George Mason University
School of Information Technology and Engineering

TCOM 503/513
Fiber Optic Networks/Optical Communications Networks

Version 11/26/07
Course meets 4:30-7:10 in Enterprise Hall, Room 278

This pair of courses covers the basic material of fiber optic components, systems, and networks. It is designed to introduce optical networking to students who wish to learn about the subject for high-level planning, business, and management purposes. As such, it assumes a rather more limited background than would a similar pair of courses for engineering majors. The key concepts needed to understand optical communications can, however, be mastered with a modest background which includes a solid high-school mathematics framework, and ideally, some physics and chemistry, though these are not required. Calculus is helpful but also not essential. However, a willingness to work to master unfamiliar concepts *is* essential, especially for those with more limited backgrounds! At the conclusion of the two courses, students will have a basic understanding of:

- The physical principles of optical devices and networks
- How fiber optic components operate
- How these components work together to create useful fiber optic networks
- How fiber optic networks are used to create large-scale communications networks
- How to buy optical communications services and what they cost
- How all-optical networks will function, and their advantages and problems
- Basic economics of fiber-based networks

The material is structured as two half-semester classes, but will be presented as a continuous progression through the semester, starting with the basic physics behind optical components, continuing with a discussion of optical components and their interconnection to make networks, and leading at the end to a discussion of large-scale all-optical networks that represent the future of networking.

Class Hours: Monday, 4:30-7:10 PM

Instructor: Dr. Thomas Fowler
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Text: *Understanding Optical Communications*, Harry Dutton, Prentice-Hall, 1998. This is the text for the first half of the semester (TCOM 503) and part of the second half (TCOM 513). For the remainder of the second half (TCOM 513), we will use *Next Generation Optical Networks*, by Tomsu and Schmutzer, Prentice Hall, 2002, ISBN 013028226X, as well as other material available on the web. The book by Dutton is available online from IBM at

http://publib-b.boulder.ibm.com/Redbooks.nsf/9445fa5b416f6e32852569ae006bb65f/4b2935ac69aa2651852565d9006e03a9?OpenDocument

Or use http://www.redbooks.ibm.com/pubs/pdfs/redbooks/sg245230.pdf

Supplementary Texts (not required):
Fiber Optic Communications, 5th Edition, Joseph C. Palais, Prentice-Hall, 2004.

Other Useful Books: *Optical Switching and Networking Handbook*, R. J. Bates, McGraw-Hill, 2001.
*Fiber Optic Reference Guide***,** David R. Goff, Boston: Focal Press, 1999.
Optical Networks: A Practical Perspective, Rajiv Ramaswami & Kumar N. Sivarajan, Morgan-Kaufmann, 1998.
Any general physics text, such as those of Tipler, Hecht, or Halliday & Resnick.

Other Material: During the course of the semester, students will be advised to download items from the Internet. To start, it is recommended that anyone enrolling in the course register at the IEC web site, www.iec.org (free) and download the following tutorials (www.iec.org/online/tutorials) (all free):

Ethernet Passive Optical Networks [Alloptic]
Light without Limits: Taming Dispersion in Tomorrow's High-Speed Networks [Phaethon]
Optical Ethernet [Luxpath]
Optical Switches: Making Optical Networks a Brilliant Reality [Tellium]
Polarization Mode Dispersion [Yafo]
Dense Wavelength Division Multiplexing (DWDM) [Lucent]
Direction of the Optical Networking Market [Adva]
Fiber Optic Technology [Corning]
Introduction to Optical Transmission in a Communications Network [Nortel]
Optical Networks [Alcatel]
Raman Amplification Design in Wavelength Division Multiplexing Systems [Virtual Photonics]
Synchronous Optical Network [Tektronix]
Synchronous Digital Hierarchy [Marconi]

Also, visit the Tektronix web site and download the following:

SONET Telecommunications Standards, address (as of 1/16/02):
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/App_Notes/SONET/&FrameSet=optical

SDH Telecommunications Standards,
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/App_Notes/SONET/&FrameSet=optical

DWDM Performance and Conformance Testing Primer,
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/App_Notes/DWDM_prmr/welcome.html&FrameSet=optical

Cisco has a good paper on waveform encoding:
http://www.cisco.com/warp/public/788/signalling/waveform_coding.html

You may wish to apply for a free subscription to *Photonics Spectra*, a trade journal, www.photonics.com

Rsoft has a demo version of their (expensive) optical network design program, available at
http://www.rsoftdesign.com/products/system_simulation/OptSim/

Physics demos relevant to the course may be found at
www.colorado.edu/physics/2000/index.pl

Homework: Problems will be assigned for completion by students. Unless otherwise indicated, students should do their own homework and not collaborate with others. Students are expected to have personal computers and Internet access. A student project will be required.

Schedule: Material for TCOM 503 will be covered in the 7 weeks before the Spring Recess (3/13-3/20). TCOM 513 will begin with the first session after the break (21 March).

Topics—TCOM 503 (Optical devices, their principles, fabrication, and operation)

Week 1: Overview of fiber optical communications systems. Fundamental drivers behind use of light as a communications medium. History of optical network technology.

Week 2: Basic principles of optics as applied to fiber optic devices. Summary of relevant background from physics. Types of optical fiber and devices, and principles of their operation.

Week 3: Light sources and detectors, light coupling to/from fibers. Types and operation of lasers and LEDs. Photodiodes and other detectors.

Week 4: Distributed networks and fiber components. Optical devices, their operation and fabrication.

Week 5: Modulation of optical signals, formats, receivers. How light is modulated and coupled into optical fiber. Practical limitations on device behavior. Formats used to transmit information using light and optics.

Week 6: Noise and detection. Types of noise and distortion which affects optical signals. Methods of reducing effects of noise and distortion. Optimal detection methods and devices.

Week 7: Optical fiber fabrication. Practical considerations with optical fiber. Test equipment and measurement techniques. Final Exam. Project outline due.

Topics—TCOM 513 (Optical network principles, design, and implementation in the real world)

Week 1: Opto-electronic networks: FDDI, Fiber channel, SONET, SDH, Ethernet on optical networks

Week 2: Basic principles of wavelength division multiplexing (WDM), including dense wavelength division multiplexing (DWDM), and corresponding architectures. Components required for WDM networks. International standards for WDM networks.

Week 3: Basics of fiber optic system design. How fiber optic systems differ from conventional systems. Assembly of a communications network from fiber optic components. Calculation of loss and dispersion. Carrier network architectures

Week 4: Data transmission technologies. Packet over SONET/SDH (POS), Dynamic Packet Transport (DPT), MPLS

Week 5: How optical networking and optical telecommunications services are marketed and sold: what you can buy, how much it costs. Existing and future optical control planes. Static and dynamic IP control planes. Wavelength conversion. Lightpath provisioning

Week 6: Optical networking in the real world. Business aspects of optical networking. Interaction among technology, finance, human factors. Why better technology doesn't always sell in the marketplace

Week 7: Future directions in all-optical networks. Free-space optical networks. Scaling limitations of optical networks. Technology directions and impact on design and deployment of optical networks. Final exam. Project due.

Student Evaluation Criteria

Each course will have its own final exam. Evaluation weightings will be as follows:

TCOM 503:	
Homework.	45%
Final exam.	45%
Project outline.	10%

TCOM 513:	
Homework	35%
Project	35%
Final exam	30%

Due to many problems in the past, I have implemented new rules for homework and grading. All work must be turned in on time. Late homework will not be accepted; however, you are allowed to miss one homework. If you cannot come to class, you can

email or fax the homework; however, it must go to the grader, not to me. If there is no grader, then it should go to me. If you submit all homework assignments, I will drop your lowest grade. If you cannot submit the homework or complete the coursework due to health or other problems, you should consult with Dr. Allnutt about dropping the course, or make some arrangement with him to retake it at a later date. So that there is no misunderstanding, NO CHANGES WILL BE MADE TO FINAL GRADES UNLESS THERE WAS A RECORDING OR CALCULATION ERROR.

TCOM 513 Project

The project for TCOM 513 will build on the proposal submitted for TCOM 503. The project should cover a network to be built using fiber optic technology.

1. It should give functional specifications to be met, explain the technology proposed and justify its selection.
2. You should supply details about type of fiber to be used, lasers or LEDs, amplifiers needed, switches needed, multiplexors/demultiplexors, etc. You can also elect to obtain service from a commercial carrier, in which case you will have to determine the cost of the service, cost of access, end user equipment, performance available from the carrier, and similar information.
3. Also, it must give a cost analysis: facilities and equipment (F&E), and operation and maintenance (O&M).
4. Your network can be a local, regional, or national one.
5. The purpose of this exercise is to show that you understand how optical networks operate and how to specify and design them at a high level.
6. Final project due at the end of the semester, May 2. It should be 5-10 pages, no longer.

Some sample papers from earlier years will be posted on the course website.

Syllabus
TCOM 503—Fiber Optic Networks
TCOM 513—Optical Communications Networks
Spring, 2008

Week	***Topics***	***Text Reading***
28 January	• Overview of fiber optical communications systems • Fundamental drivers behind use of light as a communications medium. • History of optical network technology • General background	Chapter 1; Appendix B
4 February	• Basic principles of optics as applied to fiber optic devices. • Summary of relevant background from physics. • Types of optical fiber and devices, and principles of their operation.	Chapter 2
11 February	• Light sources and detectors, light coupling to/from fibers. • Types and operation of lasers and LEDs. • Photodiodes and other detectors	Chapters 3 & 4
18 February	• Distributed networks and fiber components. • Optical devices, their operation and fabrication	Chapter 5
25 February	• Modulation of optical signals, formats, receivers. • How light is modulated and coupled into optical fiber. • Practical limitations on device behavior. • Formats used to transmit information using light and optics	Chapter 7, sec. 7.1-7.3; Tektronix SONET tutorial (from IEC); Chapter 8, sec. 8.6
25 February	• Noise and detection. • Types of noise and distortion which affects optical signals. • Methods of reducing effects of noise and distortion. • Optimal detection methods and devices	Chapter 7, sec. 7.4 - 7.7
3 March	• Optical fiber fabrication • Practical considerations with optical fiber • Test equipment and measurement techniques • Final Exam for TCOM 503 (second half of period) • Project outline due	Dutton, Chapter 7, sec. 7.8; Corning tutorial on optical fiber (IEC); Testing PMD from Agilent (IEC); Testing BER from Agilent (IEC) Measuring EDFAs from Agilent (IEC)
10 March	*** Spring Recess ***	

TCOM 513		
17 March	• Overview of opto-electronic networks • FDDI • Fiber Channel • SONET • Ethernet on optical networks • ATM on optical networks	Dutton, Chapter 8 *Synchronous Optical Network* from Tektronix (IEC) *Synchronous Digital Hierarchy* from Marconi (IEC) *Optical Ethernet* from Luxpath (IEC) *Introduction to Optical Transmission* from Nortel (IEC)
24 March	• Basic principles of wavelength division multiplexing (WDM) • Dense wavelength division multiplexing (DWDM), and corresponding architectures. • Components required for WDM networks. • International standards for WDM networks	Dutton, Chapter 9.
7 April	• Basics of fiber optic system and network design. • How fiber optic systems differ from conventional systems. • Assembly of a communications network from fiber optic components. • Calculation of loss and dispersion • Use of standard protocols and equipment. • Carrier network architectures	Dutton, Chapter 10; Tomsu & Schmutzer, Chapter 1.
14 April	• Data transmission technologies. • Packet over SONET/SDH (POS) • Dynamic Packet Transport (DPT) • MPLS	Tomsu & Schmutzer, Chapter 3
21 April	• Existing and future optical control planes • Static and dynamic IP control planes • Wavelength conversion • Lightpath provisioning.	Tomsu & Schmutzer, Chapter 4
28 April	• Present state of optical networking in the real world • Business aspects of optical networking • Interaction among technology, finance, human factors • Why better technology doesn't always sell in the marketplace	Tomsu & Schmutzer, Chapter 5.

5 May	• Future directions in all-optical networks. Free-space optical networks. • Scaling limitations of optical networks. • Technology directions and impact on design and deployment of optical networks. • Final exam for TCOM 513 (second half of period) • Project due	