

**Physics 598
Nonlinear Optics
Spring 2007**

Instructor: C. Durfee

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Class: Meyer 357, 11-12:15

Office hours (tentative): T1:30-3:30, W 1-4

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
- stimulated Raman and Brillouin scattering
- applications nonlinear effects: pulse characterization (polarization gating, transient grating), phase conjugation, electro-optic modulation (Kerr and Pockels cells)

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).

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. I'll be willing to give additional lectures outside the main class to get people up to speed, so if you haven't taken graduate quantum, but have taken 320, you should be able to do fine.

Textbooks:

The main book will be *Nonlinear Optics* (2nd edition), by Robert Boyd.

There are two 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, if you don't have it already, 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:

We will try having the weekly homework done in teams. You will be able to pick up the homework assignment from the course website. After the homeworks are collected, I will either post the solutions on the website or make them available for you to copy. I will be grading them, so show mercy and be neat.

There will be one or two (individual) take-home midterms.

Project:

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 me and your advisor. 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.

Instead of a final, you will do a mini-research project that will involve some literature research and calculations. You will need to write it up, and give a ~10 min presentation to the class on your findings. In the spirit of making sure the project is useful, you should coordinate with your advisor to identify a calculation that is relevant to your research. Or you can see me for ideas.

Grading proportions (subject to change):

Homework	30%
Midterm 1	15%
Midterm 2	15%
Final project	40%

Syllabus

- Classical models of nonlinear response
- Solutions of the nonlinear wave equation:
 - Sum, difference frequency mixing and parametric amplification
 - Harmonic generation
 - Phase matching techniques
 - Numeric solution of coupled equations
- Quantum models: perturbation theory and density matrix techniques
- Nonlinear refractive index:
 - Molecular orientation
 - Thermal effects
 - Nonlinear response of semiconductors
 - Intro to nonlinear response of plasmas, relativistic effects
- 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 Brillouin and Raman scattering
- Optical damage and multiphoton effects