Phys597002 **Special Topics in Physics:**
Ultrafast and THz Photonics
10720PHYS597002 物理專題--超快與兆赫光學

Lecture Hours: 18:30 – 21:20, Thursdays (tentative)
Location: Room Phys 208 (tentative)
Instructors: Prof. Ci-Ling Pan (潘犀靈教授)
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Office Hours: by appointment

Teaching Assistants: to be assigned.

Course Description:

Ultrafast Photonics, also known as ultrafast optics and optoelectronics, is a subject of knowledge that has had a dramatic impact on a vast array of basic scientific and technological disciplines. Soft X-ray pulses as short as 43 attoseonds (1 as = 10^{-18} seconds), with a bandwidth of ~ 100 eV (Opt. Express 25, 27506-27518 (2017)), were generated to date. The theory and understanding of propagation of optical pulses with such broad bandwidths is also essential for a variety of applications, e.g., the design of high throughput optical communications systems. Other important applications of ultrafast photonics range 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. 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. The relative new field of THz science and technology will also be covered so that students can explore their applications.

Course Objective:

This course is tailored to the interests 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. After mastering materials in this course, 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. It 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. Most of these books are available as e-book from the NTHU library. **We will heavily utilize Prof. Trebino's course material (slides and notes) on Ultrafast Optics, please surf and download materials from his website (see web resources below). The first two books are heavily used**.

References:

1. R. Trebino, *Frequency Resolved Optical Gating: The measurement of ultrashort laser pulses*, Kluwer Academic Publishers (part of Springer), 2002. (available as e-book)
2. C. Rullière, Ed., *Femtosecond Laser Pulses: Principles and Experiments*, 2^{nd} 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, 1^{st} ed., 1996, 2^{nd}. ed., 2006. (available as e-book)
4. Peter Hannaford, ed., *Femtosecond Laser Spectroscopy*, Springer, 2005 (e-book).
5. F. X. Kärtner, ed., *Few-Cycle Laser Pulse Generation and Its Applications*, New York, NY: Springer-Verlag, 2004.
6. R. Paschotta, *Field Guide to Laser Pulse Generation*, SPIE Press, Bellingham, Washington, 2008 (available as e-book).
7. A. M. Weiner, *Ultrafast Optics*, Wiley, 2009 (available as e-book)..
8. Zenghu Chang, *Fundamentals of Attosecond Optics*, CRC Press, 2011. (e-book)
9. 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
10. D. Mittleman, ed., *Sensing with THz radiation*, Spring-Verlag, New York, 2002.
11. Kiyomi Sakai (Ed.), *Terahertz Optoelectronics*, Springer, 2005 (available as e-book).
12. Yun-Shik Lee, *Principles of Terahertz Science and Technology*, Springer, New York, 2008 (available as e-book).
13. Susan L. Dexheimer, ed., *Terahertz spectroscopy: principles and applications*, Boca Raton : CRC Press/Taylor & Francis Group, 2008 (available as e-book).
14. Xi-Cheng Zhang, Jingzhou Xu, *Introduction to THz wave photonics*, New York; London : Springer, 2010 (available as e-book).
15. A. E. Siegman, *Lasers*, University Science Books, Mill Valley, CA, 1986.
16. 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. THz Science and Technology Network, http://www.tstnetwork.org/
4. Nature Photonics Focus issue on THz Optics, Vol. 7, No. 9, September 2013, http://www.nature.com/nphoton/journal/v7/n9/index.html