate. Introduction to digital signal processing and examples of DSP algorithms. Digital modems for optical core and access transmission.

Optical fibre impairments (linear and nonlinear) and implication on transmission

Description of optical fibre nonlinearities, with the main focus of the course on the Kerr effect – intensity-dependent refractive index, nonlinear phase change and interaction between nonlinearity and chromatic dispersion. The nonlinear Schrodinger equation to describe the propagation of signals in an optical fibre. Implications on optical communications systems performance and techniques for quantifying, and mitigating these impairments both in the optical and electronic domains.

Optical network design

Introduction to optical networks as a set of optical point-to-point links. Elements of graph theory and algorithmic graph theory. Description of routing in the optical domain on different length- and time-scales, static and dynamic wavelength-routed optical architectures. Why route in the optical domain. Wavelength routing problem as a graph colouring problem and bounds on the number of wavelengths, need for wavelength-conversion and the concept of the limiting cut.
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Difference between logical and physical network topologies. Introduction to heuristic algorithms for network analysis and design, and examples. Optical burst switching: analysis and synthesis in terms of wavelength-reuse, timescales and scalability. This part of the course will also include optical interconnects as an example of an optical network on short time- and length scales, for the growing application in data centres and in the interconnection of processors for high-performance computing.

Reading List

Core and metro networks, Alexander Stavdas, Wiley Series in Communications, Networking and Distributes Systems, 2010


Multiwavelength Optical Networks, T E Stern, G Ellinas and K Bala, Cambridge Univ Press 2009

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Assessment
A two and half hour unseen written examination (answer 3 out of 5 questions) will be held under UCL MSc examination regulations at UCL.

Tutorials/Workshops
A two hour tutorial will take place in the week following the course.