Phys 7650 – Nonlinear and Nano-Optics – Spring 2015

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Reading: As primary text we will use Robert Boyd, Nonlinear Optics. But as with any advanced subject, it is often useful to consult several references to see how different scholars present the same idea you may struggle to understand for the first time. Also no single book covers all the topics we will discuss in this class. Details for further reading will be discussed in class but the following is a first suggestion of useful references:
Paul Butcher & David Cotter, The Elements of Nonlinear Optics: good quantum treatment.
Y. Ron Shen, The Principles of Nonlinear Optics: 1984, but still the most authoritative text, encyclopedic, many typographical mistakes.
K. H. Benneman, Nonlinear Optics in Metals: some excellent chapters on physics of NLO response.
Andrew Weiner, Ultrafast Optics: time-domain description, techniques.
Martin Dressel & George Grüner, Electrodynamics of Solids: Physics of light-solid interaction.
Hans Kuzmany, Solid-State Spectroscopy: Fundamental, including mesoscopic solids.
Sergey Gaponenko, Introduction to Nanophotonics: nanoscale light-matter interaction.
Lukas Novotny & Bert Hecht, Nano-optics: formalism, theoretical techniques.

Prerequisite: You should have a basic understanding of electrodynamics, optics, and quantum mechanics. To refresh your knowledge, get a copy of Grant Fowles, Introduction to Modern Optics. This is a compact timeless classic (and cheap, get a <$10 copy via bookfinder.com), excellent coverage of basics, consider understanding of its contents as a prerequisite for our course.

Syllabus: The nonlinear interaction between light and matters is the most general one and thus leads to a wide range of phenomena. In this course we will discuss its fundamental concepts with a focus on light-matter interaction in solids including mesoscopic and nanoscopic effects. The overall goal is to provide the general basics as a framework for your own future development in this rapidly diversifying field. I envision that we roughly proceed as follows:

- Microscopic understanding of the nonlinear light-matter interaction, semiclassical model.
- Perturbation theory, density matrix formalism, Bloch equations, Feynman diagrams.
- Nonlinear wave equation, spatial symmetry.
- Applications I: Nonlinear wave-mixing, crystal optics, phase matching, parametric generation.
- Resonant, relaxation, and ultrafast phenomena in molecules and solids, optical Stark effect.
- Applications II: Kerr effect, self-focusing, optical solitons, phase modulation.

- Meso-/nano-scale: micro-cavities, optical antennas, nano-solids, surface plasmons, near-field optics.
- And: Dressed states, single photon nonlinear optics, extreme nonlinear optics.

Lab demos: I plan to do 2 hands on lab demos so you see NLO in action.

Homework: The homework problems are designed to strengthen your grasp of the fundamentals and to encourage further reading. One problem set will be handed out each week and is due one week later (I plan for 8 problem sets). Some problems require use of computational tools (e.g., Matlab, Mathematica). You are encouraged to collaborate but must submit your own solution. You can drop the problem set with the lowest score.

Final Project: The final project is an opportunity for you to explore in greater depth an area you find particularly interesting. I will compile a list of possible topics but you can also find your own project. If you already joined a research group your project can be related to your research or even include experimental work. You are encouraged to start as early as possible. For your writeup we will provide a word and latex style file. The last several lectures are reserved for in-class project presentations.

Grading: Midterm: 30%; Term paper with presentation: 40%; Homework: 30%

Important dates:

Midterm:	March 12
Project proposal (∼ one page outline):	April 7
In class presentations:	April 16 – April 30
Term paper due date:	Monday, May 5

Requirements for the project writeup: Your final report will be graded on: (1) its scientific merit; (2) organization and content; (3) scope of the project; (4) clear and accurate writing; and, (5) your level of understanding. We aim for a well-thought-out, well-written, and well-conceived report. Some basic suggestions:

1. Use diagrams and pictures to simplify your work and to enable the reader to come to an easier understanding of the material. They should be simple and well labeled. The content or meaning of a graph or picture with its figure caption should be self-explanatory.
2. Footnote and endnote your sources. Advances in scientific knowledge and understanding often come from rephrasing and reorganizing ideas presented by other authors. Use your own words, based on your own understanding, credited to the appropriate source.
3. Your report should have a title page, an abstract, a table of contents, the primary text, and a bibliography. Number pages. Please use 12 pt roman typeface, 1.1 line spacing (you will like it).

Requirements for the project presentation:

1. Use electronic slides (e.g., ppt, pdf). Sometimes more but less dense slides are adequate. Overall 8-10 should do.
2. Use graphs and pictures and key words but not long wordy sentences. Limit the number of equations, highlight the relevant relation, and walk the audience through carefully.
3. Clearly explain the underlying and basic science behind your work. Think: 'would I understand what I am taking about if I would hear it for the first time?' Not: If you can not convince your audience – confuse it ;-)
4. 'Less can be more': Limit your talk to the essence of your project. No more than 20 minutes per presentation. Don't try to speak faster to compensate a lack of time - speak more thoughtfully.