NONLINEAR OPTICS

OSE 6334 - 3 credit hours
Spring 2017
CREOL A214, 9:00am – 10:15 am, Tues – Thur – (some Fridays)
Office hours - door open most of the time, also Tu, Th 10:15am

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Prerequisites for this course should be OSE5111 Optical Wave Propagation, OSE5312 Fundamentals of Optical Science, OSE6432 Fundamentals of Photonics & a basic understanding of the wave equation and optical beam propagation.

Required text: Text: "Nonlinear Optics", George Stegeman, Wiley 2012

Homework + Quizzes	20%
Test 1, in class, closed book (end of first half of semester)	25%
Test 2, take home, comprehensive (near semester end)	25%
Final, in class final, open book, comprehensive	30%
Total	100%

(+ and - grades will be given on a sliding scale based on years of experience teaching NLO. grades can be picked up in my office 2 days after the final exam. Make-up exams will not be given. The final exam is scheduled for Thursday, Dec. 10 from 7:00am-9:50am)

This course gives you an introduction to the broad field of Nonlinear Optics (NLO). The goal is to prepare you to read and understand the NLO literature (i.e., to enable you to study NLO on your own). As such, we study a few basic interactions of low order nonlinear processes that most "optics types" are expected to know about, that is, the literature assumes this knowledge.

Financial Aid and Attendance: As of Fall 2014, all faculty members are required to document students' academic activity at the beginning of each course. In order to document that you began this course, please complete the following academic activity by the end of the first week of classes, or as soon as possible after adding the course, but no later than August 27. Failure to do so will result in a delay in the disbursement of your financial aid.

Topics to be covered in this NLO course are:

- ❑ wave equation and classical electron oscillator model for NLO
- ❑ frequency conversion effects including second-harmonic generation, sum and difference frequency generation, optical rectification, and parametric processes (eg. optical parametric oscillators). Understanding how to get efficient conversion will require knowledge of phase matching and the susceptibility tensor. i.e. Chi-2 ($\chi^{(2)}$) effects
- ❑ self-action and multiwave mixing. The self-action effects include two-photon absorption, self-phase modulation, self-focusing (or defocusing), and solitons (both temporal and spatial). The multiwave mixing includes degenerate four-wave mixing (DFWM), and the frequency nondegenerate counterpart, i.e. Chi-3" ($\chi^{(3)}$) effects

- "Quasi-chi-3" ($\chi(3)$) effects including molecular reorientation index changes (Kerr effect), thermal refraction, photoinduced free-carrier effects in semiconductors (free-carrier nonlinearities), the analogous excited-state effects in organic dyes, coherent antistokes Raman scattering (CARS), electrostriction, photorefraction
- + other topics of interest

We will also look at possible applications along the way. For example, optical limiting, all-optical switching, pulse compression, beam clean-up with optical phase conjugation, multi-photon microscopy, high harmonic generation, optical memory with photorefraction, fiber communication with solitons, and new frequency sources using the various phenomena as well as stimulated Raman and Brillouin scattering.

Nonlinear Optics Textbooks

Nonlinear Optics, Third Edition, Robert W. Boyd (Academic Press, Elsevier, Burlington, MA, 2008). Boyd finally changed his book from Gaussian units to MKS. This is great; however, you still need to be able to convert units since much of the literature is still in Gaussian (a pain!).

Physics of Nonlinear Optics, Kuang-Sheng Ho, Song H. Liu, and Guang S. He (World Scientific, Singapore, 2000).

Nonlinear Optics: Theory, Numerical Modeling, and Applications, Partha P. Banerjee (Marcel Dekker, NY, NY, 2004).

Light-Matter Interaction: Atoms and Molecules in External Fields and Nonlinear Optics, Wendell T. Hill III and Chi H. Lee (Wiley, 2007) (I)

Handbook of Nonlinear Optics (Optical Science and Engineering), Richard L. Sutherland (Marcel Dekker, New York, 2003).

Applied Classical Electrodynamics, V 2: Nonlinear Optics, F.A. Hopf and G.I. Stegeman, **Wiley**

Other books with sections on nonlinear optics

Photonics: Linear and Nonlinear Interactions of Laser Light and Matter, Ralf Menzel (Springer, New York, 2007).

Photonics and Laser Engineering: Principles, Devices and Applications, Alphyan Sennaroglu (McGraw Hill, New York, 2010).

Fundamentals of Photonics, (Wiley, Hoboken, 2007) B. E. A. Saleh and M. C. Teich.

Photonics: Optical Electronics in Modern Communications, Amnon Yariv and **Pochi Yeh (The Oxford Series in Electrical and Computer Engineering, Oxford, 2006)**

Handbook of Optics Vol. IV: Optical Properties of Materials, Nonlinear Optics, Quantum Optics, Third Edition, ed. M. Bass, sponsored by the Optical Society of America (McGraw Hill, NY, 2010)

Other References:
Nonlinear optics;
"The Principles of Nonlinear Optics", Y.R. Shen, Wiley
"The Elements of Nonlinear Optics", Butcher and Cotter, Cambridge
"Applied Nonlinear Optics", F. Zernike and J. Midwinter, Wiley
"Nonlinear Optics", Bloembergen, Benjamin
"Nonlinear Optical Fibers", G.P. Agrawal, Academic Press

"Introduction to Nonlinear Laser Spectroscopy", M. Levenson, Academic Press
"Solitons and Nonlinear Wave Equations", R. Dodd et. al., Academic Press
"Optical Phase Conjugation", R.A. Fisher, Academic Press
"Principles of Phase Conjugation", B.Ya. Zel'dovich, N.F. Pilipetsky and V.V. Shkunov, Springer Verlag
"Nonlinear Optics and Quantum Electronics", M. Schubert and B. Wilhelmi, Wiley
"Optics and Nonlinear Optics of Liquid Crystals", I.C. Khoo and S.T. Wu, World Scientific
"Nonlinear Optical Parametric Processes in Liquids and Gases", J. Reintjes, Academic Press
"Nonlinear Optical Prperties of Organic Molecules and Crystals", volumes I and II, D.S. Chemla and J. Zyss, Academic Press
"Nonlinear Optics", P. Harper and B.S. Wherrett, Academic Press
Lasers and interaction of light with matter;
"Intro. to Quantum Electronics", Amnon Yariv, Wiley
"Laser Electronics", Verdeyen, Prentice Hall
"Quantum Electronics", Amnon Yariv, Wiley
"Lasers", Anthony Seigman, University Science Books
"Optical Resonance and 2-Level Atoms", Allen and Eberly, Wiley
"Principles of Quantum Electronics", Dietrich Marcuse, Academic Press
"Laser and Coherence Spectroscopy, J.I. Steinfeld, (section by R.L. Shoemaker), Plenum Press
"Elements of Quantum Optics", Meystre and Sargent, Springer Verlag