# GRADUATE SPECIAL TOPIC COURSE ON "HIGH-SPEED PHOTONICS" (OSE 6938W, 3 CREDIT HOURS)

## INSTRUCTOR: SASAN FATHPOUR

SPRING 2024; MONS. & WEDS. 10:30-11:45 AM, CREOL BLDG. ROOM A214

**CATALOG DESCRIPTION**

The course reviews working principles, underlying physical effects, and the design of high-speed optoelectronic devices and circuits for optical telecommunication and interconnect applications.

**COURSE GOALS**

The course complements the OSE courses on 'fundamentals of optoelectronic devices', 'integrated photonics', and 'optical communication systems' to deepen students' education in photonic engineering. The course's goal is elucidating the key principles underlying the analysis and design of high-speed integrated photonic devices and circuits, with an emphasis on the engineering and practical aspects of them. The students should be able to understand and design devices such as high-speed photodetectors and optical modulators, as well as their associated electronic circuits and microwave components at the end of the course. The course also introduces selected advanced research topics currently pursued in the field.

**COURSE APPROACH**

To analyze and design high-speed optoelectronic devices and circuits, it is necessary to study the components that constitute them, the principles that underlie their operation, and their functional characteristics from the perspective of a device engineer. To this extent, the course will begin with a very brief review of the principles of optoelectronic devices, particularly photodetectors and electrooptic modulators. It will then quickly get into high-speed modeling of the devices, their bandwidth limitations, and other performance challenges such as noise. The course will also cover associated electronic circuits and microwave components that are usually seamlessly integrated with high-speed photonic devices.

**PREREQUISITE:**

- OSE6111 (Optical Wave Propagation) or OSE5041 (Introduction to Wave Optics)
- Basic knowledge of photonics, semiconductors, and optoelectronics at the undergraduate level is expected. Graduate-level knowledge of CREOL courses on Fundamentals of Optoelectronics (OSE5414) and Fundamentals of Optical Fiber Communications (OSE6474) is preferred.

**REQUIRED READINGS:**

**Course Website:**

https://webcourses.ucf.edu/

**SUGGESTED TEXTBOOKS:**

- G. Giovanni, *Semiconductor Devices for High-Speed Optoelectronics*, Cambridge University Press, 2009.
- W. S. Chang, *Fundamentals of Guided-Wave Optoelectronic Devices*, Cambridge University Press, 2010.
- S. L. Chuang, *Physics of Photonic Devices*, 2nd Ed., Wiley, 2009.
- J. M. Liu, *Photonic Devices*, Cambridge 2005.

**COURSE OUTLINE:**

1. Introduction: Why High-Speed Optoelectronics?
2. Dynamic Effects in Photonic Materials
    a. Low-Speed Effects
        - Thermooptics; Acoustooptics
    b. High-Speed Effects
        - Stimulated absorption; Electrooptics; Electroabsorption (Franz-Keldysh and quantum-confined Stark effects); Free-carrier plasma effect
3. High-Speed Electronic and Microwave Devices for Optoelectronics
    a. Dynamic Response of Diodes
        - Carrier transport and dynamics
        - Small-signal admittance and *C-V* relationships
        - Transient behavior and switching delay times
    b. Transmission Lines
        - Resistance and reactance lines, the Smith chart, and scattering parameters
        - Stripline, microstrip, and coplanar microwave waveguides
        - Monolithic microwave integrated circuits (MMICs)
4. High-Speed Photodetectors
    a. Basics of Photodetectors
        - Review of structure, materials, responsivity, quantum efficiency, and gain
        - Electrical bandwidth and equivalent circuit
    b. The *pin* Photodiode Frequency Response
        - Carrier diffusion and heterojunction trapping; Dynamic model and space-charge effects; Transient time analysis and space-charge effects; Capacitance-limited bandwidth; Bandwidth-efficiency tradeoff
    c. High-Speed *pin* Photodiodes
        - Waveguide, traveling-wave, velocity-matching, and uni-travel carrier photodetectors
    d. Avalanche Photodiodes (APD)
        - Analysis, responsivity, and frequency response
    e. Noise in *pin*s and APDs
    f. The Photodiode Front End
        - Signal and noise model; High-, low- and trans-impedance front ends
        - High-speed trans-impedance stages
        - Hybrid and monolithic front-end solutions
5. Optical Modulators
    a. General Modulation Parameters
        - Static and dynamic response; Optical and electrical modulation bandwidth; Chirp; Optical bandwidth; RF input matching; Linearity and distortion
    b. Low-Speed (Thermooptic and Acoustooptic) Modulators
    c. Electrooptic Modulators
        - Materials: Lithium niobate, semiconductors and polymers
        - Mach-Zehnder modulators: Efficiency-bandwidth tradeoff; Chirp
        - Lumped Mach-Zehnder modulators
        - High-speed traveling-wave modulators
    d. Electroabsorption Modulators
        - Structure; Static and dynamic response; Chirp
        - Distributed and monolithically-integrated modulators
    e. Fee-Carrier Plasma Effect Modulators
        - Structures; Static and dynamic response; Chirp
        - Application in silicon photonics

**GRADING:**

Homework Assignments: 30%
Midterm Exam: 30%
Final Exam: 40%

## University Rules on Professionalism and Ethics

Per university policy and plain classroom etiquette, mobile phones, etc. must be silenced during all classroom lectures, unless you are specifically asked to make use of such devices for certain activities.

Academic dishonesty in any form will not be tolerated. If you are uncertain as to what constitutes academic dishonesty, please consult The Golden Rule, the University of Central Florida's Student Handbook (http://www.goldenrule.sdes.ucf.edu/) for further details. As in all University courses, The Golden Rule Rules of Conduct will be applied. Violations of these rules will result in a record of the infraction being placed in your file and the student receiving a zero on the work in question at a minimum. At the instructor's discretion, you may also receive a failing grade for the course. Confirmation of such incidents can also result in expulsion from the University.

## Students with Special Testing/Learning Needs

Students with special needs and who require special accommodations must be registered with UCF Student Disability Services prior to receiving those accommodations. Students must have documented disabilities requiring special accommodations and must meet with the instructor to discuss their special needs as early as possible in the first week of classes. UCF Student Disability Services can be contacted at http://www.sds.sdes.ucf.edu/, or at (407)823-2371.

## Academic Ethics Specific to This Lab Course

It is the nature of a laboratory course that you will be working in groups. Obviously, those of you who are lab partners will be using the same raw data. You are encouraged to discuss your observations and insights with your lab partners; however, each of you has to write your own ORIGINAL lab reports.

Cheating and plagiarism are serious breaches of the UCF Code of Honor as described in the UCF Golden Rule and the UCF Creed, and will not be tolerated in this course. All cases will be reported to the Office of Student Conduct (OSC).

## Definitions

***Cheating:*** any unauthorized assistance in graded, for-credit assignments.
***Plagiarism:*** appropriating the work of others and claiming, implicitly or explicitly, intentionally or unintentionally, that it is your own.

With the increased use of the internet, digital plagiarism is becoming more of a problem on campuses everywhere. You are encouraged to use the internet; however, electronic copying and pasting of material directly into reports and papers without proper reference to the source is blatant plagiarism. **Always reference the sources of information.**

**Providing a fellow student with experimental data from an experiment in which he/she did not participate is also forbidden. All parties that are involved in such practice will be reported to the UCF Office of Student Conduct (OSC).**

If there is any question concerning acceptable practice in this laboratory course, do not hesitate to ask the instructor.