EEC 289K – Spring 2022

Ultrafast Photonics

Science, Technology, and Applications

COURSE DESCRIPTION, GOALS, AND PREREQUISITES

Description: Ultrafast lasers are rapidly finding their way into laboratories all over the world. In this course, we will explore what makes these short-pulse lasers useful for applications ranging from bio-imaging to x-ray generation. Specifically, we will cover the *essentials* of ultrafast photonics, including the basic science of ultrashort laser pulses, the technology to generate and manipulate these pulses, and a few of the numerous applications of ultrafast photonic systems.

Goals: This course will prepare students for experimental or theoretical work that involves the use of ultrafast lasers, and it will provide a taste of some of the exciting applications of such ultrafast systems.

Prerequisites: Electromagnetic waves (*e.g.* forced wave equation, linear optics, etc.), basic optics (*e.g.* Gaussian beams, Fresnel equations, etc.), fundamental mathematical methods (*e.g.* Fourier transforms, partial differential equations, etc.), basic scientific programming. Consult instructor for further information.

SCHEDULE AND STAFF

Time: TBD
Location: TBD
Instructor: William Putnam (bputnam@ucdavis.edu)
Office Hours: TBD
Course Credit: This course is 4 units

MATERIALS

Textbook:

Ultrafast Optics by Franz X. Kärtner (from MIT course 6.638 offered in Fall 2008)

Ultrafast Optics by Andrew Weiner (John Wiley & Sons, 2009)

Additional references:

Principles of Lasers by Orazio Svelto (5^{th} ed., Springer, 2010)

Nonlinear Optics by Robert Boyd (3^{rd} ed., Academic Press, 2008)

Online references:

RP Photonics Encyclopedia (https://www.rp-photonics.com/encyclopedia.html)

Refractive index database (https://refractiveindex.info/)

COURSE REQUIREMENTS

Assignments: There will be seven problem sets. These problem sets will be issued and due approximately every week.

Late Work Policy: Homework submitted late will not be graded and will not receive any credit. Each student will get one *late homework pass*; that is, each student may turn one homework assignment in up to a week late without losing any points on the assignment.

Final Project: There will be a final project in the final three weeks of the course. The purpose of the final project is to give students an opportunity to connect the material and theoretical concepts that they have learned in the class to their research (or to another research problem of current interest). The final project will primarily consist of a term paper. This paper will be based on one to three published research papers.

GRADING

Final letter grades will be based on the following breakdown:

- Homework: 70%
- Term Paper / Final Project: 30%

TOPIC OVERVIEW

The course consists of three sections: ultrafast science, ultrafast technology, and ultrafast applications. Below is an approximate breakdown of the topics that will be covered. (Each numbered item in the following list corresponds to approximately one week of the course.)

I. Ultrafast Optical Science

1. Laser pulse propagation
2. Pulse propagation, linear media, and dispersion
3. Second-order nonlinear optical processes

4. Third-order processes, solitons, and the nonlinear Schrödinger equation

II. Ultrafast Optical Technology

5. Laser Basics
6. Modelocking: active, passive, and Kerr-lens
7. Laser pulse measurement techniques

III. Ultrafast Optical Applications

8. Frequency combs
9. Ultrafast, nonlinear spectroscopy
10. Extreme, non-perturbative nonlinear optics