Course Description

EC 568: Optical Fibers and Waveguides

Spring 2022 – Time: Tue/Thu 09:00–10:45

Instructor: Prof. Milos Popovic (mpopovic@bu.edu)

Background & Content: Whether it be the FIOS internet connection at our homes, or fiber lasers powerful enough to cut metals (many automobile chassis are now made using fiber lasers), or the ability to perform endoscopic surgery and imaging, or doing frequency metrology with super-continuum sources (the basis of a few recent Nobel prizes), the optical fiber – a type of optical waveguide – has played a central, often dominant, role in many applications that impact the way we live. The main function of an optical fiber is to carry an electromagnetic (in the optical frequency) pulse over distances ranging from meters to greater than ten thousand kilometers without distortions. The Internet backbone is made of a fiber network that spans around the globe.

Today, with the end of Moore's Law, a new era of microelectronics is emerging where optical waveguides are playing a central role in the future of microchip technology. Silicon photonics is the technology that integrates optical waveguides and passive and active components into modern silicon microchips. It is currently transitioning from research to industry, with all major chip manufacturers including Intel, IBM, Samsung, TSMC, as well as data center giants (Facebook, Microsoft, Google, Apple) deeply involved in benefiting from this technology. Its applications range from high-bandwidth, low-energy microprocessor to memory communication links and networks, through LIDAR (e.g. 3D face recognition sensors in smart phones), sensors (oil prospecting, biosensors, etc.), through applications that include optical processors for quantum computing, optical accelerators and Developments in silicon photonics led recently to the demonstration of the first microprocessor with photonic I/O. There are a number of startups and established companies pushing this technology forward, and in the next decade it can be expected to be a major part of microelectronic systems.

This course will introduce the theory of optical waveguides and their applications. The key properties, and design principles that affect waveguide operation and design will be discussed, including foundational mathematical properties and practical considerations. The latter part of the course will address waveguide devices including power splitters, directional couplers, polarization converters, tapers, level changers, crossings, etc. The end of the course will address applications.

Prerequisites: EC 455 and some familiarity with the field of optics, or consent of instructor.

Reference books:

H.A. Haus, Waves & Fields in Optoelectronics.
Ghatak & Thyagarajan, "Introduction to fiber optics," Cambridge Univ. Press. 1998 (reprinted 2000)
A.W. Snyder and J.D. Love, Optical Waveguide Theory.
C. Vassallo, Optical Waveguide Concepts.
D. Marcuse, Theory of Dielectric Optical Waveguides, 2nd Ed.

Other references:

Buck: Fundamentals of Optical Fibers
Agrawal: Nonlinear Fiber Optics
Keiser: Optical Fiber Communications
Saleh & Teich: Photonics

Grading Policy:

30% Homework
30% Mid-term exam
20% Course project/presentation
20% Class Participation

*In last few lectures of course, students will make a short oral presentation and submit a 2-page report on a journal paper or own project relevant to the subject covered in the course (a list of papers to choose from will be provided).

Topics:

Week	Topic
1	Introduction to course. Optical fibers and integrated photonics. Applications (energy efficient communication links, lidar, RF signal processing, sensing). Course as a design project on a ring resonator filter in silicon photonics.
2	Review of electromagnetism. Maxwell's equations, plane waves and polarization. Transmission lines, metallic waveguide and the dielectric slab waveguide.
3	Dielectric waveguides: theory, analysis and design
4	Mode simulations
5	Phase, group velocity, dispersion and pulse propagation
6	Waveguide bends, ring resonators
7	Directional couplers – (spatial) coupled mode theory
	MIDTERM
8	Ring resonator analysis – coupled mode theory
9	Coupled-resonator filters
10	Active silicon photonic devices and circuits: modulators, detectors, thermooptic and electro-optic tuning
11	Analyzing a communication link based on photonic devices
12	Adiabatic mode evolution devices
13	Applications
14	Review and presentations