Physics 585
Nonlinear Optics
Spring 2017

Instructor: C. Durfee
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Class: Alderson Hall 141 11-12:15 TTh
Office hours: Tentative: T1-3, W11-12, 1-3. Either in my office or just outside at the table.

Summary:
In this course, we explore the origins, consequences and applications of the nonlinear response of a medium to intense electromagnetic waves. Topics include:

- semiclassical and quantum descriptions of the nonlinear response, and the interaction of intense light with two-level systems (optical Bloch equations), nonlinear optics of semiconductors
- nonlinear wave propagation: harmonic generation and parametric amplification, self-focusing, spatial and temporal soliton dynamics, nonlinear fiber optics
- applications nonlinear effects: pulse characterization (polarization gating, transient grating), electro-optic modulation (Kerr and Pockels cells)

Additional topics depend on time and student interests:

- acousto-optics
- phase conjugation
- stimulated Raman and Brillouin scattering

As a more advanced, seminar-style class, this course has room to be tailored somewhat to the interests of the students. Since we will be concentrating on topics that are current, there will be some reading from journal articles in addition to the textbook.

In this course we will work with both analytic and numeric techniques.

The course will presume knowledge of EM/physical optics (at the level of PHGN462) and Quantum Mechanics (dirac notation). Students need a minimum an understanding of QM at the level of our Modern II (320), but more is better.

Textbooks:
The main book will be *Nonlinear Optics* (3rd edition), by Robert Boyd.

There are a few additional references that I have found very useful as I've worked in this field. If you are working in optics (or are headed that way), these are good books to have. They are optional as far as the course is concerned.

- *The Quantum Theory of Light* (3rd ed), Rodney Loudon. This book concentrates on the nonlinear interactions with atoms, from an accessible QED/statistical optics point of view.
- *Nonlinear Fiber Optics* (4th ed), Govind Agrawal. This book is very good at the analysis of nonlinear guided wave propagation: self-phase modulation, solitons

and four-wave mixing, among other things. Good information on methods for numerical propagation techniques.
- *Quantum Electronics,* Amnon Yariv, is a good book covering laser physics with some nonlinear optics.

Finally, Hecht's *Optics* book is a good place to go for an easy explanation of basic optics. Plenty of pictures and practical examples.

Course website:
Most of the class information will be organized and distributed through the course website on the Department's Wiki site.
Since there is so much current research that is work going on in this area, we'll be looking at examples in current research. On the Wiki-based website, we'll add annotated links to interesting papers and websites during the semester. I'll help you develop your literature-research skills during the semester.

A good fraction of class notes will be posted on the website.

Computation:
Most of the modeling and calculations will be done with Mathematica. Let me know if you are not comfortable with the program. Other programs such as Comsol or Matlab may be used.

Homework and Projects:
The homework will be most every week. You will be able to pick up the homework assignment from the course website.

There will be one take-home midterm.

Instead of a final exam, each of you will work on a project that will involve literature research, along with analytic and/or computer-based calculations in an area of your interest. Ideally, the topic will be closely connected with your research. Coordinate the topic selection with your advisor and me. Any calculations for the project will have to be developed during the semester. There will be a written report and an oral presentation in the last week of class.

Journal article/research presentations:
Nonlinear optics figures in a vast array of current research areas. To help you learn more about what is going on, each of you will take turns talking for a couple of minutes at the beginning of class about a topic that you find interesting. See the website for details.

Grading proportions (subject to change):

Homework	35%
Midterm	25%
Final project	35%
Class participation	5%

Syllabus (subject to change)

- Classical models of nonlinear response
- Second harmonic generation
- Tensor forms for the susceptibility
- Solutions of the nonlinear wave equation:
    - Sum, difference frequency mixing and parametric amplification
    - Harmonic generation
    - Phase matching techniques
    - Numeric solution of coupled equations
- Nonlinear refractive index:
    - Molecular orientation
    - Thermal effects
    - Nonlinear response of semiconductors
    - Intro to nonlinear response of plasmas, relativistic effects
- Quantum models: perturbation theory and density matrix techniques
- Two-level atoms and the optical Bloch equations
- Nonlinear refractive index effects
    - Self-focusing
    - Four-wave mixing, phase conjugation
    - Two-beam coupling and transient gratings
    - Self-phase modulation and solitons
- Nonlinear scattering:
    - Acousto-optics
    - Stimulated Brilliouin and Raman scattering
- Optical damage and multiphoton effects