14:635:431
Fiber Optic Engineering
Department of Materials Science and Engineering

INSTRUCTOR: Professor George H. Sigel, Jr. CCR 212
Phone: (732) 445-4729
E-mail: sigel@rci.rutgers.edu

Description:
This course provides a broad overview and introduction to fiber optic waveguide design, materials processing, fiber fabrication, characterization and applications. The basic physics of light propagation in waveguide structures is introduced as well as the required fiber optic parameters to insure long distance, high bandwidth transmission of light signals. Relevant materials synthesis routes based on both conventional and chemical vapor deposition (CVD) are covered as well as the fundamentals of fiber optic preform fabrication along with the design, instrumentation, and function of fiber optic drawing towers. Specialty fiber components including light sources, photodetectors, couplers, connectors, splitters, modulators, amplifiers, isolators and sensors are covered. The optical characterization of fibers is introduced including the measurement of spectral loss, chromatic dispersion, numerical aperture, cut-off wavelength mode field diameter and index profile. The potential impact of fiber optic technology on advanced telecommunications is emphasized.

Objective:
This course is designed to provide students with the insight and understanding of all of the key aspects of fiber optic technology. In particular, it seeks to relate the fundamental properties of optical materials to the design and performance of advanced optical waveguides. It provides students with knowledge of a significant emerging contemporary discipline based on highly transparent glasses. It also exposes them to the techniques, skills and modern engineering tools that have been developed to transfer materials such as silica into high bandwidth optical transmission lines. Finally, it seeks to inspire and motivate engineering students by providing them with some exciting and dynamic examples of how advanced ceramic and glassy materials are making a difference in today's world.

Prerequisites:
There are no prerequisites for this class.

Attendance:
This course is an elective. Attendance is voluntary. The recognition by students that this is both an interesting and valuable class has been sufficient to insure almost universal attendance since this course was first offered in 1985.

Projects:
A term paper is required. This represents 25% of a student's final grade. A list of possible topics is provided (see attached list) but students are free to select any topic

subject to final approval by the instructor. A topic and one page outline must be submitted by late September. This paper serves both as a mechanism to acquaint students with the recent journal literature in the field while at the same time providing them with the opportunity to improve their written communication skills.

Texts:

Optical Fiber Communications: Principles and Practice, John M. Senior, 2nd Edition, Prentice Hall, New York, 1992

Understanding Fiber Optics, 4th Edition, Jeff Hecht, Prentice Hall, Upper Saddle River, NJ, 2001

Optical Fiber Telecommunications II, edited by Stewart E. Miller and Ivan K. Kaminow, Academic Press, New York, 1988

Class notes and handouts with each of the 15 class topics provided in this syllabus.

Topics Covered:

Week	Topic
1	Introduction, Historical Background, Basic Concepts of Light, Motivation for Fiber Optic Systems, Advantages of Fiber Technology
2	Optical Properties of Transparent Solids, Relations to Bonding and Structure, Absorption and Scattering, Extrinsic Loss Mechanisms, V-Curves, Fluorescence
3	Light Propagation in Dielectric Waveguides, Planar and Cylindrical Structures, Lossy Media, Interface Issues, Macro and Microbending Losses
4.	Fiber Waveguide Structures for Light Transmission: Single Mode, Multimode, Graded Index, Polarization Maintaining, Dispersion Shifted Fibers
5	Present Day Fiber Optic Materials, Glasses and Crystals, Oxides and Non-Oxides, Polymers, Sol-Gels
6.	Characterization of Fiber Materials, Optical, Mechanical, Thermal and Chemical Properties
7	Preform Fabrication, Vapor Phase Processing of High Silica Fiber Optic Materials - Inside and Outside Techniques (OVD, MCVD, VAD)
8.	Fiber Drawing Techniques, Design of Fiber Drawing Tower, Comparison of Crucible vs. Preform Drawing, Key Drawing Parameters,

Drawing-Induced Defects

9. In-Line Coating of Fibers, Ultraviolet and Thermal Curing of Polymers, Metals, Specialized Coatings - Strength and Aging, Static and Dynamic Fatigue

10. Fiber Measurements, Attenuation, Bandwidth, Numerical Aperture, Mode Field Diameter, Cut-Off Wavelength, Modal and Chromatic Dispersion, OTDR, Index Profiling

11 Link Considerations, Sources and Detectors, Splicing, Repeaters, Coupling, Examples of Typical Configurations, Data Transfer

12 Fiber Optic Cables, Design and Construction, Materials Selection, Microbending, Flexibility and Strength Considerations

13 Passive Optical Components, Couplers, Splitters, Stars, Bragg Gratings, Wavelength Division Multiplexers

14 Infrared Fiber Optics, Heavy Metal Fluoride Glasses, Chalcogenide Glasses, Crystalline Fibers and Hollow Waveguides

15 Present Applications of Fibers, Telecommunications, Sensors, Optical Power Transfer, Biotechnology, Imaging, Optical Amplifiers, Fiber Lasers

Grade: The grade is based on the following:

Oct. 20th	Mid-term examination	(3 hr)	37.5%
Nov. 24th	Term Paper		25 %
Dec. 10th	Final examination	(3 hr)	37.5%

Examinations are based on class lectures, reading assignments, homework problems and class handouts.

Contributions of Course to Meeting the Professional Component:
This is the first of three courses available to students in the area of fiber optics. It facilitates student development and growth in areas related to fiber optic design, manufacturing, economic impact, environmental impact and serves as the basis for both follow-on courses as well as capstone senior level projects and/or cooperative experiences.

Relationship of Course to Program Objectives:
This course meets all six of the educational objectives set forth by the Rutgers Program in Materials Science and Engineering. It is of value both for students seeking an engineering or manufacturing career in fiber optics as well as to those students seeking to go on into graduate school in areas related to photonics, optics or electro-optics. With

respect to ABET Program proficiencies, this course contributes to (a), (b), (c), (d) and (e) as well as (g), (j) and (k).

FIBER OPTIC ENGINEERING

Dr. George H. Sigel, Jr.
14:635:431

A PARTIAL LISTING OF POTENTIAL SUBJECTS FOR TERM PAPER*
(*paper is due Monday, November 24, 2008)*

Topic and outline due Monday, September 29, 2008

1. The MCVD Process
2. The VAD Process
3. Infrared Fibers (*several choices*)
4. Drawing by Double Crucible
5. Optical Power Propagation in Fibers
6. Fibers for Biomedical Applications
7. High Strength Fibers
8. Drawing Induced Defects in Fibers
9. Fiber Optic Sensors *(many choices here)*
10. Hermetic Coatings for Fiber
11. Fiber Optic Lasers
12. Environmental Effects on Fibers
13. Fiber Cable Design
14 Light Sources for Optical Fibers
15. Fiber Optic Cable Designs
16. Fluoride Glasses for Fiber Optics
17. Chalcogenide Glasses for Fiber Optics
18. Radiation Effects in Fibers
19. Sol-Gel Glasses for Fibers
20. Fiber Optic Transmitters
21. Fiber Optic Receivers
22. Optical Time Domain Reflectometry
23. Fiber Optic Connectors
24. Fusion Splicing of Fibers
25. Specialized Coatings
26. Fiber Amplifiers
27. Wavelength Division Multiplexing
28. Bragg Gratings in Optical Fibers
29. Planar Waveguide Devices
30. Dispersion Compensation
31. Fiber to the Home
32. Fibers for Upconversion
33. Fibers for Automotive Applications
34. Plastic Fiber Optics
35. Aging Effects in Fibers
36. Fibers for Smart Structures

*Term papers should be 10-15 pages in length including figures and references. Please use spellcheck on final draft. Please focus on recent developments since 2000. Useful journals include the IEEE Journal of Lightwave Technology, Optics Letters, Electronics Letters, Optical Communications, Applied Optics, Optical Fiber Communications Conference Proceedings and SPIE Conference Proceedings as well as a plethora of on-line sources. The above list is provided as a guideline for topics but you may select others with the instructor's approval.

FIBER OPTIC ENGINEERING
14:635:431
Dr. George H. Sigel, Jr.
September 2008

LIST OF IMPORTANT TERMS WHOSE DEFINITIONS SHOULD BE KNOWN

absorption
attenuation
scattering
index of refraction
waveguide
dB
core
intrinsic loss
dispersion
repeater
refraction
network modifier
electromagnetic wave
VAD
infrared
"V" curve
mode field diameter
laser
APD
fiber sensor
splitter
fusion splice
star coupler
OTDR
dispersion shifted
uv curing
amplitude modulation
forward bias
biconical
Raleigh scattering
vibrational absorption
high order mode
step index fiber
multimode
optical density
cladding
extrinsic loss
modal dispersion
silica
network former
critical angle
OVD
ultraviolet
bandgap
amplifier
Bragg grating
LED
WDM
Mach Zehnder
fluoride glass
connector
3 dB coupler
Weilbull plot
index profile
concentricity
phase modulation
reverse bias
digital
bandwidth
evanescent wave
preform
double crucible
singlemode (monomode)
graded index
wavelength
numerical aperture
material dispersion
dopant
reflection
MCVD
visible
color center
electronic absorption
cut-off wavelength
interferometer
pin diode
coherent bundle
polarization
chalcogenide
static fatigue
microbending
planar waveguide
optical isolator
upconversion
fluorescence
population inversion