Class details:

- Class syllabus
- Class Location: Meinel 305, MW, 9:30 - 10:45 AM: First lecture Jan 15, 2025
- Office hours: 1:00 - 2:00 PM on Tuesdays in Rm. 636 or by appointment

Instructor information:

- Office: Meinel 636
- email: ewan.wright@optics.arizona.edu
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Course Description:

This three unit course introduces the student to the basics of nonlinear optics and the zoology of phenomena produced by optical nonlinearities for very intense laser fields propagating in dielectric media. The treatment is centered on the classical Lorentz electron oscillator, but a quantum perspective is also given for many of the phenomena discussed. The class project requires students to have some computational skills. This class can serve as a companion class to OPTI 553 Nonlinear Photonics that provides a more detailed treatment of nonlinear optics, integrated optics, materials, and device applications.

Pre-requisites:

The class should be accessible to students who has taken and passed OPTI 501 or equivalent. A working knowledge of MATLAB or similar simulation software will be advantageous but not essential.

Learning Outcomes:

After completion of this course, it is expected that students will be able to (i) recognize and manipulate the basic equations of nonlinear optics; (ii) identify and discuss the key phenomena underpinning nonlinear effects at high intensities; (iii) be able to discuss and research classic papers from the field of nonlinear optics; (iv) be able to address and advanced topic of their own choosing by carrying out a numerical project and/or literature search.   In this way students will gain a broad appreciation of the field of nonlinear optics plus an in-depth study of one topic. For some students this may be what they require whereas for others they may seek a more in-depth class, eg. OPTI 553.

Required Texts:

There are no required texts, and class notes will be made available on D2L. An optional source book is

R. W. Boyd: Nonlinear Optics (Academic Press)

Class content:

The topics to be covered are

1. **Review of linear optics:** Linear optical properties, Maxwell's equations, plane-wave solutions, paraxial wave equation and Gaussian beam propagation, Lorentz electron oscillator model in the time and frequency domains, crystal optics basics.
2. **Second-order Nonlinearities:** Second-harmonic generation, sum and frequency generation, propagation effects, phase matching methods, quasi-phase matching.
3. **Three-wave mixing:** Parametric processes, parametric amplifiers, singly and doubly resonant optical parametric oscillators (OPOs).
4. **Third-order Nonlinearities:** Third-harmonic generation, Kerr-type nonlinearities and self-phase modulation, two-photon absorption, four-wave mixing. Applications including spectral broadening due to SPM, nonlinear pulse compression, and optical phase-conjugation.
5. **Self-focusing collapse and optical solitons:** The nonlinear Schrodinger equation, self-focusing collapse in a bulk nonlinear medium, aberrationless approximation and the critical power, spatial solitons in one-dimensional waveguides, higher-order solitons, cascaded nonlinearities in second-order media, spatial solitons in second-order nonlinear media. modulational instability of a plane-wave and filamentation. The nonlinear Beam Propagation Method.
6. **Optical breakdown in transparent materials:** Multi-photon ionization and avalanche ionization, optical breakdown for > ps pulses, plasma defocusing and arrest of collapse for short pulses, plasma blue-shifting, supercontinuum or white light generation due to collapse of fs pulses.
7. **Temporal solitons and space-time collapse:** Group velocity dispersion in optical fibers, temporal optical solitons, modulational instability, short pulse lasers. Space-time collapse in transparent dielectric media, light bullets, collapse arrest via pulse-splitting due to group velocity dispersion, long distance propagation of fs pulses in air.
8. **Stimulated Scattering:** Stimulated Raman and Rayleigh wing scattering, two-wave coupling, Raman
amplification and oscillation.
9. **Contemporary topics in nonlinear optics:** Potential topics include high-harmonic generation, attosecond pulse generation, extreme nonlinear optics and vacuum nonlinear optics, photon fluids, and analogue gravity systems.

Number of Exams and Papers:

There will be no written exams but rather two class papers, homework, along with keeping a log of key papers referred to throughout the class.

Course Policies:

Grading Policy

Grading will be based on a combination of homework (20%), keeping a log of key references discussed in class (20%), a midterm paper (30%), and a nonlinear optics project (30%) that is due before the final class on May 7. Grades will be determined based on the timeliness of completing the assignments, participation in the class, and the quality of the papers. The grade will be determined according to the cumulative percentage earned such that 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, below 60% = E.