Fundamentals of Ultrafast Optics
OSE 6445 (3 Credits)

Time: Monday, Wednesday 1:30-2:45
Place: CREOL A214
Instructor: P. J. Delfyett, CREOL A-231, (407) 823-6812, delfyett@creol.ucf.edu

Office Hours: *Open door policy* or from 3:00-4:00pm Mondays and Wednesdays; Rm A-231. Also, Zoom meetings can be scheduled at any time, if I am available.

Webcourse: Each student is REQUIRED to complete an assignment on Webcourse by the end of the first week of class.

Course Goals: To have students become proficient in understanding state of the art technical literature (i.e., scientific journal publications) in areas that develop and use picosecond and femtosecond photonic technologies for scientific and commercial applications.

Student Learning Outcomes: The successful student will be able to analyze ultrashort pulse propagation, generation, measurement systems both analytically and computationally.

Course Description:

Introductory Concepts (The following are the necessary fundamental quantities that are required in understanding the generation, transmission, detection and manipulation of ultrafast optical signals).

> Definition of Electric Fields, Intensity, Spectral Field & Intensity, Temporal and Spectral Phase, Instantaneous Frequency & Group Delay, Dispersion & Dispersion Engineering (Computer Project of Linear Pulse Propagation).

Ultrafast Optical Signal Transmission (Students learn about linear and nonlinear pulse propagation and the mathematical procedures, e.g., split-step Fourier, for predicting the characteristics, both temporal and spectral, owing to nonlinear effects.

> Optical fibers, pulse compression, soliton propagation, Bragg reflectors, saturable absorption, gain saturation, group delay dispersion (Computer project: nonlinear pulse propagation/solitons; pulse compression).

Ultrafast Optical Signal Generation (The techniques described in this portion of the course are the primary methods of generating ultrafast optical signals with temporal durations in the picosecond and femtosecond regime. The students gain practice in using the fundamental definitions in interpreting the temporal and spectral characteristics of optical signals generated by these methods).

> Mode-locking (active, AM&FM, passive via saturable absorber/saturable gain, Kerr lensing, other nonlinear effects), Gain Switching, Direct Modulation, Attosecond pulse generation (Computer Project – Numerical Simulation of Passive Mode-locking w/ Gain Saturation, Optical Frequency Combs and Stabilization).

<u>Ultrafast Signal Detection</u> (Methodologies are discussed for detecting, measuring and characterizing optical signals that are sufficiently fast and beyond the capabilities for conventional electronics).

> Ultrafast photodetectors (PIN, avalanche, photoconductive), streak camera, nonlinear optical correlation techniques, joint time-frequency measurements, and multi-heterodyne detection between 2 ultrafast lasers (computer simulation of autocorrelation, spectrogram & SHG FROG).

<u>Ultrafast Optical Signal Processing</u> (Methods for manipulating and processing of ultrafast optical signals. These are critical techniques for future optical communication networks, computer interconnects and advanced ultrahigh speed signal processing).

> Pulse shaping, arbitrary waveform generation (optical and RF), optical sampling, optical analog to digital converters, computing and logic, nonlinear switching, photonic network architectures (OTDM, DWDM, OCDMA), and matched filtering.

<u>Course Requirements:</u>
Students are required to have a background or have covered courses in the following areas: physical optics (including coherence, interference, wave propagation), differential equations (including Fourier transforms, wave equations), and lasers. Nonlinear optics is desired but not required. It is desired that students should have completed the optics core curriculum, but it is not required.

<u>Prerequisites:</u>
OSE 6111 Optical Wave Propagation and
OSE 6525 Laser Engineering or PHY 5346 or CI

<u>Computer Literacy</u>
Students are required to be able to utilize standard mathematical coding software (e.g., MatLab, MathCad, Python, Mathematica or other) to perform the simulation exercises.

<u>Exam and Grade Policy</u>
There will be a midterm exam and a final exam. Homework's will be assigned to provide guidance as to how to do problems. ***<u>An emphasis of the evaluation will be on the homework assignments that are computer based projects.</u>*** Late homework is NOT

accepted and will be graded as “zero”. The final grade will be posted electronically through UCF. The final exam will be given on the day scheduled by UCF. For written exams performed remotely, Proctor-Hub will be used, and the student must have the appropriate interface (webcam, etc.).

Approximate weighting: Homeworks: 10%; Midterm: 45%; Final: 45 %; Total: 100%.
Grading Policy: The +/- system will be used.

Plagiarism: It is your responsibility to know the rules regarding academic honesty. Failure to comply with these rules may result in failing the course, as well as expulsion from the program.

Reference Materials

1. **Ultrafast Optics, A. M. Weiner, Wiley, 2009, ISBN 978-0-471-41539-8. (Required).**
2. **Ultrashort Laser Pulse Phenomena, J. C. Diels & W. Rudolph, Academic Press, 2006, ISBN 13: 978-0-12-215493-5. (Optional).**
3. **Ultrafast Lasers, U. Keller, Springer, 2021, ISBN 978-3-030-82531-7**
4. **Femtosecond Laser Pulses, C. Rulliere -editor, Springer, (2003), ISBN 0-387-01769-0**

Other useful resources

5. Laser Electronics, 3rd. Ed., J.T. Verdeyen, Prentice Hall, 1995, ISBN 0-13-706666-X
6. Ultrashort Laser Pulses & Applications, W. Kaiser, Ed., Springer Verlag, (1988).
7. Principles and Applications of Optical Communications, M. K. Liu, IRWIN, 1996, ISBN 0-256-16415-0.
8. Fundamentals of Photonics, B. Saleh & M. Teich, J. Wiley (1991)
9. Optical Fiber Communications V:A & V:B, I. P. Kaminow, T. Li, A. Willner, Academic Press (1997) ISBN 978-0-12-374171-4.
10. Compact Sources of Ultrashort Pulses, I. Duling, Ed., Cambridge University Press (1995) ISBN 0-521-46192-8.
11. Ultrafast Lasers, Technology & Applications – M. Fermann, et al., Marcel Dekker (2003) ISBN 0-8247-0841-5.

Final Exam:

When: The Final Exam will be held during the time set by the University Final Exam Schedule – No exceptions (see below).
Monday, December 1st, 2025 1pm -4 pm, as scheduled by UCF.
Where: A-214.

Course Description:
This course covers the fundamental concepts in the generation, modulation, multiplexing, transmission and measurement of optical signals with temporal durations of picoseconds to attoseconds. Applications of these signals in areas of optical communication and signal processing will also be covered.

Instructor Intro
Peter Delfyett received the B.E.(E.E.) degree from The City College of New York (1981), the M.S. degree in EE from The University of Rochester (1983), the M. Phil and Ph.D. degrees from The Graduate School & University Center of the City University of New York (1987,1988). He did his PhD work under the supervision of Prof. Robert Alfano, discoverer of white light supercontinuum. Delfyett's thesis focused on developing and utilizing a real time ultrafast spectroscopic probe to study molecular and phonon dynamics in condensed matter, using both supercontinuum and optical phase conjugation techniques. After obtaining the Ph.D. degree, he joined Bell Communication Research as a Member of the Technical Staff, where he concentrated his efforts towards generating ultrafast high power optical pulses from semiconductor diode lasers, for applications in ultra-wideband optical signal processing and communications. Some of his technical accomplishments were the development of the world's fastest, most powerful mode-locked semiconductor laser diode, the demonstration of an optically distributed clocking network for high-speed digital switches and supercomputer applications, and the first observation of the optical nonlinearity induced by the cooling of highly excited electron-hole pairs in semiconductor optical amplifiers. In 1993, he moved to University of Central Florida, where he is currently University Distinguished Professor, Pegasus Professor and Trustee Chair Professor of Optics, ECE & Physics in CREOL, The College of Optics and Photonics, and is currently serving as the Director of the Townes Laser Institute. In 2003, Dr. Delfyett founded "Raydiance, Inc." a spin-off company developing high power, ultrafast laser systems, based on his research, for applications in medicine, consumer electronics, defense, material processing, biotechnology, automotive and other key technological markets. He is a Fellow of the APS, AAAS, IEEE, NAI, NSBP, OSA, and SPIE. He is also the recipient of the NSF PECASE Award, the APS Edward Bouchet Award, the Medalist from the Florida Academy of Science, the Townsend Harris Award, the IEEE Photonics Society's William Streifer Scientific Achievement Award, and the APS Arthur L Schawlow Prize in Laser Science. Most recently, he was elected to the National Academy of Engineering (NAE) and the Florida Inventors Hall of Fame. He has over 850 scientific publications, conference proceedings and invited presentations, and 45 US patents.

Getting Started
Welcome to Fundamentals of Ultrafast Photonics! As we get started, I encourage you to read and review the Syllabus, Calendar, and Course Expectations, as they contain information about what material will be covered, when it will be covered, and what expectations I have from you, regarding homework assignments, computer projects, and exams.