EE 599 – Microwave Photonics and Laboratory (3 Units)

The broadband and low-loss distribution attributes of photonics have enabled the development of fiber optic backbones that carry our internet traffic. Microwave photonics is a subfield of photonics that bring together the worlds of radiofrequency (RF) engineering and optoelectronics. Leveraging wavelength division multiplexing (WDM) and picosecond optoelectronics, microwave photonic technologies have led to breakthrough performances in ultra-wideband RF-transmission, antenna beamsteering, RF-signal generation and signal processing, including analog-to-digital conversion. This course will review the basics and constraints of optoelectronics devices (lasers, modulators, photodetectors, WDM filters) and optical links that operate at multi-GHz frequencies for RF-transmission. The performance metrics for photonic links, such as signal-to-noise ratio and dynamic range, will be established in relation to device characteristics. We will also discuss cutting edge system applications of microwave photonics by reviewing recent journal publications. The course will be held in a format that consists of both lectures and a laboratory workshop that demonstrates (with some hands-on experiments) the characterization of optoelectronic components and links. We will also review optical and microwave instrumentions that facilitate their measurements.

Prereqisite: EE470, EE472 or EE 474 or equivalent, or consent of Instructor
Instructor: Willie W. Ng
Text Book: *Photonics: Optical Electronics in Modern Communications*, 6th Edition, Yariv and Yeh, Oxford University Press, ISBN-13: 978-0-19-517946-0; augmented by select journal publications, especially review articles in the topics lectured

Grading:		
	Homework	20%
	Midterm Exam	30%
	Final Exam	30%
	Term Paper/Presentation	20%

Outline:

Week	Topic	Reading Assignment
1	Lecture (3 hours): Introduction to Optoelectronics - Dielectric Waveguides, Fabry Perot Etalon, Fabry-Perot Laser, Photodiodes, Bragg reflection in periodic structures	Text: Chapter 3.1-3.2, 4.0-4.1, 6.1, 11.7
2	Lecture (3 hours): Modulation of RF onto Optical Carrier I - Direct Modulation of Semiconductor Lasers: Diode laser fundamentals, DFB lasers, diode laser dynamics	Text: Chapter 15.1 - 15.5
3	Lecture (3 hours): Modulation of RF onto Optical Carrier II – High frequency Optical Modulators: Mach Zehnder (MZ) modulators and Electro-Absorption Modulators (EAM)	Text: Chapter 9.2-9.4
4	Lecture (3 hours): Introduction to Optical and RF Measurements - Tunable lasers, Optical spectrum analyzers, RF spectrum analyzers, Microwave Vector Network Analyzers, Lock-in amplifiers	Selected journal articles and brochures
5	Lecture (2 hours): Optical Links for RF Transmission – Link Budget, High Power Photodetectors, Semiconductor Optical Amplifiers (SOAs), Link performance Metrics	Text: Chapter 11 with supplemental journal articles

	Lab workshop (1 hour): Directly Modulated diode lasers, Optical spectrum and RF response	
6	Lecture (2 hours): Advanced Passive Components used in WDM Systems I – Bending Loss in Curved Dielectric Waveguides, Array Waveguide Grating (AWG) Mux/Demux, Chirped Fiber Gratings Lab workshop (1 hour): Demonstration of MZ external modulators with DFB laser as optical input - quadrature biasing, raised-cosine transfer function	Review Articles from Journals
7	Lecture (2 hours): Advanced Passive Components used in WDM Systems II – Directional Couplers, Microresonators, Optical Filters and Isolators, Mode-Transfomers Lab workshop (1 hour): RF-photonic link, generation of nonlinearities	Text Chapter 13.3, Chapter 4.8 and selected Journal articles
8	Lecture (2 hours): RF-Photonic Subsystems - WDM-based subsystems for RF-photonic Filtering, Optical Heterodyning, and Coherent Detection Lab Workshop (1 hour): Waveguide Coupling and Measurement, Passive components	Text Chapter 11.4, and selected Journal article
9	Lecture (2 hours): Picosecond Optoelectronics: Mode locking of lasers – Active and Passive Modelocking, and their Characterization Lab Workshop (1 hour): Optical heterodyning setup for the Characterization of Photodetector Response at high frequencies	Text Chapter 6.6 to Chapter 6.7
10	Lecture (2 hours): Introduction to Microwave Photonic Applications – Photonic-assisted Analog-to-Digital Conversion, Optoelectronic oscillators (OEO), True-time-delay Beamsteering, RF-Photonic Filtering Lab Workshop (1 hour): Measurement of Modulation Sidebands in the optical regime or a Mode-Locked fiber-laser if I can get a hold of one	Review Article from Journals
11	Lecture (3 hours): Impulse Sampling and Time-stretch Photonic Analog-to-Digital Conversion – Optical dispersion, Pulse broadening, Chirped pulses and Digital linearization of links	Text: Chapter 7.2 and Selected Journal Article
12	Lecture (3 hours): Optoelectronic Oscillators (OEO)– Basics of OEO, Performance of OEO and its comparison with all RF-oscillators at different frequencies	Selected Journal Article
13	Lecture (3 hours): Photonic Integrated Circuits – Microresonator based infinite impulse response (IIR) filters as an example, design approaches; Introduction to Si Photonics	Selected Journal Articles

14	Lecture (2 hours): Advanced topics in Optical Instrumentations – Optical Vector Network Analyzer (OVA), Optical Bragg Reflectometers, Applications to the measurement of low loss waveguides and Chirped Fiber Bragg gratings Lab Workshop (1 hour): RF-Photonic Link or an OEO (if there is sufficient components to construct one)	Selected Journal Articles
15	Advanced Topics and Projections (Optional Material or Student Presentations)	Selected Journal Articles
16	Final Exam	

Supplemental References (tentative list):

1. R. Hui and M. O'Sullivan, "Fiber Optic Measurement Techniques," Elsevier Academic Press (2009), ISBN: 978-0-12-373865-3.
2. Handbook of Silicon Photonics, Edited by Laurent Vivien and Lorenzo Pavesi, CRC Press
3. Silicon Photonics Design: From Devices to Systems, Lukas Chrostowski and Michael Hochberg, Cambridge University Press
4. Fundamental of Photonics, Saleh and Teich, Wiley, 2nd Edition