Phys597003 **Special Topics in Physics: Ultrafast and THz Photonics**

Lecture Hours: 18:20 – 21:10, Wednesday (tentative)
Location: Room Phys 313 (tentative)
Instructors: Prof. Ci-Ling Pan (潘犀靈教授)
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Office Hours: by appointment

Part of the Course will be taught by
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Course Description:

Ultrafast Photonics, consisting of ultrafast optics and optoelectronics, have had a dramatic impact on a vast array of basic scientific and technological disciplines. An ultrafast laser is one that generates laser pulses shorter than 100 fs in duration. The theory and understanding of propagation of broad bandwidth optical signals is essential for many applications, e.g., the design of high throughput optical communications systems. Ultrafast photonics, however, also has applications ranging from studying basic processes in semiconductors and devices, watching and controlling the formation and breaking of chemical bonds, nonlinear frequency conversion for new light sources, biological and medical sensing and imaging, machining and material modification, among others. Terahertz (THz) wave, the electromagnetic radiation in a frequency interval from 0.1 to 10 THz, occupies a large portion of the electromagnetic spectrum between the infrared and microwave bands. In recent years, remarkable progress has been made in the development of Terahertz optoelectronic sources and detectors. With the development of simple solid-state femtosecond lasers and integrated optoelectronic THz-devices, a new era of fundamental and applied THz science is opening up. THz studies ranging from investigations of problems in fundamental physics, e.g., ultrafast dynamics in materials to ranging, medical and environmental imaging are actively explored. The relative new field of THz science and technology will be covered so that students can explore their applications.

Course Objective:

This course is devoted to the education of scientists and engineers who wish to use ultrafast and THz photonics as a research tool and who are not yet specialists in lasers or even optics. This course will introduce the principles of ultrafast and THz optics, including the basic theory behind generation, amplification, propagation, and manipulation of ultrafast optical and THz pulses. Current state of the art technology in these areas will be reviewed. Experimental techniques are covered. Students would be prepared for work in the modern photonics laboratories with ultrafast photonic and THz tools or to understand and evaluate the research of others working in the field of ultrafast and THz photonics. The course is appropriate for advanced seniors, masters, or Ph.D. level students, and is intended to bridge the gap between the theoretical treatment of the wave equation from courses in Electromagnetics and the practice of ultrafast and THz photonics.

Course Contents:

- Introduction;
- Laser basics;
- Generation of Ultrashort Laser Pulses;
- Linear and Nonlinear Pulsed Optics;
- Characterization of Laser Pulses;
- Manipulation and Control of Laser Pulses;
- Ultrafast Spectroscopic Techniques;
- Ultrafast Optoelectronics;
- Terahertz Science and Technology;
- Attosecond Optics
- Selected hot topics in Ultrafast and THz Photonics.

There is no specific textbook. Please consult references below. **We will heavily utilize Prof. Trebino's course material on Ultrafast Optics, please surf and download materials from his website (see web resources below)**.

References:

1. R. Trebino, *Frequency Resolved Optical Gating: The measurement of ultrashort laser pulses*, Kluwer Academic Publishers, 2002.
2. C. Rulliére, Ed., *Femtosecond Laser Pulses: Principles and Experiments*, 2nd ed., Springer, 2005 (available as e-book).
3. J. C. Diels and W. Rudolph, *Ultrashort Laser Pulse Phenomena: Fundamentals, Techniques, and Applications on a Femtosecond Time Scale*, Burlington, MA: Academic Press, 1st ed., 1996, 2nd. ed., 2006.
4. Peter Hannaford, ed., *Femtosecond Laser Spectroscopy*, Springer, 2005 (available as e-book).
5. F. X. Kärtner, ed., *Few-Cycle Laser Pulse Generation and Its Applications*, New York, NY: Springer-Verlag, 2004.
6. A. M. Weiner, *Ultrafast Optics*, Wiley, 2009.
7. Zenghu Chang, *Fundamentals of Attosecond Optics*, CRC Press, 2011.
8. Lukas Gallmann and Ursula Keller, *Femtosecond and Attosecond Light Sources and Techniques for Spectroscopy* [DOI: 10.1002/9780470749593.hrs086], in Handbook of High Resolution Spectroscopy, F. Merke, ed. Wiley, 2011
9. D. Mittleman, ed., *Sensing with THz radiation*, Spring-Verlag, New York, 2002.
10. Kiyomi Sakai (Ed.), *Terahertz Optoelectronics*, Springer, 2005 (available as e-book).
11. Yun-Shik Lee, *Principles of Terahertz Science and Technology*, Springer, New York, 2008 (available as e-book).
12. Susan L. Dexheimer, ed., *Terahertz spectroscopy: principles and applications*, Boca Raton : CRC Press/Taylor & Francis Group, 2008 (available as e-book).
13. Xi-Cheng Zhang, Jingzhou Xu, *Introduction to THz wave photonics*, New York; London : Springer, 2010 (available as e-book).
14. A. E. Siegman, *Lasers*, University Science Books, Mill Valley, CA, 1986.
15. Current literature

Pre-requisites:

Undergraduate electromagnetic theory; modern physics or elementary quantum mechanics; undergraduate applied or engineering mathematics. Prior exposures to optics or lasers are helpful.

Grading

Grades will be determined by incidental problem sets, a term paper with presentation, and class participation. The formula that will be used to calculate your final grade is:

Problem Sets: 40%
Term Paper: 40%
Class Participation: 20%

Resources on the Web (partial list):

1. Prof. R. Trebino's course material on Ultrafast Optics, notes by various contributors can be found at http://frog.gatech.edu/prose.html. Slides can be downloaded at http://frog.gatech.edu/lectures.html.
2. Prof. F. Kartner's course material on Ultrafast Optics, available as MIT Open Course Ware, http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-977-ultrafast-optics-spring-2005/index.htm.
3. Virtual Journal of Ultrafast Science, http://www.vjultrafast.org/
4. http://thznetwork.net/

Area I Applied Physics and Devices: Photonics. Photonics is the modern science and technology of generating, manipulating, propagating and using light. Novel lasers and other sources permit the generation of light at wavelengths extending from the far infrared to the extreme ultraviolet and with characteristics that make possible a wide range of applications.Â Femtosecond lasers are developed for studies of ultrafast phenomena in materials and devices, for optical clocks and frequency combs, for arbitrary waveform generation, for photonic analog-to-digital conversion and for signal processing based on ultra-precise synchronization and timing distribution. This Special Issue aims at highlighting all developments in the broad area of THz photonics. We will consider theoretical, numerical, and experimental papers that cover, but are not limited to, these topics: (1) Advances in THz sources and detectors. (2) Progress in THz components, and sensing/imaging systems. (3) Novel THz devices and materials, such as ferroelectrics, superconductors, nanostructures, metamaterials, plasmonic materials and low- and two-dimensional materials. (4) Ultrafast carrier dynamics and THz nonlinear science, and new quantum physics in advance materials. (5) THz applica